The Capture and Reuse of Design Cost Information in Architecture

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ABSTRACT

The procurement process has been the subject of considerable study in the construction industry. Whilst some of this research has examined the architectural design process, this has generally not focussed on the commercial aspects of architectural practice. Similarly, the estimation of project costs have focused more on the ‘construction’ aspects rather than on design cost forecasting. This paper reports on the initial stages of research that aims to develop a methodology to enable more accurate design bids to be made for public-funded projects. The aim is to identify the issues and approaches that can be adopted to facilitate the effective capture and reuse of design cost information. A review of how information and knowledge of the time required to carry out an architectural commission is managed, is presented. A conceptual framework and methodology of how this can be achieved is proposed and the paper concludes with suggestions for further research.

KEYWORDS:


1. INTRODUCTION

Following the abolition in the UK in 1981 of institutionally set mandatory fee scales for architects (RIBA, 1972), the winning of architectural commissions frequently requires participation by the architectural firm in some form of competitive bidding. This usually requires a process of estimating and fixing a lump sum or percentage fee bid on the basis of information provided in

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an invitation to tender. The Royal Institute of British Architects (RIBA, 2004) set out four “options for the calculation of architects’ fees”:

1. A quoted percentage of the final cost of the building works;
2. A fixed calculated lump sum;
3. Time charges; or
4. Another agreed basis.²

In public-funded projects, for example, an examination of invitations to tender published in the Official Journal of the European Community (OJEC) shows that these inevitably use either 1 (percentage fees), or 2 (fixed lump sum fees) as the basis for fee submissions. In practice, formulating a bid for either of these requires the same process of calculation (for percentage fees the figure is simply expressed as a percentage of the contract sum).

For all architectural commissions in the UK, it is rarely the case that fees are paid on a reimbursable basis (i.e. paid on the basis of the hours worked and costs incurred). Fees are more commonly paid as a pre-agreed fixed percentage of the construction contract or as a fixed lump sum.

The calculation of the percentage or lump sum fee offer can be derived in a number of ways including the use of historic data held by the bidding firm; the use of published data (for example, publications by Mirza and Nacey, 2006); or on some form of resource costing projection. The process frequently results in an unusually wide spread of submitted prices which may be explained by commercial considerations including variations in productivity, attitudes to risk or profit aspirations; or may call into question the accuracy and the application of the data used in formulating the bid.

This paper introduces research that is aimed at developing an objective methodology to enable more accurate design bids to be made. The aim here is to define the key issues involved in design cost information and forecasting and to outline the various strategies to accomplish this. A brief description of the research being undertaken is provided and this is followed by a discussion of various strategies for the capture and reuse of design cost information that will enable more accurate estimation of design costs. The paper concludes with recommendations for further research.

2. COST ESTIMATION IN CONSTRUCTION

The process of tendering is widely used in the UK construction sector. The procedures are well understood by both the supply and demand sides and procedures for capturing historic construction cost information are well established. This happens both at the level of the firm, where outturn costs for individual contracts are recorded for re-use, and at institutional level where professional organisations such as the Royal Institution of Chartered Surveyors (RICS) gather industry wide building cost data through the Building Cost Information Service (BCIS) for dissemination by subscription.

² The term ‘another agreed basis’ is a catch all contained within the RIBA Standard Form of Appointment contract which allows the parties to agree any other legal basis for payment (e.g. ‘Value Added Fees’ – RIBA (2004)).
To be successful in a competitive tender the bidder must arrive at a price that is low enough to be the most attractive offer, but also high enough to recover the bidder’s costs and a profit. Where all other things are equal, and this is generally the case following a pre-qualification process, the most attractive offer will usually be the lowest financial bid. The calculation of the bid requires access to information including:

1. The nature of the project (the design, the specification, the function, location, complexity, the form of procurement and so on).
2. The contractual terms.
3. The programme or schedule for the works.
4. The cost and availability of the resources (materials, labour, plant).
5. The time required to carry out the commission.
6. The company cost base (overhead recovery and expectations of profit).

This information can be considered in four categories:

- Information held by the commissioning body and made available (to varying degrees of detail and certainty) to the bidder.
- Information held by the bidder.
- Information held by a third party and potentially available to the bidder (e.g. project information such as reports of site investigations; or generic commercial information such as published historic cost data).
- Information held by a third party and not available to the bidder (for example commercial information held by competitors).

A number of private publishing houses collect, analyse and publish construction cost data electronically and in paper form (for example Spon, 2006). The procedures for defining, recording and classifying building cost data is highly formalised (e.g. through the use of the Standard Method of Measurement (RICS, 1998)) and well established and understood by players in the UK construction industry. But this extends only to the construction stage of the project. Some broad statistical information on design fees is available (Mirza and Nacey, 2006 and BCIS, 2000) but there is no analytical information relating to the build up or the components of the figures recorded. This lack of analysis is significant as the design stage typically can account for 10 –15% of the total project costs.

Cost Estimation in Architecture

Classical contract theory is founded on the principle that a transaction is determined at formation. That is to say that all the circumstances are envisaged, known and fixed at the point that the deal is struck. In reality the bidding environment for architectural commissions is characterised by low levels of project knowledge and a high degree of project uncertainty – the project, by necessity, is not clearly defined until at least some basic feasibility or study has been completed. This is in contrast with construction stage bidding where there are (usually) clearly defined detailed studies, specifications, contract terms and design intent drawings (although it would
be a mistake to assume that this means that all the circumstances are envisaged, known and fixed – more, rather than all are known). The bid price for an architectural commission is fundamentally the product of: (a) the total time required to carry out the commission (typically considered in units of hours) multiplied by: (b) the cost per unit of hour for each operative. The total cost for each operative would include: (i) salary and employment on-costs; (ii) a proportion of the firm’s overhead recovery; and (iii) an element of profit. Commission specific expenses and disbursements would usually be recovered separately.

This research is concerned primarily with an examination of how information and knowledge relating to (a) (i.e. the time required to carry out a commission) is managed, how it is recorded, retrieved, categorised and reused. In particular the research examines the potential for a system of recording and categorising of historic time data that defines the specific project context and the common circumstances. It is anticipated that in any case the reuse of knowledge will require a degree of judgement and that the final price will be informed by other commercial considerations (e.g. attitudes to risk, continuity of work, and aspirations of profitability).

A distinctive attribute of architectural practice is that the work is project based. Each project will have unique characteristics and this requires a knowledge management and pricing process which allows these to be made explicit and accounted for. Examples of special characteristics, which may influence the overall time to complete a commission, include: the contractual terms (in particular the scope of work for the commission); the functional complexity of the building use; the technical complexity of the design; any onerous statutory or legal constraints on the design. The ability to accurately predict with any degree of confidence, the time required to carry out a particular architectural commission is typically inhibited by:

- Limitations in accuracy or availability of historic data.
- Imperfect knowledge of the resources required to complete a task.
- Imperfect knowledge of the ability and productivity of individual human resources (operatives).
- Knowledge of the type (e.g. architect) and level of staff required.
- The difficulty of predicting the time taken to complete a creative process – how long does it take for inspiration to come?
- Difficulties in understanding, analysing and categorising the architectural design process at a general level and in a specific project.
- The difficulty of predicting the time to obtain third party regulatory approvals, some of which are technical; some of which have both a technical (building regulations) and political dimension (planning approval); and some of which involve commercial or other negotiation.
- Imperfect tender knowledge - for example lack of clarity in the scope of work or the contract terms.
- Managing project change – e.g. defining what constitutes a ‘project change’ as opposed to ‘design development’. Importantly in cost terms is the issue of how the distinction between a change to the project definition and design development is dealt with in the contract terms.
Given the high degree of uncertainty together with the lack of a useful and accessible knowledge base, it is tempting to say that architectural bidding is, in its current form, more a matter of luck, rather than the synthesis of knowledge and judgement - the “faith, hope and fifty percent method” of pricing (Wilson, 1972).

To pursue this to the level of the firm rather than the individual project it could be said that architectural firms survive commercially (i.e. make a profit or at least don’t make a consistent loss) by ‘getting it right as often as they get it wrong’ - they overprice as often as they under price and the ‘super profit’ from the overpriced jobs subsidises the loss making commissions. However, on closer examination this is unlikely to be the case as Winch (1989) points out “Errors in estimating are also likely to involve the omission of costs; errors of inclusion do not outweigh these because the latter estimates are unlikely to be the basis of successful tenders.” Given this uncertainty in the costing and pricing process, understanding how architectural firms maintain profitability remains an important area of investigation for this research.

In practice, evidence of effective architectural job costing systems is patchy and anecdotal. Most rely on storing time recorded on time sheets with perhaps some rudimentary categorisation often in the UK based on the RIBA Plan of Work, which can be retrieved for pricing new opportunities. A review of the effectiveness of these pricing systems gives rise to many questions, for example:

1. Is it possible to (cost-effectively) capture and record sufficient information to meaningfully improve the accuracy of cost predictions?
2. How can a bidder improve the capture and reuse of design cost data?
3. What would make the knowledge reusable?
4. Is there a role for applications such as Artificial Neural Networks?.
5. Is there an opportunity to capture and share information at an institutional level or by for-profit publication?
6. Is it possible to overcome or alleviate cognitive errors in interpreting the stored data?

Research Aim and Objectives

The aim of the research reported here, is to develop an objective methodology for assessing the factors that impact on the time required to complete an architectural commission; the recording, classification and re-use of these. The specific objectives are:

1. To develop a theoretical framework for managing time (and cost) data.
2. To undertake a detailed study of the project characteristics that impact on the time required to carry out architectural design functions.
3. To identify and classify the factors that significantly impact on design time and design costs (possibly, but not necessarily the same factors)
4. To develop a firm-based methodology for managing design time and cost knowledge.
3. PROPOSED STRATEGY FOR DESIGN COST FORECASTING

Capture and Reuse of Design Cost Information

The key strategy for developing a methodology to more accurately estimate design cost at the bidding stage is centred on the capture and reuse of design project information. The ability to learn from experience is now considered to be a vital ingredient for business success in organisations, and is a cornerstone of various knowledge management (KM) initiatives and strategies in recent times (Kamara et al. 2002a). While the trend is for more formalised strategies, there has been a long tradition within the construction industry to capture lessons learned in standard operating procedures, best practice guides and codes of practice (for example, the BCIS cited above) (Kamara et al. 2002a).

Another common approach used to capture lessons learned is to rely on people. This is based on the assumption that the knowledge acquired from one project can be transferred by that individual to other projects or to an organisational knowledge base (if that exists). Figure 355.1 illustrates a scenario of how knowledge is captured and reused within a construction (or architectural) firm implementing many projects. Knowledge from the organisational knowledge base (OKB) (whether shared or held with various individuals) is used to bid for, and implement a project. The learning from this project is captured and stored in the OKB on with individuals. If projects are implemented sequentially, then the capture and reuse of learning between projects is via the OKB (or individuals); if they are implemented concurrently, then you can have transfer between projects as shown in Figure 355.1 (Kamara et al. 2005).

![Figure 355.1](image-url)
The means by which knowledge is captured from one project to the next is either by formal post project reviews or other strategies (e.g. communities of practice). However, given the risks with relying on people (e.g. loss of knowledge when staff leave the organisation) and lack of sufficient time for meaningful post project reviews, more proactive strategies are being proposed to ensure that lessons learned are effectively captured and reused in subsequent activities. These include recent research into the Capture and Reuse of Project Knowledge in Construction (CAPRIKON) (Tan et al 2006), and the use of an approach called Knowledge-Event Management to capture the learning from the day-to-day problems of construction site managers (Boyd and Xiao, 2006). In the CAPRIKON project, the idea of a Project Knowledge File (PKF) is proposed for the collaborative capture of learning from participants and other project settings (e.g. meetings and documents). The knowledge captured in the PKF, which is based on a template developed from the research undertaken in CAPRIKON, can be reused during and after the completion of the project.

Given that effective KM depends on the context and content of the knowledge to be managed (Kamara et al. 2002a), it is necessary that an appropriate strategy is adopted for this particular situation (i.e. the capture and reuse of design cost information).

Selecting a Design-Cost-Knowledge Capture and Reuse Strategy

Previous research by Kamara et al. (2002b) proposed a four-stage process (referred to as the ‘CLEVER framework’) for the selection of appropriate KM strategies for construction firms. The stages in this process are: (a) define KM problem; (b) identify ‘to-be’ solution; (c) identify critical migration paths; and (d) select appropriate KM process. The ‘define KM problem’ stage involves the definition of the KM problem within the context of the business (e.g. what is the current ‘as-is’ situation). The ‘identify “to-be” solution’ stage defines the desired (‘to-be’) state (e.g. creating a shared knowledge resources from a situation where knowledge is held by individuals). The ‘identify critical migration paths’ stage focuses on specifying how to get from the ‘as-is’ to the ‘to-be’ situation. Finally, the ‘select appropriate KM process’ stage describes the selection of suitable KM processes that support the preferred migration paths to move from the ‘as-is’ to the ‘to-be’ situation. The application of the CLEVER framework is facilitated by four tools to correspond with each stage in the framework: a problem definition template, knowledge dimensions guide, migration path tools, and generic KM process models (Kamara et al. 2002b). This research will adapt the CLEVER framework in the development of a design-cosy-knowledge capture and reuse strategy.
Possible Design-Cost-Knowledge Capture and Reuse Strategies

Table 355.1 outlines how the ‘CLEVER framework’ can be applied to the problem of developing a methodology for design cost estimating. The application of each stage of the framework to the context of design-cost-knowledge capture and reuse, and the research issues involved, are briefly described. The ‘define KM problem’ and ‘identify “to-be” solution’ stages correspond respectively to the research problem and objectives outlined in this paper. The ‘identify critical migration paths’ and ‘select appropriate KM process’ stages include, for example, issues to deal with the transfer of tacit individual knowledge to a shared explicit knowledge base, identifying sources of knowledge, defining format for shared knowledge base, developing cost estimating model, and a strategy for capturing, representing and reusing the knowledge that will feed into the model.

Table 355.1: Applying the CLEVER framework to design-cost-knowledge capture and reuse.

<table>
<thead>
<tr>
<th>CLEVER Framework</th>
<th>Design-Cost Strategy</th>
<th>Research Issues</th>
</tr>
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<tbody>
<tr>
<td>Define KM Problem</td>
<td>It is difficult to make an objective estimation of design costs based on the information provided in tender documents</td>
<td>Research problem: unavailability of historic cost data &amp; supporting information to define limitations of and conditions for re-use of such data</td>
</tr>
<tr>
<td>Identify ‘to-be’ solution</td>
<td>To have a robust, firm-based mechanism to objectively estimate design costs at the bidding stage</td>
<td>Research objective: to ensure more accurate bids for design work</td>
</tr>
<tr>
<td>Identify critical migration paths</td>
<td>e.g. Moving from ‘individual tacit’ to ‘shared explicit’ knowledge</td>
<td>Identify sources of knowledge, define format for shared knowledge base</td>
</tr>
<tr>
<td>Select appropriate KM Process</td>
<td>Capture of actual design costs into a model that can assist with estimating future design costs</td>
<td>Develop cost model &amp; mechanisms for capture, representation &amp; reuse of knowledge in model</td>
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The fourth stage of the CLEVER framework, ‘select appropriate KM process’ was based on the assumption that there are already many generic KM solutions relating to knowledge generation, capture and reuse (Kamara et al. 2002b). The crucial issue, however, is the contextual application of these tools. While further research is required to determine the ‘specifics’
for the research reported in this paper, there are a number of KM techniques that might be suitable for the capture, representation and reuse of design-cost knowledge (Table 355.1).

In the first instance, the collaborative capture techniques adopted in the CARPIKON project described above, can be adapted in this case. This might result in the development of a design-cost-knowledge file (DCKF). However, since the issue of cost requires more precise information (e.g. cost indices), it is helpful if any strategy adopted combines both quantitative and qualitative ‘knowledge’ (to include, data, information and knowledge). Techniques such as Artificial Neural Networks (ANN) and Case-Based Reasoning (CBR) can therefore be suitable for this purpose.

An Artificial Neural Network “consists of hardware or software that attempts to emulate the processing patterns of the biological brain” (Laudon and Laudon, 2001). It “uses rules it ‘learns’ from patterns in data to construct a hidden layer of logic … [which] processes inputs and classifies them based on the experience of the model” (Laudon and Laudon, 2001). ANNs “learn by example to map nonlinear relationships, to adapt for changes in the operating conditions...[and] reasonably respond[s] to incomplete and noisy data...to generalise solutions for future situations” (Elhag et al. 2006). It is therefore suitable for, and has been used in tender price estimation and in the prediction and optimisation of financial forecasts, and most importantly, as an aid to human decision making (Laudon and Laudon, 2001; Elhag et al. 2006).

CBR originated from the observation that humans learn from, and use past experiences to make decisions about present and future problems (Johansson and Popova, 2002). It involves the capture and storage of organisational knowledge in a database of ‘cases’. The solution to a current problem is formulated based on similar cases in the database, which can be modified to fit the unique context of the current case. In our particular case, this might involve the creation of a database of design costs for various bids, which will be used to formulate bids for new projects.

4. DISCUSSION, CONCLUSIONS AND FURTHER WORK

This paper has introduced research into the development of an objective methodology to enable a more accurate estimation of design cost in bids. The focus of this research is on the capture and re-use of cost information, which will lead to more accurate bids. The significance and relevance of this research arises from the fact that it addresses a need for research into the estimation of design costs. Whilst there has been considerable research on construction procurement (e.g. Winch, 2000; Erwin et al 1991; and Cox and Townsend, 1998), and on the architectural design process (e.g. Lawson, 1994 and 1997; Lawson and Pilling, 1996; and Broadbent, 1984), very little has been done on the commercial or economic aspects of architecture. Work by Nicholson (1992), Greenwood and Walker (2004), Schneider and Davies (1995), Worthington (2000) and Gray et al (1994) have examined aspects of the commercial and institutional context of
architectural design, although not the capture and re-use of cost data. Other work by Byron (2001) and Nicholson (2003) focuses mainly on practical advice to architects in practice on the process of fee bidding.

The potential benefits of this research for architectural firms would include reduced transaction costs, improved profitability and the reduction of commercial risk. Firms will have access to data, to guidelines on how to assemble and use this, and potentially a practical IT application, for job costing knowledge management, which can be used both to reduce the time required to calculate and formulate a bid and to increase accuracy. The capture of the knowledge will contribute to the knowledge of project based performance measurement. It is recognised that in particular circumstances a firm submitting a bid may choose to make a financial offer at a ‘no profit’ level (or even at a loss); this strategy is acknowledged by and recognised in the behaviour of architectural firms (see Pinnington and Morris, 2002, and Winch and Schneider, 1993) and is an example of ‘market based’ rather than ‘full cost pricing, as discussed earlier. However, this can only be a conscious business strategy if the firm is able to accurately establish, with a reasonable degree of confidence, their break-even cost for a particular commission. For any firm knowing the cost is not the same as knowing the price you may wish to submit for a particular commission; or the bid that would secure the commission. Whilst it may well be the case for architectural firms that more detailed information on cost would be available when measured relative to the information available on other factors such as market conditions or competitor behaviour; that is not to say that the information is adequately detailed. An important test of adequacy in practice would be the utility or ‘usefulness’ of the information in preparing a new bid and it is anticipated that an area of future research would be measuring this utility.

The potential benefits at a national level would include an increase in economic output; reduction in business failures, and a better understanding of the process and motivation of architectural firms. For customers of the construction industry an understanding of the bidding process in architecture could give rise to greater clarity in the invitation to treat documentation, which could give rise to more competitive tendering. The outputs of this research will also have applications either directly, or on the basis for future work, in related construction professional services and in other creative industries. For the research community this work would contribute to the knowledge base and inform the architectural management and architectural informatics research and teaching agendas.

There is however, need for further research to ensure that the potential benefits outlined above are fully realised. This will involve the consideration of the research issues outlined in Table 355.1 above. In particular, this will include: the identification of the sources of reusable design knowledge within architectural firms; the development of a format for the capture and representation of this knowledge; and the development of the cost model and mechanisms for the ongoing capture, representation and reuse of the knowledge in the model.
5. REFERENCES


