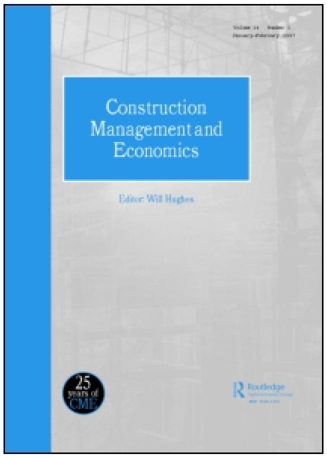

Total project cost: a simplified model for decision makers

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Total project cost: a simplified model for decision makers

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A simplified model for total project cost is developed in this paper to meet the numerous requests from decision makers for a model that can be used to estimate the total project cost from the estimated cash flows and, more importantly, to check the accuracy of the project cost estimates in feasibility studies that require prudent decisions. It begins with a base cost estimate in constant dollars and discrete cash flows with discrete inflation rates as practised by the construction industry. The discrete inflation rates are used to estimate the current dollar costs of the project. The effects of inflation are estimated as escalation during construction. Using the future value concept, interest during construction is estimated, in a simplified approach, to estimate the total project cost. Data from an actual feasibility study is used to highlight the strengths and weaknesses of the simplified model. The model is extended to treat discrete cash flows with continuous inflation rates.

Keywords: Total project cost, inflation rates, escalation, interest, future value, cash flows.

Introduction

In studying the feasibility of an infrastructure development project, it is necessary to make forecasts of future events dealing with time, cost and revenue. Most infrastructure projects have lengthy development life cycles. Thus, there is a large degree of uncertainty associated with forecasts that one is required to make regarding the project duration, project cost and project revenue. Of these three, an accurate estimate for project cost can reduce the uncertainty of the investment significantly.

Some authors have modelled project cost as a deterministic value (Thompson, 1976; Ashley and Teicholz, 1977; de la Mare, 1979; Sears, 1981; Cusack, 1985; Russell and Ranasinghe, 1991), while others have modelled it as an uncertain variable (Bjornsson, 1977; Flanagan and Norman, 1980; Diekmann, 1983; Perry and Hayes, 1985; Flanagan *et al.*, 1987; Jaafari, 1988; Russell and Ranasinghe, 1992; Yeo, 1990; Ranasinghe, 1994). Whatever the assumption that is made to model uncertainty, there are some common features to project cost. Firstly, project cost is a summation of quantities multiplied by rates (Yeo, 1990; Ranasinghe, 1994). Secondly, project cost is the parameter that is generally best defined at the commencement of the project. Thirdly, it is the parameter that if properly estimated can make a project a success and if badly estimated a disaster.

The objective of this paper is to present a simplified model for total project cost that can be used, by decision makers in developing countries, to either model project cost from the estimated cash flows or, more importantly, check the accuracy of project cost estimates in the feasibility studies for infrastructure development projects that require prudent decisions. The motivation for this development is the numerous requests, by decision makers in Sri Lanka, for a model which simplifies the estimation of total project costs of infrastructure projects and which can be used to check quickly the detailed estimates for project costs given in feasibility studies for infrastructure development projects.

In general, project costs consist of the following.

1. The base cost which is also called the constant dollar (value) cost in the literature (Tanchoco *et al.*, 1981; Riggs *et al*, 1983; Buck, 1983; Russell and Ranasinghe, 1992).

2. The escalation during construction which contains the effects of inflation (Reisman and Rao, 1973; Perry and Thompson, 1977; Przybylski, 1982; Warszawski and Rosenfeld, 1982).
3. The interest during construction on the funds borrowed during construction.

Then, the total project cost (*TPC*) can be obtained from the following equation:

$$TPC = \text{base cost} + EDC + IDC \quad (1)$$

where *EDC* is the escalation during construction and *IDC* is the interest during construction. The total project cost estimated by Equation 1 is the nominal total project cost as it is based on values that are generally reported in feasibility study reports.

This paper is structured as follows. In the next section, the theoretical basis for the simplified model for total project cost is developed. It is presented as the general case using discrete cash flows with discrete inflation rates, as practised by the construction industry of today. The assumptions of that development are highlighted. The inclusion and treatment of different rates for inflation in the calculation of the *EDC* and the inclusion of the interest rate for the calculation of the *IDC* are discussed. The third section using a numerical example demonstrates the application of the model to evaluate and or check total project cost. A Lotus 123 spreadsheet was used to develop the computer model to estimate the total project cost of the numerical example. The model is extended to treat discrete cash flows with continuous inflation rates in the fourth section. Finally, the advantages of using this model for total project cost, its strengths and weaknesses are summarized in the fifth section.

Total project cost

This section will develop the theoretical basis for the simplified model for total project cost as practised by the construction industry of today. This development will consider that the cash flows are discrete and the inflation rates are discrete (see Figure 1).

Assumptions

Before we begin to develop the theoretical basis, it is important to identify the general assumptions under which the simplified model for total project cost is valid. The main assumptions are as follows.

1. The cash flows are known and they are in constant values. The cash flows are generally defined as forecasted receipts and payments with respect to time (Riggs *et al.*, 1983). The accuracy of cash flow estimates are always suspect because the future cannot be predicted completely. The estimates made by analysts using the information available today are assumed to reflect the future developments as accurately as possible.
2. The cash flows are discrete and the inflation rates are discrete. The cash flows are assumed to occur at the end of equal time periods (intervals) and the inflation of costs occur at those points in time. In reality we never make all the payments in one lump sum at the end of the period, may it be a year, a month or a week. The cash flow in any project is continuous in nature. Neither is it true to consider that the time value of money increases only at an end of a predetermined period. Tanchoco *et al.* (1981), Buck (1989) and Russell and Ranasinghe (1992) have shown the advantages of using continuous cash flows under continuous compounding. However, in most developing countries the investment alternatives are still analysed as discrete cash flows under discrete compounding. Hence, the use of discrete inflation rates for the simplified model. The justifications for using the discrete assumption are that it is easy to understand, easy to apply, it provides adequate precision and as all competing alternatives are analysed using the same methodology, the shortcomings in the approach will effect them all equally.
3. The land appreciates at the same rate as the discount rate. This assumption permits us to remove the cost of the land as a base cost and is often implicitly used when a public project is developed on a public land.
4. No interest is paid on the borrowed funds during construction and the interest rate will remain constant throughout the construction period. Most lending institutions require the client to pay interest during construction on commercial borrowings, even though the repayment of the capital is deferred by a predetermined grace period. However, for some

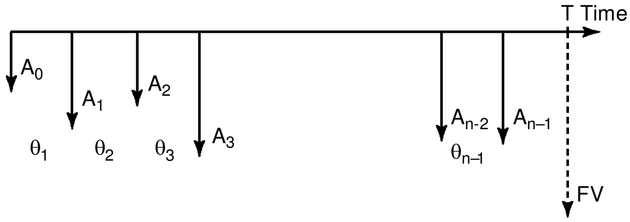

Figure 1 Constant value cash flows and inflation rates

infrastructure projects the interest is also accrued until the end of construction and then included in the amortization package. This assumption in general will overestimate the interest during construction.

5. The equity and borrowed funds will make up the total financing required by the project.

Base cost

Consider a project consisting of n cash flows (A_0, A_1, A_2 ..., A_{n-1}) in constant value dollars as shown in Figure 1. The first cash flow occurs at time zero and the nth cash flow at the end of the n −1th time period. All the constant value cash flows are based on market prices of a predetermined year, generally the year in which the analysis is done. When the constant dollar cost of the project is C_0, then

$$C_0 = A_0 + A_1 + A_2 + \ldots + A_{n-1} \tag{2}$$

$$= \sum_{j=0}^{n-1} A_j \tag{3}$$

The constant dollar cost is also referred to as the base cost of the project.

Escalation during construction

The current dollar cost of a project is the actual cost that will be incurred to complete the project if the forecasted inflation rates occur. It is the summation of current value estimates of each of the constant value cash flows given in Figure 1. Warszawski and Rosenfeld (1982) stated that the current cost will yield a more realistic estimate, in particular at a time of high inflation. According to Warszawski and Rosenfeld (1982), it requires a highly professional treatment and is prone, as far as external factors are concerned, to errors of judgement in the evaluation of the current costs involved. For this reason, its successful application depends on a formal and well-defined evaluation procedure (Warszawski and Rosenfeld, 1982).

Therefore, the effects of inflation, generally referred to as the escalation during construction (*EDC*) is the difference between the current dollar cost and constant dollar cost. In other words

$$EDC = C - C_0 \tag{4}$$

where the current dollar cost of the project is given by C.

Let us assume that the forecasted discrete inflation rate for each period is θ_k^d. Then, according to Reisman and Rao (1973), the current value of the A_jth constant value cash flow given by $A_j^\star$ is

$$A_j^\star = A_j \prod_{k=0}^{j} (1+\theta_k^d) \tag{5}$$

where $\theta_0^d = 0$ and θ_k^d is the discrete inflation rate for the kth time period.

Assuming that constant (base) cost values are based on values at the beginning of the project, the current value cost of the project given by C is

$$C_0 = A_0 + A_1(1+\theta_1^d) + A_2(1+\theta_1^d)(1+\theta_2^d) + \ldots$$

$$+ A_{n-1}(1+\theta_1^d)(1+\theta_2^d)\ldots(1+\theta_{n-1}^d) \tag{6}$$

$$= \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j} (1+\theta_k^d) \tag{7}$$

On the other hand, if the base year on which the analysis was done and the start of the project is different as in most large infrastructure development projects, then the effect of inflation during that period can be substantial and therefore, should be included. Then, the current value of the project can be modified as

$$C = \prod_{i=0}^{m} (1+\theta_i^d) \left[\sum_{j=0}^{n-1} A_j \prod_{k=0}^{j} (1+\theta_k^d) \right] \tag{8}$$

where θ_i^d is the inflation rate for the ith year (time period) between the analysis and actual starting of the project and m is the number of years (time periods) between the analysis and actual starting of the project.

For the rest of the derivation we will assume that the constant (base) dollar cost values are based on values at the beginning of the project for an easier understanding. However, if necessary this correction can be easily included into the model. This development also permits one to use different inflation rates for different components of costs for the same period. Then, all one has to do is to segregate the constant dollar (base) cost for that time period to different cost components for which different inflation rates will be used.

Since the *EDC* is the difference between current dollar cost and constant dollar cost of the project, *EDC* can be given by

$$EDC = \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j} (1+\theta_k^d) - \sum_{j=0}^{n-1} A_j \tag{9}$$

Future value of the cash flows

The future value of each of the current dollar cash flows in some future time T, as depicted in Figure 1, can be evaluated by obtaining the equivalent value for some compound rate r. The equivalent value is generally defined as the value when one is indifferent to a quantity of money now or the assurance of some other sum of money in the future or a series of future sums of money (Riggs *et al.*, 1983). Then, the equivalent value of the current dollar cash flows at some future time T, given by FV is

$$FV = A_0(1+r)^T + A_1(1+\theta_1^d)(1+r)^{T-1} + A_2(1+\theta_1^d)(1+\theta_2^d)(1+r)^{T-2} + \dots + A_{n-1}(1+\theta_1^d)(1+\theta_2^d)\dots(1+\theta_{n-1}^d)(1+r)^{T-n-1} \quad (10)$$

$$= \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j} (1+\theta_k^d)(1+r)^{T-j} \quad (11)$$

Interest during construction

Let us assume that all the funds needed to complete the project are borrowed at an interest rate of r and the borrowed funds and the accrued interest on it are due in some time T. This is the fourth assumption of our model. If we assume that the compound rate used in the earlier section is equal to the interest rate of the borrowed funds, then the amount of the construction loan and its accrued interest is equal to the future value calculated in the previous section.

However, in most infrastructure development projects the client has to contribute an equity portion. Let us assume that the equity fraction of current value cost is f. Since interest during construction (IDC) is calculated only for borrowed funds, which is the $(1-f)$ fraction of the current value cost of project, IDC can be given by

$$IDC = (1-f)\,(FV - C) \quad (12)$$

Then

$$IDC = (1-f)\left[\sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d)(1+r)^{T-j} - \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d)\right] \quad (13)$$

Since, the fourth assumption of the model considers that interest on the borrowed funds will be paid only after the end of construction and the interest rate on the borrowed funds will remain constant, the estimated IDC will be an overestimation as the interest accrued on funds borrowed in earlier years will be much larger than when it is assumed that the interest is paid on the year it accrues.

Total project cost

As defined earlier, in general, the total project cost can be obtained from Equation 1. Then, substituting Equations 3, 9 and 13 into Equation 1, the total project cost can be evaluated as follows.

$$TPC = \sum_{j=0}^{n-1} A_j + \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j} (1+\theta_k^d) - \sum_{j=0}^{n-1} A_j + (1-f)\left[\sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d)(1+r)^{T-j} - \sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d)\right] \quad (14)$$

Rearranging Equation 14, the total cost for any infrastructure development project is

$$TPC = f\sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d) + (1-f)\left[\sum_{j=0}^{n-1} A_j \prod_{k=0}^{j}(1+\theta_k^d)(1+r)^{T-j}\right] \quad (15)$$

Case study

Background

This section will use, as a case study, cost estimates from a proposed hydropower project in Sri Lanka. The project however is not identified for confidentiality. The objective of the case study is to compare the proposed model for total project cost. We will use values from the actual project feasibility study to compare with those calculated from the proposed model. In addition, we will predict the behaviour of the model when compared to actual values. Since the values in the feasibility study have been calculated by project analysts, using more precise models, we can assume those estimates as bench-marks for the comparison.

The model for total project cost developed in the previous section can be easily computerized making it a useful estimating and checking tool. A Lotus 123 spreadsheet was used to develop the computer model to estimate the total project cost of this numerical example.

Table 1 illustrates the basic data extracted from the feasibility study. It includes the constant dollar costs (all the values are in US$) as local and foreign portions for the different years of construction, the estimated

Table 1 Basic data for costs from the feasibility study (US$ thousand)

Year	Constant dollar cost			Duties and taxes	Inflation rates	
	Local	Foreign	Total		Local	Foreign
1992	–	–	–	–	0.094	0.028
1993	–	–	–	–	0.075	0.039
1994	2 646	5 566	8 212	1 670	0.065	0.039
1995	6 212	26 045	32 257	7 813	0.060	0.038
1996	3 275	16 102	19 377	4 830	0.050	0.038
1997	5 494	34 252	39 746	10 276	0.050	0.038
1998	4 852	30 943	35 795	9 283	0.050	0.038
Total	22 479	112 908	135 387	33 872	–	–

Table 2 *EDC* and *IDC* from the feasibility study (US$ thousand)

Year	*EDC*			*IDC*
	Local	Foreign	Total	
1994	407	526	933	152
1995	1 907	3 541	5 448	2 088
1996	1 452	2 884	4 336	4 517
1997	3 532	7 671	11 203	7 563
1998	3 823	8 369	12 192	11 624
Total	11 121	22 991	34 112	25 944

local duties and taxes in current dollars and the forecasted inflation rates for local and foreign costs. Table 2 gives the *EDC* and *IDC* given in the feasibility study.

The borrowed funds for this case study is only the foreign portion of the current dollar cost of the project. It is stated in the feasibility study that the foreign portion of the current dollar cost can be borrowed at an annual interest rate of 10%. The client has to provide as equity the current dollar local cost portion, duties and taxes and the interest during construction.

Base cost

The local and foreign portions and total base costs from Table 1 are, respectively, US$22.479 million, US$112.908 million and US$135.387 million. From Equation 3 the constant dollar cost of the project is US$135.387 million, showing that the starting points of the actual study and the model are the same.

Escalation during construction (*EDC*)

Table 3 contains the current dollar costs for the different years calculated using Equation 5. For example, for the year 1994, the estimated current dollar cost for the local and foreign portions and the total are, respectively, US$3.314 million, US$6.177 million and US$9.491 million. Then, the current dollar cost of the project, evaluated using Equation 7, is US$169.431 million.

The *EDC*s for the different years are calculated by subtracting the constant dollar costs from the current dollar costs for those years. For example, for the year 1994, the base cost is US$8.212 million while the current dollar cost is US$9.491 million. Then, the *EDC* for 1994 is US$1.279 million. The estimated

Table 3 Current dollar costs and escalation during construction (US$ thousand)

Year	Current dollar cost			*EDC*			Duties and taxes	Total current cost
	Local	Foreign	Total	Local	Foreign	Total		
1994	3 314	6 177	9 491	668	611	1 279	1 670	11 161
1995	8 247	30 002	38 249	3 035	3 957	5 992	7 813	46 062
1996	4 565	19 253	23 818	1 290	3 151	4 441	4 830	28 648
1997	8 042	42 511	50 553	2 548	8 259	10 807	10 276	60 829
1998	7 457	39 864	47 321	2 605	8 921	11 526	9 283	56 604
Total	31 625	137 807	169 432	9 146	24 889	34 045	33 872	203 304

Table 4 Comparison of *EDC* (US$ thousand)

Year	Local			Foreign			Total		
	Study	Model	(%)	Study	Model	(%)	Study	Model	(%)
1994	407	668	64	526	611	16	933	1 279	37
1995	1 907	3 035	59	3 541	3 957	12	5 448	5 992	10
1996	1 452	1 290	–11	2 884	3 151	9	4 336	4 441	2
1997	3 532	2 548	–28	7 671	8 259	7	11 203	10 807	–3
1998	3 823	2 605	–32	8 369	8 921	6	12 192	11 526	–5
Total	11 121	9 146	–17	22 991	24 899	8	34 112	34 045	–0.2

values for other years are given in Table 3. The *EDC* for the project from Equation 9 is US$34.045 million.

The comparison of *EDC* values estimated by the model to *EDC* values estimated in the feasibility study is given in Table 4. There is considerable variation between the *EDC* values estimated in the feasibility study and the *EDC* values estimated by the model for individual years. The *EDC*s estimated by the model for earlier years are higher than the *EDC*s estimated in the feasibility study, while for later years it is lower, showing that the values from the model are more conservative for the earlier years of the project than the method adopted in the feasibility study. These variations are more pronounced (64 to –32%) when the inflation rates are high, as assumed for the local portion of the annual costs. It is not possible to give an explanation for this variation because the equations and the methodology that was adopted by the feasibility study to estimate the *EDC* are not reported. However, when the total *EDC* estimated by the model is compared to the total *EDC* estimated in the feasibility study, the difference is only –0.2%.

Interest during construction

To calculate the interest during construction (*IDC*), it is necessary to identify the point at which the construction loan and interest on it becomes due. The fourth assumption of the model considers that interest on borrowed funds will be payable after the end of construction and that the interest rate on borrowed funds will remain constant. This assumption permitted the construction loan and accrued interest on it to be made equal to the future value of the cash flows of borrowed funds.

Table 5 Current dollar foreign costs, future value and *IDC* (US$ thousand)

Year	Current cost foreign portion	Future value	*IDC*
1994	6 177	9 485	3 308
1995	30 002	41 881	11 879
1996	19 253	24 433	5 180
1997	42 511	49 045	6 534
1998	39 864	41 809	1 945
Total	137 807	166 653	28 846

The future values of the foreign portion of current dollar costs for the different years are calculated using Equation 10. For this calculation it is assumed that the future value is at the end of the construction period. That is, at the end of 1998. To obtain the future value, a compound rate of 10% is assumed, the same value as the interest rate for borrowed funds used in the feasibility study. It is assumed that discrete cash flows of annual costs occur at the middle of each year. It seems that a similar assumption was made in the feasibility study. However, it is not certain. For example, the future value of US$6.177 million, the foreign portion of current dollar cost for the year 1994, is US$ 9.485 million. Then the *IDC* of funds borrowed for the year 1994 is US$3.308 million. The foreign portions of current dollar costs, their future values and the *IDC*s calculated by the model for different years are given in Table 5.

When the *IDC* values calculated by the model are compared to those given in the report there is a considerable overestimation in the earlier years and underestimation in the latter years (see Table 6). For example, for the year 1994, the variation is 2076%. This variation is due to the fourth assumption of the model, where it was assumed that no interest is paid on borrowed funds during construction. Then, interest accrued on funds borrowed in earlier years would be much larger than when it is assumed that the interest is paid in the year it accrues because the model assumption estimates the future value of the amount that is borrowed each year. When interest is paid on a yearly basis it is based on the total amount that is outstanding on any year. Then interest paid on earlier years will be smaller while interest on latter years will be much larger as shown in Table 6. If it is assumed that discrete cash flows for the annual costs of the

Table 6 Comparison of *IDC* (US$ thousands)

Year	Study *IDC*	Cash flows at mid-year		Cash flows at beginning	
		IDC	% change	*IDC*	% change
1994	152	3 308	2 076	3 771	2 381
1995	2 088	11 879	469	13 924	567
1996	4 517	5 180	15	6 373	41
1997	7 563	6 534	−14	8 927	18
1998	11 624	1 945	−83	3 986	−66
Total	25 944	28 846	11	36 981	42

model occur at the beginning of different years, then the variations with the feasibility study values are more pronounced (see Table 6).

The cumulative effect of the fourth assumption is an overestimation of the total *IDC*. Therefore, when this model is used to check a feasibility study, one should expect the model to have a larger value for the *IDC* than that which is calculated. The future value of the total foreign portion of current dollar costs from Equation 11 is US$166.653 million. This amount is equal to the accumulated construction loan and accrued interest on it at the end of the construction period. The *IDC* is obtained from Equation 13. When the foreign portion of current dollar costs is US$137.807 million, the *IDC* is US$28.846 million. When this *IDC* value is compared to the *IDC* of US$25.944 million estimated in the feasibility study, there is an overestimation of 11%. When it is assumed that discrete cash flows for the annual costs occur at the beginning of different years, the overestimation is 42%. Hence, it seems that the feasibility study has also assumed that discrete cash flows occur at the middle of different years.

Total project cost

The total project cost can be obtained from Equation 15 or in general from Equation 1. For this case study, in addition to the *EDC* and *IDC*, the duties and taxes should be added to the constant dollar cost. Then, the total project cost calculated by the model is US$232.15 million. The total project cost that is reported in the feasibility study is US$229.315 million. There is an overestimation of 1.24% by the model. The value calculated by the model has to be slightly larger than that reported in the feasibility study because the fourth assumption of the model overestimates the *IDC*. Therefore, in checking a feasibility study report one should expect a slightly larger value from the model than from the more accurate feasibility analysis.

Continuous inflation rates

The simplified model for the total project cost was derived assuming that inflation rates are discrete. This is the assumption that is generally made today in most feasibility studies for infrastructure development projects. However, in reality inflation is continuous. This section extends the model to treat continuous inflation rates with discrete cash flows.

Definition

Reisman and Rao (1973) stated that we can think of the inflation rate as the relative change in the purchasing power defined by

$$\theta(t) = \frac{\mathrm{d}P(t)/\mathrm{d}t}{P(t)} \tag{16}$$

where P(t) represents the price index at time t (base $t = 0$) of a unit of currency and the time derivative of the said unit of currency $\mathrm{d}P(t)/\mathrm{d}t$ gives the rate of change of the price index of the same unit of currency at time t. Hence, $\theta(t)$ is the continuous inflation rate.

Reisman and Rao (1973) state that when $\theta(t)$ is deterministic and independent of t, then we can say that the continuous inflation rate is constant and equal to θ. The relationship between the purchasing power $P(t)$ and the continuous inflation rate, θ, can be obtained by solving differential Equation 16, obtaining

$$P(t) = P(0)e^{\theta t} \tag{17}$$

A fundamental relationship between the discrete inflation rate and the continuous inflation rate can be established from basic calculus as

$$(1 + \theta^{\mathrm{d}}) = e^{\theta} \tag{18}$$

In other words, this relationship gives equivalent values between discrete (effective) and continuous (nominal) inflation rates.

Escalation during construction

Let us assume that the continuous inflation rate for each period is θ_k. Then, according to Reisman and Rao (1973), the current value of the A_jth constant value cash flow given by $A_j^\star$ is

$$A_j^\star = A_j\, e^{\sum_{k=0}^{j}\theta_k} \tag{19}$$

where $\theta_0 = 0$ and θ_k is the continuous inflation rate for the kth time period.

Then, the current dollar cost of the project given by C is

$$C = A_0 + A_1 e^{\theta_1} + A_2 e^{\theta_1} e^{\theta_2} + \ldots + A_{n-1} e^{\theta_1} e^{\theta_2} \ldots e^{\theta_{n-1}} \tag{20}$$

$$= \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k} \tag{21}$$

Since the EDC is the difference between the current dollar cost and constant dollar cost of the project, the EDC can be given by

$$EDC = \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k} - \sum_{j=0}^{n-1} A_j \tag{22}$$

Future value of the cash flows

Similar to a previous subsection, the future value of each of the current dollar cash flows in some future time T can be evaluated by obtaining the equivalent value for some compound rate r. Then, the equivalent value of current dollar cash flows at some future time T, given by FV is

$$FV = A_0(1+r)^T + A_1 e^{\theta_1}(1+r)^{T-1} + A_2 e^{\theta_1} e^{\theta_2}(1+r)^{T-2} + \ldots + A_{n-1} e^{\theta_1} e^{\theta_2} \ldots e^{\theta_{n-1}}(1+r)^{T-n-1} \tag{23}$$

$$= \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\,(1+r)^{T-j} \tag{24}$$

Interest during construction

Similar to a previous subsection, let us assume that the equity fraction of current value cost is f. Since the IDC is calculated only for borrowed funds which is the $(1 - f)$ fraction of the current value cost of project, then

$$IDC = (1-f)\left[\sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\,(1+r)^{T-j} - \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\right] \tag{25}$$

Total project cost

Then, substituting Equations 3, 22 and 25 into Equation 1, the total project cost, when cash flows are discrete and inflation rates are continuous, can be evaluated as follows:

$$TPC = \sum_{j=0}^{n-1} A_j + \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k} - \sum_{j=0}^{n-1} A_j + (1-f)\left[\sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\,(1+r)^{T-j} - \sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\right] \tag{26}$$

Rearranging Equation 26, the total cost for any infrastructure development project when the inflation rate is continuous is

$$TPC = f\sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k} + (1-f)\left[\sum_{j=0}^{n-1} A_j\, e^{\sum_{k=0}^{j}\theta_k}\,(1+r)^{T-j}\right] \tag{27}$$

Summary

This paper has presented a simplified model for total project cost. The model began with annual base costs or constant value costs. The forecasted discrete inflation rates were used to estimate the current value (dollar) costs of the project. The current dollar costs of the project are the actual costs that will be incurred to complete the project if forecasted inflation rates occur. The effects of forecasted discrete inflation rates were estimated as escalation during construction (EDC). Using the principle of future value, interest during construction (IDC) was estimated for the borrowed component of the current value cost. The total cost of the project was estimated using the base cost, the EDC and the IDC. The application to the case study showed that the simplified model behaved as predicted. The model was then extended to treat continuous inflation rates with discrete cash flows. This model can be used by decision makers to model project costs from the estimated cash flows and/or check the accuracy of project cost estimates in the feasibility studies for infrastructure development projects that require prudent decisions.

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