Predicting Construction Duration of Building Projects

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SUMMARY

This research is based on the analysis of the 'actual time' taken to construct buildings in the UK. The objective is to provide a tool to aid clients and their consultants in estimating or benchmarking the construction duration at the earliest stages of future projects.

Time predictability has been identified as one of the key performance issues to be addressed in providing best value to construction clients.

Following feedback on previous research in this area this paper describes the development of the tool to predict the likely construction duration of a project based on a set of known variables:

- Construction duration
- Project sector
- Building type
- Procurement route
- Contractor selection method
- Client type
- Contract value
- Building function

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1. INTRODUCTION

'Significant Contract overruns are almost invariably traced to weaknesses on the part of the client as opposed to the professional consultants and contractors engaged to deliver the project. The most common deficiencies are weak client briefing and frequent client changes during the design and construction phases' [6]

As part of the initial briefing process the client will normally have some idea of their desired timescale. Consultants, both in house and external have always used their experience to provide a reality check on these perceptions, to provide advice on realistic timescales or on the ramifications of sticking to faster programme. This paper reports on research in the UK to provide benchmark data to back up this advice and explores its relevance in the USA.

Various studies produced for the UK Government have highlighted poor prediction of client costs and construction duration period as key problems for the construction sector. The Egan report *Rethinking Construction* [4] specifically recognised such issues stating:

'(Construction) Projects are widely seen as unpredictable in terms of delivery on time, within budget and to the standards of quality expected.'

Rethinking Construction proposed a specific set of performance measures be developed as Key Performance Indicators (KPIs) including measures of time and cost predictability.

BCIS has been involved in the development of these since their first publication in 1999. The latest set available where published by Constructing Excellence in 2005 [2] and data collection is underway for the 2006 KPIs.

To date, the KPIs demonstrate that the industry's ability to predict the time a building will take to construct is considerably worse than its ability to predict how much it will cost.

The 2005 KPIs show that while some 20% of projects experience increased costs over the construction period, nearly 40% overrun their agreed contract period.

There are two possible reasons for this:
- increases in time taken, unlike increases in costs, always affects the predictability
- the lack of information on the actual time taken on projects.

Increased costs that occur during a building project will be allocated between the client and the contractor in accordance with the terms of the contract. Therefore they may, or may not, affect the predicted cost.

Time is much less flexible. Whoever is responsible for a delay, and even if financial settlement is made, the client receives his completed project later than predicted.

There are, of course, a multiplicity of factors that will affect the time taken to construct a particular project, such as:

- Phasing
- Design
- Site access
- Site conditions
- Market constraints or opportunities
- Complexity
- Availability of resources
- Availability of finances

However, many of these factors will be unknown when early advice is required.

Based on information collected to produce the time predictability KPI BCIS undertook some research in2004 looking at the relationship s between actual construction period size of project and some other known variables.

The results were published in the BCIS *Guide to Building Construction Duration* [1]. The Guide also contained a calculator that produces estimates of likely construction duration based on a multiple linear regression model.

2. FEEDBACK FROM PREVIOUS RESEARH REPORT

The research report was well received but it was the calculator that prompted most interested.

The major feedback points from users in the UK were:

- That the functional grouping variables were too broad eg.
  - 'Administrative, Commercial, Protective Facilities' included offices and retail.
  - 'Health, Welfare Facilities' included hospitals, clinics and homes.
  - 'Residential Facilities' included houses, flats and hotels.
- The adjusting of future costs to the model cost base, 2nd quarter 2003 using time limited forecast figures as the default has required some external calculations to provide the required input data into the calculator.
- What the client actually wants to know is how long will it take to deliver the project not just the construction period.
- There were one or two disgruntled purchasers who, in spite of our best efforts to make clear that it was a tool for providing early advice to clients, expected it to be a planning (scheduling) tool.
- Our own internal review suggested that we should test further transformations of the data to provide a best-fit model. The final transformations in the existing model were the

square root of the duration, the log of the contract sum, the square root of the log of the contract sum was also incorporated as a further parameter.

As a result of this feedback we are updating the study based on an expanded data set including a larger sample of projects to produce a new calculator for the UK.

3. DATA

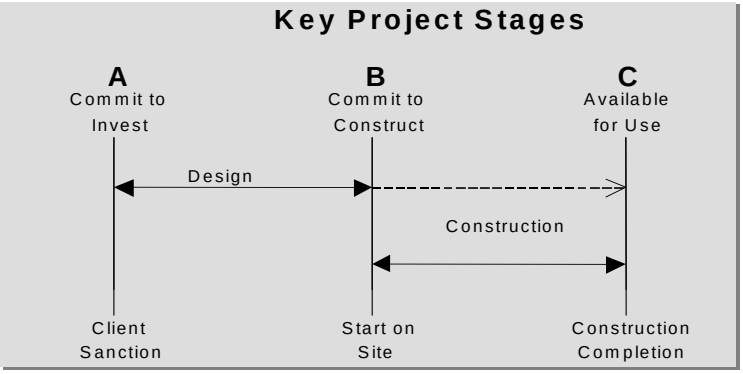
The data used in this study was collected from construction industry clients and consultants as part of the annual Key Performance Indicators survey carried out by BCIS on the behalf of the Department of Trade and Industry (DTI). The data set analysed was a subset of the full KPI data set:

- The study is based on over 2,700 building projects completed in the UK between 1998 and 2006.
- Only new build building projects were included.
- Infrastructure, refurbishment, and repair and maintenance projects are excluded.
- Projects for which some of the project variables were missing were excluded.

The KPIs record data at three points.

- A: Commit to invest – Client sanction
- B: Commit to construct – Start on site
- C: Available for use – Construction completion

Figure 1: Key project Stages for KPIs



Building project duration is defined as ‘the period between the date of client sanction to the project and the date of practical completion, in weeks’ (A-C).

Building construction duration was defined as ‘the period of time between the date of the construction contract start on site and the date of practical completion, in weeks’ (B-C).

To eliminate the effect of regional variations in construction costs, all costs were adjusted to UK mean location using the BCIS Regional Location Factors. Similarly, the total

construction costs derived from the DTI data were adjusted to a base date using the BCIS Tender Price Index to remove the effect of time related cost change.

Total construction cost was defined as 'the final amount paid to the contractor at the base date, UK mean location prices excluding VAT and consultants fees.'

The known variables and their classification for the projects in the sample are:

Variable

Project Sector

- Classification
  - Private housing
  - Public housing
  - Private non-housing
  - Public non-housing

As defined in DTI Construction Statistics [5]

Procurement route

- Classification
  - Design and build
  - Traditional lump sum
  - Construction management
  - Design, manage and construct
  - Management contracting
  - Other procurement methods

Contractor selection method

- Classification
  - Single Stage
  - Two Stage
  - Partnered
  - Negotiated
  - Other Contractor Selection Methods

Client type

- Classification
  - Local Government
  - Other Public Sector
  - Housing Association
  - Private Sector (Housing)
  - Private Sector (Non-Housing)

Region

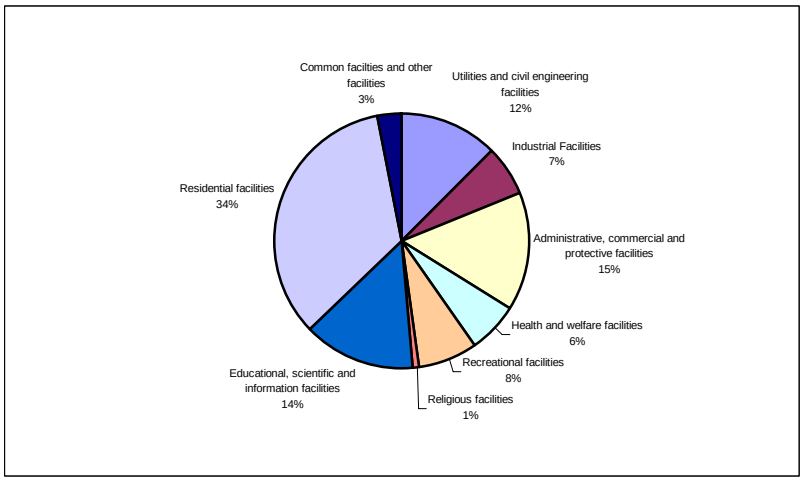
- Classification

- North
- Yorkshire and Humberside
- Midlands
- East Anglia
- South East
- London
- South West
- Wales
- North West
- Scotland
- Northern Ireland

Building Function

Each project has been coded for building function as defined in *Uniclass* Table D [3]. Figure 2 shows the analysis of the projects by broad functional grouping.

Figure 2: Projects by functional group



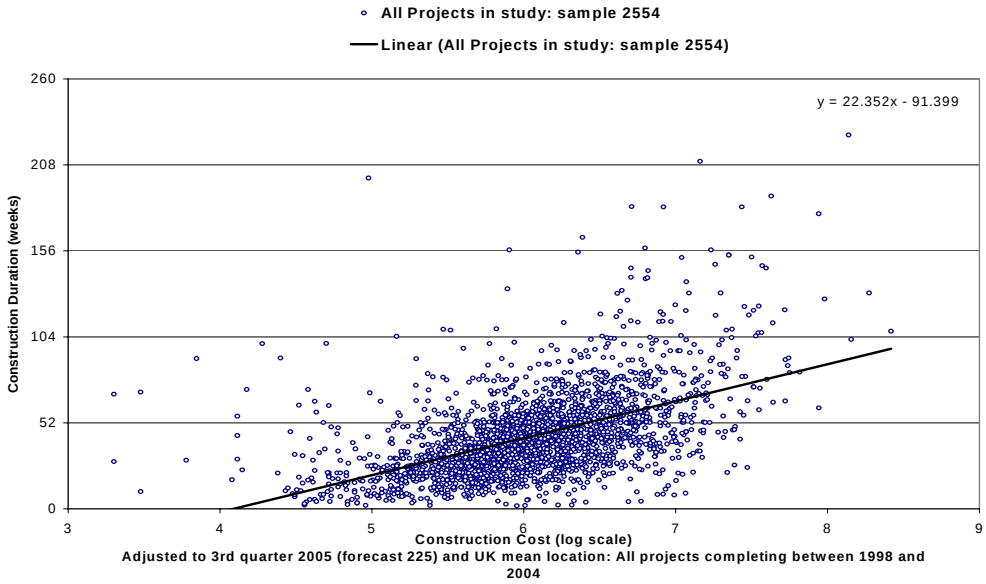
There were 148 building types within the 2554. Similar types of building were grouped to give a list of 29 building types. 146 projects were not allocated and 225 were only coded at the group functional level.

See appendix A for full list of building types.

4. CONSTRUCTION DURATION AND BUILDING FUNCTION

The complete sample was plotted as a scatter diagram relating the Log of the construction cost against the contract period in weeks. This shows a clear relationship see Figure 3.

Figure 3: Construction duration – all projects in study



Similar graphs were plotted for each building type.

Examples are shown below:
- Factories - Figure 4
- Offices - Figure 5
- Hospital buildings – Figure 6
- Schools – Figure 7

Figure 4: Construction duration - Factories

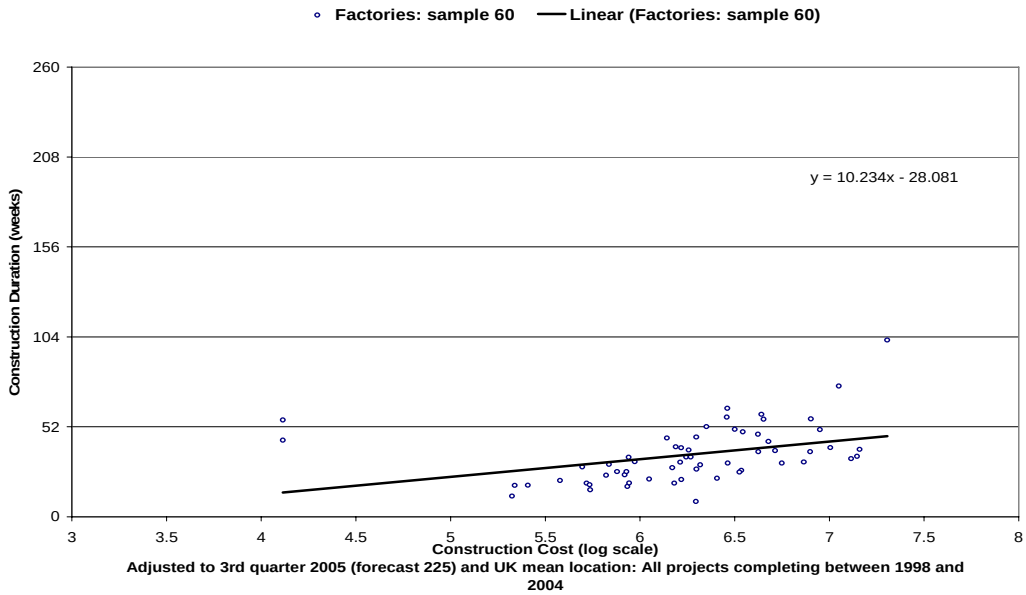


Figure 4: Construction duration - Offices

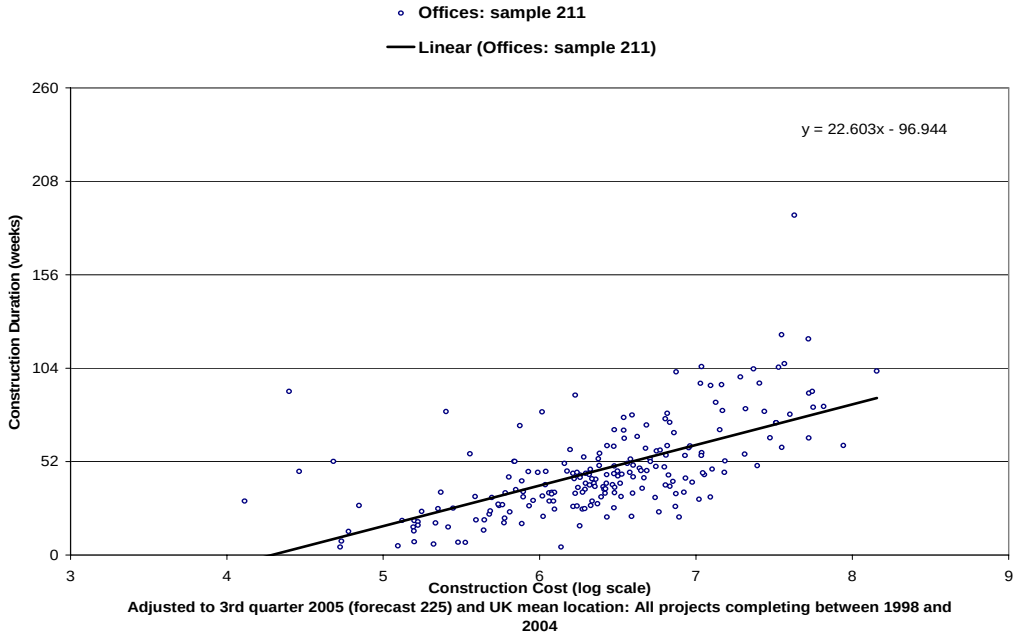


Figure 5: Construction duration - Hospital buildings

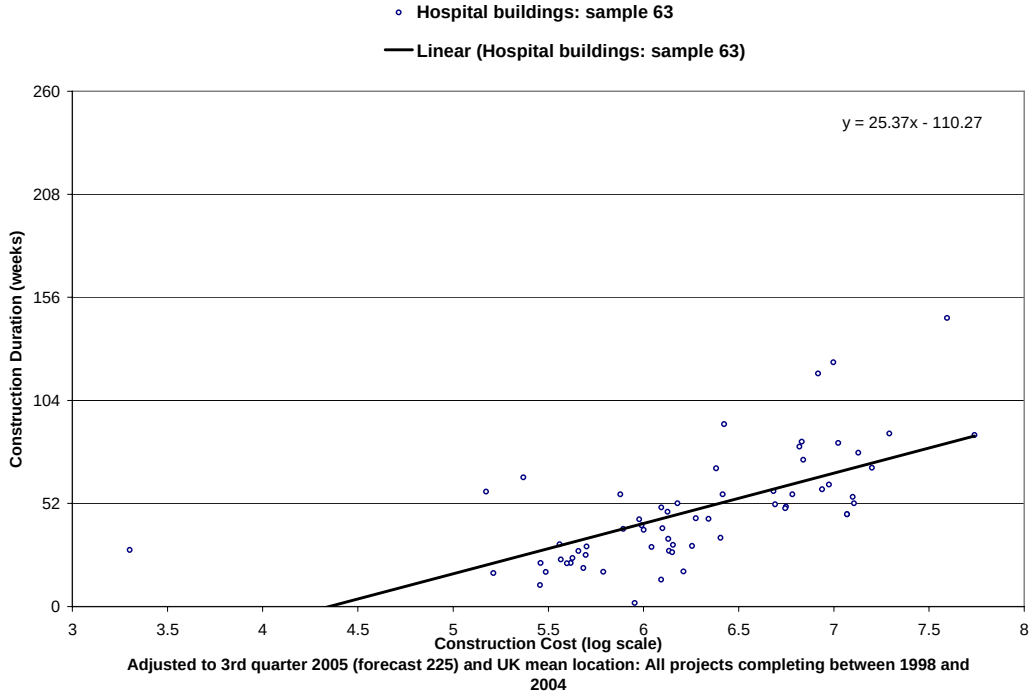
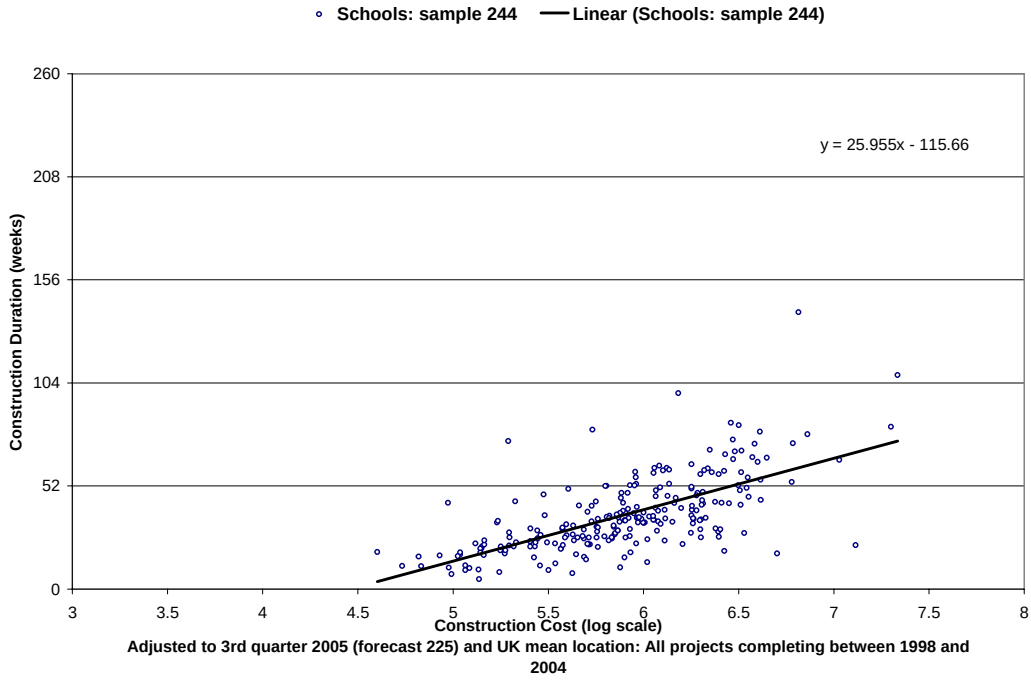


Figure 6: Construction duration – Schools



The formulae for the trendlines for each building function are given in Appemdix B.

All the equations show duration increasing with increased value with the exception of catering buildings which on a small sample show a flat line suggesting that within the cost range of the projects in the study the construction duration is not influenced by the total cost of the project.

Swimming pools and libraries show the steepest slopes suggesting that the value of the project has a significant influence on the construction period, while factories, warehouses and hotels/motels have the shallowest slopes.

5. GENERATION OF PREDICTIVE MODELS

The starting point for the predictive model will to use a least squares linear regression to calculate a combined relationship between construction duration, construction cost, procurement, contractor selection, client type, building function and region. The results will yield a model that can be used to estimate the average construction period for projects with given parameters.

The starting point will be the previous model, which showed an interdependence of the project variables: sector, client and function (i.e. client and function define the sector), the project sector variable will be omitted from the model. An analysis of variance (ANOVA) will be used to confirm the validity of the results.

The relationship between log contract sum and contract period is was found not a straight line. Schemes at either end of the range tend to take longer than implied by the regression line. To better model this relationship, a further parameter of log contract sum squared was introduced.

It was also found that construction duration was positively skewed, ie. there is a bigger spread of figures above the mean duration than below. In order to improve the model, the square root of the construction duration was used as the dependent variable. The resulting data is approximately normally distributed which allows a better calculation of the prediction interval.

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BIOGRAPHICAL NOTES

Joe Martin is Executive Director of the Building Cost Information Service Ltd (BCIS Ltd). He is a Fellow of the Royal Institution of Chartered Surveyors and a Member of the Chartered Management Institute. He has been responsible for setting up and developing the BCIS Ltd information data bases for capital and running cost of buildings, including the BCIS *Online* service which provides online access to price information on over 15000 projects. He has been involved in the development of price deflators, Key Performance Indicators, and capital and whole life cost benchmarks for the UK Government. He has been involved on many industry bodies including the Consultative Committee for Construction Industry Statistics, The Steering Group for Unified Classification for the Construction Industry, European Committee for Construction Economics (CEEC), International Construction Information Society Working Group 3 on Elemental Classification, The DTI Working Group on Indices, RICS Construction Design and Economics Practice Panel. He recently chaired the whole project cost group of the Cross industry response to the Barker report and worked with the NAO on their report *Using modern methods of construction to build homes more quickly and efficiently.*

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APPENDIX A
Building Function classification

	Special Function Heading	Sample size
1	Road vehicle buildings	32
2	Factories	60
3	Warehouse stores	92
4	Offices	211
5	Retail	90
6	Animal welfare	11
7	Health centre clinics	36
8	Homes	29
9	Hospital buildings	63
10	Catering	20
11	Community centres halls	52
12	Pavilions / clubhouses	15
13	Sports buildings	65
14	Swimming pools	13
15	Religious facilities	11
16	Labs	17
17	Libraries	14
18	Museums / exhibition spaces	38
19	Schools	244
20	Universities / colleges	53
21	"One-off" housing	44
22	Flats only	89
23	Hotels and motels	17
24	Housing only	113
25	Mixed housing and flats	671
26	Residences	33
27	Sheltered housing	18
28	Conference centres	26
29	Sanitary blocks	6
	Subtotal	**2183**
Add:	*Projects coded to x00 level only*	*225*
Add:	*Projects not allocated to a special function heading*	*146*
	Total sample projects completed 1998-2004	**2554**

APPENDIX B

Linear regression trendline formulae
x = Log 10 of Construction cost
y = construction duration in weeks

Special Function Heading	Trendline formula
Road vehicle buildings	y=12.192x-46.51
Factories	y=10.234x-28.081
Warehouse stores	y=11.399x-41.28
Offices	y=22.603x-96.944
Retail	y=15.857x-61.083
Animal welfare	y=30.164x-141.16
Health centre clinics	y=21.365x-87.98
Homes	y=30.27x-133.82
Hospital buildings	y=25.37x-110.27
Catering	y=-0.3614x+23.642
Community centres halls	y=15.847x-57.622
Pavilions / clubhouses	y=20.106-86.392
Sports buildings	y=33.216x-161.57
Swimming pools	y=54.486x-262.93
Religious facilities	y=20.362x-80.505
Labs	y=17.115x-54.20
Libraries	y=47.082x-238.17
Museums / exhibition spaces	y=19.28x-85.845
Schools	y=25.955x-115.66
Universities / colleges	y=34.777x-171.01
"One-off" housing	y=30.912x-130.77
Flats only	y=32.985x-146.36
Hotels and motels	y=5.9369x+2.6144
Housing only	y=32.795x-146.14
Mixed housing and flats	y=25.048x-97.826
Residences	y=12.235x-29.603
Sheltered housing	y=34.776x-158.86
Conference centres	y=20.958x-89.943
Sanitary blocks	y=32.793x-151.79