The Effects of Variability of the Mathematical Equations and Project Categorizations on Forecasting S-Curves at Construction Industry

M. T. Banki* and B. Esmaeili

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Abstract: *Cash flow forecasting is an indispensable tool for construction companies, and is essential for the survival of any contractor at all stages of the work. The time available for a detailed pre-tender cash flow forecast is often limited. Therefore, contractors require simpler and quicker techniques which would enable them to forecast cash flow with reasonable accuracy. Forecasting S-curves in construction in developing countries like Iran in compare with developed countries has many difficulties. It is because of uncertainty and unknown situation in nature of construction industry of these countries. Based on knowledge of authors there is a little attempt for cash flow forecasting in construction industry of Iran. As a result authors produced An S-curve equation for construction project from historical data which has reasonable accuracy. A sample of 20 completed projects was collected and classified in to the three different groups. In order to model S-curves for each group, a simple and reliable method of S curve fitting has been used. S-curves were fitted into each group by using different techniques. Errors incurred when fitting these curves were measured and compared with those associates in fitting individual projects. At the end, accuracy of each model has been calculated and an equation has been proposed to forecast S-curves.*

Keywords: *S-curves, Cash flow, Financial forecasting, Project management, Construction industry, Developing countries*

1. Introduction

Cash is one of the most important of a construction company's resources, because more companies become bankrupt due to lack of liquidity for supporting their day-to-day activities, than because of inadequate management of other resources [1]. Insolvency is more likely to occur in this industry than any other [2].

Cash flow forecasting is essential for the survival of any contractor at all stages of the work. Ideally, cash flow forecasts should be based on the construction program and a bill of quantities [3]. Cash flow forecasting at the tendering stage needs to be simple and fast, although, there are some barriers such as the short time available and limited knowledge about the associated cost. Contractors rarely prepare a detailed construction plan at this stage, and usually wait until winning the contract. Therefore a simple and fast technique for forecasting cash flow accurately is required.

The majority of cash flow forecasting models developed have been based on standard value S-curves, representing the running cumulative value of work, and using data from completed construction projects. S-curves are widely used in the industry for controlling projects throughout their execution phases. They are valuable to project management in stating current status and predicting the future of projects. Although they are used in scheduling and planning, for reporting actual, earned and planned values and for resource loading various activities of a project [4], their reliability and accuracy is still in question.

The paper begins with a clear statement of the main objectives of the research followed by a detailed literature review based on previous attempts at developing models to forecast S-curves. A section on how the data was collected and used in the development of the model is then discussed. The accuracy of the present model is again tested against relevant previous research models and conclusions are made to determine whether or not the current research has improved on existing research.

* *Corresponding author. Email: bankimt@yahoo.com*

1 *Department of Civil Engineering, Amirkabir University, Tehran, Iran*

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2. Previous work

Wray (1965) outlined the importance of project control and suggested the use of cumulative plots of cost versus time, and cumulative value versus time. He argued that the contractor or client should plot their cumulative monthly value or monthly cost and compare it with envelopes of the budgeted S-curves. He concluded that the so called Project Status Reporting System (PSRS) would provide senior managers with a clear, concise picture of the overall financial situation.

Jepson [5] argued that S-curves representing labor man hours or labor costs can only act as indices for financial control. He claimed that a contractor might, due to a change of method, be losing money while labor costs remain less than forecasted. Moreover, he showed that the net cash flow was unlikely to be a good tool for the control of performance on site because actual values tend to vary widely from forecast ones.

In the early 1970s, with high interest rates and more appreciation of financial management, there was a surge in cash flow forecasting in both contractor and client organizations. Money was invested by construction clients (mainly public authorities) into research and hence more study was dedicated to the client's cash flow forecasting. This was demonstrated by the development of a series of typical value S-curves by many researchers [4],[6-14]. All of these have been obtained by fitting selected functions (mostly polynomial regression) to the available data.

Several models for clients to use were developed using these value curves. Balkau [8] derived the Bromilow and Henderson S-curve in an empirical formula to allow prediction of the cumulative cash flows. This formula was first used in a capital work's programming model [8] and in a life cycle costing model [15] and later updated [16].

The majority of these models were based on the idea of developing standard S-curves to represent the running value or cost of different types of construction projects. Typically this was achieved by collecting data relating to the monthly valuations and the projects' general characteristics. These projects would then be classified and distributed into groups and average S-curves would then be fitted on the individual groups ([8, 9]; [11]; [13]; [4]; [14]; [17]). Several mathematical models were used to fit the S-curves (e.g. alpha-beta cubic equation, Weibull function, DHSS model etc.). These models could be used, given that the total value and duration of the projects to be constructed are known, to forecast the cumulative monthly (or at any other time interval), value/cost of that project. The accuracy of these previous models is in question (see [2], for detailed analysis of previous models).

Kenley and Wilson [18], argued that the underlying principle of the idiographic approach is that the value curves are generally unique and that they should be modeled separately, hence a curve should be fitted for each project. This concept acts as a basis for the work involved in this paper.

The two main findings of the literature search applicable to this research revealed that previous attempts to forecast S-curves have not been accurate. First, that cash flow forecasts are likely to be inaccurate due to the fact that construction projects are unique and the progress of work varies greatly from one project to another, and second, that the choice of project groupings in previous work has been poor. These problems helped shape the nature of this research.

3. The idiographic approach

The failure of the aforementioned authors to produce typical value curves indicates the shortcomings of nomothetic models - that is, models which aggregate groups of projects in order to develop a single standard curve. This points the way to the introduction of an idiographic approach. The basic principle of this methodology is that value curves are generally unique and should be modeled separately (i.e. a curve should be fitted for each project).

Berny and Howes [19] modified a nomothetic approach to reflect the specific form of individual projects. By proposing an equation for the general case of an individual project curve, as distinct from the curve of the general (standard)

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function, they moved from a nomothetic to an idiographic approach.

Kenley and Wilson [18] applied the idiographic methodology further and used the Logit transformation to fit data. They analyzed 72 commercial and industrial building projects in two groups of data. They also developed a value S-curve for each individual project and an average one for each of the two groups. The error obtained from the two average curves was much higher than that of the individual fits. This meant that the systematic error involved in the group regression was high and the individual curves took a unique shape. They concluded by saying that it was their belief that group models are both functionally as well as conceptually in error.

It is important to acknowledge that idiographic models are only useful for analytical purposes. Forecasting requires the use of a standard curve developed out of a group of projects similar to the one to be executed (i.e. nomothetic models). The need for cash flow forecasting (and cost control) and the failure of previous work to prove the feasibility of standard value curves made it necessary to choose another variable that could be modeled more accurately and thus used to calculate the value curve. This is the major objective of this paper.

4. The process of developing the cost commitment model

In the absence of accurate standard value curves, the contractor should rely on another variable which can be used to derive the cost curve and hence the cash flow forecast. The variable was chosen and modeled in the following steps:

(i) Actual cost commitment values for 20 construction projects were collected under the proposed criteria. These projects were divided in tree group.

(ii) The tree model to fit the S-curve nomothetically and idiographically was chosen.

(iii) The fitting technique was used to model a series of S-curves.

(iv) The accuracy and feasibility of the model was tested.

(v) The results were then compared between models.

5. Data collection

It was necessary to include project with similar characteristic in the construction industry to provide validate S-curves. The information was sought from clients, contractors, and quantity surveyors as it was believed that these would be the most likely to yield the detailed cost and program information required. The sample is consisted of 20 projects from different part of Iranian construction industry. These projects were divided into tree different groups based on characteristics of activities in each project. The first group (A) is harbor construction projects and includes 12 projects. Major activities in this group are constructing piles, barriers, excavation, installing harbor equipments, and building facilities near sea. These projects were constructed in Persian Gulf and Caspian Sea. The second group (B) is refinery construction projects and includes 4 projects. Major activities in this group are constructing and installing on-shore facilities for refineries. These projects were

Table 1. cost breakdown of data used

Project type	Projects used	Minimum value of project ($m)	Maximum value of project ($m)	Average value of project ($m)	Total value of project ($m)
Harbor construction	12	0.28	73.42	33.63	403.58
Refinery construction	4	158	2012	1306	5225
Massive concrete cast	4	26.72	452.73	167.35	669.38

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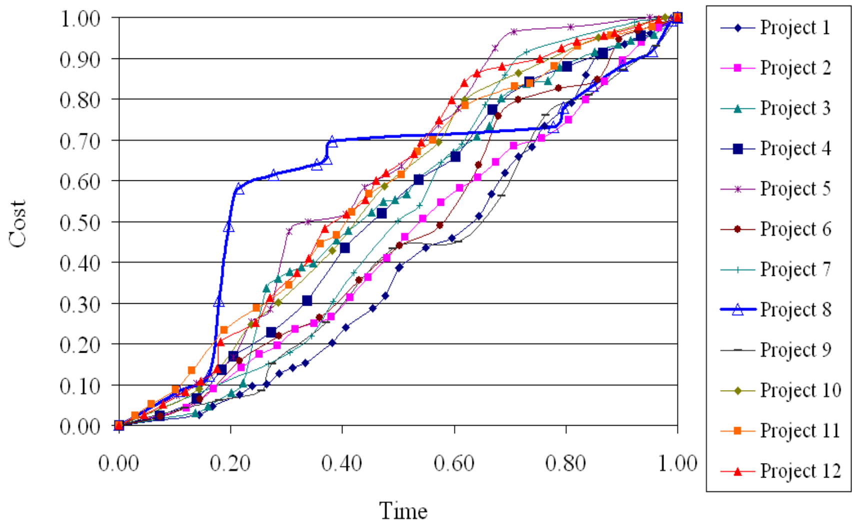

Fig. 1. The real S curve for project group A

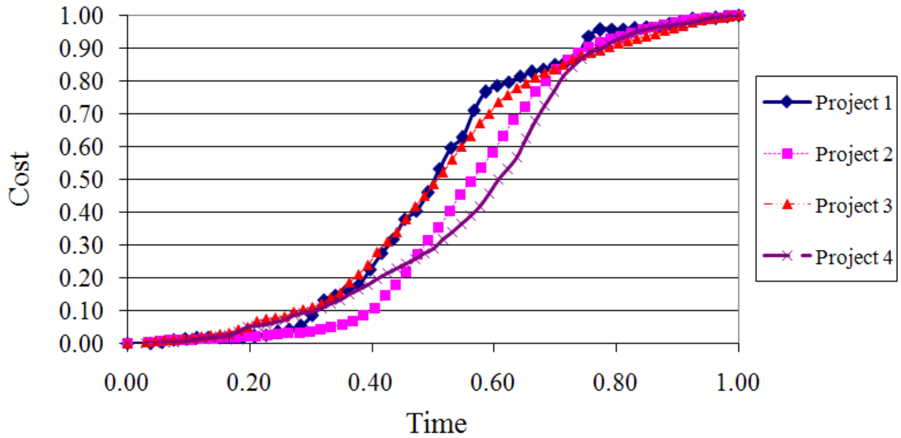

Fig. 2. The real S curve for project group B

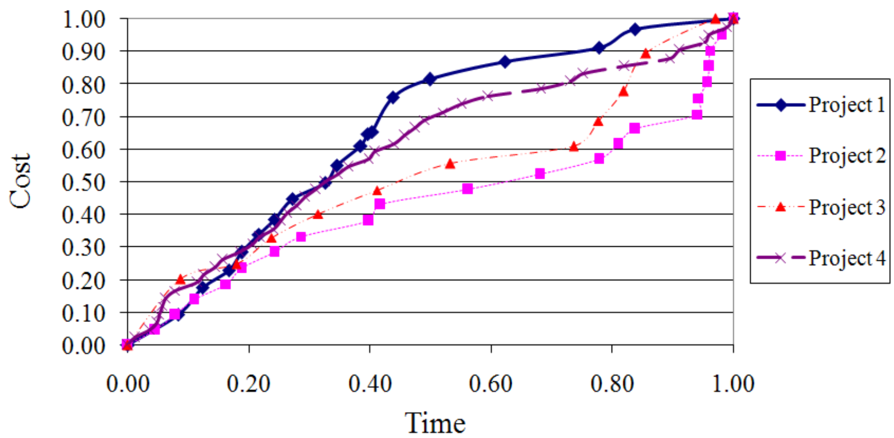

Fig. 3. The real S curve for project group C

constructed in sought parse area. The third group (C) is massive concrete cast for dam projects and includes 4 projects. These projects were part of Abaspour and Karoon (IV) dams. The cost breakdown for the each project groups can be seen in Table I. The real S curve for three group projects is shown in figures 1, 2, and 3.

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6. Measuring the accuracy of fit

It is necessary to measure the accuracy of fit for the S-curves of any given project for three reasons. The first reason is to compare the actual and predicted curves with each other for any given project. Second, to compare a project's S-curves with other curves for that given project type. And third, to draw comparisons with this and other calculated models.

The measure chosen, the "standard deviation about the estimate of Y", or "SDY", was first put forward as a risk index by Jepson [5], and was later adopted by Berny and Howes [19]. It was used by Kenley and Wilson [18], in their idiographic value model. Kaka and Price [2], Evans and Kaka [21], Petros [22], and Al-Jifri [23], also used this method. "SDY" adopts the common measure of dispersion and is calculated as follows:

$$SDY = \sqrt{\sum (Y - YE)^2 / (N-2)} \qquad (1)$$

Where: Y is the actual value at any accounting period.
YE is the estimated (or fitted) value.
N is the number of observation (accounting periods).

This allows models to be compared with one another. The model with the lowest value of SDY has the best fit, and hence is the most accurate.

7. The Logit model

In order to model different groupings and individual actual cost curves, a simple and reliable method of S curve fitting is needed. Investigations have shown that specific transformations of sigmoid (S) curves can produce linear functions. The parameters of the sigmoid function are provided by the parameters of the linear equation, which in turn are found through linear regression. The equation of the curve of best fit for data which approximates to one of the S-curve functions can be found by linear regression of suitably transformed data and then substitution of the linear parameters into the S-curve function.

The selection of an appropriate S-curve function was examined by Ashton [20], who outlined four of the best known S-curves and their transformations (the integrated normal curve, the logistic curve, the sine curve and the urbans' curve). Ashton found the above curves to be very similar in shape, with most variation found at the extremes. He concluded that the selection of an appropriate S-curve was more a matter of application than anything else.

Kenley and Wilson [18] showed that value curves, cash in and cash out curves approximate the S-curves listed above and hence used the logit transformation successfully. The actual value commitment model developed in this paper also adopted the logit model as it is the simplest of the transformation techniques and most easily allows the change to double transformation necessary in the model analysis. The linear equation is found by a logit transformation of both the independent and dependent variables:

$$Logit = \ln \frac{Z}{1-Z} \qquad (2)$$

where Z is the variable to be transformed and Logit is the transformation. The logistic equation for cost commitment flows can be expressed as:

$$\ln \frac{c}{1-c} = \alpha + \beta \cdot \ln\{t/1-t\} \qquad (3)$$

where (c) is the actual cost (dependent variable) in a particular time (t) (the independent variable). α and β are constants. It can also be expressed as:

$$c = \frac{F}{1+F} \quad \text{where} \quad F = e^{\alpha}\left(\frac{t}{1-t}\right)^{\beta} \qquad (4)$$

The cost commitment model given above uses scales from 0.0 to 1.0 where the ratio (on the abscissa or ordinate) 1.0 is equivalent to 100%. As percentage scales are to be used with convention, the equations should be expressed as follows:

$$c = \frac{100 \times F}{1+F} \quad \text{where} \quad F = e^{\alpha}\left(\frac{t}{100-t}\right)^{\beta} \qquad (5)$$

The practical application of the logit transformation model implies that construction project cost flow curves approximate the S-curve

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Table 2. SDY values measured for every three project group by using Logit model and proposing different Percentage exclusion range

	Percentage exclusion range					
Project type	0%	5%	10%	15%	20%	25%
Harbor construction	14.94	14.31	13.69	10.57	13.72	14.10
Refinery construction	24.60	23.50	22.68	20.48	14.22	19.38
Massive concrete cast	20.90	20.64	7.01	4.70	4.83	15.83

yielded by Equation 1. This being so, a transformation of the data should approximate to a line described by Equation 2 and with parameters α and β.

$$Y = \alpha + \beta \cdot X \tag{6}$$

where $Y = \ln \frac{c}{100 - c}$ and $X = \ln \frac{t}{100 - t}$

In order to transform data for a particular project, X and Y must be calculated for each value of t and c respectively. Deriving the constants cc and is thus a simple linear regression of the transformed data. For further details see Kenley and Wilson [18].

The Logit transformation has been used to conduct regression on data. A systematic process of trial and error has been employed to locate an optimum exclusion range in their value curves. The SDY values which are the result of these processes are shown on tables 2. The trend for these exclusion ranges have been shown on figures 4, 5, and 6.

8. Bromilow model

The Bromilow model was developed at the division of building research, common wealth scientific and industrial research organization (CSIRO) in the 1960s. Although the model has become an important tool in the Australian industry, Bromilow has not published the method or results of his analysis, but has used the conclusion to illustrate his later work. The purpose of this work was to achieve the forward planning of large programs of building works in the normal operation of government works departments and similar institutions.

Bromilow used polynomial regression (least squares) to find the equation of best fit for the curve. An inverted cubic function $X = f(Y)$ was found to have the smallest residual variance, and as no systematic differences were found between the four projects only one curve was generated.

The equation derived is of the form:

$$T = C_0 + C_1 \cdot P + C_2 \cdot P^2 + C_3 \cdot P^3 + C_4 \cdot P^4 \tag{7}$$

Where T is the percentage of construction time since start to practical completion, P is the target cumulative payment expressed as a percentage of planed cost and C_s are constants.

The authors calculated C_s and SDY values for every tree group projects by using Bromilow model. The results are shown in Tables 3, 4, and 5.

The average C_s has been used for conducting regression analysis on tree group projects. The SDY values which are the result of these regressions are shown on tables 6, 7, and 8.

9. Boussabain and Elhag model

Boussabain and Elhag (1999) developed a model specifically targeted at the idiographic nature of construction project cash flow profiles. To do this however, they needed an originating profile, which they derived from an analysis of 30 projects. The model is a compound equation, using Cooke and Jepson's (1979) breakdown of the three stages of the project into (i) parabolic growth for the first third, (ii) linear accumulation for the middle third, and (iii) decaying accumulation for the final third.

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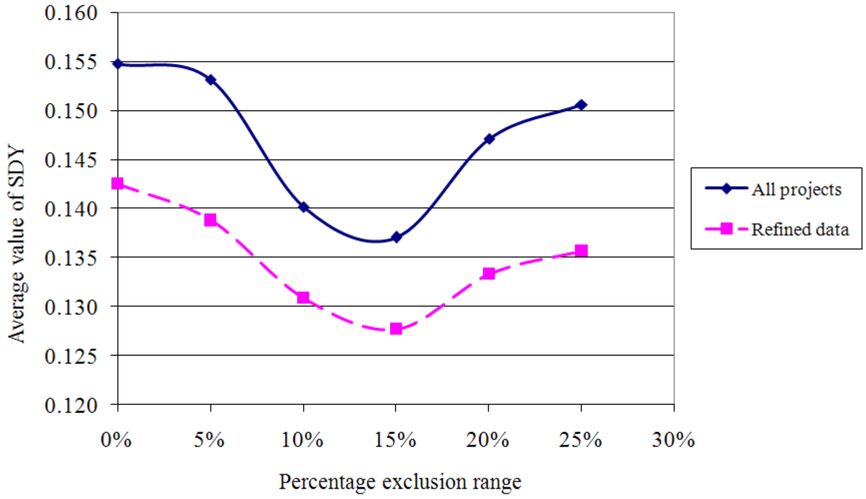

Fig. 4. Mean sample SDY against exclusion range for project group A

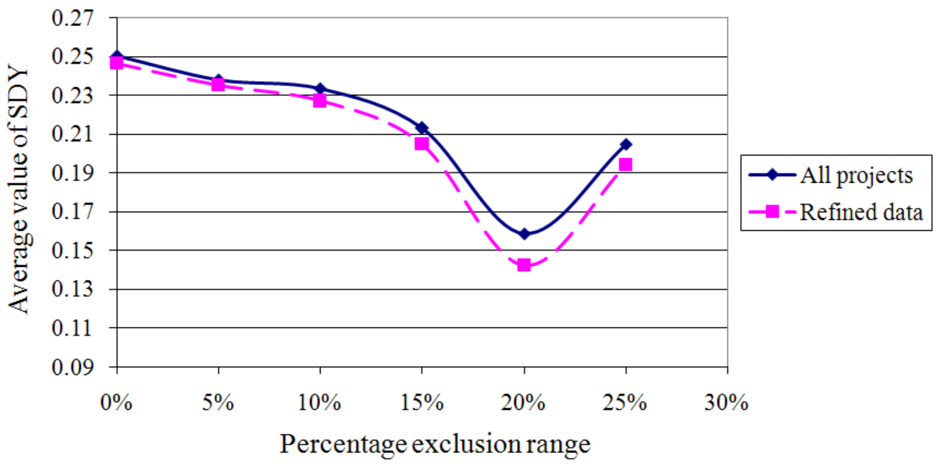

Fig. 5. Mean sample SDY against exclusion range for project group B

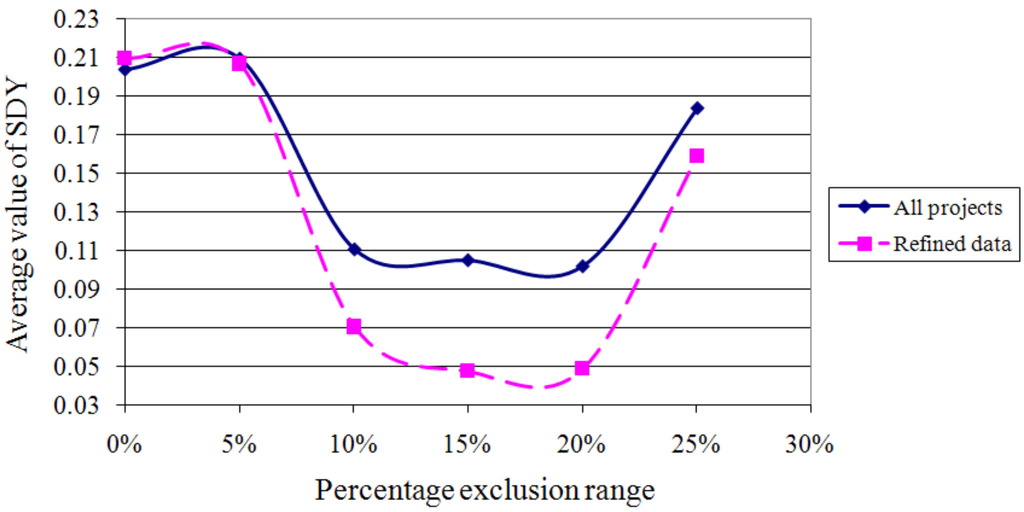

Fig. 5. Mean sample SDY against exclusion range for project group C

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Table 3. Bromilow model parameters for project group A

Project Number	C_0	C_1	C_2	C_3	C_4	R^2
1	0.0575	2.2106	-3.8014	3.7993	-1.2916	0.9938
2	0.0153	1.9894	-3.8234	5.1068	-2.3032	0.9975
3	0.0871	0.9589	-1.5573	2.4625	-0.9672	0.9857
4	0.0266	1.3582	-1.4544	0.8285	0.2450	0.9975
5	0.0218	1.027	-0.4483	-0.9035	1.1997	0.9655
6	0.0286	1.3435	-0.1202	-1.6446	1.3859	0.9931
7	0.0129	1.7856	-1.3253	-1.4445	1.9357	0.9903
8	-0.0305	3.4015	-16.979	28.96	-14.366	0.9627
9	0.0323	2.2718	-4.162	4.6496	-1.7874	0.9886
10	0.0168	1.0244	0.0957	-1.9125	1.7599	0.9971
11	0.0102	0.8485	0.252	-1.3445	1.2255	0.9979
12	0.0357	0.5953	1.9521	-5.0032	3.3976	0.9882
Average for all samples	0.0262	1.5679	-2.6143	2.7962	-0.7972	0.9882
Average for refined samples	0.0323	1.4386	-1.3944	0.5497	0.3600	0.9930

Table 4. Bromilow model parameters for project group B

Project Number	C_0	C_1	C_2	C_3	C_4	R^2
1	0.0984	2.4302	-5.5057	4.9052	-0.9895	0.9819
2	0.1070	3.4172	-9.1651	9.8086	-3.2333	0.9739
3	0.0557	2.6484	-6.0456	5.7292	-1.4151	0.9964
4	0.0762	2.4037	-3.5370	1.3232	0.6872	0.9940
Average for all samples	0.0843	2.72.49	-6.0634	5.4416	-1.2377	0.9866
Average for refined samples	0.0768	2.4941	-5.0294	3.9859	-0.5725	0.9908

Table 5. Bromilow model parameters for project group C

Project Number	C_0	C_1	C_2	C_3	C_4	R
1	0.0019	0.8084	5.1410	-9.5084	4.5597	0.9
2	0.0031	1.0209	1.7689	-6.0635	4.2411	0.9
3	0.0062	2.2042	-4.3156	4.4597	-1.3247	0.9
4	0.0205	1.2867	1.8106	-4.7982	2.6680	0.9
Average for all samples	0.0079	1.3300	1.1012	-3.9776	2.5360	0.9
Average for refined samples	0.0085	1.0387	2.9068	-6.7900	3.8229	0.9

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Table 6. SDY values measured for project group A by using Bromilow model

Project Number	SDY
1	9.35
2	6.44
3	5.67
4	2.54
5	11.07
6	3.97
7	5.03
8	17.77
9	8.86
10	5.96
11	6.68
12	8.81
Average for all samples	7.68
Average for refined samples	5.64

Table 7. SDY values measured for project group B by using Bromilow model

Project Number	SDY
1	4.60
2	6.50
3	2.54
4	3.78
Average for all samples	4.35
Average for refined samples	3.64

Table 8. SDY values measured for project group C by using Bromilow model

Project Number	SDY
1	9.16
2	12.17
3	7.42
4	3.64
Average for all samples	8.10
Average for refined samples	6.74

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$$\text{If } 0 \le x \le \tfrac{1}{3} \text{ then } y = \frac{9x^2}{4}$$

$$\text{Or if } \tfrac{1}{3} \le x \le \tfrac{2}{3} \text{ then } y = \frac{3x}{2} - \frac{1}{4}$$

$$\text{And if } \tfrac{2}{3} \le x \le 1 \text{ then } y = \frac{9x}{2} - \frac{9x^2}{4} - \frac{5}{4}$$

Which together form the algorithm (8)

The authors calculated SDY values for every tree group projects by using Boussabain and Elhag equation. The results are shown in Tables 9, 10, and 11.

10. Comparison between models

Finally the result of different models for three group projects has been compared with each other to choose the best model for forecasting S curve. As it is shown on table 12, Bromilow model has the lowest SDY for all three group project. One of the reasons for more accuracy in Bromilow model is due to use of polynomials equation. Although, Boussabain and Elhag model is conditions for all conditions, the result of this model is better than Logit model. This can be referred to use three equations for different phases of project.

Application of model is simple. For example as you can see in figure 6, for group project a time and has been calculated using Bromilow mode. Values are in percent and S-curve has been plotted. Staff in project management office just need to multiple actual time and cost of project in to percentages to achieve real cost and time for each project. In preconstruction stage and bidding phase, final cost and time can be obtained from bidding documents; therefore, without any information about schedule of a project, a rough estimation can be made about S-curve.

This estimation will help project management team to provide enough cash resources for project. In addition, it can even effect their decision to participate in a bid (bid/no-bid) due to lack of enough cash resources for conducting a project. Furthermore, by recognizing critical part of project regarding cash flow management, appropriate measures can be made to level resources or include cost of providing cash (e.g. interest rate of loans) in bidding cost.

Table 9. SDY values measured for project group A by using Boussabain and Elhag equation

Project Number	SDY
1	8.02
2	7.57
3	7.77
4	7.75
5	7.65
6	7.62
7	7.52
8	8.37
9	7.89
10	7.11
11	7.24
12	7.37
Average for all samples	7.57
Average for refined samples	7.43

Table 10. SDY values measured for project group B by using Boussabain and Elhag equation

Project Number	SDY
1	7.26
2	11.07
3	5.13
4	10.59
Average for all samples	8.51
Average for refined samples	7.66

Table 11. SDY values measured for project group C by using Boussabain and Elhag equation

Project Number	SDY
1	22.51
2	8.12
3	5.09
4	14.95
Average for all samples	12.67
Average for refined samples	9.39

11. Conclusions

Cash is one of the most important resources of

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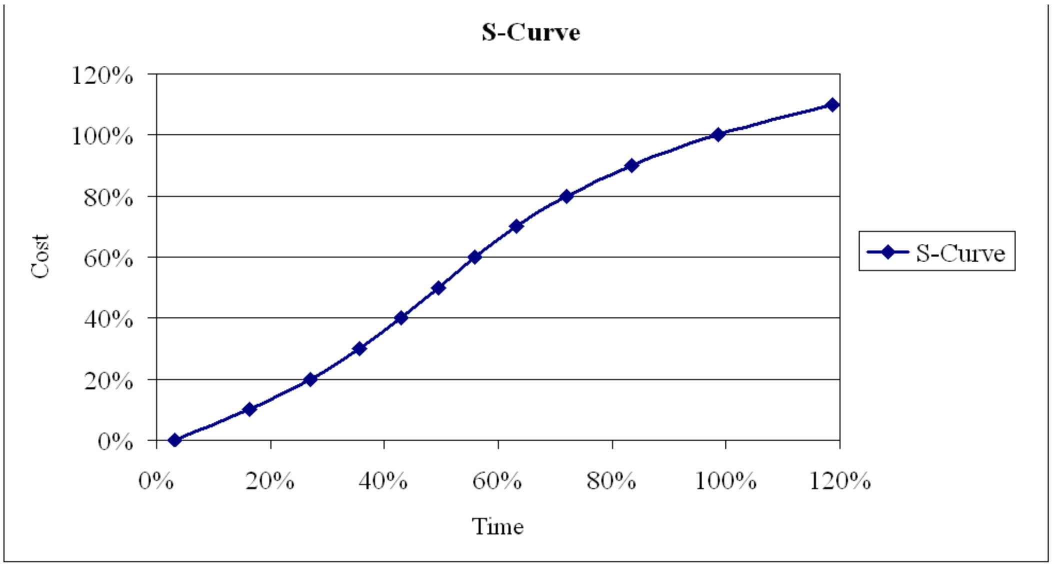
Table 12. comparison between models

Project Group	Model	Characteristic of model	SDY
A	Logit	α = - 0.14 and β = 0.68	8.26
	Bromilow	$T = 0.0323 + 1.4386.P - 1.3944.P^2 + 0.5497.P^3 + 0.36.P^4$	5.64
	Boussabain and Elhag	It is constant for all conditions.	7.43
B	Logit	α = 0.0879 and β = 0.3664	14.7
	Bromilow	$T = 0.0768 + 2.4941.P - 5.0294.P^2 3.9859.P^3 - 0.5725.P^4$	3.64
	Boussabain and Elhag	It is constant for all conditions.	7.66
C	Logit	α = -0.1209 and β = 1.5063	8
	Bromilow	$T = 0.0085 + 1.0387.P + 2.9068.P^2 - 6.79.P^3 + 3.8229.P^4$	6.74
	Boussabain and Elhag	It is constant for all conditions.	9.39

contractors and using effective cash flow management can play a fundamental role in success of a project. The potential to influence cash flow decreases as the project commences. The most effective measures to improve cash flow management can be made during preconstruction phases. Authors in this research attempted to shed light on to this part of project and help project managers to take more accurate decisions. Findings of this research will provide an opportunity for project managers to forecast cash flow in preconstruction phase and estimate necessary resources for each period of project.

The use of cost curves for the production of standard S-curves has been developed and successfully tested. Previous value and cost models have been discussed and the inadequacies of each have been established. Sample data



Time	3%	16%	27%	36%	43%	49%	56%	63%	72%	83%	99%	119%
Cost	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	110%

Fig. 6. Forecasting S-curve using proposed Bromilow equation for project group A based on percent progress

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which used here were consisted of project with similar type such as harbor construction, lead to more accurate forecasted S-curves. It is concluded that grouping projects based on their characteristics is one of the best approaches to forecast S-curves. Cost curves for projects are different because of differences in the projects' characteristics.

The conclusion, of course must be treated with some caution. The results are drawn from small sample of data. More projects would be needed to substantiate these conclusions. Major criteria for selecting projects were type of project. Future research can be conducted to evaluate effect of other criteria such as size and duration.

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