THE RELATIONSHIP BETWEEN ECONOMIC INDICATORS AND BROMILOW'S TIME-COST MODEL: A PILOT STUDY

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The existing heuristic-based estimation of construction time has been considered as inefficient, and could result in disparity between the actual construction time and the contract duration. An empirical study carried out by Bromilow in 1969 on time-cost relationship has led to the development of a forecasting model (BTC model) for construction duration based on the cost of the project. Since the pilot study by Bromilow in 1969, further studies on the BTC model have been conducted in 1977, 1980 and 1988. The results of these studies indicated that the construction speeds are constantly changing as a result of the changing economic conditions. In this paper, the BTC model is refitted with a new set of 93 Australian construction projects between 1991 and 1998. The aim of this pilot study is to investigate the relationship between the BTC model (i.e. construction speed) and commonly used economic indicators in the construction industry. The results indicate that the construction speed (i.e. *K* value in the BTC model) is positive correlated to some economic indicators.

Keywords: Bromilow model, correlation, cost, economic indicators, time, empirical survey.

INTRODUCTION

Construction time, cost and quality are the three most commonly used measures for project performance. Despite the importance of completing a construction project within the predefined cost and quality standards, Construction Time Performance (CTP) remains a crucial success factor for a construction project as project delays could also lead to cost overrun and poor quality.

In fact, contract time overrun is not unusual in the construction industry, and delays in building projects could lead to contractual disputes causing unnecessary aggravation for all stakeholders. Contractors may be financially affected from construction time overruns and obligate to pay additional impact costs (as a result of resource replanning and changes in construction), overhead costs and damages that are proportional to time, thereby reducing the contractor's profit margin and reputation (Bromilow and Henderson, 1976). Clients may also pay for poor time performance through additional holding charges, professional fees and income lost through late occupancy.

An empirical survey in CTP was conducted in Australia by Bromilow (1969), which led to the development of a predictive model for construction time estimation. The predictive model, often called Bromilow's Time-Cost (BTC) model, enables the construction period to be calculated according to the estimated final cost of a project.

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Since the pioneering works of Bromilow in 1969, many research studies have been conducted in Australia to establish the CTP and to calibrate the BTC model (Bromilow and Henderson, 1974; Bromilow *et al*, 1980, 1988; Ireland, 1983, 1985; Mak, 1991; Sidwell, 1984; Walker, 1994, 1995). Similar research studies have also been carried out in the United Kingdom (Kaka and Price, 1991), Hong Kong (Chan, 1999; Chan and Kumaraswamy, 1995) and Malaysia (Yeong, 1994). The BTC model has been widely conceived as a standard for estimating or benchmarking the contract period of construction projects (Ireland, 1983).

However, since the BTC model is based on the CTP surveyed over a specific time frame, there is a possibility that the construction speed has gained or dropped over time as a result of the changing economic environments. A recent study conducted by de Valence (1999) reveals that the productivity of the construction industry in Australia had a 9% increase between 1978-1990. Another study in Australia (Australian Bureau of Statistics, 1990) indicates that the construction labour productivity grew at an annual rate of 1.9% per year between 1975-1990. The aims of this paper are to update the BTC model based on the current CTP in Australia and investigate the relationship between economic indicators and BTC model.

BROMILOW'S TIME COST MODEL

In 1969, Bromilow derived a Time Performance Ratio (TPR) to measure CTP of construction projects, and the TPR was established by referring to the relationship of the original contract time and the actual time for construction. An empirical survey based on 329 projects in major cities of Australia (i.e. Canberra, Melbourne and Sydney) was conducted by the CSIRO (Bromilow, 1969), and the results revealed that only 12% of project surveyed were completed on time while the average time overruns were 48% of the contract duration. Similar studies have been conducted in 1988 and 1993, and the time overruns were 22% (Bromilow, 1988) and 9% respectively (CIDA, 1993).

Many researchers suggest that the heuristic-based estimation of construction time is inefficient, which could lead to a disparity between the actual construction time and the contract duration. In some cases, the original contract duration allowed for the project may be too optimistic, and this could cause unnecessary delays and hence a poor CTP.

Bromilow (1969) conducted a major empirical survey in time-cost relationship, which led to the development of a forecasting model for construction duration based on the cost of the project. The time-cost model as developed by Bromilow is shown in equation (1):

$$T = K \bullet C^{B} \qquad (1)$$

Where *T* = *duration of construction period in working days from the date of possession of site to practical completion.*

C = final cost of project in millions of dollars

K = *a constant describing the general level of time performance for a $1 million project.*

B = a constant describing sensitivity of the time performance affected by project size as measured by cost.

Bromilow's (1969) study revealed that the time taken to construct a project is highly correlated with the size as measured by cost. Construction time in working days (*T*) could be expressed as a function of final contract sum in millions of dollars (*C*) based on the regression line of best fit and upper and lower quartile limits derived from the historical data on CTP.

However, one potential shortcoming of the BTC model is that it fails to consider factors other than cost when establishing the construction time (Walker, 1994). Several research studies (Ireland, 1983; Laptali *et al*, 1996b) have been carried out to improve the accuracy of the BTC model.

Ireland (1983) attempted to develop a multiple regression model based on the construction time, cost, area, number of storeys, quality and managerial actions. However it is extremely complex to identify and evaluate all the variables that influence CTP. After considered other managerial and procurement variables, Ireland (1983:137) concluded that Bromilow's time-cost model to be "*the best predictor of construction time from building cost*".

Walker (1994) investigated other measures of project scope in terms of Gross Floor Area, project complexity and project team effectiveness. The problem was that construction project which includes a significant external works component may present difficulties in measuring construction scope per unit of construction time. Walker (1994) concluded that construction costs provides the best measure for project scope

> *"the principal advantage of using construction cost per time period as a measure of project scope is that all elements of a building can be expressed in a single unit of scope measurement"*

The form of relationship between construction time and cost of building has been investigated by RAIA (1989) and been found to have continuing validity. The BTC model was also used in recent research studies (*cf:* Walker and Sidwell, 1997) to improve the CTP within the construction industry.

The most recent study examined the change of *K* and *B* values of the BTC equations developed over the last 30 years (Ng *et al*, 2000). The results revealed that the *K* values have changed significantly from 1969 to 1998 representing a general improvement in construction speed over the last three decades. However, it was not known whether such changes were related to the change in economic conditions.

RESEARCH

To identify the relationships between the BTC equations and the changing economic conditions, the actual construction duration and cost of recently completed construction projects were collected and analysed. The data was used to develop up-to-date BTC equations (i.e. the *K* and *B* values) for different years, and to establish the correlation between the BTC equations and the commonly used economic indicators in the construction industry.

The survey population for this pilot study was confined to projects having a contract value in excess of AUS$500,000 completed in the past eight years. Projects below AUS$500,000 were considered to have limited scope and complexity. A survey conducted by CIDA (1993) concluded that one major factor leading to time overrun was the prevailing economic climate. There is a need to examine whether the variation in the *K* and *B* values is due to the economic change over the years.

Construction companies from two biggest cities of New South Wales, Australia, i.e. Sydney and Newcastle, were considered in this study. Names and addresses of construction companies were obtained from the telephone directories under the classification of "Building Contractors". A simple random sampling technique was adopted, and every next twentieth company in the telephone directories was selected. A total of 100 companies were selected for this study.

However, it was not known whether the selected companies would like to participate in the survey and completed any construction projects above AUS$500,000 between 1991-1998. As a result, telephone interviews were conducted. 44 companies indicated that they were interested in the study and had projects of the required size.

A survey package containing a covering letter, survey instructions, six separate sets of survey questionnaire and stamped self-addressed envelopes was distributed to each company. The companies were asked to provide the details of up to six projects for analysis. However, due to the sensitivity of the data required, 12 companies dropped out from the study. Only 32 companies responded, returning 93 completed project surveys. This represents a response rate of 35% (based on 264 project surveys distributed), which is very encouraging for research of this kind.

The average actual time for construction was 237 working days. The longest actual time for construction was 864 working days and the shortest actual time for construction was 60 working days. The average completion value of projects in the sample was $19.5 million. The highest contract value was $619 million and the lowest contract value was $0.5 million. The details of project surveyed are summarised in Table 1.

Table 1: Details of projects surveyed

Category	Classification	Number
Industry sector	Public	31
	Private	62
Project type	Residential	11
	Industrial	26
	Educational	15
	Recreational	9
	Other	32
Contract	Lump sum	61
	Design and Construct	16
	Construction Management	8
	Other	8
Contractor selection	Open	15
	Selective	59
	Negotiated	19

Category	Classification	Number
Contract Duration – Original (Days)	≤ 100	20
	100 - 200	34
	200 - 300	15
	300 - 400	11
	400 - 500	8
	> 500	5
Time Overrun	> 20 %	33
	10 to 20 %	15
	0	33
	-10 to -20 %	5
	> -20%	7
Cost (Adjust to 98 Price) ($ million)	≤ 1	20
	1 – 10	51
	10 – 50	13
	50 – 100	5
	> 100	4
Cost Overrun	> 20 %	21
	10 to 20 %	42
	0	24
	-10 to -20 %	4
	> -20%	2

Since the projects analysed were constructed between 1991 to 1998, it was necessary to bring the costs to a common base year. All costs were updated to March 1998 prices using the Building Price Index (BPI) in the price book (Rawlinsons, 1998). The BTC equations were derived by determining the logarithm of the dependent variable *time* (measured in working days) and the independent variable *cost* (measured in $million). Logarithmic transformations were adopted as they could reduce the dependence of the variance of the error term on the cost of the project (explanatory variable). This process is consistent with the methodology adopted in previous research studies (e.g. Bromilow, 1969).

THE RESULTS

Figure 1 shows the results of the overall BTC analysis. The *x*-axis of the scatter diagram represents cost while the *y*-axis represents time, and the regression line was established accordingly. The gradient of the regression line represents the *B* value, and an increase in the *B* value indicates that projects would take longer to complete as cost increases. The *K* coefficient is calculated by determining the intercept of the regression line and the *y*-axis, i.e. the regression line *y* value when $x = 0$. The *K* value could be determined by taking the anti-log of the figure at the interception. A lower *K* value represents the industry's CTP is improving.

The results of an regression analysis show that the *K* and *B* values derived from all 93 are $K_{all} = 131$ and $B_{all} = 0.31$. The *K* and *B* values can be represented in the research BTC equation (T_{all}) as Eqn. 2:

$$T_{all} = 131 \cdot C^{0.31} \quad (2)$$

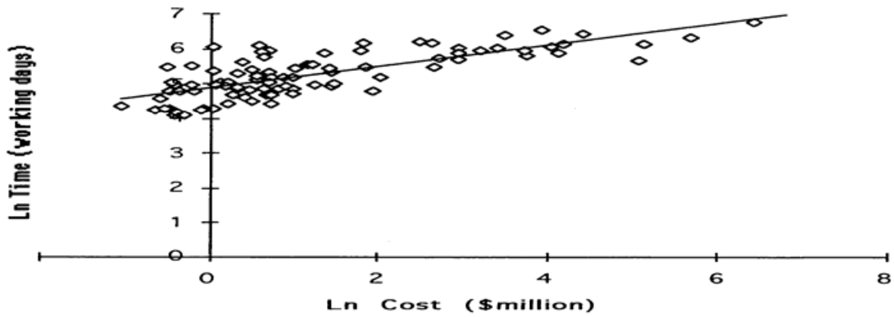

Figure 1: Scatter diagram for time and cost – all projects

Since the economic environment may change from year to year, BTC equations were also derived according to the year of project commencement. However, since there were only two samples in 1991 and one sample in 1993, they were not considered in this analysis. Table 2 shows the results of the regression analyses. The coefficient of determination (R^2) represents the goodness of fit of a linear model. The results indicate that the R^2 for the "all years", 1992, 1994, 1996 and 1998 have a strong linear relationship between the time and cost. However, the results from 1995 have relatively poor linear relationship. Despite this, the 1995 BTC equation was still used in the later analysis.

Table 2: Results of regression analysis

Year Commenced	Number of Project	K	B	R^2	Adjusted R^2	F Ratio
All Year (91-98)	93	131	0.31	0.588	0.584	130.029
1991	2	--	--	--	--	--
1992	5	90	0.39	0.645	0.526	5.440
1993	1	--	--	--	--	--
1994	6	125	0.34	0.716	0.645	10.083
1995	10	146	0.21	0.245	0.151	2.602
1996	20	138	0.31	0.616	0.595	28.910
1997	21	148	0.30	0.490	0.463	18.222
1998	28	153	0.47	0.655	0.642	49.316

Economic indicators used in this analysis included those representing the National economy (e.g. Australia consumer price index, value of Australia building approved, value of Australia building commenced, and value of Australia building completed) and those representing the NSW State economy (e.g. Sydney consumer price index, Sydney building price index, value of NSW building approved, value of building commenced, and NSW building completed). The *K* value of each year is plotted against these economic indicators in Figure 2 and 3.

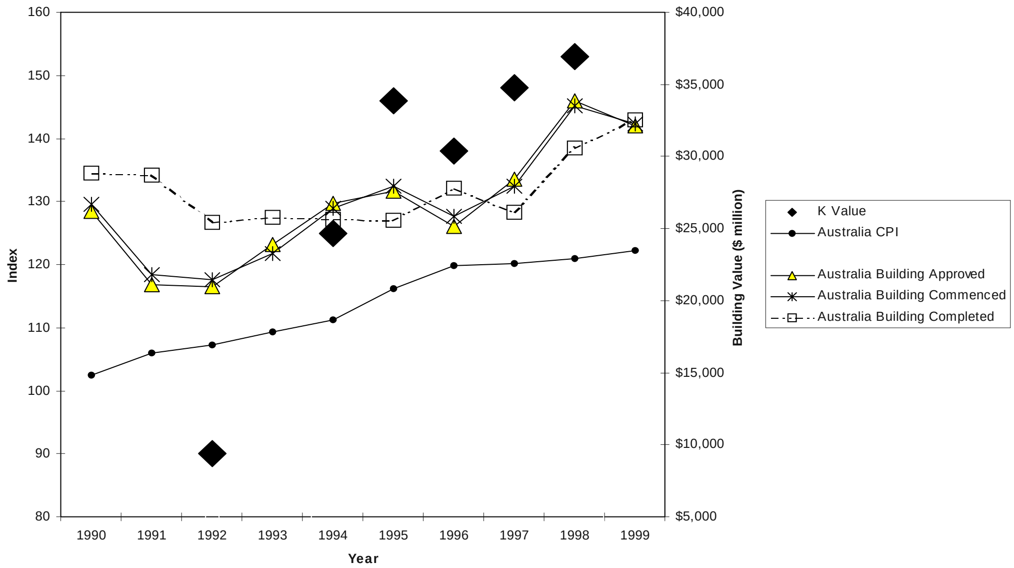

Figure 2: Relationship of *K* value with Australia Economic Environment

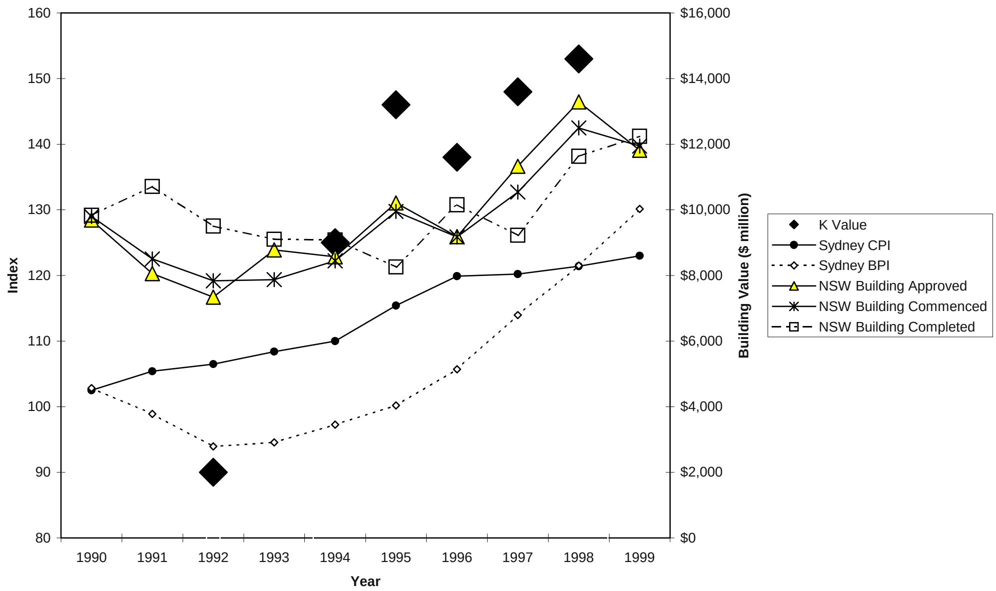

Figure 3: Relationship of *K* value with NSW/Sydney Economic Environment

To enable a more detailed analysis on the relationships between the BTC equations and economic indicators, a Pearson Correlation analysis was carried out with the economic indicators and the *K* values derived for different years. The results of the Pearson Correlation analysis are illustrated in Tables 3 and 4. It is found that the *K* values are highly correlated with both the National and NSW State economic indicators. Almost all economic indicators are positively correlated to the *K* values at a significance level of 5%. These indicators include Australia consumer price index

(+0.915), value of Australia building approved (+0.847), value of Australia building commenced (+0.863), Sydney consumer price index (+0.894), value of NSW building approved (+0.850), and value of NSW building commenced (+0,817). The Sydney building price index was positively correlated (+0.763) to the *K* values at 10% significance.

Table 3: Correlation with *K* Value

Variable	Coefficient	Significant	
Sydney Consumer Price Index	0.894	0.016	**
Sydney Building Price Index	0.763	0.077	*
NSW Building Approved	0.850	0.032	**
NSW Building Commenced	0.817	0.047	**
Australia Consumer Price Index	0.915	0.010	**
Australia Building Approved	0.847	0.033	**
Australia Building Commenced	0.863	0.027	**

* Correlation is significant at the 0.10 level (2-tailed)
** Correlation is significant at the 0.05 level (2-tailed)

In contrary, the *B* values have a strong positive correlation with the value of NSW Building completed (+0.853) at 5% level of significance. The correlation between the value of Australia building completed and *B* values was +0.649, which was beyond the 10% significance level.

Table 4:Correlation with *B* Value

Variable	*Coefficient*	*Significant*	
NSW Building Completed	*0.853*	*0.031*	**
Australia Building Completed	*0.649*	*0.163*	

** *Correlation is significant at the 0.05 level (2-tailed)*

DISCUSSION

K value is a constant describing the general level of time performance for a $1 million project (Bromilow *et al*, 1988). Inspection of Table 3 shows that the *K* value has strong positive correlation (coefficients ranged from +0.763 to +0.915) with both the National and NSW State economic indicators. The better the economy (e.g. a higher consumer price index, building price index, and values of building approved and commenced), the longer the contractors take to complete a construction project. The requirements for longer construction periods during good economic conditions could be due to an excessive amount of works in hand, labour and material shortages, etc.

B value is a constant that describes how the time performance was affected by project size as measured by cost (Bromilow *et al*, 1988). The larger value for *B* implies longer construction time as contract amount increases. A recent study reveal that the *B* values remain fairly steady over the last three decades (Ng *et al*, 2000). Despite a strong positive correlation between the *B* values and the NSW State building completed (+0.853), the correlation between the *B* values and the value of Australia building completed was rather low (+0.649). The relationships between the *B* values and the economic indicators should be a subject of further investigation when more data becomes available.

CONCLUSIONS

BTC model has been used extensively in Australia and many other countries for estimating or benchmarking the duration of construction projects. However, since the BTC model is derived from the contract time performance of projects surveyed over a specific time frame, there is a possibility that the construction speed has gained or dropped over time as a result of changes in economic. As a result, a pilot study has been carried out in New South Wales, Australia to establish the relationships between the BTC model and the commonly used economic indicators for construction industry.

CIDA (1993) asserted that one major factor on CTP is the prevailing economic climate. The results of this pilot study have confirmed that the *K* value has a strong positive correlation with both that National and NSW State economic indicators. The highest correlation coefficient was between the CTP and Australia consumer price index (+0.915), Sydney consumer price index (+0.894), Australia building commenced (+0.863) and NSW building approved (+0.850). The results indicate that the construction speed (*K* values) could be longer when the prevailing economic condition is favourable.

With a lack of standards in CTP, the BTC model could provide an efficient means of estimating and benchmarking contract duration. However, to ensure that the BTC model could be used as an industry standard, constant updating of the model using current project information is inevitable. The updating of BTC model could be based on the prevailing economic climate by referring to the commonly used economic indicators for construction industry. Further studies are being conducted by authors to determine the possibility of updating the BTC model using different economic indicators.

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