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IMPLEMENTATION OF A NEURAL NETWORK MODEL FOR THE COMPARISON OF THE COST OF DIFFERENT PROCUREMENT APPROACHES

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Existing research which has attempted to determine differences between the costs of the different procurement routes has consistently aimed to determine a single figure for the difference for projects as a whole. No attempt has been made to provide a difference which is project specific (Duff et al., 1998). Furthermore, no previous research has determined the cost to the client using any objective method.

The absence of such a technique is significant. It means that the client’s advisors have no means of providing an objective measure of the cost of following different procurement routes. The client must depend upon the judgement of the advisors, which is based on their own perception of both the project and the different procurement routes, and is hence subject to their opinions and prejudices.

This paper reports on the development of a neural network model which is able to determine the total cost to the client of following different procurement routes, as well enabling the project specific comparison of alternative procurement routes.

Keywords: Cost Modelling, Early Stage Estimating, Neural Networks, Procurement.

INTRODUCTION

The selection of the procurement route is believed to have a significant influence on the final cost of a building project. Despite this, however, very little research has aimed to provide any indication of the relative costs of this decision. Research that has been carried out has tended to be quite subjective, and often fails to consider the total cost to the client. In addition, the research has aimed to provide a flat percentage difference, which is assumed to be fixed for all projects.

The research presented in this paper involves the development of a model that is able to objectively predict the full cost to the client of following different procurement routes. This is achieved by modelling not only the final account cost of the building contract, but also the professional fees and the cost of the resources the clients invest in the project themselves. The type of model to be used (a neural network) will permit the full cost of the project to be objectively evaluated from past data under different procurement routes. The model will make this evaluation using information available at an early stage, the time when the strategic decision is taken of which procurement route to follow.

PREVIOUS RESEARCH

The costs associated with the procurement were first evaluated subjectively. The Building Economic Development Committee [The Building Economic Development Committee (1974)] produced a guide in which cost performance on projects designed by different types of consultant was measured by comparing the percentage of projects completed within 5% of the estimated cost. This does not however, truly compare the relative costs, but only how close the final account figure would be to the contract sum.

The Department of Industry and the Department of the Environment [Department of Industry & Department of Enviroment (1982)] made a subjective comparison between traditional, design & build and management procurement routes. Differences in cost were not quantified but subjectively evaluated as "higher" or "lower" than the traditional procurement route.

A subjective comparison was also made by Brandon et al (1988), who suggested that the cost of the procurement route be taken into account by means of an addition. The additions range from 0% for the
conventional and design & build systems to 15% for construction management, apparently based on experience.

The first attempt at an objective evaluation was made in a recent report on design & build [Reading University (1996)]. The Centre for Strategic Studies in Construction concluded that the design & build procurement system is "at least 13% cheaper than traditional procurement". The analyses were carried out using multiple regression and identified 11 variables, including choice of procurement system, but which together explained only 51% of the variability in project cost.

Masterman [Masterman (1994)] investigated procurement system selection methods and found that references to the financial aspects of selection are limited to clients' strategic objectives, such as whether uncertainty on price is acceptable, price competition is important, or a firm price is required before work can commence. The actual cost of the choice of procurement cost was not objectively evaluated, simply because there was no means of doing so.

A more recent evaluation of the cost of the procurement route was made by Elhag et al. [Elhag (1998)]. They compared the average tender prices per m² for the three different procurement systems for 13 office projects and 28 industrial projects. With the office buildings, the cost per m² was found to be highest for management contracts, and lowest for the traditional route. For industrial buildings, design and build was found to be cheaper than traditional, the reverse of that for the office projects. This suggests that the relative costs of different procurement routes are not constant for all projects. However, this result cannot be relied upon with much confidence, as no test of statistical significance was performed on the results, and the number of projects is very small. In addition the comparison failed to take into account the influence of other cost significant variables, which could be substantial.

THE MODEL

While earlier research was aimed at establishing a general cost difference, it is recognised in this current research that the true difference in cost is not necessarily a blanket figure, independent of other cost significant variables. This means that while one procurement route may be cheaper for one type of project, it cannot be assumed that that same route will be cheaper for another type of project. Therefore, the relative cost of different procurement routes must be determined specifically for each project. The simplest way of determining this cost difference between procurement routes is to create a model that is able to predict the cost of the project from all the cost significant variables, including procurement. This model can then be used to evaluate the expected costs of the project under different procurement routes, and the differences between the predicted costs observed.

In order to accurately evaluate the differences in cost between the different procurement routes for any particular project, the model is required to model the complex and little understood interrelationships which exist between the cost and all the cost significant variables which exist at this early stage of the project. Because the relationships between the different variables are so difficult to identify and quantify, a neural network was selected as the modelling tool to use. Neural networks are able to model any function to an arbitrary accuracy without those functions having to be identified in advance, and are therefore ideal for use when the interrelationships between variables are not understood. It has the ability to implicitly quantify all the interrelationships between the variables by examining the outcomes of a large set of past projects. This process is called “training”.

Despite the abilities of neural networks to model any function, the accuracy to which it is able to do so is dependent upon the number of projects it uses in training. The fewer the projects, the less the accuracy. This poses a problem for using a neural network for this research, because collecting data from past projects is a difficult and time consuming process, and the number of projects required is around 500. In order to maximise the accuracy of the model, it is therefore necessary to employ techniques and strategies which maximise the accuracy of the neural network for a fixed number of projects.

This has already been done by careful consideration of the inputs to the neural network by Harding et al. [Harding (1999)]. This paper discussed how the project may be defined at an early stage in terms of 40 variables, which fall into three main groups. These are: project strategic variables, such as procurement and tender strategy; site related variables, such as the topography and site access; and design related variables, such as the frame type and gross internal floor area.
**Defining the output from the model**

The importance of the accuracy of the neural network arises from the desire to accurately model the final cost of the project to the client. Creating this model of the total cost requires the training of the neural network on accurate project data. That is to say, the model must be trained on data which really represents the **whole** cost of the project to the client.

A criticism of previous literature is that it has tended to use only the tender price to evaluate the cost of the project. In reality, the cost to the client of a building contract is not the tender price, but the final contract sum. In addition, the whole cost to the client includes not only the final contract sum, but the professional fees and the cost of whatever resources the client has to provide to the project themselves. Therefore it is necessary to consider all three sources of cost to the client. Therefore the costs of the project are being collected as follows:

- The final cost of the contract
- External client costs
- Internal client costs

The final cost of the contract – the amount of money that client actually pays the contractor – is very seldom the same as the tender price. Corbett et al. [Corbett (1999)] suggested that the provision of tender price by the BCIS was not sufficient, and that the final account sum should be made available to cost planners. This was to enable cost planners to provide the actual cost of the contract. In order to provide this within the model, it is necessary to use the final account, rather than the tender price.

As well as the final account, it is also necessary to determine the cost of the various professional services the client will have to pay for in addition to the contract. These services include fees for the professionals involved with the project, such as the QS, the architect, the services engineers, et cetera, who are not paid for in the contract sum. In addition, the client will also be required to pay planning fees and building regulations fees. These must also be included in the cost to the client as the external client costs.

The final cost of the contract and fees for professional services constitutes all the external costs the client must pay for. However, the client will also make a substantial contribution to the project themselves in terms of both time and resources. This can range from the cost of time spent at meetings required throughout the project to the cost of a full project team which is active on the project. Whether the client is an individual or an organisation, this time input to the project has an associated cost, whether it is a direct employment cost, or an opportunity cost. This cost, as well as the cost of associated resources (travel, consumables, etc.) should be included in the whole cost to the client, and represents the client’s internal costs.

Now that these cost attributes have been defined it is possible to ensure that the correct costs are being taken into account by the model. However, it must be remembered that the costs of any particular building will vary from place to place. In addition, the effects of inflation will mean that a building completed four years ago will cost less than a building completed more recently. Therefore all the project costs should be reduced to a common base date and location. The former can be done using the building cost inflation indices, and the latter using location indices, both of which are available from the BCIS. Thus, when the model is actually used, the output of the model can be adjusted from the common base date and location to the base date and location of the project in question.

**THE COST OF THE BUILDING**

As well as ensuring that the costs used in the modelling are set to a common base, it is also necessary to ensure that no items are included in the project cost which are not defined by input variables. The model aims to predict the cost of the building, and variables being collected from past projects reflect this. However, building projects often include items that are not suitable for definition within the project model. These are as follows:
• External works
• Demolition
• Fittings
• Specialist services

**External works**

External works vary significantly from project to project. They may include such items as external drainage, landscaping, tree planting, tarmac, paving, fencing, street lighting, et cetera. Furthermore, the actual area covered by the external works may vary significantly. Of the projects collected so far, the external works can represent as little as 1% of the total contract sum, while at the other end of the scale it can be as much as 30%, or even higher.

The modelling of the external works is a very difficult task, and would involve the collection of a great many more variables than are currently being collected. In addition to this, there is a clear division in the project between the actual building and the external works. Therefore the cost of the external works is removed from the final contract sum, and the model is restricted to analysing the final cost of the building. In addition, it will also be necessary to remove from the contract preliminaries and client costs any costs which relate to the external works and not to the building. Where this data is not available explicitly, it may have to be removed on a proportional basis, based on the external work’s proportion of the contract sum.

This means that when the cost planner aims to make an estimate using the model, some additions would have to be made to the value to account for the external works involved in the project.

This practice of excluding the external works is valid when the proportion of the external works to the contract cost is fairly low. However, when the proportion of external works becomes very high, the external works can become a significant cost driver for the project. If this is the case then it is possible that the selection of procurement method will have a significant impact on the cost of the external works as well as the building cost. As this is difficult to measure, it could influence the model detrimentally and decrease its accuracy. Therefore it is necessary to exclude such projects from the database altogether.

While this may appear restrictive, it is necessary to be realistic about the application of the model. While it may be possible to model the cost of the external works, including the effects of the project strategic variables, this is beyond the scope of this research. In the future it may be possible to utilise such a model, in tandem with the model developed, to break projects with a high proportion of external works down to the external works and the building. This would permit the effects of the selection of the procurement route on such projects to be modelled more accurately.

**Demolition**

Demolition, like external works, can easily be excluded from the model. It is performed before the actual process of construction the building actually begins, and is therefore quite separate from that process. However, as a demolition contract is fairly straightforward, it is assumed not to incur any significant additional client costs. Any further cost influences arising from the fact that demolition has been performed are assumed to be included by the input variable which indicates whether the site is greenfield or brownfield.

**Fittings**

The cost of the fittings is also far simpler to deal with than the cost of the external works. The costs of fittings are simply the cost of procuring the items, which remain fairly constant from project to project. Therefore the solution is to remove them from the contract sum. As with external works, the cost planner would simply add the cost of any fittings to the estimated contract sum when generating the estimate.
Specialist services

Some buildings include specialist services beyond those usually included within the mechanical and electrical services, which contribute significantly to the cost of the building. While fittings are items that simply need to be placed in the buildings, many specialist services, such as large refrigerated rooms or swimming pools need to be integrated within the design of the building. Sometimes they may need special foundations or other structural elements, or perhaps have additional requirements in terms of power supply.

The problem with trying to include projects with this type of service within the model is that the specialist services cannot be excluded because of the way they are integrated with the building in a way that external works and fittings are not. Therefore, if these models are to be included within the database some way must be found of quantifying such services. However, these services vary significantly in both type and scope. To represent them as a set of additional variables would be difficult, if not infeasible. Even if a variable or number of variables could be found to represent their inclusion, these variables would only be meaningful for those projects that included such services, which would constitute less than 5% of all projects in the database. Neural networks are not able to model the effect of variables which take a single value for over 95% of cases. Therefore the neural network will be unable to model the inclusion of specialist services accurately. This fact means that any project with a significant amount of specialist services must be excluded from the database.

COLLECTION ISSUES

The collection of accurate data is vital to the success of the project. Once the correct information to collect has been identified, it is important to ensure that the data collected is accurate. This is, of course, obvious. However, it has proved not to be very straightforward in practice. The collection of the input variables and final account figure are fairly simple. The vast majority of the data is available from the project documentation, and that little which is not can be ascertained by asking the surveyor involved on the project. Similarly the external client’s costs are usually easy to collect because the client keeps a record of them. However, this does not apply to the client’s internal costs. It is our experience that many clients are simply unaware of how much money they would spend internally, and have very little idea how they even go about recording or collecting such information. This applies to repeat and one-off developers alike.

The challenge for this project is therefore to create some means of determining the client’s internal costs for the project, so they can be modelled along with the other costs. In order to do this, the following must be ascertained:

- Whether any professional services (architects, QS, project management, et cetera) were provided by the client.
- How many personnel from the client’s organisation were involved the project, and how many man-days they worked.
- How many meetings were attended at each stage of the project.

Some of this information may not be certain, particularly the number of man-days spent on the project by the client. This is primarily because the client does not collect such information, and is therefore required to make an estimate. This could make the accuracy of the clients internal costs lower than that of the contract sum and external costs. Nevertheless, it should provide an estimate of a cost that is currently ignored, and thereby permit its inclusion in the model.

It is unlikely that the reduced accuracy of the client’s internal costs will have a significant effect on the accuracy of the model as a whole, because the internal cost’s proportion of the total cost is low. The final contract cost is much higher than the client’s internal costs (at least ten times higher), and it is our expectation that the output from the model of the contract sum is will only be 90% accurate, or 95% at best. Therefore, in order for error in the client’s internal costs to add significantly to the error already present in the modelling of the contract sum, the error would have to be very large (more than 50%).
In addition to this, the accuracy of the costs will not stop the neural network generalising very well providing sufficient data is collected. This generalisation, while not necessarily providing an accurate actual cost of the client’s internal costs, should provide an accurate indication of the cost differences associated with following different procurement routes. Indeed, this argument can be extended beyond the selection of the procurement route to any other strategic variables that have a significant influence on the client’s internal costs.

Access

The method of collecting the data is now fully defined, and collection has been progressing for some time. The route for collection chosen initially was through QS practices. Collection of the data that defines the project was made by extraction from the project documentation, as well as the final account, tender sum, and costs to be excluded. However, the practices have not usually had access to the client’s costs, and on the rare occasions when they have had the external costs, they have been reluctant to share them, at least without the client’s permission.

In order to address this, it has been necessary to ask the client for this cost data. The actual process of asking the client is usually left to the surveying practice. This is because the surveyors feel that for a third party to ask the client for information regarding a project may draw the surveyors confidentiality into question and damage the relationship between the surveyor and the client. Typically, however, having the QS ask the client has resulted in a success rate of slightly less than 50% in clients agreeing to provide the costs, with the primary reason for opposition being that of confidentiality.

This response rate was, it was felt, quite low, particularly when it was considered that the primary beneficiaries of the operational model would be the clients. It was suggested that part of the reason for their resistance to the collection of data was that the surveyor was not really “selling” the benefits of the model, because they had to be very careful that whatever they said was not detrimental to their relationship with the client. Therefore it was proposed that client organisations be contacted directly, with the aim of collecting all the project information from them, rather than QS practices. Therefore, a number of repeat developing client organisations were contacted directly. It was found that the response rate was very high, at around 40%, and respondents were very enthusiastic. While this value is less than the 50% achieved by going through the QS, it is a very high response rate for an unsolicited approach, around twice that obtained when contacting surveying practices. In addition, these responses were to a request to collect all the data from the client organisation, which demands more time on the part of the client than the collection of the client’s costs alone.

Therefore it would appear that collecting data directly from clients is the most effective route to take, although existing contacts with QS practices must continue to be exploited.

FURTHER WORK

While the motivation for the development of this predictive model is to develop a model capable of predicting the comparative costs of different procurement routes, it will also create a model capable of predicting the cost of a project from an early stage. This, once developed, could be an important tool in the early stage cost estimator’s toolbox. However, the model and the data as it will stand at the end of this project will also permit comparative investigation beyond the initial purpose – to compare the costs of following different procurement routes.

The completed model will allow not only the comparison of different procurement routes, but also of other strategic variables, such as the tender strategy and duration. This would be useful strategic information for the client, but it would also be useful from a research point of view to see how, typically, changing these variables would affect different types of project. There are two components to this. The first is how significant an effect the variable has on the cost of the project, and the second is what this effect is and how it varies between different types of project.

This type of comparison is not restricted to those variables that represent strategic choices for the client to make. It can also be useful for the comparison of different types of project function, and also for comparing speculative and owner-occupied buildings. Indeed this comparison could expand beyond project strategic
variables to issues of location, site, type of frame, et cetera. Comparison of such options would permit the identification of how and to what extent each of these variables influences the project costs.

In addition to information that might be obtained from the model, other information is also being collected whose analysis might prove useful. The first is the tender price. By modelling this it would be possible to compare the differences in tender price and final account and how they vary from project to project. Similarly, the planned project duration could be compared to the actual duration, which would provide an indication of whether certain types of project are more likely to overrun than others.

By comparing these two values it may be possible to quantify both cost and duration certainty. This would permit the client’s advisors to provide objective advice on the cost risk associated with a particular project.

CONCLUSIONS

The ongoing development of a model to assess the differences in procurement costs has been discussed. This model aims to provide an accurate comparative cost of following different procurement routes which is project specific. This is achieved using a neural network model of building cost, which includes procurement route as a variable.

Particular reference has been made to how the final cost of the building is to be collected accurately. This involves removing any demolition, the external works, the fittings and any specialist services which are easily separated from the project. Wherever specialist services do exist, the projects are excluded from the data set, as are projects with a very high external works content. This ensures that the data set used to train the neural network model is as accurate as possible.

In order to determine the whole cost of the project, it has also been necessary to collect the client’s costs. This has included not only the fees for professionals, but also the costs incurred by the client by having employees involved in the project. A means of collecting these costs was established, and issues regarding the collection of client data were also raised. It was found that it was more successful to contact client organisations directly to obtain data, which was significantly better than collecting project information from QS practices in the first instance.

The possibility of performing further analysis with the model and data obtained was also discussed, and potential benefits outlined.

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