Forecasting cash flow expenditure at pre-tender stage: Case studies in New Zealand construction projects

Andrew Heaps
School of Engineering and Advanced Technology, Massey University
Andrew.Heaps@nz.rlb.com
Niluka Domingo
School of Engineering and Advanced Technology, Massey University
n.d.domingo@massey.ac.nz

Abstract

Construction projects are extremely reliant on cash flow to survive. Cash flows from the client to the contractor and onto the subcontractors through monthly progress payments. Knowing the value of each progress payment in advance is essential for clients to arrange their sources of funding to ensure timely payments. The creation of a cash-flow forecast is a complex process, especially in the pre-tender stage of a project. There have been a number of past studies done in the area of cash-flow forecasts for construction projects at various stages. The 4th degree polynomial and the Logit model have been identified in the literature as the most effective methods of forecasting cash flows at pre-tender stage. However, no significant study has been done in New Zealand to identify the most accurate model to predict cash flow at the pre-tender stage.

This research aims to develop a robust model to effectively forecast cash flows for construction projects in New Zealand at the pre-tender stage. Interim payment valuations in nineteen completed projects were analysed, using Logit model and 4th degree polynomial, to identify the best model to forecast cash flow.

The 4th degree polynomial was identified as the most effective model for modelling cash flows. However, due to the unique nature of construction projects, no standardised curve was identified to represent cash flow forecast. It was discovered that an idiographic approach is needed to forecast cash flows, by adding or subtracting the unique features of the project from the base model. The findings of the research would be of benefit to quantity surveyors and construction clients in predicting cash flow in construction projects at the pre-tender stage.

Keywords: cash flow, construction industry, forecasting, New Zealand, pre-tender stage

1. Introduction

Cash flow plays an important role in construction project financing for both clients and contractors. It flows from the client to the contractor and on to the subcontractors and suppliers. It is beneficial for clients to know the cash flow plan in advance, to arrange funding sources accordingly, and ensure smooth functioning of the project (Kenley, 2003). Similarly, accurate cash flow forecasting is essential for the survival of any contractor at all stages of the work (Banki and Esmaeeli, 2008). Much research has been done on cash flow forecasting for construction projects, with a number of different solutions being offered to address the problem. However, predicting cash flow during the pre-tender stage is considered difficult, due to limited information and time availability.

A number of different statistical approaches have been used to develop cash-flow forecasting models. The majority of cash-flow forecasting models developed have been based on polynomial regression, which was first used by Bromilow and Henderson (1977). They collected data from past projects, modelled into a standard curve using regression. This method was further expanded by Tucker (1986), Kaka and Price (1991), Khosrowshahi (1991) and Ng et al. (2001), by grouping projects into different types, and developing standard curves to match each group/type. All these approaches were nomothetic, and had the belief that a standard curve for a type of project could be found. This approach is challenged by the idiographic approach, which treats each project as unique. Projects are modelled by creating a curve for each project individually. Research has shown the idiographic to be correct (Banki & Esmaeili, 2009; Kaka, 1999; Kaka & Price, 1991; Kenley, 2003; Kenley & Wilson, 1989; Min-Yuan & Andreas, 2010) when tested on completed projects. However, the idiographic approach of modelling is useless for forecasting, as identified by Banki and Esmaeeli (2008), as it can only be used for analysis. A standard curve is needed for forecasting, as grouping the projects according to their different parameters improves the accuracy of the standard curves. However, the accuracy of the standard curves is still not ideal (Kenley, 2003), and they have been proven to be unreliable in forecasting cash-flow expenditure.

Further research is required to improve the standardised curves to provide more accurate results. Furthermore, no significant research has been conducted in a New Zealand context to develop a model to forecast cash flow at the pre-tender stage, which is the focus of this study.

2. Previous research

There are a number of different ways to forecast cash flow for construction projects; these include S-curves, cumulative value and cost-loaded programs. A large amount of research has been done on cash-flow forecasting at various stages of the construction project. The S-curve models were regarded as the fastest and easiest methods to forecast cash flow at the pre-tender stage of a project (Banki & Esmaeeli, 2008). Much research has been done to find S-curve models to represent the cash flow of a project more accurately.

2.1 Bromilow Model

Bromilow developed one of the early models to forecast cash flow in the 1960s at the building research division of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Kenley, 2003). Bromilow used polynomial regression to develop the model.

The Bromilow's equation:

$$T = C_0 + C_1 P_1 + C_2 P_2 + C_3 P_3 + C_4 P_4$$

Where T is the percentage of time since the start of construction, P is the percentage of expenditure, and C are the constants.

In developing this model, Bromilow used a very small sample and very little thought was given to the unique characteristics of different project types. This model has been used as the basis for further research by Bromilow and others (Balkau, 1975; Bromilow & Henderson, 1977; Jarrah et al., 2007; Khosrowshahi, 1991; Ng et al., 2001; Skitmore & Ng, 2001; Skitmore & Ng, 2003; Tucker, 1986).

2.2 DHSS model

Hudson (1978) at the British Department of Health and Social Security (DHSS) developed a model to forecast cash flow using polynomial regression, which was later called the in full first time (DHSS) model. However, unlike the Bromilow model, this model used only two constants to define the shape of the curve.

The DHSS model:

$$y = s\left[x + cx^2 - cx - \frac{6x^3 - 9x^2 - 3x}{k}\right]$$

Here c and k are the two parameters that define the model, x is the proportion of contract completed, and S is the contract sum.

Hudson published a range of c and k values for different project types and total project costs. Berny and Howes (1983), have done further work to the DHSS model to address the issues of cost overruns, and came up with a new, extra-exponential equation. Keller and Ashrafi (1984), compared the DHSS model with the Keller-Singh Model; the latter was developed with relatively complex mathematics, including three constants. The comparison concluded that both models performed well in forecasting cash flows for construction projects, however, the DHSS model was preferred over the Keller-Singh Model due to the availability of standard constants. The DHSS model was further tested by Skitmore (1992) for different types of project. The above study recommended the use of the DHSS model to forecast cash flow in different project types, although it was originally developed for hospital projects. This has expanded the use of the DHSS model more than other models to forecast cash flow (Kenley, 2003).

2.3 Logit Model

Instead of the nomothetic approach, the idea of an idiographic approach to find a model was introduced by Kenley and Wilson (1986). Their work was based on the hypothesis that each project is unique and therefore the cash-flow model cannot be developed from grouped data. Kenley and Wilson (1986) used a Lorenz curve in their model, to show the cash flow forecast in cumulative form, which allows progress payments to be identified. The Logit model is used to create the curve. A good-fit test was done using the risk index and the standard deviation of the estimate of Y (SDY). This allows models to be compared with other models to select the best fit, with the lowest SDY.

The Logit model:

$$v = e^{\alpha}\left(\frac{t}{1-t}\right)^{\beta} \Big/ \left[1 + e^{\alpha}\left(\frac{t}{1-t}\right)^{\beta}\right]$$

(Source: Kenley & Wilson, 1986)

Where v is the value of the contract complete and t is time complete, both expressed as a percentage, and α and β are the constants.

Kaka and Price (1991;1993) reinforced the need for an idiographic approach to cash-flow forecasting, as introduced by Kenley and Wilson (1986). This study used data from 150 completed projects and used the Logit model function to set a best-fit curve. The projects were defined by four distinguishing features; type of project, size of contract, construction company and type of contract. The authors used SDY as the basis to compare the model with the data set to find the best-fit curve. To give a clear representation of the curve's fit, a boxplot was used to graphically represent the data. The ANOVA test was used to identify how different groups affected the shape of the curve, and further identified the fit for the groups. After finding the curve, a test was done to compare the fit of data to that from different groups. Kaka and Price (1993) concluded that the idiographic approach to forecasting cash flow had inherent advantages over standard curves. The drawback of the lack of grouping of data can be overcome by deriving constants for each criterion. This concept was taken further by Banki and Esmaeeli (2008), who agreed with the idiographic approach to forecast cash flow. However, this study emphasised that the idiographic approach can only be used effectively to analyse completed projects, which is a drawback in the methodology. Hence, the study concluded that the nomothetic approach is more suitable to forecast cash flow at the pre-tender stage of a project.

Apart from the above, a number other models have been developed by many researchers to forecast cash flow in construction projects. Boussabaine and Elhag (1999) developed a model using fuzzy logic, which was based on an idiographic approach. It predicts the average outcome of the cash flow at any particular point on the curve. Boussabaine and Elhag (1999) believed that fuzzy logic averaging would be a good compromise to the standard cash-flow curve.

However, there appears to be no published research on developing a model to forecast cash flow in a New Zealand context. The industry currently uses both nomothetic and idiographic cash flow forecasting models, with varying degrees of accuracy, to forecast cash flow in construction projects. The literature suggests the Logit model and 4^{th} degree polynomial as the most common models for forecasting cash flow, in other countries. Hence, this research focuses on selecting the most appropriate model for construction projects in the New Zealand context for forecasting cash flow.

3. Research method

This study aims to identify the most suitable cash-flow forecasting model for the New Zealand construction industry. The data was collected from progress payment valuations in nineteen completed projects; seven supermarket projects and twelve healthcare projects. Since variations are changes to the contract work that cannot be forecast, the total value of variations was excluded from the total interim payment amount in the analysis. Also, the total cost of retention and GST were disregarded, as they can be added later, depending on the requirements of the cash-flow forecast. Along with the total project cost, project duration and project type were also considered in the analysis. The Logit model and 4^{th} degree polynomial, which were identified in the literature as the two main forms of model that forecast cash flow, were tested using Microsoft Excel software to assess the most suitable model in the New Zealand context.

4. Findings and analysis

4.1 Analysis of data using Logit Model

The cumulative percentage of time (t) and cost (v) in all nineteen projects were transformed into Logit values using the Logit transformation equation as follows:

$$Logit = In(z/(1-z)$$

The v and t values were then used to find the alpha and beta values for the Logit equation using linear regression, where alpha is the intercept of the v and t values and beta is the slope (refer to Table 1). After the creation of the curve, the fit of the data to the Logit curves was found by calculating the SDY.

Table 1: Project Alpha, Beta and SDY values

Supermarket Projects	**Alpha**	**Beta**	**SDY**	**Healthcare Projects**	**Alpha**	**Beta**	**SDY**
1	0.8211	2.0353	3.15%	8	-0.3959	1.4486	2.11%
2	-0.5682	1.5435	3.50%	9	0.6453	2.1027	12.08%
3	-0.1291	1.6625	6.76%	10	0.1402	1.6545	3.59%
4	-0.0359	1.5947	2.00%	11	-0.3494	1.7845	2.67%
5	-0.9745	1.7867	1.98%	12	-0.0765	1.2614	1.59%
6	-0.5402	1.9141	5.54%	13	-0.5183	1.4693	2.79%
7	-0.43	1.4395	2.80%	14	-0.4885	1.3699	1.39%
				15	-0.38	1.41	5.92%
				16	-0.6157	1.4774	4.82%
				17	-0.0672	1.3229	1.81%
				18	-0.2686	1.7363	2.86%
				19	-0.3937	1.5418	2.73%

The projects were then grouped according to their types, and the average Alpha and Beta values were calculated as shown in Table 2.

Table 2: Projects grouped by construction type with average Alpha and Beta values

Project type	**Alpha**	**Beta**
Supermarkets	-0.2652	1.7109
Healthcare	-0.149	1.5844

Using the above Alpha and Beta values to form a curve for the project type, each project's original data was modelled back against this curve to find the SDY value, as shown in Table 3.

Table 3: Average SDY for average Alpha and Beta values

Supermarket projects	**SDY**	**Healthcare projects**	**SDY**
1	13.48%	8	3.91%
2	5.96%	9	5.08%
3	5.37%	10	7.32%
4	2.09%	11	4.90%
5	11.11%	12	4.68%
6	8.44%	13	8.27%
7	3.18%	14	6.93%
Average	**7.09%**	15	10.24%
		16	11.77%
		17	4.08%
		18	2.44%
		19	5.95%
		Average	**6.30%**

The SDY values calculated using average alpha and beta values in both supermarket and healthcare projects are considerably higher than SDYs calculated using alpha and beta values in individual projects. Hence, further categorisation of projects has been done using both project type and total project cost, to assess the suitability of the Logit model. Based on the project cost of construction, supermarket projects were divided into three groups: $5-$10 million; $10-15 million; and $15-25 million. Similarly, healthcare projects also divided into four groups; up to $5 million, $5-$10 million, $10-15 million and $15-25 million. After the above categorisation, some groups were disregarded, as they had only one project in the category. Average alpha and beta values of both supermarket and healthcare projects are shown in Table 4.

Table 4: Average Alpha and Beta values

Type of project	***Project cost***	***Alpha***	***Beta***
Supermarket projects	*$5 to 10 million*	*-0.0463*	*1.7459*
	$15 to 25 million	*-0.3487*	*1.603*
Healthcare projects	*$5 to 10 million*	*-0.289*	*1.5736*
	$10 to 15 million	*-0.2305*	*1.4324*
	$15 to 25 million	*-0.1046*	*1.7195*

The projects were modelled against these new curves to find the fit-to-curve using SDY. The values were averaged to find the overall fit of the curve to the data samples, as shown in Table 5.

Table 5: Average SDY based on project cost

Supermarket projects	***SDY***	***Healthcare projects***	***SDY***
$5 to 10 million	*7.36%*	*$5 to 10 million*	*5.99%*
$15 to 25 million	*4.13%*	*$10 to 15 million*	*4.50%*
		$15 to 25 million	*6.19%*

Apart from supermarket projects with a total construction cost from $5 to 10 million, the average SDY values have been reduced slightly, with the further categorisation of projects in the sample based on their total project cost. This indicates that grouping projects based on their characteristics would give better results in forecasting cash flow using the Logit model.

4.2 Analysis of data using 4th Degree Polynomial Model

The 4th degree polynomial curve has four constants that define the shape of the curve, unlike the Logit model. A similar process to the Logit model analysis has been conducted to assess the fit of the data to the 4th degree Polynomial model. The process consists of four steps:

1. Initially, the constants were calculated for individual projects and SDYs were calculated to assess the fit of the data to the model, as shown in Table 6.

Table 6: SDY values of individual projects using 4th degree Polynomial model

Supermarket projects	***SDY***	***Healthcare projects***	***SDY***
1	*1.89%*	*8*	*0.86%*
2	*2.40%*	*9*	*2.74%*
3	*1.49%*	*10*	*1.76%*
4	*1.59%*	*11*	*1.84%*
5	*1.64%*	*12*	*1.18%*
6	*2.40%*	*13*	*1.48%*
7	*1.66%*	*14*	*1.16%*
Average	***1.87%***	*15*	*1.94%*
		16	*2.15%*
		17	*1.18%*
		18	*2.03%*
		19	*1.94%*
		Average	***1.69%***

2. Secondly, the average values of constants were calculated separately for healthcare projects and supermarket projects and SDYs calculated to assess the fit of the data to the model, as shown in Table 7.

Table 7: Average SDYs of healthcare and supermarket projects

Project type	***SDY***
Supermarkets	*6.55%*
Healthcare	*5.23%*

3. Thirdly, projects were further grouped based on their type and total project cost and the average value of constants calculated.

4. Finally, SDYs were calculated for each group, to assess the fit of the data to the model, as shown in Table 8.

Table 8: Average SDYs based on project type and project cost

Supermarket projects	SDY	Healthcare projects	SDY
$5 to 10 million	7.09%	$5 to 10 million	4.74%
$15 to 25 million	3.93%	$10 to 15 million	4.66%
		$15 to 25 million	5.81%

It is interesting to note in these results that the 4th degree polynomial model always provides low SDY values when compared with the Logit model. Hence, the 4th degree polynomial was identified as the best model for representing cash flow in New Zealand construction projects. After identifying the 4th degree polynomial as the most effective model to forecast cash flow, the analysis moved on to finding a standard curve, by grouping the projects. The groups were formed based on construction type and project cost. Figures 1 and 2 show the standard curves developed for supermarket and healthcare project groups respectively.

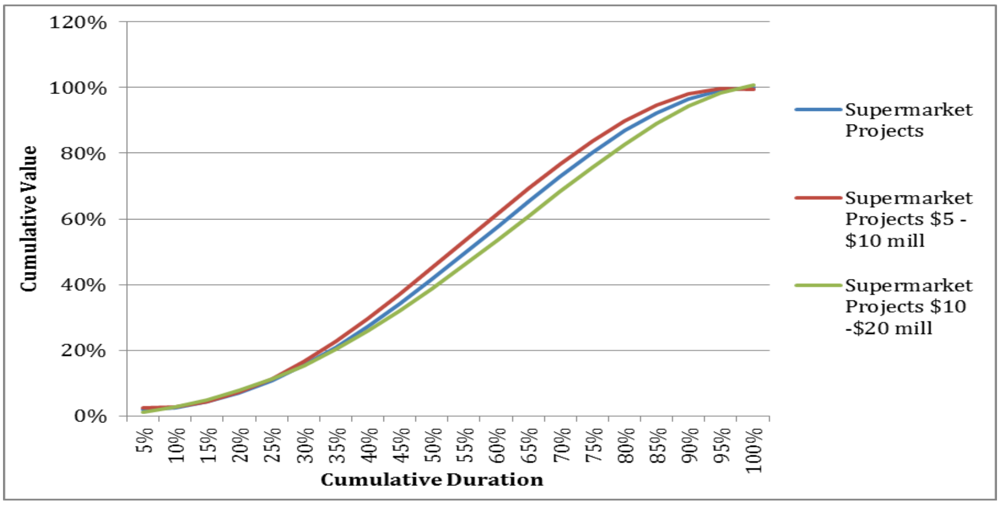

Figure 1: The 4th degree polynomial curves of the supermarket project groups

The graph illustrates that supermarket projects with a lower value have a steeper curve than projects with higher values. Interestingly, healthcare project curves are completely opposite to the supermarket projects; here projects with a high value have a much steeper curve than projects with a low value.

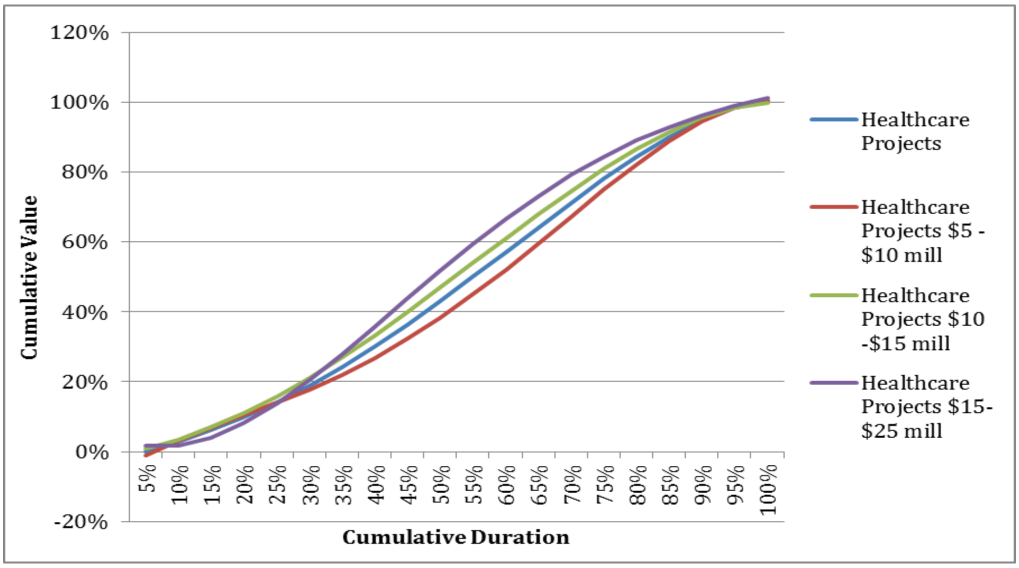

Figure 2: The 4th degree polynomial curves of the healthcare project

The aforesaid findings clearly indicate that developing a standard curve is difficult, due to unique nature of construction projects. However, further categorisation of projects based on their own characteristics would produce a better curve fit to the data. This is where the idiographic approach to forecasting is needed, as the great inaccuracies of standard curves do not provide accurate cash flow forecasts. Previous research on the idiographic approach by Kenley (2003) used the Logit model, however, the 4th degree polynomial proves a better fit to the data when modelled individually; this was further confirmed by the findings in this research. It is also important to draw the attention of users to the aforementioned drawbacks in the polynomial model, to use it effectively by taking mitigation measures to minimise errors during the practical application of the model.

5. Conclusions

This research aimed to identify the best model to predict cash flow in construction projects, using existing models in the literature. The 4th degree polynomial model was identified as the most suitable model to predict cash flow at the pre-tender stage of construction projects in NZ. With every construction being unique, it was concluded that no standardised curve could accurately be used to forecast cash flow. This research gives some insight into a complex problem, and provides industry professionals in New Zealand with a basis for forecasting cash flow. However, further research is required to group projects with more specific parameters that affect cash flows, to find precise models to alleviate the risk of inaccurate forecasts. It also opens up some already existing concepts, such as the idiographic approach, for further investigation.

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