PERGAMON

International Journal of Project Management 20 (2002) 23–35

INTERNATIONAL JOURNAL OF PROJECT MANAGEMENT

www.elsevier.com/locate/ijproman

Compressing construction durations: lessons learned from Hong Kong building projects

Daniel W.M. Chan *, Mohan M. Kumaraswamy

Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Abstract

This paper explores explanations for possible causative patterns and suggestions for strategies to compress the construction durations of various types of building projects, on the basis of the lessons learned from recent Hong Kong-based surveys and research findings. A review of the literature from different countries is first provided — on the factors affecting construction durations, reasons for project delays and existing statistical models for duration forecasts. This is followed by the presentation of a regression-based model — developed from Hong Kong public housing construction project data — for predicting the durations of the primary work packages in the building process and the overall completion period. Finally, the principal survey results of three parallel investigations which sought out the critical contributors to faster construction in Hong Kong within each of three different building sub-sectors — public housing, public non-residential buildings and private sector buildings — are presented and discussed. Both similarities and differences are noted among the many perceived important contributory factors and factor categories, across the various types of industry practitioners, i.e. clients, consultants and contractors. Based on the factors identified as significant from the above recent research findings, specific technological and managerial strategies for reducing construction periods (increasing construction speed) in particular building sub-sectors are formulated in order to improve the construction time performance of local building projects. The research methodology developed for the reported investigations can well be extended to similar studies in other sub-sectors in Hong Kong, as well as in other countries for international comparisons — so as to expand our existing body of knowledge of the critical success factors in compressing the building construction process.

Keywords: Construction durations; Project delays; Prediction models; Faster construction; Hong Kong

1. Introduction

It is almost axiomatic of construction management that a project may be regarded as 'successful' if the building is completed on time, within budget, without any accidents, to the specified quality standards and overall client satisfaction. Realistic 'construction time' is now increasingly important because it often serves as a crucial benchmark for assessing the performance of a project and the efficiency of the project organization.

A review of the literature has established that poor performance of projects in terms of time overruns over the last three decades is commonplace in the construction industry. For example, there was an announced 50–80% delays on 1627 World Bank sponsored projects between 1974 and 1988, together with an average of 23.2% time overrun on UK Government construction projects from 1993 to 1994 [1], while average time overruns on samples of public building projects, private building projects and civil engineering works, which were studied in 1994 in Hong Kong, were found to be 9, 17 and 14%, respectively [2] 'Construction time performance' may be argued to be critical in most Hong Kong projects, also given that Hong Kong has itself acquired a reputation for remarkable speeds of construction [3].

Project delays can lead to cost overruns as well, for example through additional overheads and potential claims between client and contractor. But many national construction industries or representative organizations have set themselves targets for the purposes of measuring and improving the current levels of construction time performance on different categories of projects. This would assist particularly in reducing durations for construction on a realistic basis, that also does not adversely impact on other priorities. For instance, the US Construction Industry Institute established goals

* Corresponding author. Tel.: +852-9300-3340; fax: +852-2559-5337

E-mail address: danielchan@graduate.hku.hk (D.W.M. Chan).

0263-7863/01/$20.00
PII: S0263-7863(00)00032-6

to improve project costs and schedules by 20% between 1990 and 2000 [4]; while Sidwell's investigations reported the targeted potential time savings of 25–40% in Australia by reducing non-value-added activities in the building process [5].

With the intention of enhancing construction time performance of projects, it is important to identify the significant factors that affect construction durations and contribute to delays. It was decided at the outset to shift the focus from exploring the negative scenarios (factors responsible for delays) to extracting the more positive aspects from the faster projects, i.e. factors facilitating faster construction, and hence to formulating some possible strategies for reducing construction periods for various types of buildings. The positive factors and consequential recommended strategies were then sought through a PhD research programme, three BEng final year projects completed in June 1998 and a university funded research project in Hong Kong. The outcomes from these research studies are found to be useful in measuring and suggesting improvements to the present levels of 'construction time performance' in building projects, with particular attention to practical measures for shortening the completion time of public housing blocks, so as to meet the accelerated programme to produce an average annual output of 85,000 new units in the next few years up to 2001 [6]. A strong potential is noted for extending the reported research strategy and methodological approach to other categories of construction projects in Hong Kong, as well as in other countries.

2. Literature review of construction time performance

Studies in various countries appear to have contributed significantly to the body of knowledge relating to construction time performance and delays in construction projects over the past three decades.

3. Factors that affect construction durations

The mid-1990s in Hong Kong has seen another construction boom due to the accelerated residential demand from both public and private sectors, and the ten New Airport Core Programme (ACP) projects including the new modernized airport construction at Chek Lap Kok and the related infrastructure developments. It is widely accepted that construction time performance has been regarded as one of three critical success factors (together with cost and quality) for a construction project [7,8].

A review of the literature suggests that the construction duration of a project is affected by a vast number of factors and to varying extents. Nkado found an absence of consensus in the literature on the identification of factors which influence planned or actual construction times [7]. However, it was proposed in a recent PhD research exercise [9] that these time-influencing factors in Hong Kong can be classified into the following four major factor categories, as for example also identified in other countries [10,11]:

a. Project-scope;
b. Project complexity;
c. Project environment; and
d. Management-related attributes.

The above four factor categories were explored in association with their constituent causal factors, to gain a sound understanding of their significance with regard to project construction times [9]. Fig. 1 has been developed to show the four categories and their principal associated factors that could influence construction project durations.

4. Factors causing delays in construction projects

Factors responsible for project delays can be regarded as adverse manifestations of general factors that affect construction durations. Conversely, a study of the delay factors could help identify many of the significant factors influencing project durations as well. Table 1 is developed to present a consolidated comparison of the findings from the present literature review — on the reasons for delays in construction projects across different countries. It provides an interesting overview of commonly recurring factors that may be explored further.

5. Previous statistical models for duration estimates

There is an increasing need for more reliable front-end predictions of construction durations at the planning and even the tender preparation stages, for example, for incorporating a realistic duration in the tender package. Such duration estimates are needed even before designs are complete and/or before detailed programmes can be prepared.

A number of statistical models were previously developed for predicting the duration of a construction project: for instance in Australia [10,23]; in UK [24,25]; as well as in Hong Kong [26,27]. While all of these models were based on the use of project-scope factors as the primary variable(s), for example measured in terms of construction cost, gross floor area and/or project complexity levels, some models also incorporated management attributes, e.g. effectiveness of communications and speed of decision-making among contracting parties. Table 2 is developed to provide a consolidated summary

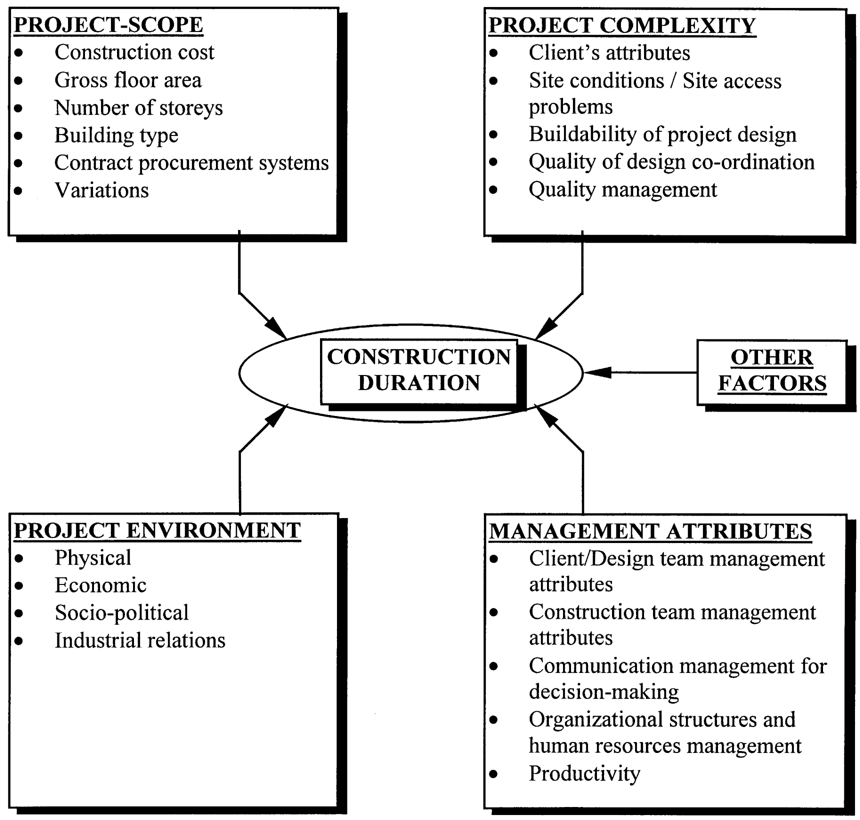

Fig. 1. Summary of principal factors affecting construction durations of projects (source: [9]).

Table 1
A cross-section of related observations on the major factors causing delays in construction projects[a]

Factors causing project delays	Country where survey was conducted and investigator(s)										
	US [12]	UK [13]	Developing countries [14]	Turkey [15]	UK [16]	Nigeria [17]	UK [18]	Nigeria [19]	Saudi Arabia [20]	Hong Kong [21]	Indonesia [22]
Inclement weather	*	*			*						
Labour shortage/low labour productivity	*			*					*		*
Poor subcontractors' performance/high degree of subcontracting	*	*			*				*		
Variations (design changes/extra work)		*		*	*				*	*	*
Unforeseen ground conditions		*			*					*	
Materials shortage/late materials delivery		*		*	*	*		*			*
Inadequate construction planning			*	*							*
Financial difficulties				*		*		*	*		
Delays in design work/lack of design information				*	*						
Poor site management					*	*		*	*	*	
Impractical design					*						
Poor communication					*					*	
Inappropriate type of contract used							*				
Lack of designer's experience							*				
Inaccurate estimating								*	*		*

[a] Source: Ref. [9].

Table 2
Summary of existing statistical models used to predict construction durations of projects[a]

Proposer(s)	Type of project surveyed	Country of project surveyed	Sample size	Type of model relationship	R^2-value	Significance level	Main parameters included in model			
							Project scope	Project complexity	Project environment	Management attributes
[23]	Building	Australia	329	Log linear	–	–	*			
[28]	Commercial	Australia	25	Log linear	0.576	0.001	*			
				Linear	0.73	–	*	*		*
[29]	• Building	UK	661	Log linear	0.61,0.68	–	*			
	• Roadworks	UK	140	Log linear	0.97	–	*			
[24]	Commercial	UK	29	Linear	0.79	0.00	*	*		
[10]	Non-residential, non-civil	Australia	33	Log linear	0.9987	–	*	*		*
[30]	Building	Australia	87	Log linear	–	0.00	*			
		Malaysia	51	Log linear	–	0.00	*			
[11]	Building	UK	15	Log linear	0.99731	–	*	*		*
[26]	• Public building	Hong Kong	37	Log linear	0.6561	–	*			
	• Private building	Hong Kong	36	Log linear	0.4761	–	*			
	• Civil works	Hong Kong	38	Log linear	0.64	–	*			
[27]	Building	Hong Kong	110	Log linear	0.84972	0.00000	*			
[25]	Housing	UK	54	Log linear	0.927 (adjusted)	–	*	*		
[31]	Building	UK	17	Log linear	0.99994	–	*	*	*	*

[a] Source: Ref. [9].

of these previously proposed statistical models for forecasting the construction durations of projects. This summary facilitates convenient comparisons of the various model attributes.

6. Construction time prediction models for Hong Kong public housing blocks

Chan and Kumaraswamy reported the detailed results of a recent research study which aimed at formulating benchmark measures (industry norms) for overall construction period for the different standard types of public housing blocks (e.g. the 'Harmony' Series of housing blocks) in Hong Kong [32]. A set of regression-based models were derived from a sample of 71 case studies of standard type housing blocks, by modelling the durations of the primary work packages in the building construction process and their respective sequential start-start lag times. The primary work packages were classified as piling, pile caps/raft, superstructure, E&M (electrical and mechanical) services and finishes. These models were developed by 'regressing' against a postulated group of 84 potentially significant variables — comprising both qualitative and quantitative items of project data [9].

A total of 11 regression model equations were derived to model (a) durations of each of the five primary work packages; (b) durations of each of the four sequential start-start lag times between such work packages; (c) planned overall construction duration; and (d) actual overall construction duration; in respect of each of the three types of standard blocks: (i) 'Harmony Type 1' blocks; (ii) 'All Harmony Type' blocks; and (iii) 'New Cruciform Type' blocks.

Independent variables that eventually emerged as significant in the 33 regression model equations were not very surprising in general; but the exercise was also found to be useful in identifying the relatively less significant variables. While the significance of the former can be rationalized, an appreciation of their relative strengths (in terms of their influence on the corresponding dependent variables) is another useful product of the exercise. The relative strengths of the influences of the different independent variables were specifically reflected in the respective coefficients in the regression equations. It was also evident from the regression results that start-start lag times between consecutive work packages were found to be related to preceding and/or subsequent work packages, along with other (previous) lag times [32].

Fig. 2 illustrates the significant variables identified (from these regression exercises) as influencing the (a) planned overall duration; (b) actual overall duration; and (c) duration of superstructure as an example of primary work packages, for the grouping of 'All Harmony Type' housing blocks in Hong Kong. The quantitative variables in the model equations were mainly project-scope factors such as construction cost and gross floor area; while the qualitative variables were primarily non-project-scope factors, i.e. management-related or people-oriented variables, for example, speed of decision-making and information flow among project participants.

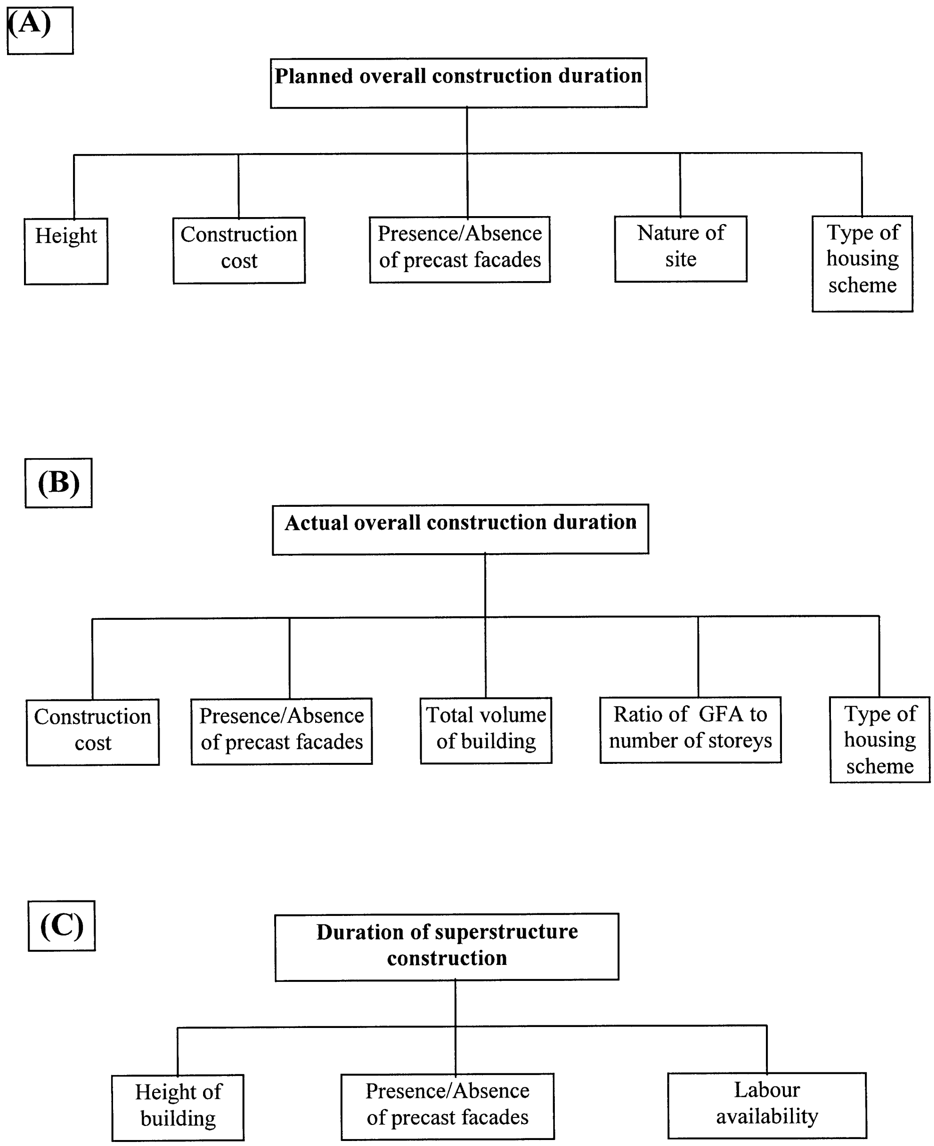

Fig. 2. Significant variables identified as influencing the following durations of standard Harmony housing blocks in Hong Kong: (A) planned overall construction duration; (B) actual overall construction duration; and (C) duration of superstructure.

The following is an example of the model equation derived for the 'Superstructure' duration for 'All Harmony Type' housing blocks (time unit: months):

SUPERSTR $= 4.0511 + 0.1316 \times$ height of building $+$
precast facade (0 for with facades;
1.6216 for without facades) $+$
labour availability (-0.8319 for readily available;
0 for somewhat difficult)

It is evident that some of the regression model equations derived in this research study for various standard types of public housing blocks in Hong Kong, contain regressor variables which are closely related to the effectiveness of communications and speed of decision-making among contracting parties, e.g.:

1. speeds of decision-making involving all project teams, within client's team, within consultant's team, and within contractor's team; and
2. information flows between client and consultant.

These kinds of 'communication management' variables are seen to have a significant influence upon the durations of the primary work packages and the whole project. The forecasting performance of the three sets of prediction models was tested by comparing the predicted values of work package durations and their lag times derived from the regression model equations, with the observed (actual) values in an independent (new) set of 'test' projects. It was concluded that the model predictions fell within a reasonable range of the estimates of construction planners; and the models can thus be applied to the overall time predictions in the public housing industry in Hong Kong for future projects with a reasonable degree of reliability (percentage error to within about ±10%).

It was also decided to present the above research findings on these significant variables to 10 senior industry practitioners in order to test their validity and applicability. The findings from the regression models that were in turn derived from the 71 case studies were later submitted to and endorsed as realistic by these experienced practitioners. It was then agreed that they could form the basis of effective 'managerial' strategies to reduce construction durations.

Having elicited the critical factors (significant variables) that affect construction durations of public housing projects, it was considered worthwhile to launch specific studies into the important contributors to faster construction in other building sub-sectors in Hong Kong. The factors that emerged as significant (in determining construction durations from the three sets of public housing model equations) were compared with the outcomes of the three parallel subsequent sub-sector surveys that are described in the following sections of this paper.

7. Three building sub-sector studies in Hong Kong

7.1. General data collection methodology

Opinion surveys supplemented by site visits and preliminary interviews of industry experts were carried out in three independent (parallel) BEng final year projects from late 1997 to early 1998, with the aim of identifying the principal factors facilitating faster construction in specific building sub-sectors in Hong Kong. The primary thrust of these surveys was to compile and compare the collective experience-based perceptions of different industry practitioners, i.e. clients, consultants and contractors, as to the factors that assist in speeding up the construction process of building projects. Such a distillation of factors contributing to faster construction was hoped to suggest possible strategies which would substantially improve construction time performance of future projects.

The experience-based judgements of the various types of industry practitioners were mainly sought through structured questionnaire surveys and formal follow-up interviews. Three sets of questionnaires were designed for the different sub-sectors in late 1997:

a. Public housing;
b. Public non-residential buildings; and
c. Private sector buildings.

They were formulated on the basis of international literature reviews, a series of site visits and semi-structured interviews with local building clients, design consultants (architect/engineer) and building contractors, to determine potentially relevant 'factors' (and 'factor categories') within their respective sub-sectors; followed by questionnaire surveys to seek individual perceptions of practitioners regarding the relative importance of such 'factors' (and 'factor categories'). Table 3 compares the basic profiles of the three parallel investigations. It may be noted that the factors and factor categories in each of the sub-sectors were deliberately not standardized. While standardization would have facilitated convenient comparisons, it was felt that this would restrict/distort the free flow of observations from each sub-sector. Thus the project supervisor (one of the authors of this paper) encouraged each of the field researchers to draw out and categorize the factors within each of the three sub-sectors, as they became evident through the above approaches (rather than 'force-fitting' into pre-conceived semantics and categorization).

Detailed presentations of the research methodology, further breakdowns, the precautions taken and the validations undertaken cannot be easily accommodated in the limited length of this paper. Nevertheless, the smaller sample sizes in two of the building sub-sectors (i.e. public non-residential and private sector) render the corresponding observations more indicative, rather than conclusive. But they are still useful for comparison purposes across different sub-sectors.

To elicit the extent of the effect of each of the factors on faster construction, the survey respondents were asked to choose an appropriate influence rating against the specified scale, for each of the postulated factors. A rating scale of 1 to 5 was adopted for each of the three parallel building sub-sector surveys because of its simplicity and suitability for evaluating and comparing the effect of each factor, based on the respondents' own experiential judgements. The following was the semantic/numerical equivalence scale, as formulated to standardize and compare the respondents' ratings:

- Extremely significant (E.S.) 5
- Very significant (V.S.) 4
- Moderately significant (M.S.) 3
- Slightly significant (S.S.) 2
- Not significant (N.S.) 1

In addition to the postulated (suggested) factors in each sub-sector, the respondents were also encouraged to cite any additional factors that they thought were likely to shorten the construction periods of building projects in that sub-sector in Hong Kong.

7.2. General data analysis methodology

Ratings made against the five-point scale described previously were combined and converted into relative importance indices for each factor, adopting the 'relative

Table 3
General descriptions of the three parallel building sub-sector investigations in Hong Kong

Building sub-sector	Questionnaires			Factors	Factor categories
	Distributed	Returned	Response rate (%)		
Public housing	93	38	41	96	11
Public non-residential	84	18	21	85	12
Private sector	164	22	13	78	8

importance index' ranking technique, as for example used by Shash [33] and Kometa et al. [34]. This determined the relative ranking of the different factors by comparing the individual relative importance indices for different factors in descending order of significance. These rankings also made it possible to cross-compare the relative importance of the factors as advocated by the three different groups of respondents (i.e. clients, consultants and contractors). The individual numerical ratings of each of the identified factors were transformed to relative importance indices to assess the relative ranking of the factors, by using the following formula:

$$\mathrm{RII} = \frac{\sum r}{A \times N}, (0 \leqslant \mathrm{RII} \leqslant 1)$$

where

RII = relative importance index;
r = rating given to each factor by the respondent; ranging from 1 to 5 where '1' is 'not significant' and '5' is 'extremely significant';
A = highest rating (i.e. 5 in this case);

and

N = total number of respondents responding to that factor.

It was next decided to test for the degree of agreement in the rankings (in respect of the individual 'factors', and the 'factor categories') between various groups of project participants. The 'rank agreement factor' method used by Okpala and Aniekwu was found to be useful in estimating the degree of agreement/disagreement between any two groups [17]. This reflects the average absolute difference in the rankings of the individual factors (or factor categories).

The RIIs of each of the pre-identified 'factor categories' (i.e. factors which had been grouped together into a category in each questionnaire of the studies) were taken as the 'arithmetic means' of the RIIs of all individual factors within the same category. These factor category RIIs were then used to rank the order of importance of the factor categories according to their perceived significance by various groups of industry experts.

8. Presentation and discussion of survey results

8.1. Public housing

Ninety-six factors, which were hypothesized to contribute to faster construction on public housing projects in Hong Kong, were categorized into 11 factor categories in this study [35]. The target groups consisted of the client organization (the Hong Kong Housing Authority, HKHA) and its registered building contractors.

Nineteen completed questionnaires were returned by the HKHA professional staff (architects/structural engineers) and another nineteen by project managers of the contractors, amounting to 38 valid responses to the survey. Relative importance indices (RIIs) were calculated for all factors and factor categories within each group. Tables 4 and 5 show the top five factors (out of a total of 96) and the top five factor categories (out of a total of 11) in terms of the values of their RIIs, across each group of respondents [35].

Fig. 3 shows the 'top two' factors found within each factor category, as derived from the HKHA and contractors' representative groups — as illustrated in a format of a causative-pattern-type fish-bone diagram. The preliminary findings from this sub-sector study were followed up by proposing some possible strategies for faster construction in these projects to the same group of survey respondents. Based on their subsequent feedback on these proposals (incorporated in a second questionnaire), the four most favoured measures were on:

- Managerial aspect — better selection procedures of project managers;
- Managerial aspect — improved training schemes of project architects;
- Contractual aspect — inclusion of foundation contract with superstructure contract; and
- Managerial aspect — improved training schemes of project managers

8.2. Public non-residential buildings

In spite of the lower standardization of building designs than in public housing, similarities in the contract administration matters relating to public non-residential buildings

Table 4
Perceived significant factors that contribute to faster construction in public housing projects

Rank	Client's staff	RIIs[a]	Contractors' staff	RIIs[a]
1	Adequate supply of workforce	0.947	Adequate supply of workforce	0.905
2	Appropriate labour deployment	0.937	Timely delivery of materials to site	0.895
3	Adequate contractor's experience	0.905	Favourable site conditions	0.884
4	Adequate skill/ experience of workforce	0.905	Adequate pre-construction planning	0.874
5	Identifying critical activities	0.874	Suitable leadership style of project manager	0.874

[a] RIIs, relative importance indices.

Table 5
Perceived significant factor categories that contribute to faster construction in public housing projects

Rank	Client's staff	RIIs[a]	Contractors' staff	RIIs[a]
1	Labour management	0.816	Organization and co-ordination between all project teams	0.800
2	Organization and co-ordination between all project teams	0.795	Project characteristics	0.780
3	Design aspects	0.792	External factors	0.775
4	Equipment management	0.784	Design aspects	0.773
5	Progress scheduling and control	0.756	Labour management	0.773

[a] RIIs, relative importance indices.

were expected to yield a greater homogeneity in causative patterns than in private sector buildings. A review of the literature, together with a series of site visits and preliminary interviews with professional staff from the Architectural Services Department who supervise many such government non-residential building projects (e.g. hospitals and schools), resulted in the identification of 85 hypothesized factors facilitating faster construction in such projects under 12 factor categories [36]. Unlike public housing, the sample size of this study was relatively small (18) and the responses were largely obtained from contractors (17 out of 18). The factors and factor categories with the highest significance are enumerated in Table 6.

Specific recommendations for reducing construction durations in this sub-sector (for example, arising from improved construction productivity and enhanced design buildability) are found in the report by Li [36]. Table 6 reveals that there are greater variations in building designs and project management procedures than in public housing. It is recommended that greater emphasis should be placed on both communications among the different groups of project participants and pre-construction planning.

8.3. Private sector buildings

The non-standard building designs and greater variabilities in construction management practices in the private sector, suggest a strong potential for a greater diversity in the significant factors facilitating faster construction in this sub-sector. Seventy-eight factors within eight factor categories were identified for further investigation in the survey questionnaire [37].

Of the 22 responses received, 13 were from consultants (architects/engineers) and nine from contractors. Tables 7 and 8 indicate the top five factors (out of a total of 78) and the top five factor categories (out of a total of eight) respectively, across the two groupings of respondents. The 'percentage agreement' between 'consultant' and 'contractor' groups, as to their rankings of factor categories was found to be 68.8%, while the average 'percentage agreement' on their rankings of factors within each category was 67.3%. These 'percentage agreements' were based on 'Rank Agreement Factors' computed according to the formulae described by Okpala and Aniekwu [17].

The significant factors that emerged in this sub-sector study also generated some important insights towards more expeditious construction in these projects through: (1) clearer client's project brief; (2) simplified and quicker approval procedure of design drawings and related documentations by the Buildings Department; and (3) earlier involvement of contractors in building designs [37].

9. Cross-comparisons among the three building sub-sectors

Interesting and useful observations were obtained from the factors perceived to contribute significantly to faster construction in the three parallel building sub-sector investigations, i.e. public housing, public non-residential

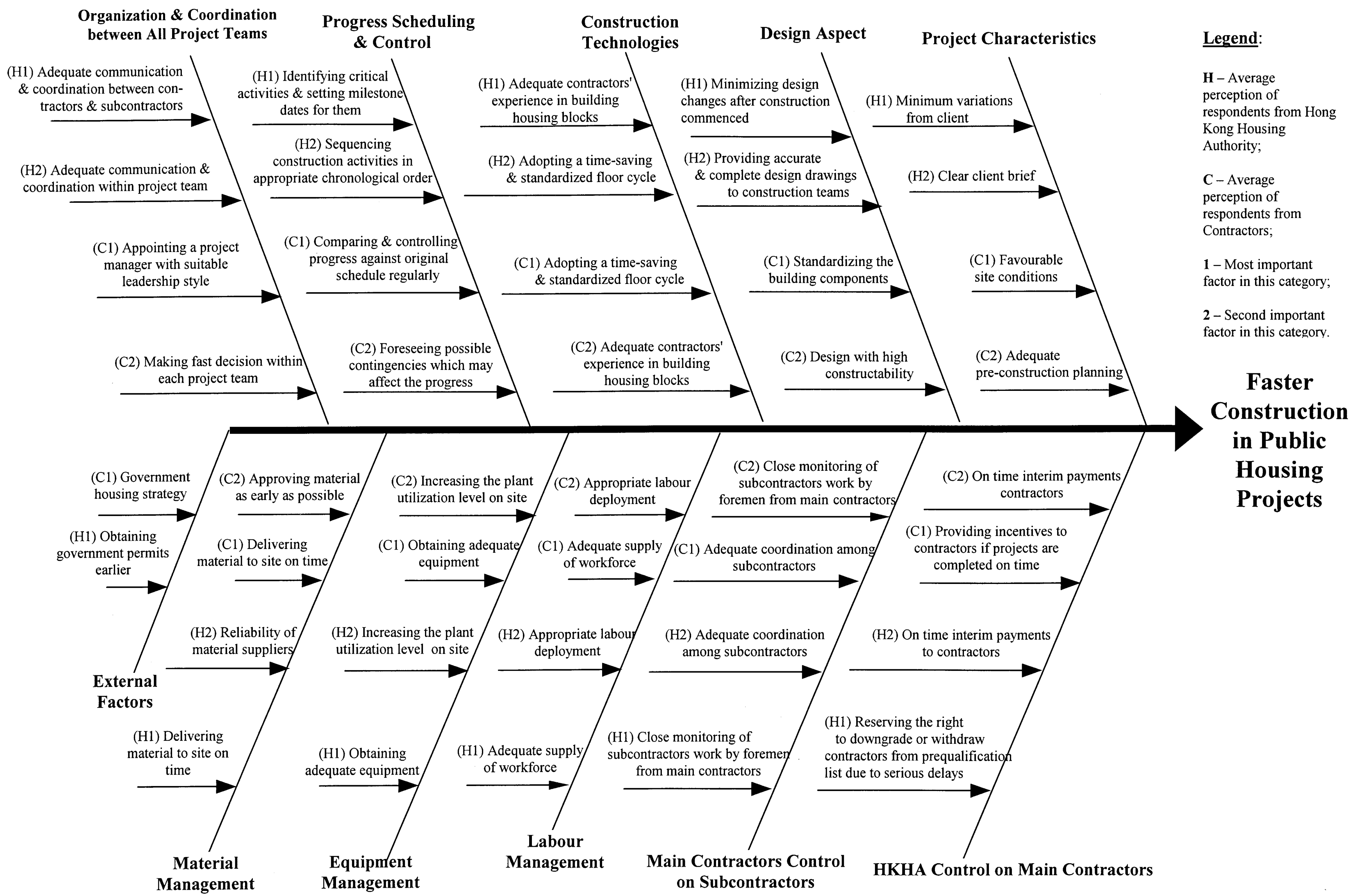

Fig. 3. Fish-bone diagram indicating the two most important factors contributing to faster construction in public housing projects as perceived in each factor category by each group of survey respondents (source: [35]).

Table 6
Perceived significant factors and factor categories contributing to faster construction in public non-residential building projects

Rank	Factors	RIIs[a]	Factor categories	RIIs[a]
1	Fast information flow	0.822	Communication	0.796
2	Encouraging teamworking	0.822	Quality	0.722
3	Minimizing mid-stream design changes	0.822	Pre-construction stage(Site planning)	0.716
4	Less conflict between consultant and contractor	0.811	Plant/equipment	0.700
5	Checking the actual progress regularly	0.811	Contractor-related factors	0.691

[a] RIIs, relative importance indices.

Table 7
Perceived significant factors facilitating faster construction in private sector building projects

Rank	Consultants' staff	RIIs[a]	Contractors' staff	RIIs[a]
1	Clear client's requirements	0.877	Well-experienced client	0.889
2	Adequate communication between consultant and contractor	0.877	Quick approval of design drawings	0.875
3	Adequate communication between client and consultant	0.862	Involvement of contractor in building design	0.875
4	Fast decision-making by client	0.862	Suitable client management staff	0.867
5	Appropriate selection of contractors	0.862	Adequate budget of client	0.867

[a] RIIs, relative importance indices.

Table 8
Perceived significant factor categories facilitating faster construction in private sector building projects

Rank	Consultants' staff	RIIs[a]	Contractors' staff	RIIs[a]
1	Organizational characteristics	0.789	Organizational characteristics	0.808
2	Human resources characteristics	0.724	Client characteristics	0.742
3	Client characteristics	0.715	Construction characteristics	0.720
4	Plant and material characteristics	0.700	Design characteristics	0.718
5	Construction characteristics	0.699	Plant and material characteristics	0.710

[a] RIIs, relative importance indices.

and private sector buildings. Further insights were next sought by comparisons of the findings across the sub-sectors. However, it was decided as unjustifiable to conduct direct quantitative comparisons by means of the relative importance indices (RIIs) across the sub-sectors due to the necessary differentiations in the questionnaire formats (e.g. any particular features/factors in one particular sub-sector may be initially considered more influential than in another sub-sector) and sample compositions (e.g. there was no target group of consultants in the case of public housing; while there was no target group of clients in the case of private sector buildings). Therefore, it was found that a qualitative comparison of perceived important factors led not only to some common insights which spanned across these sub-sectors, but also suggested specific priorities within the sub-sectors themselves.

For example, there were similarities between the significance of: (a) 'fast information flow' and 'encouraging teamworking' in public non-residential buildings; as well as 'communications among clients, consultants and contractors' in private sector buildings; and also 'communication-related factors' (e.g. speed of decision-making involving all project teams) in the standard 'Harmony' Series public housing blocks, as described in the previous section of this paper; and (b) the factor category 'organization and co-ordination between all project teams' in public housing; 'communication' in public non-residential buildings; and 'organization characteristics' in private sector buildings.

On the other hand, 'labour supply and management' and 'contractor's experience' were observed to be more important factors in the most standardized public housing sub-sector; factors such as 'minimizing mid-stream design changes' appeared to be significant in the procedurally standardized public non-residential sub-sector; while client characteristics such as 'experience' and 'clear requirements' were seen to be more critical in the usually non-standard private sector building projects.

10. Strategies for reducing construction durations

The present vast public housing programme in Hong Kong contains a planned average annual production rate of about 85,000 new flats in the next few years up to 2001. The recommended strategies for shortening the construction durations in public housing projects flowed primarily from the findings of the third phase of the principal author's PhD research programme, as previously described in this paper. The third phase aimed at seeking out the critical factors that affect the primary work package durations and overall project durations of public housing blocks in Hong Kong [9]. The proposed strategies are broadly categorized into 'technological' and 'managerial' approaches.

11. Technological strategies

The recommended strategies mainly focus on accelerating the cycle time for each typical floor across any type of standardized block design and hence reducing the duration for the 'superstructure' erection, which is the most critical activity in determining the overall project durations.

- Enhance the buildability of project design, by integrating early inputs of the contractor in the design phase;
- Encourage standardization, modularization and repetition in the design of building elements and construction details;
- Maximize the mechanization of the construction process;
- An efficient and simple construction sequence;
- Increase the number of tower cranes and the sets of large panel steel formwork used in a single project;
- Use hydraulic boom concrete pumps with a higher pump rate in casting all floor slab components;
- Adopt jack-up working platforms (e.g. climb-form and jump-form) which carry with them proprietary wall forms, thus saving the crane time for transporting the formwork around the site;
- Encourage more symmetrical block designs so that the contractors can adopt innovative construction methods/system formwork (e.g. using the Jump-form system in constructing the 'Concord' Block Series);
- Mandatory use of precast concrete facade panels and semi-precast concrete floor slabs in all public housing contracts, even if a project needs to erect only one single block;
- Install the precast façades by pre-installation, rather than post-installation (as compared to floor slab construction), in order to achieve a 4-day working cycle;
- Set up precast slab (plank) and façade casting yards with gantries, and concrete batching plants on-site or as near as possible, in preference to off-site or further away, to ensure a smooth and adequate supply of precast concrete components and ready mixed concrete within the normal working hours; and
- Increase the use of prefabrication of other building components, e.g. fabric reinforcement for all structural wall erections, for rapid fixing on-site (cf. [38]).

12. Managerial strategies

The suggested strategies are based on the 'communication management' variables identified as significant from the regression model equations, e.g. information flows and speeds of decision-making among contracting parties.

- Ensure continuous workflow for each critical resource such as tower crane, large panel formwork, pumped concrete and any other related resources e.g. site labourers to facilitate a 4-day working cycle;
- Improve the effectiveness of site management and supervision to ensure a co-ordinated workflow among all work trades. Close liaison among all contracting parties is essential;
- Seriously consider the appropriateness in each project scenario of alternative (innovative) procurement methods, e.g. fast-track, design-and-build and negotiated contracts, as well as a 'partnering' approach;
- Establish appropriate overall organizational structures and integrated information communication network systems across professional boundaries throughout the construction process;
- Clearly define the roles and responsibilities of each project participant;
- Increase the co-ordination of the design and construction teams at the design–construction interface;
- Clearly identify and mobilize the designated decision-makers;
- Provide decision aids for decision-makers, e.g. construction management decision support systems, perhaps incorporating expert systems and simulation models; and
- Provide training programmes and formal education for industry practitioners to better foster communication management skills through using integrated management information systems and advanced information processing technology for promoting faster information flows among the project team members.

13. Summary and conclusions

This paper explores the construction time performance of projects in three building sub-sectors, i.e. public housing, public non-residential and private sector. A review of the literature on the factors that affect construction durations and the causes of project delays, together with existing regression-based models for duration estimates derived in different countries, provide a sound background, and also a basis for launching specific investigations in Hong Kong. The investigations consisted of a research programme on "modelling the construction durations for public housing projects" and three parallel building sub-sector studies which singled out the potent factors contributing to faster construction across different types of buildings. After the former research exercise identified the significant factors influencing construction durations of public housing projects, it was considered useful to undertake further studies into the contributors to faster construction across other building sub-sectors as well. Similarities and differences are observed among the many perceived important factors and factor categories by the different groups of industry practitioners, i.e. clients, consultants and contractors, as summarized in the derived tables and figures presented in this paper.

On the basis of the factors emerging as significant in the studies reported in this paper, specific technological and managerial strategies for reducing construction periods (increasing the speed of construction) in particular building sub-sectors are proposed, in order to upgrade the construction time performance of local building projects. The outcomes from the original research exercise (on modelling public housing construction durations) and the three subsequent parallel sub-sector surveys led to a 'common' conclusion that effective communications and fast information transfer between project participants are crucial 'soft' prerequisites that help to accelerate the building construction process. However, even within this general conclusion, specific needs were noted as meriting attention in particular sub-sectors, for example, the better selection and training of project managers for public sector housing; and the need for faster approaches in private sector buildings.

It should also be noted that the construction time prediction models developed for the Hong Kong public housing industry provide only first-order approximations of duration estimates for the purposes of planning and tender document preparation. Detailed construction programmes need to be prepared and analyzed using advanced/available programming computer softwares such as Primavera Project Planner 2.0 and Microsoft Project 98.

The research methodology described in the present investigations can well be extended to similar studies in other construction sub-sectors in Hong Kong, and also in other countries for international comparisons — to add to the existing body of knowledge regarding the important ingredients for basing realistic construction schedules and facilitating faster construction.

Acknowledgements

The authors wish to acknowledge the contributions of The University of Hong Kong BEng final year undergraduates, Mr. Alan Wong Hok Ming, Mr. Alan Li Yick Kiu and Mr. Raymond Lee Lap Man, who assisted in conducting the three parallel building sub-sector studies in 1997/1998. Support from The University of Hong Kong Committee on Research and Conference Grants (CRCG) via Grant No. 337-061-0015 is also gratefully acknowledged, in that it has enabled the continuation and further focusing of this research and the dissemination of these results.

References

[1] Bordoli DW, Baldwin AN. A methodology for assessing construction project delays. Construction Management and Economics 1998;16:327–37.
[2] Kumaraswamy MM, Chan DWM. Contributors to construction delays. Construction Management and Economics 1998;16:17–29.
[3] Kumaraswamy MM, Chan DWM. Determinants of construction duration. Construction Management and Economics 1995;13:209–17.
[4] Tucker RL Re-engineering the project delivery process. In: Proceedings of the First International Conference on Construction Industry Development: Building the Future Together, vol. 1, 9–11 December 1997, Singapore. p. 63–8.
[5] Sidwell AC. Effective procurement of capital projects in Australia. In: Proceedings of the First International Conference on Construction Industry Development: Building the Future Together, vol. 1, 9–11 December 1997, Singapore. p. 38–62.
[6] HKHA. Hong Kong Housing Authority Annual Report 1996/97. Hong Kong: Hong Kong Housing Authority (HKHA).
[7] Nkado RN. Construction time-influencing factors: the contractor's perspective. Construction Management and Economics 1995;13:81–9.
[8] Walker DHT. An investigation into construction time performance. Construction Management and Economics 1995;13:263–74.
[9] Chan DWM. Modelling construction durations for public housing projects in Hong Kong. PhD thesis, The University of Hong Kong, Hong Kong, 1998.
[10] Walker DHT. An investigation into factors that determine building construction time performance. PhD thesis, Royal Melbourne Institute of Technology, Australia, 1994.
[11] Blyth SM. An investigation into the development of a benchmark for UK construction time performance. MSc thesis, University of Glamorgan, UK, 1995.
[12] Baldwin, J.R., Manthei, J.M., Rothbart, H. and Harris, R.B. Causes of delay in the construction industry. Journal of Construction Division, ASCE, 97, (1971), 177–87.
[13] NEDO. Faster building for industry. Millbank, London, (UK): National Economic Development Office (NEDO), 1983.

[14] Chalabi FA, Camp D. Causes of delays and overruns of construction projects in developing countries Proceedings of the Fourth International Symposium on Organization and Management of Construction: Developing Countries, vol. 3, October 1984, Waterloo, Canada. p. 723–34.
[15] Arditi D, Akan GT, Gurdamar S. Reasons for delays in public projects in Turkey. Construction Management and Economics 1985;3:171–81.
[16] NEDO. Faster building for commerce. Millbank, London (UK): National Economic Development Office (NEDO), 1988.
[17] Okpala DC, Aniekwu AN. Causes of high costs of construction in Nigeria. Journal of Construction Engineering and Management, ASCE 1988;114:233–44.
[18] Naoum SG. Procurement and project performance — a comparison of management contracting and traditional contracting (Occasional paper no. 45). Ascot, UK: The Chartered Institute of Building, 1991.
[19] Mansfield NR, Ugwu OO, Doran T. Causes of delay and cost overruns in Nigerian construction projects. International Journal of Project Management 1994;12:254–60.
[20] Assaf SA, Al-Khalil M, Al-Hazmi M. Causes of delay in large building construction projects. Journal of Management in Engineering, ASCE 1995;11:45–50.
[21] Chan DWM, Kumaraswamy MM. A comparative study of causes of time overruns in Hong Kong construction projects. International Journal of Project Management 1997;15:55–63.
[22] Kaming PF, Olomolaiye PO, Holt GD, Harris FC. Factors influencing construction time and cost overruns on high-rise projects in Indonesia. Construction Management and Economics 1997;15:83–94.
[23] Bromilow FJ, Hinds MF, Moody NF. AIQS survey of building contract time performance. The Building Economist 1980;19:79–82.
[24] Nkado RN. Construction time information system for the building industry. Construction Management and Economics 1992;10:489–509.
[25] Khosrowshahi F, Kaka AP. Estimation of project total cost and duration for housing projects in the UK. Building and Environment 1996;31:373–83.
[26] Chan DWM, Kumaraswamy MM. A study of the factors affecting construction durations in Hong Kong. Construction Management and Economics 1995;13:319–33.
[27] Chan APC. Determinants of project success in the construction industry of Hong Kong. PhD thesis, University of South Australia, Australia, 1996.
[28] Ireland V. The role of managerial actions in the cost, time and quality performance of high-rise commercial building projects. Construction Management and Economics 1985;3:59–87.
[29] Kaka AP, Price ADF. Relationship between value and duration of construction projects. Construction Management and Economics 1991;9:383–400.
[30] Yeong CM. Time and cost performance of building contracts in Australia and Malaysia. MSc thesis, University of South Australia, Australia, 1994.
[31] MacKenzie J. The influence of a benchmarking system for construction time performance of contracts in South Wales. MSc thesis, University of Glamorgan, UK, 1996.
[32] Chan DWM, Kumaraswamy MM. Modelling and predicting construction durations in Hong Kong public housing. Construction Management and Economics 1999;17:351–62.
[33] Shash AA. Factors considered in tendering decisions by top UK contractors. Construction Management and Economics 1993;11:111–8.
[34] Kometa ST, Olomolaiye PO, Harris FC. Attributes of UK construction clients influencing project consultants' performance. Construction Management and Economics 1994;12:433–43.
[35] Wong AHM. Faster construction in public housing projects BEng final year project dissertation, The University of Hong Kong, Hong Kong, 1998.
[36] Li AYK. Faster construction in government non-residential building projects BEng final year project dissertation, The University of Hong Kong, Hong Kong, 1998.
[37] Lee RLM. Faster construction in private building projects BEng final year project dissertation, The University of Hong Kong, Hong Kong, 1998.
[38] Salim M, Bernold LE. Effects of design-integrated process planning on productivity in rebar placement. Journal of Construction Engineering and Management, ASCE 1994;120:720–38.