ANALYSIS OF THE RELATIONSHIPS BETWEEN CAUSES OF DELAY IN CONSTRUCTION PROJECTS IN BANGLADESH

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There is an impression that, over the last two decades, high-rise construction projects in Dhaka, Bangladesh have been suffering from delays. Consequently, in-depth interviews, supported by a questionnaire, were conducted with 110 developers, consultants, project managers and contractors on thirty randomly selected private projects regarding the variables causing delays. Seventy-two probable delay variables were identified from a literature review and were included in the questionnaire in twelve groups over four operational stages. The thirty-one most important variables were identified based on the respondents' perception. This paper describes the application of factor analysis and stepwise regression techniques to provide a deeper understanding of the relationships among these variables. Factor Analysis was applied to the data from the survey to group them into factors in each of four different stages of the construction process. The paper also describes how the relationship among factors was established between stages using stepwise regression. Conclusions are drawn on the appropriateness of factor analysis and stepwise regression in enhancing the understanding of the relationships among causes of delays in construction projects. Although the data are Bangladesh specific, these statistical techniques can be usefully applied to other construction projects. In this application, factor analysis and stepwise regression showed that there was little association between factors that cause delays in one stage of the study and those in the next stage.

Keywords: Bangladesh, high-rise construction; delays, factor-analysis, stepwise-regression.

INTRODUCTION

The capital of Bangladesh, Dhaka, is one of the fastest growing cities in the world with a typical annual growth rate of 2.03% (Bangladesh Bureau of Statistics, 1996). In 1999, Dhaka had a population of 128 million. The main reasons for such a population increase have been known for some time, being a decrease of cultivable land in rural areas, lack of decentralization of modern facilities and unbalanced urbanization (Seraj and Alam, 1991). All socio-economic groups in Dhaka face housing problems and over the past two decades a trend of housing construction has been developed in the private sector which is largely known as apartment / real estate development where developers target middle to upper income groups. Typically, an individual or organization constructs multi-storey projects comprising several flats that are sold to purchasers.

Multi-storey apartment projects in Bangladesh, similar to those in Indonesia (Kaming *et al.* 1997), suffer from delays. The major issues, which this paper sets out to address are:

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the identification of important delay variables;
the application of factor analysis to group these important variables according to the stages of the project;
the application of stepwise regression to find and analyse links between delay variables at the different stages of the project;
the assessment of the appropriateness of these statistical methods in risk analysis.

METHODOLOGY

The overall objective of the research programme is to develop a practical Risk Management Process (RMP) for the effects of delays in high-rise construction projects in Bangladesh. At the heart of the RMP will be a risk analysis model of the effects of time delays on the procurement, design and construction programmes of typical high-rise construction projects. In order that decisions could be made on the form of the risk analysis model, it was necessary to develop a full understanding of the nature of variables causing delays in the projects and the nature of the interaction between these variables. Initially 72 delay variables were categorized in 12 groups as used by Asaf *et al.* (1995) and put in 4 operational stages (inception, plan and design, construction and transfer). A list of the variables is given in Table 1.

A comprehensive data collection program was undertaken using in-depth, face-to-face interviews, supported by a questionnaire, (February to August 1998) to investigate the variables causing time and cost overruns in multi-storied (6 stories upward) real estate projects in the private sector in Dhaka, Bangladesh. This approach enabled both qualitative and quantitative data to be collected and a full explanation of, and justification for, this approach has been reported elsewhere (Salam *et al.*1999). The survey involved in total 110 respondents (developers, consultants, project managers and contractors) connected with 30 randomly selected private projects.

The questionnaire gave respondents an option to rate the variables, according to their perception of likelihood of contribution to overruns by responding, on a linear scale from 5 (most important) to 1 (least important) as used by Tummala *et al.* (1997). Also, an additional column was kept for respondents' comments providing qualitative data that will be analysed elsewhere. The quantitative data were analysed using the statistical software package Minitab. The mean value of respondents' importance was termed as Relative Importance Index (RII). The RII values for the variables are given in Table 1. Ranking from most important to least important was done in ascending order using RII. Additionally, the percentage of respondents scoring up to a certain level of scale, as used by Chan and Kumaraswamy, (1997), was used to avoid problem with variables having same RII.

Table 1: Time overrun variables
(Relative Importance Index (RII); 1 = lowest to 5 = highest and rank of time overrun variables)

No	Variables / causes of time overrun	Consultant		Contractor		Developer		Proj. Man.	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
A	**Inception stage**								
1	Planning	1.62	32	1.15	63	1.38	48	1.04	62
2	Surveying	1.41	40	1.15	64	1.38	49	1.04	63
3	Land acquisition	1.62	29	1.30	56	1.38	50	1.08	61
4	Change of planning	2.10	14	1.82	20	2.10	11	1.79	23
B	**Planning and design stage**								
	Planning and design related								
1	Delayed soil investigation	1.07	65	1.41	49	1.38	47	1.08	58
2	Client's decision making	2.35	8	1.59	29	1.72	22	1.58	32
3	Insufficient communication between the owner(s) and the consultant(s)	1.41	41	1.52	42	1.63	27	1.58	31
4	Delayed completion of planning and design	1.76	23	1.74	23	2.07	12	2.17	12
5	Change of planning and design by client	2.24	10	1.52	38	2.00	14	1.88	20
6	Financing by client to planner and designer	1.07	66	1.44	47	1.40	43	1.29	47
	Government relations								
1	Obtaining planning and design permission	2.10	15	1.93	16	2.79	3	2.25	8
2	Obtaining permission for gas, water and electricity	1.97	19	2.37	6	1.79	18	2.08	14
3	Obtaining permission for road cutting	1.14	59	1.59	31	1.52	36	1.25	50
4	Excessive bureaucracy	2.10	16	1.37	53	1.86	16	1.17	54
C	**Construction stage**								
	Material								
1	Slow delivery of materials	1.21	54	1.63	28	1.55	34	1.38	44
2	Shortage of construction materials	1.00	68	1.07	68	1.14	66	1.00	67
3	Damage of materials in storage	1.17	58	1.30	55	1.21	63	1.54	34
4	Material changes in types and specifications during construction	2.07	17	1.56	35	1.66	28	2.04	17
5	Delay due to quality of materials	1.62	31	1.78	21	2.20	9	2.17	11
6	Material price escalation	1.45	38	1.52	39	1.48	37	1.54	33
7	Imported materials	2.17	12	2.26	10	1.93	15	1.88	21
8	Delay in the production of special manufacture of building materials	1.38	47	2.00	12	1.55	32	2.50	5
	Manpower								
1	Shortage of labour	1.69	26	1.96	14	2.14	10	2.21	10
2	Labour skill	2.03	18	1.56	36	1.83	17	1.79	24
3	Labour productivity	1.14	60	1.19	61	1.34	53	1.08	59
	Equipment								
1	Slow delivery of equipment	1.31	50	1.56	37	1.38	45	1.29	48
2	Equipment shortage	1.62	33	1.44	44	1.24	59	1.79	28
3	Equipment failure	1.79	22	1.96	13	1.55	33	1.79	27
4	Equipment productivity	1.38	45	1.26	57	1.66	25	1.46	37
5	Unskilled operators	1.41	42	1.30	54	1.21	62	1.42	42
	Financing								
1	Financing by contractor during construction	1.86	21	1.59	30	1.79	19	2.25	9
2	Delays in contractors' progress payment by owners	1.69	27	1.96	15	2.03	13	1.42	41
3	Cash flow problem during construction	2.69	5	1.89	18	2.76	5	1.88	19
4	Non- or delayed payments of instalments by customers	3.38	3	2.56	4	2.97	2	2.92	2
5	Bad debts	1.00	72	1.00	72	1.00	72	1.00	72
	Changes								
1	Design changes by owners or their agents during construction	3.21	4	2.67	3	2.76	4	2.75	4
2	Design errors made by designer	1.62	30	2.14	11	1.69	23	1.79	25
3	Change of contractor(s), sub-contractor(s) or engineers	2.24	11	2.30	9	1.62	29	1.79	26
4	Errors committed during construction	1.55	35	1.74	24	1.62	31	2.33	7
5	Unpredictable site (geological, water table etc.) conditions	1.35	48	1.78	22	1.31	55	1.50	35
6	Mistakes in soil investigation	1.03	67	1.07	70	1.14	65	1.00	66

Table 1 (continued)

No	Variables / causes of time overrun	Consultant		Contractor		Developer		Pro. Man.	
		RII	Rank	RII	Rank	RII	Rank	RII	Rank
	Scheduling and control								
1	Preparation and approval of site / shop drawings	1.21	55	1.52	43	1.24	58	1.46	40
2	Waiting for sample material approval	1.97	20	1.93	17	1.45	40	1.63	30
3	Planning and scheduling deficiencies	3.59	2	3.22	2	2.45	6	2.92	3
4	Lack of training personnel management support to model the construction operations	2.14	13	2.56	5	1.76	20	2.04	15
5	Lack of data base in estimating activity duration and resources	1.10	62	1.41	48	1.34	51	1.21	53
6	Judgement and experience of the involved people in estimating time and resources	1.14	61	1.11	66	1.07	68	1.04	64
7	Inspection and testing procedure used in the project	1.24	52	1.44	46	1.28	56	1.46	38
8	Accidents during construction	1.34	49	1.37	51	1.24	60	1.25	51
9	Type of contract used (design-build, general contracting, turn key...etc.)	1.41	43	1.11	65	1.31	54	1.13	57
10	Application of quality control	1.76	24	1.52	41	1.38	46	1.38	45
11	Inadequate early planning of the project	1.10	63	1.07	67	1.07	69	1.00	69
	Social and environmental issues								
1	Bad weather condition at construction site	2.69	6	2.33	7	2.41	7	2.42	6
2	Insufficient utilities available on construction site	1.55	36	1.70	25	1.48	38	1.88	22
3	Social and cultural factors	1.66	28	1.59	32	1.48	39	1.21	52
4	Strike / disruption	2.55	7	2.30	8	2.24	8	1.92	18
5	Unpredictable or catastrophic events	1.41	44	1.37	50	1.66	24	1.25	49
	Contractual relationship								
1	Uncooperative owners	1.48	37	1.63	26	1.76	21	1.38	43
2	The joint ownership of the project	1.00	69	1.07	69	1.14	67	1.00	68
3	Slowness of the owner decision making process	1.10	64	1.37	52	1.24	61	1.50	36
4	Poor organization of the contractor or consultant	2.28	9	1.56	34	1.66	26	2.17	13
5	The relationship between subcontractors' schedules in the execution of the projects	1.72	25	1.89	19	1.62	30	2.04	16
6	Conflict between contractor(s) and consultant(s)	1.00	70	1.04	71	1.07	70	1.00	70
7	Difficulty of co-ordination between various parties (contractor, sub- contractor, owner consultant) working on the project	1.21	56	1.59	33	1.41	42	1.29	46
8	Legal disputes between various parties in the construction project	1.00	71	1.19	62	1.28	57	1.46	39
9	Controlling sub-contractors by general contractors in the execution of work	1.38	46	1.19	60	1.21	64	1.08	60
10	Unavailability of financial incentives for contractor to finish a head of schedule	1.21	57	1.22	59	1.03	71	1.00	71
11	Negotiation and obtaining contracts	1.24	53	1.63	27	1.38	44	1.13	56
12	Unavailability of professional construction management expertise	1.62	34	1.44	45	1.45	41	1.13	55
D	**Transfer stage**								
1	Non-compliance of financial obligations by customers	3.62	1	4.00	1	4.21	1	4.00	1
2	Default by contractors	1.45	39	1.52	40	1.55	35	2.75	29
3	Default by developers / clients	1.28	51	1.22	58	1.34	52	1.00	65

Initial analysis of the data revealed a sudden drop of RII value after the 31st more important variable and therefore only these variables were retained and used for further analysis. These are included in Table 2. These variables were firstly subjected to factor analysis (e.g. Hair 1995) to group them into interpretable themes, thus further reducing the potential complexity of any future risk model. Then relationships between the identified factors at the various stages of the project were then investigated using stepwise regression (e.g. Draper and Smith 1998).

FACTOR ANALYSIS

Factor analysis is a widely used multivariate statistical technique to identify a small number of latent themes from a large number of explanatory variables. Principal components factor analysis was used on the data collected from the 31 most important variables identified at the interviews. The relative importance of factors is given by their eigenvalue, which is the amount of the total variance explained by the factor. Factors were retained using Kaiser's criterion (i.e. factors with eigenvalues greater than one were retained). To aid interpretation, varimax rotation was used and only variables with a factor loading of magnitude greater than 0.5 were reported.

Separate factor analyses were performed on two of the stages in the construction project, planning and design and construction, but not on the inception or transfer stages as these had only one delay variable. Three and nine factors were identified in the planning and design and construction stages respectively. Table 2 shows the variables (in decreasing order of importance with their RII and ranks) contributing to each factor and (in parentheses) the factor's eigenvalue. Whilst factor analysis suggest groupings of variables, the validity of the suggested grouping must be reviewed within the context of the Bangladeshi construction industry.

Stage1 (Inception)
Change of planning is the only inception related variable from the 31 highest ranking variables. It is common for clients within Bangladesh to change their mind frequently regarding plans as they get ideas from different sources resulting in time overruns.

Stage2 (Planning and Design)
Factor 2.1: This is the most important factor in this stage and it consists of two variables; obtaining permission for gas water and electricity, and obtaining planning and design permission. This grouping would appear to be logical and the factor can be termed 'permissions'. Obtaining planning and design permission is a common cause of delays in Bangladesh even though only one authority is involved. However, obtaining permission for gas, water and electricity must be obtained from several organizations, which cumulatively could cause longer delays.

Factor 2.2: This factor termed 'change of plan' consists two variables, change of plan and design by client and delayed completion of plans and designs by consultants. This grouping would appear to be logical as in Bangladesh, it is common at this stage of the project for developers to change their plans which ultimately causes delays to consultants.

Factor 2.3: This factor consists of a single variable: client's decision making.

Stage 3 (Construction)
Factor 3.1:

This factor can be termed 'management' and consists of four variables, equipment failure, planning and scheduling deficiencies, waiting for sample material approval and lack of training personnel management support to model the construction operations. This grouping would appear to be logical. There is a lack of training of personnel in the management of construction operations and modern construction project management software are not practised in Bangladesh. Only a few consultants are familiar with some design software. In contrast, in Thailand most contractors use bar chart for planning and monitoring (Ogunlana, *et al.* 1996).

Table2: RII and rank of variables in factors

Inception (Satge-1)			**Plan and design (Stage – 2)**			**Construction** (Stage – 3)			**Transfer** (Stage – 4)		
Variables	**RII**	**Rank**	**Variables**	**RII**	**Rank**	**Variables**	**RII**	**Rank**	**Variables**	**RII**	**Rank**
						Factor3.1 (4.33)					
						Equipment failure	1.77	28			
						Planning and scheduling deficiencies	3.05	2			
			Factor2.1 (1.456)			Waiting for sample material approval	1.74	29			
			Obtaining permission for gas, water and electricity	2.05	11	Lack of training personnel management support to model the construction operations	2.12	9			
						Factor3.2 (2.31)					
			Obtaining planning and design permission	2.28	7	Poor organization of the contractor or consultant	1.90	17			
						Material changes in types and specifications during construction	1.80	25	Factor 4.1		
			Factor2.2 (1.189)			**Factor3.3** (2.16)			Non-compliance of financial obligations by customers	3.95	1
			Change of planning and design by client	1.92	16	Insufficient utilities available at construction site	1.64	30			
Factor1.1						The relationship between subcontractors' schedules in the execution of the projects	1.81	23			
Change of planning	1.92	13				Delay due to quality of materials	1.94	14			
			Delayed completion of planning and design	1.93	15	Delay in the production of special manufacture of building materials	1.83	21			
						Factor3.4 (1.82)					
						Cash flow problem during construction	2.33	6			
						Non- or delayed payments of instalments by customers	2.96	3			
						Imported materials	2.06	10			
			Factor2.3 (1.00)			**Factor3.5** (1.56)					
			Client's decision making	1.83	20	Labour skill	1.81	24			
						Financing by contractor during construction	1.86	19			
						Factor3.6 (1.41)					
						Change of contractor(s), sub-contractor(s) or engineers	1.82	22			
						Errors committed during construction	1.79	27			
						Factor3.7 (1.26)					
						Strike / disruption	2.27	8			
						Design errors made by designer	1.86	18			
						Design changes by owners or their agents during construction	2.85	4			
						Factor3.8 (1.21)					
						Bad weather condition at construction site	2.47	5			
						Shortage of labour	1.99	12			
						Factor3.9 (1.06)					
						Uncooperative owners	1.57	31			

*Delays in contractors' progress payment by owners (26) was not included in any factor.

Factor 3.2: This factor can be termed 'selection of consultant and contractor' comprises two variables, poor organization of the contractor/consultant and material changes in types and specifications during construction. This would appear to be logical as in Bangladesh, the selection of material regarding quality, price, availability, location, buildability, etc is organized by both the contractor and consultant.

Factor 3.3: This factor, termed 'site management', consists of four variables, insufficient utilities available at construction site, the relationship between subcontractors' schedules in the execution of the projects, delay due to quality of materials and delay in the production of special manufacture of building materials. Traditionally, in Bangladesh, there has been a lack of utilities on-site, a deficiency which can be improved by good site management. Efficient site management can help with planning different subcontractors' schedules and making available the few quality and special items of material that may not be readily available in the market locally.

Factor 3.4: This factor, termed 'cash flow' incorporates three variables highly rated by respondents, cash flow problems during construction and non- or delayed payments of instalments by customers together with delayed payments by customers for imported materials. Cash flow plays vital role on construction delays especially with small developers whereas large developers can manage cash flow problems by arranging finance from other projects or business.

Factor 3.5: This factor, termed 'labour payment' logically links shortages of labour skills and contractor's payment to labourers.

Factor 3.6: This factor 'construction error' suggests a link between changes of contractor(s) or engineer(s) and errors committed during construction.

Factor 3.7: This factor, 'disruption' consists of labour disruption, design errors made by designer and design changes by owners or their agents during construction. These variables are logically interrelated.

Factor 3. 8: The factor, 'weather', consists of bad weather condition at construction site and shortage of labour. The latter could be the consequence of bad weather condition at construction site especially in rainy season.

Factor 3.9: This factor consists of only one variable, the uncooperative owner.

Stage4 (Transfer)

Factor 4.1: The only variable in this factor 'non-compliance by financial obligations by customers' which was the most important variable of the 71 considered. At this stage the project is almost complete and the type of delay is different. Different flats are sold to different customers, but due to financial obligations, some flats may not be transferred to the respective customers as they can not occupy the flat until payment is completed.

The application of factor analysis has been shown to be successful. The initial list of 72 variables has been progressively reduced using RII and factor analysis to 13 factors in what would appear to be logical groupings of variables. This should reduce the complexity of any subsequent risk model of the programme for high-rise projects. However, it is necessary before the final selection of the form of the risk model to investigate the extent of inter-relationships between the factors.

STEPWISE REGRESSION

Stepwise regression is a statistical technique used to select the best subset of a possibly large set of explanatory variables to predict, in a multiple linear regression model, an independent variable. The algorithm is as follows:

Step 1: Find the variable (X_i say) with the highest correlation with the independent variable. This variable is included in the model provided that its t ratio (mean divided by standard error) has a magnitude greater than 2.

Step 2: Find the variable (X_j say) with the largest t ratio when it is included with X_i. This variable is included in the model provided that its t ratio (mean divided by standard error) has a magnitude greater than 2.

Step 3: The t ratio of each variable is calculated and a variable is removed if its t ratio has a magnitude less than 2.

Step 4: Calculate the t ratio of each of the remaining variables when it is added to the existing model. The variable with the largest t ratio is included provided it has magnitude larger than 2.

Steps 3 and 4 are then repeated until no variable is added or removed from the model.

This algorithm provides an efficient method to choose a form of risk assessment model as it ensures that only important variables are included and retained in it.

The technique was used to evaluate relationships between the factor scores in one stage of the construction process to those in the previous stage. For example the scores from factor 3.1 in the construction stage was defined as the independent variable and the scores of the three factors found at the planning and design stage were possible explanatory variables. This was repeated a further 12 times, once for each of the factors in the planning and design, construction and transfer stages of the construction process, to uncover relationships amongst causes of time overruns at different stages of the project. Overall, relationships were established in only two cases as follows.

Factor 3.8 (weather) in the construction stage was found to be linearly related to factors 2.1 (permission) and 2.2 (change of plan) in the planning and design stage although the relationship was not strong ($R^2 = 17.4\%$). It is possible that delays caused by these two factors at the planning and design stage may mean that construction is delayed into the rainy season when inclement weather causes more delays.

Factor 4.1 (non-compliance of financial obligations by customers) was found to be linearly related to factors 3.3 (site management), 3.7 (disruption) and 3.1 (management) although the relationship was not strong ($R^2 = 18.0\%$). It is possible that customers might refuse to pay promptly a developer with poor general, site and labour management that they perceive may have caused delays in the completion of the project.

The weak association between factors at successive stages of the project may seem surprising. However, further evidence is provided by the small pairwise correlations as shown below in Table 3.

Table 3: The correlation between factors in successive stages of the project

	Factor 2.1	Factor 2.2	Factor 2.3	Factor 4.1
Factor 1.1	0.179	-0.357	0.050	
Factor 3.1	0.158	-0.143	-0.133	0.182
Factor 3.2	-0.009	-0.048	-0.123	0.085
Factor 3.3	-0.204	0.200	-0.034	-0.321
Factor 3.4	-0.383	0.059	0.023	-0.041
Factor 3.5	0.000	0.037	0.182	-0.084
Factor 3.6	-0.026	0.162	-0.019	0.134
Factor 3.7	-0.110	0.192	0.010	-0.211
Factor 3.8	-0.370	0.192	-0.023	-0.008
Factor 3.9	0.115	-0.072	0.039	-0.123

To illustrate the advantage of using stepwise regression, consider fitting a multiple regression model to predict factors in stage 3 (construction) as the dependent variable using the three factors in the previous stage (planning and design) as independent variables. We first consider relating factor 3.1 (the most important factor in the construction stage) to the three factors 2.1 to 2.3. The stepwise regression technique showed that no variable was entered into the model at step 1 and hence we conclude that factor 3.1 is not linearly related to any combination of the factors 2.1 to 2.3. The multiple regression model for factor 3.1 is shown below with the t ratio in parentheses.

Factor 3.1 = - 0.0000 + 0.158 (Factor 2.1) - 0.143 (Factor 2.2) - 0.133 (Factor 2.3)

(1.67) (-1.51) (-1.40)

This model has an R^2 value of 6.3% and the p values for each of the independent variables are greater than 0.05, indicating that these variables do not contribute much to the model. This is consistent with the stepwise regression approach. Next we consider relating factor 3.8 to the three factors 2.1 to 2.3. The stepwise regression technique showed that factor 3.8 is linearly related to factors 2.1 and 2.2 but not factor 2.3. The multiple regression model for factor 3.8 is shown below with the t ratio in parentheses.

Factor 3.1 = - 0.0000 –0.370 (Factor 2.1) + 0.192 (Factor 2.2) - 0.023 (Factor 2.3)

(-4.17) (2.17) (-0.26)

This model has an R^2 value of 17.4% and the p values for the independent variables factors 2.1 to 2.3 are 0.000, 0.032 and 0.793 respectively, indicating that the first two variables contribute significantly to the model but the third does not. This is consistent with the stepwise regression approach.

The stepwise regression approach outlined above provides an efficient mechanism to determine relationships among a large number of independent variables. As illustrated above the results are consistent with those found from the corresponding multiple regression models. However only 13 stepwise regressions were performed compared with 587 separate multiple regression required to produce all possible models.

The lack of strong relationships amongst the factors means that modelling causes of time overruns can be simplified as a high degree of independence between the components of the model can be reasonably assumed and hence the discrete stages of the project can be considered independently.

CONCLUSIONS

The application of the RRI approach enabled the 31 most important variables causing delays in high-rise construction in Bangladesh to be identified from an initial list of 72 variables. Of these variables the most important were cash flow, planning and scheduling and plan and design changes.

The application of factor analysis enabled an initial appraisal of the relationship between these variables to be made. It proved possible to use the method to group the 31 variables in 13 representative factors according to the stages of the project. The reduction from 72 variables to 13 factors should make risk analysis a more feasible proposition.

The application of stepwise regression demonstrated an absence of any strong links between the factors affecting delay at the different stages of the project. It had been speculated that there could be strong links among delay factors in different stages throughout the construction process thereby limiting the application of simulation in a risk analysis model of the project programme. The stepwise regression shows rather weak links and it is concluded that the application of a standard critical path package with simulation of activity duration's is appropriate for the risk analysis model in a practical RMP for high-rise construction projects in Bangladesh.

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