IS CONSTRUCTION GETTING QUICKER?

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ABSTRACT

Construction time performance has been a frequent topic of discussion in the literature and government reports in which the performance of the UK construction industry has been reviewed. It is evident that construction duration is one of the measures by which the success of a project is measured and there has been a great deal of research to develop reliable methods of predicting construction duration. There has been significant research identifying factors which have an effect on the duration of a construction project but little research has been undertaken which considers the changes in construction duration over time. This paper reports on a desktop study considering project duration by collecting data from the Building Cost Information Service (BCIS) and modelled in a general linear model (GLM) and an analysis of variance (ANOVA) to investigate the relationships between the contributory factors for construction duration for projects constructed in the UK between 1995 and 2014. The paper draws a conclusion which suggests that the meeting of the targets set in Construction 2025 of a reduction of time by 25% is unrealistic is drawn; counter intuitively the duration of construction projects in the UK was seen to have increased between 1995 and 2014.

Keywords: *Construction Duration; Building Cost Information Service (BCIS); General Linear Model (GLM); Analysis of Variance (ANOVA); UK.*

1. INTRODUCTION

The construction industry in the UK accounts for over 280,000 businesses, 3 million jobs, and contributes approximately 6.4% in value added (BIS, 2013; ONS, 2014). The industry reports by Latham (1994); Egan (1998); Wolstenholme (2009) which gave a review of the problems and recommendations for the industry highlight the importance of this. Latham (1994) explained that cost overruns and delays in the construction industry are largely related to the adversarial contract relationships which often lead to dispute. In the report 30 recommendations were made to address the industry problems and the Construction Industry Board was set up as one of the outcomes (Latham, 1994). There had been some improvements when the Egan (1998) report was published, however these improvements were not considered to be significant enough. Egan (1998) proposed targets of cutting construction cost and time by 10% each year, and highlighted the importance of setting such targets and creating measures of project performance. Similar concerns were raised just over 10 years later by Wolstenholme (2009) who found that only 48% of respondents believed the projects they work on are completed to time. In order to encourage the construction industry to change its approaches public sector projects were identified to be exemplars of best practice.

This paper reports on research which considers the modelling of factors that influence contract period and to identify if construction has got quicker. The data were collected from completed public and private sector projects over a twenty year time period which allowed a contrast to be made between the two sectors and an assessment over the time period; this supported some tentative conclusions about the effect the interventions have had. Prior to data collection a review of extant literature was undertaken to identify the significant factors influencing contract periods and approaches to modelling contract time.

Much of the previous research concentrates on the relationship between construction cost and construction time (Martin *et al*., 2006; Kaka and Price, 1991; Kumaraswamy and Chan, 1995; Mak *et al*., 2000). Kaka and Price (1991) in particular considered the relationship in some detail using Building Cost Information Service (BCIS) data and found that there is a positive correlation between the two variables. To improve client satisfaction it is clearly important to accurately predict the duration of a construction

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project (Blyth *et al*., 2004). The majority of research focuses on the overall construction duration (Bhokha and Ogunlana, 1999; Boussabaine, 2001; Chan and Chan, 2004; Pewdum *et al*., 2009), whereas Blyth *et al*. (2004); Nguyen *et al*. (2013); Zhang *et al*. (2004) focus primarily upon individual construction activities. There are two main types of techniques for modelling the duration of a construction project and these are simulation techniques and multiple linear regression modelling.

2. SIMULATION TECHNIQUES

2.1. ARTIFICIAL NEURAL NETWORKS

Bhokha and Ogunlana (1999) applied artificial neural networks (ANNs) to forecast construction duration. The ANN links give weights to various inputs which provide an output through a logistic transformation function to capture a decision making process (Bhokha and Ogunlana, 1999). Pewdum et al. (2009) also use an ANN to predict the construction duration of highways projects in Thailand. Bhokha and Ogunlana (1999) acknowledge that ANNs lack user friendliness and explanation facilities. Moreover, Lowe *et al*. (2006) found that ANNs had a greater percentage error in all models apart from one when compared to the regression models in their study. Zhang *et al*. (2004) utilise fuzzy discrete-event simulation which looks at the activities of constructing buildings to model the uncertainty in construction duration.

2.2. MULTIPLE LINEAR REGRESSION MODELLING

Greenwood and Shaglouf (1997) considered a number of models to predict construction and conclude that the planning methods used by the client are generally the most accurate, with multiple linear regression being the most effective out of the remaining models. Chan and Kumaraswamy (1999) applied multiple linear regression to predict the construction of high-rise public housing projects. The study by Blyth *et al*. (2004) also produced low error levels of 15% for activity level predictions and 7% for overall duration. Moreover, according to Blyth *et al*. (2004) the multiple linear regression model is the most suitable method to establish the relationship between variables for a statistically small sample size. In order to establish an analytical framework to test the hypothesis that construction is getting quicker, the influential factors had to be identified.

3. INFLUENTIAL FACTORS

3.1. COST

The first notable research on the relationship between construction time and cost was that by Bromilow (1969) when Bromilow's time-cost model was introduced. Kaka and Price (1991) utilised data from the Building Cost Information Service identified that the relationship changes depending on the type of project and type of client being considered. Mak *et al*. (2000) further updated Bromilow's time-cost model for Australian projects built between 1991 and 1998. The K-value in the time-cost model was found to be correlated with the state economic indicators, suggesting that when there are longer construction periods when the economy is doing well (Mak *et al*., 2000). The most recent study showing the relationship between time and cost was conducted by Martin *et al*. (2006) who confirmed the relationship using a data set of 2500 projects constructed between 1998 and 2004; this research was the basis of the BCIS model.

3.2 FLOOR AREA

The floor area is a factor which affects the duration of a construction project (Bhokha and Ogunlana, 1999; Blyth *et al*., 2004; Martin *et al*., 2006; Chan and Chan, 2004; Chan and Kumaraswamy, 1999; Elhag and Boussabaine, 1999; Greenwood and Shaglouf, 1997; Kumaraswamy and Chan, 1995; Lowe *et al*., 2006; Walker, 1995).

3.3. PROCUREMENT METHOD

Blyth et al. (2004); Martin *et al*. (2006); Chan and Chan (2004) identify that the method of procurement used has an impact on the duration of the project. Although according to Boussabaine (2001) design and build projects have a longer duration, whilst other procurement methods have little effect.

3.4. COMPLEXITY OF PROJECT

Another group of factors highlighted by researchers related to the complexity of a project and can include the construction methods and methods of contractor selection (Bhokha and Ogunlana, 1999; Blyth *et al*., 2004; Martin *et al.,* 2006; Chan and Chan, 2004; Chan and Kumaraswamy, 1999; Lowe *et al*., 2006; Walker, 1995). Boussabaine (2001) found that the selection method of negotiation in particular has a higher tender price and duration. Likewise Zhang *et al*. (2004) consider construction duration uncertainties related to the construction method such as weather conditions, equipment properties and supply of materials.

3.5. FUNCTION OF THE BUILDING

Clearly the function of a building as well as the client it is being built for has an impact on the duration of construction (Bhokha and Ogunlana, 1999; Blyth *et al*., 2004; Martin *et al*., 2006; Chan and Chan, 2004; Lowe *et al*., 2006). Furthermore Bhokha and Ogunlana (1999); Blyth *et al*. (2004); Martin *et al*. (2006) suggest that the location of the building effects the construction duration.

3.6 OTHER FACTORS

There has been a great deal of research into modelling and predicting the duration of construction projects (Blackman and Picken, 2010; Bromilow, 1969; Bromilow *et al*., 1988; Kaka and Price, 1991; Walker, 1995; Chan and Kumaraswamy, 1999). However there has been very little, if any, research into whether construction has become any quicker over the past twenty five years, following on from the aforementioned seminal reports.

4. RESEARCH APPROACH

The main focus of this study was to investigate whether construction periods were getting shorter over time. It was decided that a 20 year period would sufficient to investigate this, particularly as this would show any impact of the Latham, Egan and Wolstenholme reports. Data from the BCIS on projects constructed between 1995 and 2014 were collected and variables such as those identified above were recorded. In order for the data from the BCIS to be interpreted easily it needed to be formatted. For the projects to be comparable the contract value was adjusted for location (UK mean) and the quarter in which it has been priced the values were rebased to the final quarter of 2014 (Kaka and Price, 1991).

5. DATA COLLECTION AND ANALYSIS

5.1. DATA COLLECTION

The database was used to collect newly built projects in the UK between 1995 and 2014 from the public and the private sector which could be analysed to achieve the research aim. The public sector was represented by buildings built for education such as schools, universities and libraries, and the private sector projects were made up of supermarkets, factories, hotels, offices and sports facilities. In total 604 private projects and 886 public projects were collected. The frequency tables which show how many of these projects were built in the years being investigated is shown in Appendix A. Furthermore, many of the variables being considered were categorical variables with a large number of categories. These variables, such as location, were reduced into a smaller number of categories so that it could be reasonably seen how they affect the contract period. It was also required that these variables were coded so that they could be included within a model, the variables are shown in Appendix B.

5.2. DATA MANIPULATION

Results of a general linear model are very difficult to interpret if large numbers of variables and categories are used. Hence, the detailed BCIS data was collected into groups based on similar projects. The categorical variable of time that was considered was the year in which the projects contract value was priced. To help determine suitable groups of years a graph of the mean contract period for each year between 1995 and 2014 was considered for both the public and the private data. Four year periods were subsequently selected to be used in the general linear model to investigate the trend of contract period over the year groups. The variable for year was condensed into the four year categories 1995-1998, 1999-2002, 2003-2006, 2007-2010 and 2011-2014 which are coded as 1, 2, 3, 4 and 5 respectively The categorical variables for the public data and the private data are summarised in Appendix C. The coding of the independent variables can be viewed in Appendix D.

5.3. DATA ANALYSIS

A general linear model was used to investigate the relationship between the agreed contract period and the year in which the project was priced, the method of contractor selection, and whether the project was public or private. This was selected as it allowed for an interpretive approach to the quantitative analysis. A planned contrast was utilised to investigate whether there was polynomial relationship in contract period with respect to year. Moreover, the interactions between the variables in the general linear model were investigated to determine whether the trend in the length of contract period is similar for the different categories of variable or not. Furthermore for the BCIS data the distribution of the variables was checked and the rebased building cost was transformed using a logarithm.

6. RESULT AND DISCUSSION

6.1. THE GENERAL LINEAR MODEL

The general linear model (GLM) is a mathematical model which allows for all of the statistical tests of hypotheses such as t-tests, analysis of variance, correlation and regression analysis to be applied in broad analytic framework (Rochowicz, 2014). Support for the use of such a framework rather than separate isolated tests was found (Maxwell and Delaney, 2004; Rochowicz, 2014).

6.1.1. SELECTING THE INDEPENDENT VARIABLES

The ultimate aim of this research was to investigate the change in contract period over the years 1995 to 2014. Hence the categorical variable year was included in the model. Furthermore, the ANOVA model was used to analyse whether the contract period follows a linear trend with respect to year. The selection of contractor method was included in the ANOVA model as an independent categorical variable to test for the significance of the relationship between contract period and the contract selection method.

6.1.2. ANALYSING THE MAIN EFFECTS

Effect of contractor selection and project type

After running the GLM for the full factorial model it was important to consider the main effect of each of the independent variables. The output from SPSS can be observed in Table 1. The F-ratio and degrees of freedom for the model and the residuals can be reported in the form $F(dfM,dfR)=value$ where F represents the F-ratio, dfM are the degrees of freedom for the model and dfR are the degrees of freedom for the residuals (Field, 2013). The p-value of this ratio was considered to be significant if $p<0.05$. There was a significant main effect of the year in which the project was constructed when the method of contractor selection and project type was ignored, (4,1451)=3.888, p=0.004. This main effect was considered further in the planned contrast to help evaluate how the contract period changes for the different time periods and is reported below. For the variable for selection of contractor (3,1451)=3.218, p=0.022 which was also a significant p-value. Therefore the method of contractor selection also influences the contract period when whether a project is public or private, and the year in which the

project was built is ignored. Moreover it was clear that the main effect of the project type (public or private) was not significant, (1,1451)=1.696, p=0.193. This suggests that the contract period for the project does not differ depending on whether the project is public or private. However, it is misleading to interpret the main effects of the independent variables when there is a significant interaction in the model (Field, 2013).

Table 1: Full Factorial ANOVA

Dependent Variable: Contract Period (Weeks)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	50957.176[a]	38	1340.978	4.723	.000
Intercept	516802.378	1	516802.378	1820.079	.000
YearPeriod	4415.868	4	1103.967	3.888	.004
ContractorSelection	2741.526	3	913.842	3.218	.022
PublicPrivate	481.705	1	481.705	1.696	.193
YearPeriod * ContractorSelection	3425.126	12	285.427	1.005	.441
YearPeriod * PublicPrivate	894.369	4	223.592	.787	.533
ContractorSelection * PublicPrivate	2943.613	3	981.204	3.456	.016
YearPeriod * ContractorSelection * PublicPrivate	1529.751	11	139.068	.490	.911
Error	412004.140	1451	283.945		
Total	2791053.000	1490			
Corrected Total	462961.316	1489			

Interactions between independent variables

To establish whether the time period had an influence on the contract period of a public sector or private sector project and analysis of the interaction of the year of construction, contractor selection and project type was required. The interactions between the independent variables were analysed using the F-ratios in the same way as the main effects. For the interaction between year and method of contractor selection, (12,1451)=1.005, p=0.441 which was not a significant p-value. Therefore the effect of the year group on the contract period of the project was not significantly different for the different contractor selection methods. Furthermore there was a non-significant interaction between the year group and the project type (public or private), (4,1451)=0.787, p=0.533. Hence it can be concluded that the effect of year group on the agreed contract period is the same for public and private projects.

Impact of contractor selection

The interaction between the method of contractor selection and public or private project was significant, (3,1451)=3.456, p=0.016. It was found that the effect of the contractor selection method on the agreed contract period was significantly different for public and private projects. When further analysis was undertaken for the public sector projects it was found that those public projects which used two stage projects were generally longer, however selected competition lead to a longer contract period than both open competition and negotiated. This interaction can be broken down using simple effects for the interaction between the contractor selection method and the project type (public or private) analysis to look at the effect of the project being public or private at each level of the selection of contractor (Field 2013). The output from the simple effects analysis can be viewed in Table 2. The analysis indicated that there was a significant difference in contract period between public and private projects when selected competition and open competition are used (p=0.000 and p=0.031 respectively). On the other hand there is no significant difference between public and private projects for those that were negotiated (p=0.987) and for those using two stage tendering (p=0.320). Finally the three way interaction between all of the independent variables was non-significant, (11,1451)=0.490, p=0.911. This suggests that the effect of the selection of contractor method and the year group on contract period does not differ between public and private projects.

Table 2: Simple Effects Analysis for the Interaction between Contractor Selection Method and Project Type

Univariate Tests

Dependent Variable: Contract Period (Weeks)

Recoded selection of contractor		Sum of Squares	df	Mean Square	F	Sig.
1	Contrast	24785.176	1	24785.176	86.070	.000
	Error	426763.263	1482	287.964		
2	Contrast	1335.116	1	1335.116	4.636	.031
	Error	426763.263	1482	287.964		
3	Contrast	.072	1	.072	.000	.987
	Error	426763.263	1482	287.964		
4	Contrast	285.375	1	285.375	.991	.320
	Error	426763.263	1482	287.964		

Planned contrasts

Planned contrasts were undertaken to investigate how the agreed contract period differed across the factors. A simple contrast was used to compare the contract periods of each of the methods of contractor selection to selected competition. In addition, a polynomial contrast was used to investigate how the contract period changed across the year groups from 1995 to 2014. The SPSS output for the polynomial contrast for the year group is shown in Table 3. The output for the linear trend gave a significant p-value of p=0.037 which suggested that the contract period changes with the year group in a linear fashion.

Table 3: Polynomial Contrast of Year Group

Contrast Results (K Matrix)

Recoded year Polynomial Contrast			Dependent Variable: Contract Period (Weeks)
Linear	Contrast Estimate		5.356
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		5.356
	Std. Error		2.560
	Sig.		.037
	95% Confidence Interval for Difference	Lower Bound	.334
		Upper Bound	10.378
Quadratic	Contrast Estimate		-3.681
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-3.681
	Std. Error		2.428
	Sig.		.130
	95% Confidence Interval for Difference	Lower Bound	-8.444
		Upper Bound	1.082
Cubic	Contrast Estimate		-4.013
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		-4.013
	Std. Error		1.936
	Sig.		.038
	95% Confidence Interval for Difference	Lower Bound	-7.809
		Upper Bound	-.216
Order 4	Contrast Estimate		.360
	Hypothesized Value		0
	Difference (Estimate - Hypothesized)		.360
	Std. Error		1.713
	Sig.		.824
	95% Confidence Interval for Difference	Lower Bound	-2.981
		Upper Bound	3.741

Table 4: Marginal Means of the Variable for the Year Group

1. Recoded year

Dependent Variable: Contract Period (Weeks)

Recoded year	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	36.344	2.208	32.013	40.676
2	37.258	1.776	33.774	40.742
3	42.927	1.659	39.672	46.182
4	45.721	1.570	42.641	48.801
5	40.883	3.036	34.928	46.838

By observing the marginal means for the variable for year shown in Table 4 it can be seen that the mean contract period increases between 1995 and 2010. However, the mean for 2011-2014 shows a decrease again. This decrease could be the reason for the significant p-value for the cubic trend in the polynomial contrast (p=0.038). Overall the polynomial contrast can be concluded as significant, (4,1451)=4.323 with p=0.002. The contrast did not suggest a decrease in contract period as was suggested by Government reports. In fact the results of the analysis suggested the opposite.

7. CONCLUSION

The General Linear model found that the main effects for the year and the method of contractor selection were significant, whilst the project type was not. On the other hand there was a significant interaction between the project type and the contractor selection method which suggested that the effect of the contractor selection method differs between public and private projects. These significant differences occurred when selected competition and open competition were used, and there was no significant difference between the contract period of public and private projects when negotiation and two stage tendering are used. By considering a planned contrast the differences in contract periods between the contractor selection methods were considered; open competition did not significantly differ from selected competition, however negotiated and two stage tendering were significantly different to selected competition. Additionally a planned contrast was used to specifically address the main research question; is construction getting quicker? The polynomial contrast used suggested that there was a significant linear trend in contract period over the year groups, however the trend showed an increase in contract period rather than a decrease. The target of reducing construction periods by 25% as identified by Construction 2025 (BIS, 2013) does seem a difficult achievement based on these findings.

The first major limitation of this study is that by using the secondary data source of the BCIS data the projects are not randomly selected. However, all of the projects that were found between the years 1995 and 2014 for the building functions selected were included, unless they had data values missing, to attempt to eliminate the possible bias.

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Appendix A: Data in year group

Year

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1995	45	5.1	5.1	5.1
	1996	60	6.8	6.8	11.9
	1997	55	6.2	6.2	18.1
	1998	41	4.6	4.6	22.7
	1999	42	4.7	4.7	27.4
	2000	54	6.1	6.1	33.5
	2001	59	6.7	6.7	40.2
	2002	41	4.6	4.6	44.8
	2003	53	6.0	6.0	50.8
	2004	48	5.4	5.4	56.2
	2005	49	5.5	5.5	61.7
	2006	49	5.5	5.5	67.3
	2007	52	5.9	5.9	73.1
	2008	54	6.1	6.1	79.2
	2009	47	5.3	5.3	84.5
	2010	48	5.4	5.4	90.0
	2011	20	3.2	3.2	93.1
	2012	23	2.6	2.6	95.7
	2013	24	2.7	2.7	98.4
	2014	14	1.6	1.6	100.0
	Total	886	100.0	100.0	

Appendix B: BCIS data

Variable	Definition	Categories (if applicable)
Contract value	The anticipated cost of construction at the time of the anticipated start date.	-
Building function	The primary use of the building during occupation. The building functions have been grouped into similar building types.	Road vehicle buildings; Factories; Warehouse stores; Offices; Retail; Emergency services; Health centre clinics; Hospital buildings; Care homes; Animal welfare; Catering; Community centres/halls; Pavilions/clubhouses; Sports buildings; Swimming pools; Religious facilities; Laboratories; Libraries; Museums/exhibition spaces; Schools; Universities/colleges; Mixed housing and flats; Housing estates; One-off housing; Flats; Hotels and motels; Halls of residence/hostels; Sheltered housing; Sanitary blocks
Procurement	The process which best describes the way in which the project will be procured.	Traditional lump sum; Traditional lump sum with quants; Traditional lump sum without quants; Design and build; Management contracting; Construction management; Design, manage, construct; Other
Selection of contractor	The option which best describes the way the contractor will be selected.	Single stage tendering; Two stage tendering; Negotiated; Partnering; Other
Client organisation	The sector of the client organisation.	Public; Private
Quarter	The quarter of the year in which the contract value has been priced.	-
Location factor	Adjusts the contract value to UK mean location, or a region or county level, using BCIS location factors.	-

Appendix C: Condensed variables

Variable	Categories
Building function	**Public data:** Adult education facilities; Colleges; Laboratories and research facilities; Libraries; Nursery schools/creches; Primary schools; Schools for the handicapped; Secondary schools; Universities **Private data:** Factories and warehouses; Hotels and guest houses; Offices and mixed facilities; Religious and community buildings; Restaurants, cafes and public houses; Sports facilities; Supermarkets, shops and retail warehouses
Region	East Midlands; East of England; London; North East; North West; Northern Ireland; Scotland; South East; South West; Wales; West Midlands; Yorkshire and Humber
Selection of contractor	Negotiated; Open competition; Selected competition; Two stage tendering
Year	1995-1998; 1999-2002; 2003-2006; 2007-2010; 2011-2014

Appendix D: The codes used in the GLM to represent the independent variables

Sector	Selection of contractor	Year	Project was
0	1	1	Public project through selected completion built 1995-1998
0	1	2	Public project through selected completion built 1999-2002
0	1	3	Public project through selected completion built 2003-2006
0	1	4	Public project through selected completion built 2007-2010
0	1	5	Public project through selected completion built 2011-2014
0	2	1	Public project through open competition built 1995-1998
0	2	2	Public project through open competition built 1999-2002
0	2	3	Public project through open competition built 2003-2006
0	2	4	Public project through open competition built 2007-2010
0	2	5	Public project through open competition built 2011-2014
0	3	1	Public project negotiated and built 1995-1998
0	3	2	Public project negotiated and built 1999-2002
0	3	3	Public project negotiated and built 2003-2006
0	3	4	Public project negotiated and built 2007-2010
0	3	5	Public project negotiated and built 2011-2014
0	4	1	Public project through two stage tendering built 1995-1998
0	4	2	Public project through two stage tendering built 1999-2002
0	4	3	Public project through two stage tendering built 2003-2006
0	4	4	Public project through two stage tendering built 2007-2010
0	4	5	Public project through two stage tendering built 2011-2014
1	1	1	Private project through selected completion built 1995-1998
1	1	2	Private project through selected completion built 1999-2002
1	1	3	Private project through selected completion built 2003-2006
1	1	4	Private project through selected completion built 2007-2010
1	1	5	Private project through selected completion built 2011-2014
1	2	1	Private project through open competition built 1995-1998
1	2	2	Private project through open competition built 1999-2002
1	2	3	Private project through open competition built 2003-2006
1	2	4	Private project through open competition built 2007-2010
1	2	5	Private project through open competition built 2011-2014
1	3	1	Private project negotiated and built 1995-1998
1	3	2	Private project negotiated and built 1999-2002
1	3	3	Private project negotiated and built 2003-2006
1	3	4	Private project negotiated and built 2007-2010
1	3	5	Private project negotiated and built 2011-2014
1	4	1	Private project through two stage tendering built 1995-1998
1	4	2	Private project through two stage tendering built 1999-2002
1	4	3	Private project through two stage tendering built 2003-2006
1	4	4	Private project through two stage tendering built 2007-2010
1	4	5	Private project through two stage tendering built 2011-2014