PREDICTIVE COST MODELLING: INVESTIGATION UTILISING A QUALITATIVELY BIASED RESEARCH METHODOLOGY

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Predictive cost modelling research has developed in the context of the traditional separation of design and construction activities of the building procurement process. This division is often considered an obstacle to the development of improved predictive cost modelling techniques, owing to the exclusion of the contractor's expertise from the design process. Recent shifts in procurement strategies, resulting in greater contractor involvement in the design stage of construction projects, provide fresh opportunities to investigate this perceived panacea. This paper reports upon research currently in progress into predictive cost modelling techniques utilised by design and construct contractors. In particular, the design and implementation of a predominantly qualitative research methodology, supplemented by quantitative techniques, is examined and postulated as the most appropriate medium for addressing the objectives of the research. Within this context, a theoretical resource based predictive cost modelling technique is developed. The model is subsequently tested utilising case-studies analysis. Preliminary results indicate a "fitness for purpose" of the methodology in the context of the research, although drawbacks are identified.

Keywords: cost modelling, design and construct, procurement

INTRODUCTION

Research into predictive cost modelling techniques has generally been conducted utilising quantitative methods of inquiry, particularly through the use of survey instruments. This paper reports upon predictive cost modelling research in progress, with particular emphasis given to the development of the research proposition, and the design of a predominantly qualitative based research methodology to address the proposition. An overview of the research methodology is presented, followed by an examination of each stage of the research. Conclusions are then drawn in relation to both the research itself, and the suitability of the chosen methodology.

OVERVIEW OF RESEARCH METHODOLGY

The research methodology and progress to date is outlined in Figure 1.

The methodology of the research follows a staged process that commences with a review of the literature and development of the research proposition and study questions. To investigate the research proposition, a theoretical resource based cost model is constructed which is subsequently applied in a qualitative case study

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environment. The case studies are analysed both individually and collectively. The conclusion of this stage represents the current status of the research. It is proposed to supplement the methodology with a quantitative survey to both generalise the findings and triangulate the validity of the research. The final component of the research involves the review of existing theory in light of the findings.

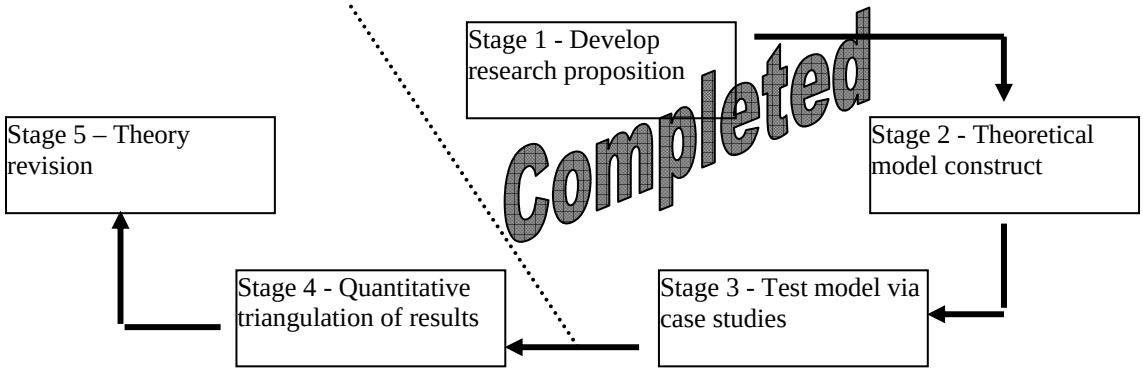

Figure 1: Research methodology outline and progress to date

STAGE 1 - DEVELOPMENT OF THE RESEARCH PROPOSITION

Predictive cost modelling is the process of representing, in the context of building design, the cost consequences of an event or decision. The process utilises various cost modelling techniques that are technical aids which enable management decisions to be made (Skitmore and Marston, 1999). Studies by Fortune and Lees (1996) and Fortune and Hinks (1998) investigating specific cost modelling techniques usage during "early cost advice" by "organisation", found a number of such techniques in widespread use. Those techniques are summarised in Table 1 below.

Table 1: Predictive cost modelling techniques in widespread use (Source: Fortune and Lees, 1996, and Fortune and Hinks, 1998)

Technique	Description
Judgement	The use of professional expertise and intuition to formulate strategic cost advice.
Functional Unit	A monetary rate applied to a unit commensurate with the function of the building e.g. $/ carparking space.
Superficial	A single rate applied to the floor area of a building e.g. $/m2.
Principal item	A single $ rate applied to the major item of a project.
Interpolation	The application of costs from previous projects by way of interpolation.
Elemental Analysis	A summation of the application of costs to the design elements within a project.
Significant items	The measurement and pricing of significant items of work.
Approximate Quantities	The measurement and pricing of a small number of grouped items.
Detailed Quantities	The measurement and pricing of many items, such as a bill of quantities.

These predictive cost modelling techniques are referred to as ***product*** based cost models (Skitmore and Marston, 1999), because they model the completed building product. Such models are considered useful on the basis of their ease of application, familiarity and speed, and a tolerable level of accuracy (Ashworth, 1995).

However, the same models have also been criticised on the basis that they:

are not (explicitly) founded upon construction production criteria as the generator of cost (Morton and Jaggar, 1995)

do not fully represent the relationship between design decisions and the resulting construction processes (Bowen, 1993) and

fail to consider the uncertainties of the construction process (Bowen, 1993).

Beeston (1987) considers the greatest opportunity for improved accuracy in predictive cost modelling lies in aligning the techniques used as closely as possible with the generators of such costs, i.e the construction method or resources by which they arise. Such ***resource*** based cost models are considered to be inherently more reliable than their product based counterparts (Skitmore and Marston, 1999).

In response, attempts have been made to develop resource based cost modelling techniques, including the operational bill of quantities (Skoyles, 1968), the construction unit planning approach (Bowen, 1993, Morton and Jagger, 1995), the British Property Federation system (Morton and Jaggar, 1995), the cost of contractors operations system (Beeston 1973), pre-established critical path method networks (Bowen, 1993), and simulation computer packages (Bennet and Ormerod, 1984). Data integration systems incorporating both product and process based information have been advocated by Morton and Jaggar (1995), and Kim *et al* (1999).

All such alternatives share a common theme of utilising the contractor's resource based cost data during the design process. However, the previous studies by Fortune and Lees (1996) and Fortune and Hinks (1998) confirm a low level of usage of such resource based cost modelling techniques in "early stage cost advice". Reasons proffered for such infrequent usage include:

the additional assumptions required to convert design information into production information (Skitmore and Marston, 1999).

a lack of understanding of construction processes by design consultants (Formoso as cited in Bowen 1993).

a lack of, and unfamiliarity with, process data available during the design phase (Ogunlana, 1989).

the additional time constraints imposed by such methods (Ogunlana, 1989).

Notwithstanding the time constraints imposed by such methods, it is postulated that any such lack of understanding of construction processes on the part of design consultants is predominantly a function of traditional methods of building procurement. Love *et al* (1998) consider the traditional fragmentation of the design and construction functions has created “walls” around the project participants resulting in ineffective communication processes. Such “walls” create an environment in which processes such as predictive cost modelling are often conducted in a climate of self-perpetuating isolationism. In such an environment, design consultants may “suffer” from cost modelling a design that does not explicitly represent all the cost generators which are fundamental to the accuracy of the cost model. Kim *et al* (1999) consider such a problem to result from the “functional gap” created from differing data requirements and “traditional barriers” existing between professionals. Latham (1994) acknowledges the lack of co-ordination between design and construction inherent under traditional forms of procurement, whilst Egan (1998) points to the barrier to utilising the skills of the contractor in the design process.

To overcome this barrier requires the construction process expertise of the contractor to be made available to design consultants. This may be achieved by the use of:

computerised simulation programs (Brandon, 1982).

"Expert" computer systems which effectively "bottle" or "capture" the expertise of the contractor and make it available to consultants during the design process (Bowen, 1993).

alternative procurement methods that involve the contactor in the design process, such as design and construct (also known as design and build etc).

It is the third of these conditions with which this research is concerned. The potential advantages of using alternative methods of procurement within this context have been recognised. Akintoye (as cited by Azam et al 1999) notes the potential of such alternatives to improve the general level of integration between building design and production. More specifically Ross (1998), identifies the opportunities such procurement systems present to utilise resource based cost modelling techniques during the design phase of building procurement. Thus the proposition of the research is that:

> *design and construct methods of building procurement provide an opportunity to implement resource based cost modelling techniques in the design phase of building procurement.*

In order to confirm or reject this proposition, four specific study questions are identified as requiring investigation as follows:

Are resource based cost modelling techniques used during the design phase of projects procured under design and construct methods, and what is the evidence of usage?

To what extent are resource based cost modelling techniques used during the design phase of projects procured under design and construct methods? i.e at what stages of the design process, if any, are resource based cost modelling techniques employed?

If resource based cost modelling techniques are not used during the design phase of projects procured under design and construct methods, why not?

To what extent, and at what stages of the design process, are product based cost modelling techniques employed under design and construct methods?

STAGE 2 - THEORETICAL MODEL CONSTRUCT

In order to address these study questions, a theoretical resource based cost model was constructed for testing. The model design is an attempt to capture the factors that determine a contractor's resource costs for a project. Hutchison (1993) considers such factors to include:

Quantity determined resource costs; whereby a relationship exists between the quantity of completed work and its base resource requirements in terms of labour, material, plant and equipment.

Quality determined resource costs; whereby a relationship exists between the quality of completed work and its base resource requirements in terms of labour, material, plant and equipment.

Method determined resource costs; those which are determined by the way in which a building is to be constructed, and the complexity of construction.

Construction period determined resource costs; those which are a function of the overall time of construction.

The theoretical model construct is represented diagrammatically in Figure 2.

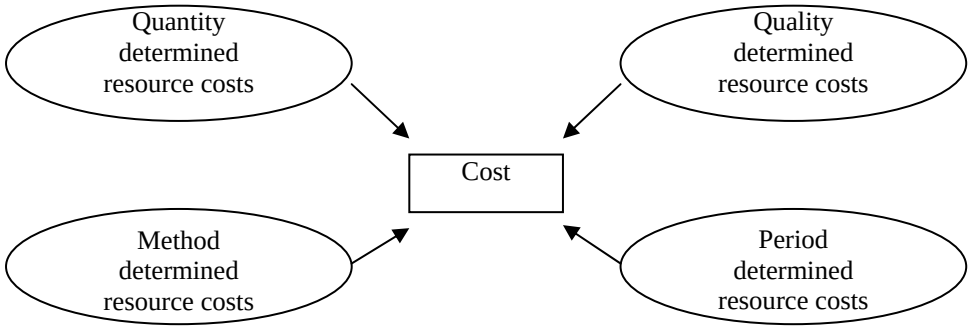

Figure 2: A theoretical resource based cost model (After Hutchison 1993)

In order to utilise the model to address the study questions, key indicators of model usage were determined. Such indicators provide tangible representation of the four categories of resource costs of the model, as outlined in Table 2 below.

Table 2: Theoretical resource based cost model cost generators matched against indicators of model usage

Resource cost category	**Indicator of model usage**
Quantity determined resource costs Quality determined resource costs	a pricing mechanism which directly reflects there source requirements (labour, material, plant and equipment)of a particular work item.
Method determined resource costs	a method statement that portrays a method by which the project is to be constructed and cognisance is taken of the cost implications of such a statement.
Construction period determined resource costs	a construction programme which portrays a project plan and duration by which the project is to be constructed and cognisance is taken of the cost implications of such a programme.

The indicators provide the evidence of model usage for investigation within the case study framework. For example, if any of the indicators are present, it is considered that the theoretical resource based cost modelling technique has been used. Additionally, the indicators can identify at what stage(s) of the design process the model has been utilised (either in whole or in part), thereby providing a measure of extent of model usage. The next stage of the research was to test the model within design and construct case study projects.

STAGE 3 – CASE STUDIES – A QUALITATIVE ENVIRONMENT FOR MODEL TESTING

The selection of an appropriate research methodology is critical to maximise the possibility of achieving the aims and objectives of the research. Common research methodologies available include experiments, surveys, histories and case studies. Yin (1994) notes that each strategy has its own particular advantages and disadvantages, and the decision of when to use each strategy is determined by three conditions:

the type of research question(s) posed.

the extent of control the investigator (researcher) has over actual behavioural events, and

the degree of focus on contemporary, as opposed to historical, events.

In relation to the first condition, the research involves questions of the 'how', 'how much' (to what extent), and the 'why' nature. Each research strategy might be considered suitable for application to these types of questions. However, the research does not require control over behavioural events (condition 2), but rather is concerned with observing such behaviour untampered. Hence, the experiment method is not considered suitable for the research. Finally, the research focuses upon contemporary events as far as is practically possible. As such, the archival history research methodology is inappropriate, as it is a method of specifically dealing with the "dead" past, when no relevant persons are alive to report what occurred (Yin, 1994).

Therefore, the appropriate research methodologies are the survey and the case study.The use of the survey based research methodologies is prevalent in the field of construction research. Edwards and Bowen (1998) considered the nature and findings of sixteen survey-based research publications in relation to construction risk and identified the following areas of concern (in terms of the surveys themselves):

the surveys did not reveal a consistent standard of rigour.

sample frames and response rates were often inadequate.

the design of some survey instruments was seemingly poor.

the difficulty of undertaking extensive cross tabulation of responses, particularly in view of the heterogeneous nature of the construction industry.

lack of uniformity in the use of terminology.

a general lack of scoring calibration for rating type questions, which in turn permits subjectivity in the responses, and hence creates problems for subsequent data analysis and interpretation.

the generic nature of much survey based research, and the lack of connection with the context in which the answers to the survey questions are developed.

In the context of this research, a "superficial" status quo of usage levels of the theoretical resource based cost modelling technique utilised under design and construct methods of building procurement may be established by the use of survey based research methodologies. However, to determine when and why such techniques have been used at the major stages of the design process, and the allied evidence of (or lack of) such usage, requires a "deeper" investigation of the context and circumstances of the respondent. Such "deep" investigation is not permissible through survey techniques, as it necessarily involves a consideration of the larger context of a particular project in which cost modelling techniques are applied. One method of achieving such "data richness" is through the use of case-study methodologies.

The appeal of a qualitative case-study methodology lies in the ability to investigate a phenomenon within it's real context (Yin, 1994); the phenomenon in this research being predictive cost modelling, and the context being design and construct projects. Edwards and Bowen (1998) argue in favour of the use of case-study based research methodology, in light of the nature of the industry itself, noting that construction is primarily a project driven endeavour, and the understanding of phenomenon is likely to be found in the context of the project environment.

Adopting this methodology, a pilot and three subsequent case studies were undertaken. The primary methods of enquiry for the case studies were semi-structured interviews and document inspection. Several evaluation methods have been promoted for qualitative case study data evaluation. Such methods include the illustrative method, methods of agreement and difference, domain analysis, ideal types (Neuman, 1997), content analysis (Berg, 1989), pattern matching, explanation building and time series analysis (Robson, 1999).

A two-stage evaluation methodology was adopted as illustrated in Figure 3 below. Stage 1 considered the analysis and evaluation of each case study in isolation. Individual case studies are presented in descriptive terms, and subsequently related back to the original study questions utilising the illustrative method of qualitative data analysis. Such a method employs empirical evidence to illustrate or anchor pre existing theory, such evidence confirming or rejecting the theory (Neuman, 1997).

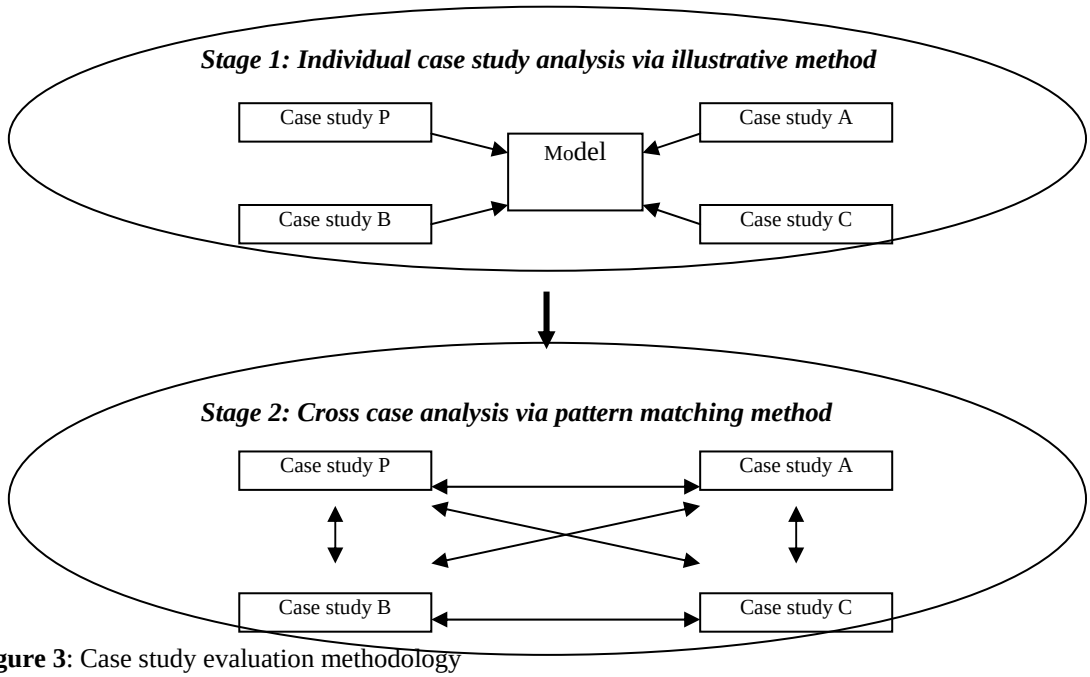

Figure 3: Case study evaluation methodology

Stage 2 of the evaluation process involved undertaking a cross-case analysis. Such an analysis is intended to compare multiple case studies in order to identify areas where the indicators of the model (and hence the study questions and research propositions) can either be confirmed, rejected or modified. To undertake such an analysis requires the identification of similarities, differences and trends; in other words the establishment of patterns. Hence a pattern matching strategy was adopted whereby the propositions of the research, and the outcomes of the case studies, are plotted by way of matrix to enable patterns to be identified.

It is not possible to fully describe the findings of the research here. Preliminary results of the analysis reveal that each case-study had a structured procedural approach to design stage predictive cost modelling, similar to the British RIBA plan of work, or the Australian NPWC cost control manual. All case studies utilised a combination of both product and resource based cost modelling techniques during their design phase.

Generally, the case-study projects made greater usage of product based cost modelling techniques earlier on in the design process, with an increased emphasis on resource based cost modelling techniques toward the end of the design stage. On all projects,

two of the three the key indicators of the theoretical model construct (resource based pricing mechanism and construction program) were evident. On only one project was the third key indicator (method statement) present. The resource based pricing mechanism was utilised more toward the end of the design phase, generally in accordance with the greater level of information then available. Additionally, it was used to separate labour and material budgets, the latter often intended to be procured directly by the head contractor, with the former provided by way of sub-contract. The use of sub-contractor prices was also prevalent toward the end of the design process. On all projects, the use of a costed construction program was undertaken early on in the design process. The construction program was developed to model both the contractor's preliminaries resource requirements, and the likely cashflow profile, for the project.

The preliminary findings of the research indicate a "fitness for purpose" of the methodology to date. The methodology has been able to identify patterns of usage of the specific indicators of the theoretical resource based cost modelling technique. Additionally, the methodology has permitted identification of cost modelling technique usage at the major stages of the design process. Importantly, it has been possible to establish why various techniques were or were not used. By extension, the context in which such decisions are made provide indicators as to those aspects of resource based cost modelling techniques considered important by the design and construct contractors. The methodology has also revealed shortcomings both in terms of the research itself, and case studies as a mode of inquiry. In respect of the former, the research has encountered difficulties due to the sensitive nature of the subject. This has created obstacles in personnel and document access in certain circumstances, particularly when a lack of familiarity exists between the researcher and the respondent of the case study. The case-study mode of inquiry itself is dependent upon human recollection and interpretation, which as a minimum may be to merely supplement other forms of evidence, such as document inspection and observation. At the other extreme, it may be the predominant source of evidence. At either extreme, or at any point in between, human recollection and interpretation are necessarily influenced by the context in which the respondent views the project. Naturally, this will vary from person to person, which inevitably leads to a degree of subjectivity with respect to case-study interpretation. Whilst this may be minimised by case study validation procedures such as having a case-study protocol and using multiple sources of evidence etc., it cannot be totally eliminated.

STAGES 4 AND 5 – QUANTITATIVE GENERALISATION OF FINDINGS AND THEORY REVISION

Stages 4 and 5 of the research methodology remain to be undertaken, and form the future direction of the research. The patterns identified in the results analysis represent aspects of resource based cost modelling considered potentially important to the overall predictive cost modelling process, and when in that process they might be employed. However, until they can be generalised and confirmed in the larger family of design and construct projects (and hence contractors), they remain simply indicators. If such generalisation can be achieved, it may then be possible to compare the specific predictive cost modelling technique usage of contractors with those of design consultants, and identify areas of mismatch. Such mismatches may highlight areas where design consultants could or should adopt resource based cost modelling techniques. One method of achieving this is to consider the results of the case studies

as not the conclusions, but rather the identification of more specific issues than otherwise may be gleaned from the literature. In terms of the research, such issues would include the extent of usage of the resource based cost modelling indicators identified previously; the resource based pricing mechanism, method statement and costed construction program. Such issues can be put to the wider industry (both contractors and design consultants) via a quantitative survey. The design of such a survey would benefit from being developed in light of the case-study outcomes by being particularly focussed, specific and concise, eliminating much of the criticism of survey techniques identified earlier. If the results of the survey correlate with those of the case studies, the latter have been generalised, and hence of wider application. In addition, the survey results may "triangulate" the research and hence provide validation. Lenard *et al* (1997) consider that two data "points" (in this instance, the literature review and the case studies) provide simply a measure of agreement or disagreement. Information from a third source (i.e. the survey) can aid the confirmation of the initial agreement / disagreement between these two points; in much the same way as a witness to a crime is able to corroborate the evidence.

Completion of such a quantitative "broadening" of the research findings will enable the initial propositions of the research to be answered, and permit a re-examination of the theoretical resource based cost modelling construct. It is envisaged such re-examination will result in some form of predictive cost modelling theory modification and / or confirmation and hence complete the research process in its current iteration, thus continuing to reduce the gap between "the know and the knowable" of this field.

CONCLUSION

The development of alternative methods of building procurement involving the contractor in the design stage of construction projects provide fresh opportunities to investigate design stage predictive cost modelling techniques. In particular, the use of resource based cost modelling, long considered a panacea to the drawbacks of traditional product based cost modelling techniques, can be investigated in this context. A qualitatively biased case study method of inquiry is considered to be the most appropriate methodology to identify the contexts within which different aspects of a theoretical resource based cost model are implemented. The "data richness" of case studies provides indications as to the extent of usage of both resource based and product based cost modelling techniques. Future work in this area is intended to augment the methodology with a quantitative survey to generalise and validate the case-study results, and hence develop an eventual modification and / or confirmation of existing predictive cost modelling theory.

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