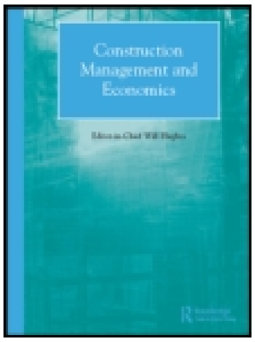

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Modelling building durations in Hong Kong

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The duration of Australian construction has been modelled by a time–cost formula expressed in the form of $T = KC^B$, where T is the actual construction time in working days, C is the final cost of contract in millions, K is a constant characteristic of building time performance, and B is a constant indicative of the sensitivity of time performance to cost level. This paper applies the relationship to building projects in Hong Kong using time and cost data from 110 projects. Regression analysis was used to compute the values of K and B and check how well the model actually fits, and the best predictor of average construction time of building projects in Hong Kong is found to be $T = 152C^{0.29}$. It is also found that the Hong Kong private sector takes a shorter time (120 days) to complete a hypothesized project with a contract sum of HK$1 million (at December 1994 price) than its government counterpart (166 days). The time–cost relationship serves as a convenient tool for both project managers and clients for predicting the actual optimum time required for delivery of a building project.

Keywords: Time cost relationship, regression model, building projects, Hong Kong

Introduction

Hong Kong has developed into the undisputed commercial centre of Southeast Asia, the world's fastest growing economic region (Chan, 1991a). The relative importance of various economic sectors can be assessed in terms of their contributions to the gross domestic product and to total employment (Lek, 1990). Table 1 shows the GDP at current factor cost by economic activity (Rowlinson and Walker, 1995).

The property and construction sector plays a significant role in the Hong Kong economy. Its contribution to the GDP has averaged over 24% since 1980. It is the second largest sector, exceeded only by the conglomerate sector (wholesale, retail, import/export trades, restaurants and hotels) a reflection of its true significance.

Attempts to predict construction durations represent a problem of continual concern and interest to both researchers and project managers (Bromilow and Henderson, 1976; Bromilow *et al.*, 1980; Ireland, 1983, 1985, 1986; Sidwell, 1984; Walker, 1990; 1994a,b,c,d, 1995, 1996; Nkado, 1992, 1995; Chan and Kumaraswamy, 1995; Kumaraswamy and Chan, 1995). Given the significant impact of the property and construction sector on the Hong Kong economy, this paper attempts to establish a time–cost relationship based on 110 building projects in Hong Kong. The unique characteristics of the industry in the local context will be reviewed, and the time–cost formula ($T = KC^B$) developed by Bromilow (1974) will be used as a basis to verify whether such a relationship holds in the Hong Kong building industry.

Characteristics of the construction industry in Hong Kong

There is hardly any country in the world that is comparable with Hong Kong in terms of population, land area, stage of economic and political development and emphasis on construction and real estate development (Walker and Flanagan, 1991). Lam (1990), Rowlinson and Walker (1995), and Ganesan *et al.* (1996), identified the following unique characteristics of the construction industry in Hong Kong.

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Table 1 Contribution to GDP by re-ordered economic sectors[a]

Economic sectors	Contribution to GDP
Wholesale, retail and import/export trades, restaurants and hotels	24.0%
Property and construction	23.5%
Community, social and personal services	14.6%
Manufacturing	14.3%
Financing, insurance and business services	13.6%
Others	10.0%

[a]Source: *The Construction Industry in Hong Kong*, Rowlinson and Walker (1995), p.14.

High rise construction

Due to the scarcity of land, many buildings in Hong Kong are high rise, constructed of reinforced concrete or steel frames. Buildings are designed to the maximum possible extent to make utmost gain from the expensive floor area, with the result that most construction sites are congested (Chan, 1991b). Efficiency of internal traffic is of paramount importance. Therefore high speed lifts and escalators are common features of any compatible office and residential tower blocks, which house other sophisticated building services equipment. The latter point is worth mentioning because in today's pricing, building services can account for 50% of the building cost.

Labour intensive construction methods

Despite the increasingly complex building requirements, the majority of the construction workforce is still using traditional labour skills. The large number of small and medium contractors are used to traditional styles of management with centralized decision making. Procurement of construction plant and equipment is often hindered by the lack of capital and further by the lack of space for storage after use. However, plant hire is available. Some large contractors are taking initiatives in mechanized methods of construction, such as slip form. This is further enhanced by government leadership in enabling the use of mechanized construction methods in public housing, such as the new Harmony Block Series, through improved standardization of design (e.g. the use of large panel steel formwork and precast concrete facade elements).

Labour shortage

During the last decade Hong Kong has experienced several demographic and other changes (Standard Chartered Bank, 1993). The growth rate of Hong Kong's labour force has fallen steeply in the last few years, from an annual average rate of 1.8% during the period 1982–1987 to 0.5% during 1988–1992. Labour supply primarily reflects the rate of population growth, the labour force participation rate and migration balance (Ganesan *et al.*, 1996). Based upon current population projections and labour participation trends, it is projected that the labour force is estimated to increase by 1% per annum during the next five years (Standard Chartered Bank, 1993). This is inadequate in comparison with the projected future labour requirements, particularly as the working population will continue to age. One implication for the labour market is that there will be a diminishing supply of young people with higher educational qualifications. At the same time, demand from the service sector continues to increase as Hong Kong's economy restructures and integrates itself more fully with PRC's economy. Labour shortage will continue to be a problem, at least in the immediate future, underscoring the definite need to improve the productivity of Hong Kong's labour force.

Procurement method

The procurement method used in Hong Kong is still very traditional (Tam, 1992). The use of selective tendering dominates the market. There have been only a few records of management contracting or design and build contracts, and they were normally confined to the very large projects (Rowlinson *et al.*, 1993).

Lack of research and development in construction

There is negligible expenditure on research and development (R&D) related to the industry. Inquiries with the Census and Statistics Department revealed that there are no measures of R&D activity. A few research programmes are currently running in the academic institutions. There is little or no coordination between various institutions or between departments, and much of the direction comes from individual inclinations or interest. Data on individual projects and amounts of expenditure show a total around HK$10 million per annum, which amounts to approximately 0.02% of the annual gross output. Compared with the typical R&D expenditure of 1% of the annual turnover in most Japanese large contractors (Overseas Construction Association of Japan, 1989), this is insignificant.

Foreign competition

One of the features of the Hong Kong construction industry is that it remains open to overseas contractors.

Table 2 Number of approved contractors on government lists[a,b]

	1992				1993			
	List 1			List 2	List 1			List 2
Works category	A	B	C		A	B	C	
Building works	21	21	37	15	21	19	38	14
	(57)	(32)	(38)	(22)	(54)	(35)	(19)	(22)
Port works	0	2	12	24	0	3	14	20
	(0)	(13)	(2)	(24)	(0)	(12)	(1)	(23)
Road and drainage	14	9	28	23	14	12	29	20
	(29)	(13)	(7)	(21)	(26)	(12)	(8)	(25)
Site formation	0	9	14	22	0	7	15	21
	(0)	(38)	(4)	(19)	(0)	(36)	(7)	(21)
Water works	8	3	15	15	7	3	17	12
	(12)	(6)	(2)	(18)	(14)	(6)	(2)	(22)

[a]Figures in parentheses represent contractors on probation.
[b]Source: number of approved contractors on government list, compiled from Hong Kong Government Gazettes.

This has in the past led to fierce competition between local and overseas contractors, particularly in the years 1984–86, which gave rise to a certain amount of friction as the overseas counterparts gradually gained a greater share of the market. Table 2, from the *Construction Handbook 1993/1994* (CIB, 1993/1994) shows the recent trend in the distribution of contractors in the public works sector.

Managerial ideology of the Hong Kong Chinese

Chinese culture has a major influence on the management style adopted by the Hong Kong project managers. The Hong Kong Chinese have been described as basically loyal, hard working, pragmatic and preferring a directive leadership style (Evans *et al.*, 1982; Redding and Tam, 1985; Wong, 1986). However, under the influence of Western culture and a high level of industrialization which tends to generate more 'organic' organizations (Chan, 1995), a participative leadership style is emerging. Kerr *et al.* (1986) stated that as a society develops its management style will inevitably converge towards the democratic style adopted in the developed Western countries. The traditional cultural characteristics, as influenced by Western culture, together with the level of industrialization, have moulded a managerial ideology specific to the Hong Kong Chinese. Research by Rowlinson *et al.* (1993) indicated that project leaders in the Hong Kong construction industry tend to use a supportive style in the feasibility study and pre-contract stages of works. As far as site staff are concerned, the participative and directive styles are common leadership styles in the Hong Kong construction projects, while the supportive and the achievement-oriented styles are secondary styles.

Modelling construction time

Having reviewed the characteristics of the construction industry in Hong Kong, the requirement is to establish a time–cost relationship for its building projects. Various construction time models and their applications will be discussed.

Bromilow (1974)

Bromilow (1974), from a survey of 370 Australian building projects, developed a model which predicts construction time in the form of the formula:

$$T = KC^{B} \quad (1)$$

where T is the duration of the construction period from date of site possession to practical completion, in working days, C is the final cost of building in millions of dollars, adjusted to constant labour and material prices, K is a constant describing the general level of time performance for a $1 million project, and B is a constant describing how the time performance is affected by project size, as measured by cost. This model indicates that one factor (scope of the project as measured by construction costs in 1972 Australian dollars) principally determines construction time. This model was a function of the cost C of the project. The relationship may be summarized (Bromilow, 1974) as

$$T = 313\ C^{0.3} \quad (2)$$

Bromilow made use of mathematical models to show the relationship between cost and time, variations, and preconstruction time. These provided norms for the speed of the building process and the occurrence of variations. He also analysed overruns on time and cost, which provided a measure of the accuracy of the industry's time and cost prediction.

Ireland (1983)

Ireland (1983) reported similar research to predict the construction time of high-rise commercial projects in Australia. He concluded from an analysis of 25 high-rise building construction projects that the best predictor of average construction time of high-rise commercial buildings based on cost (in millions indexed to June 1979) was:

$$T = 219C^{0.47} \tag{3}$$

This result gave an R^2 value of 0.576 and a significance level of 0.001.

Kaka and Price (1991)

Kaka and Price (1991) conducted a similar survey not only on buildings but also on roadwork projects that commenced within the period 1984–1989 in the UK, and a similar empirical relationship was deduced. They found that even when there is a significant variation in the duration performance of estimated and actual values, the relationship between value and duration remains the same. On the other hand, both the type of client and the type of project were found to have influenced the value–duration relationship.

Yeong (1994)

Yeong (1994) studied the time–cost relationship of building projects in both Australia and Malaysia. Based on 67 Australian government projects, 20 Australian private projects and 51 Malaysian government projects, Yeong's study confirmed the Bromilow's model at the 0.00 level of significance and that the time–cost relationships of the various projects could be represented by the following equations.

Australian private projects

$$T = 161C^{0.367} \tag{4}$$

Australian government projects

$$T = 287C^{0.237} \tag{5}$$

All Australian projects

$$T = 269C^{0.215} \tag{6}$$

Malaysian (government) projects

$$T = 518C^{0.352} \tag{7}$$

Kumaraswamy and Chan (1995)

Kumaraswamy and Chan (1995) investigated the factors affecting construction project duration and conducted a pilot survey in Hong Kong for both building projects and civil engineering projects. Over 400 questionnaires were issued and 111 responses were received. They found that the time–cost relationships for both types of project can be modelled in the form of $T = KC^B$. They also postulated that besides the project characteristic macro variables (for example, construction cost, gross floor area and number of storeys) and the micro factors that affect productivity, other significant factors also influence construction durations. They recommended that future research should be conducted to test the validity of the proposed model relationships as well as to identify other significant variables (Chan and Kumaraswamy, 1995).

Formulation of the research hypothesis

In this paper we shall validate Bromilow's time–cost relationship in the Hong Kong building industry. This time–cost relationship formula can serve as a convenient tool for both the clients and contractors for estimating the likely construction time required for a given type of project. For statistical verification of the time–cost relationship, Equation 1 is rewritten in the natural logarithmic form as:

$$\ln T = \ln K + B \ln C \tag{8}$$

The hypothesis proposed is that:

$\ln T = \ln K + B \ln C$, where an increase in $\ln T$ is associated with an increase in $\ln C$.

If this hypothesis is true, then the time–cost relationship of Equation 1 is also true.

Sample size

Time and cost data (Chan, 1996) were obtained from 110 Hong Kong building projects which were completed between the late 1980's and the early 1990's. The sample was obtained by approaching clients, professional practices and contractors in the Hong Kong building industry. Those who expressed a willingness to cooperate were asked to complete a questionnaire for two recently completed projects with which they were associated. A total of 55 respondents agreed to contribute. Each of them was asked to provide details for two projects, which gave a total of 110 cases. Of these 110 cases, the majority are residential and commercial projects (31.5% and 22.2%, respectively). Education and industrial developments represent the next categories on the list (14.8% and 7.4%, respectively). Hotel and health developments represent only a small portion of the projects (5.6% and 4.6%, respectively). Table 3 shows the percentage of cases by project type.

Table 3 Percentage of cases by nature of project

Nature of project	Percentage
Residential	31.5%
Commercial	22.2%
Education	14.7%
Industrial	7.4%
Hotel	5.6%
Health	4.6%
Others	13.9%

The contract values range from HK$1m to HK$2750m, with more than 65% of the projects falling in the range of HK$10m–300m. Figure 1 shows the number of projects by contract value.

Data analysis

A simple linear regression technique was used for the verification of the Bromilow's time–cost relationship. By using the regression analysis of the SPSS package (SPSS, 1993), the values of K and B, the calculated values of the test statistic F and the level of significance of association between $\ln T$ and $\ln C$ were computed at 5% significance level. An important part of this statistical procedure that derives models from empirical data is to indicate how well the model actually fits, or its goodness of fit. A commonly used measure of the goodness of fit of a linear model is R^2, or the coefficient of determination. If all the observations fall on the regression line, R^2 is 1. If there is no linear relationship between the dependent and independent variables, R^2 is 0. The R^2 value is widely accepted to be an indicator of how well the model fits the population. The model usually does not fit the population as well as it fits the sample from which it is derived. The statistic adjusted R^2 attempts to more realistically reflect the goodness of fit of the model in the population.

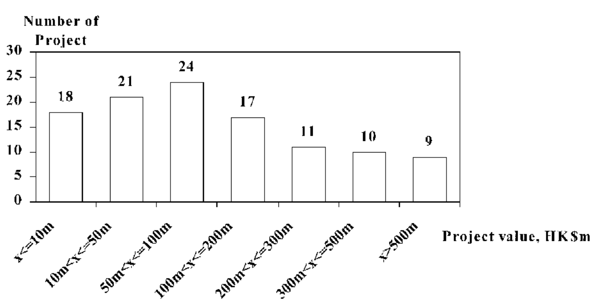

Figure 1 Number of projects investigated, by contract value in HK$

Results

The results in Table 4 show that the time and cost relationships for all building projects sampled, all public projects and all private projects may be represented by the following equations.

All building projects:

$$T_{\text{all}} = 152C^{0.29} \tag{9}$$

All public projects:

$$P_{\text{public}} = 166C^{0.28} \tag{10}$$

All private projects:

$$T_{\text{private}} = 120C^{0.34} \tag{11}$$

Since the F values for all cases are greater than the table value of F at the level of significance of 0.0000, therefore the null hypothesis of no relationship is rejected. It is concluded that statistically the time–cost relationship for all the Hong Kong building projects sampled, all public projects sampled, and all private projects sampled can be expressed in the form $T = KC^B$.

Searching for violations of assumptions

A search focused on residuals is conducted to test the validity of the linear regression model. For the bivariate situation as in this research, a scatterplot is a good means for judging how well a straight line fits the data. Figure 2 is a scatterplot of $\ln T$ and $\ln C$, and shows that a straight line fits the data reasonably well. Another method is to plot the residuals against the predicted values. If the assumptions of linearity and homogeneity of variance are met, there should be no relationship between the predicted and residual values (Norusis, 1993). Figure 3 shows a residual plot for the dependent variable $\ln T$. It shows that the residuals are randomly distributed in a band clustered around the

Table 4 Correlation and regression results of the time–cost relationships

	All projects	Public projects	Private projects
$\ln K$	2.18208	2.22078	2.07762
K	152.082	166.257	119.569
B	0.29161	0.28098	0.33725
R	0.92180	0.95432	0.85372
R^2	0.84972	0.91072	0.72883
Adjusted R^2	0.84597	0.90576	0.71527
F	226.173	183.622	53.7551
Significance (F)	0.00000	0.00000	0.00000

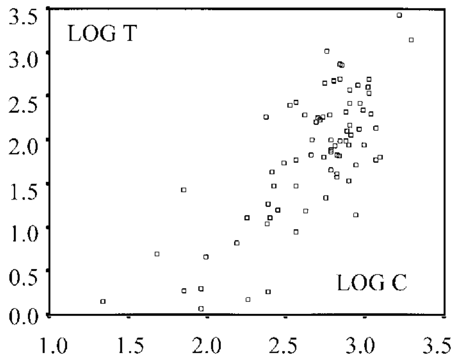

Figure 2 Scatter plot of the ln T/ln C relationship

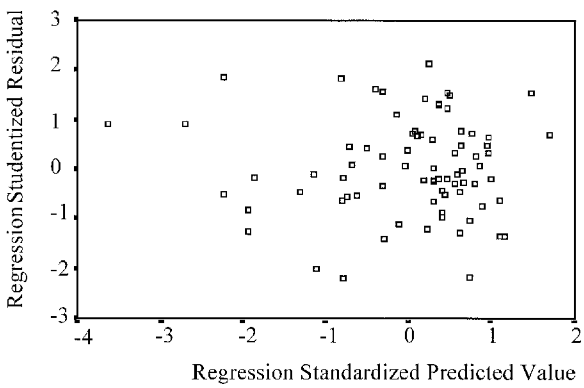

Figure 3 Scatter plot of the dependent variable ln T

horizontal line through 0. Hence, it can be interpreted that the assumptions of linearity and homogeneity of variance are met.

Discussion of the results

From the correlation and linear regression analyses shown in Table 4, the hypothesis that an increase in ln T is associated with an increase in ln C in the form of ln T = ln K + B ln C is true at the 0.00 level of significance. This reinforces the findings of Ireland (1983), Bromilow *et al.* (1988), Kaka and Price (1991), Yeong (1994), and Kumaraswamy and Chan (1995).

In Equations 9–11, the time T is the actual construction duration in days while the cost C is the final contract sum in millions (indexed at December 1994 prices). These equations can serve as convenient tools for project managers and clients for predicting the actual optimum time required for the delivery of a building project. This provides an alternate and objective method of estimating construction time to supplement the current practice of estimation based mainly on the individual project manager's experience. The equations serve also as an important benchmark for future research to study the time performance of building projects in Hong Kong and facilitate international comparison of time performance.

Publicly funded project versus privately funded project

Since $T = K$ when $C = 1$, the expected actual construction duration in days for a HK$1 million project (indexed at December 1994 prices) is given by the value of K. It was observed that generally the Hong Kong private sector takes a shorter time (120 days) to complete a hypothesized project with a contract sum of HK$1 million than its government counterpart (166 days).

The present results reinforce the previous researchers' findings (Bromilow, 1969; Bromilow *et al.*, 1980, 1988; Sidwell, 1982; Rowlinson, 1988; Naoum, 1989; Kaka and Price, 1991; Yeong, 1994) that public buildings take longer, on average, than private buildings. This may be due to the speculative environment in Hong Kong that private clients are more concerned with time than public organizations. Private clients, like manufacturing firms, hotels developers, and retailers, have to complete their projects as soon as possible in order to start operating that part of the business and get returns on investments (Kaka and Price, 1991). Moreover, private clients tend to leave the duration of the contract open for competition; hence, the contractor with the shortest submitted duration is likely to head the shortlist. In public projects, however, cost is normally the determining criterion in order to maintain public accountability.

Other factors influencing construction duration

Walker (1995) established that construction time performance is determined by numerous factors. Kumaraswamy and Chan (1995) also derived a hierarchy of factors that can contribute to construction project duration. Other researchers have linked worker attitude and management practices to construction time performance. Ireland (1983) investigated the impact of managerial action upon cost, time and quality performance in building and Sidwell (1982) investigated the impact of client decision-making upon the construction process and project success. Nkado (1995) found that factors influencing construction time can be prioritized. Those high on the priority list are generally identifiable from project information, and directly quantifiable by the contractor. Their impact on construction time can be assessed explicitly. This research is limited to validate Bromilow's time–cost relationship in the Hong Kong building industry, and therefore does not incorporate the effects of other factors as suggested by previous researchers. Future research work can be directed to test sensitivities to other factors and incorporate coefficients or weightings as appropriate.

Conclusions

Hong Kong has developed into the undisputed commercial centre of the Southeast Asia. The city also has a reputation for completing major construction projects satisfactorily in incredibly short times (Chan and Kumaraswamy, 1995). The main objective of this paper is to check whether the time–cost relationship developed in Australia in 1974 still holds for the building projects in Hong Kong. The unique characteristics of the Hong Kong building industry and the various models for predicting construction times for building projects were reviewed. Analysis of 110 building projects in Hong Kong has confirmed that the contract time and cost have a relationship in the form of $T = KC^B$. The best predictor of average construction time of building projects in Hong Kong is $T = 152C^{0.29}$. It was found that the Hong Kong private sector takes a shorter time (120 days) to complete a hypothesized project with a contract sum of HK$1 million than its government counterpart (166 days).

The time–cost relationship identified in this research serves as a convenient and useful tool for project managers and clients to predict the reasonable time required for the delivery of a construction project. The derived time–cost relationship, expressed in the form of $T = KC^B$, provides an alternative and objective method of estimating construction time to supplement the current practice of estimation based largely on the individual project manager's experience. The identified equations also provide an important benchmark for future research to study the time performance of building projects in Hong Kong and facilitate international comparison of time performance.

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