Estimating Project Costs and Time under Uncertainties: A Stochastic Model for Inflation and Supply Changes During and After the Covid19 Pandemic

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Abstract

Rising inflation rates have influenced the profitability of many ongoing projects in many economies in 2022. In addition, supply shortages due to the Covid19 pandemic have delayed many projects. Accurate estimation of project time and costs for a project bid in such uncertainties minimizes the risks of financial losses incurred in an awarded project. Conversely, the failure to anticipate the changes in prices and supplies in estimation models decreases the profitability and continuance of awarded projects, leading to some ripple effects in society. This paper examines the stochastic model to include inflation and supply shortage in estimation models. It suggests a solution for project estimators to estimate project costs and time more accurately, given the risks of rising inflation and supply shortage.

Keywords
Risk, Estimation, Stochastic, Project

1. Introduction
Accurate estimation of project time and costs for a project bid in uncertainties minimizes the risks of financial losses incurred in an awarded project (Rostami & Oduoza, 2017). To achieve this risk minimization objective, project planners add inflation changes in the discount rates to calculate net present values (NPV) (Visconti, 2012). From 2021 to 2022, the soaring inflation reduced the present values of investment projects (Figure 1).

The question raised here is how cost estimators can prepare accurate cost estimates. On the side of contractors, how can they offer a bidding price that maximizes the expected values of their bid projects? Specifically, what discount rate can be used in a project considering the inflation rate? What are the different outcomes for strategies dealing with inflation to generate an optimal value?

In the transport infrastructure projects, the private enterprises canceled their projects mainly because their forecast usage of the project roads was too optimistic (Demirel et al., 2022; Harris et al., 2003). This requires the planner to prepare the other scenarios: pessimistic and most likely events. According to a World Bank report (Harris et al., 2003), for the period 1990-2001, 73% of private infrastructure projects in developing countries were undergoing renegotiation in concessions or contracts due to unforeseen lost revenue.

Of the reasons why the private sector cancelled public-private partnership project, the financial loss is apparent due to surging inflation (Ruiz Díaz, 2020). Moro Visconti (2012, p. 206) states that "unless properly contracted, monitored and managed, inflation may so have a disrupting and unbalanced impact" on projects (Visconti, 2012). Therefore, cost estimators are supposed to include inflation changes in their formula for net present value. This paper examines a stochastic model for project selection, which helps managers to evaluate project risks related to the inflation rate, which influences the expenditures of the awarded project. (Figure 1)

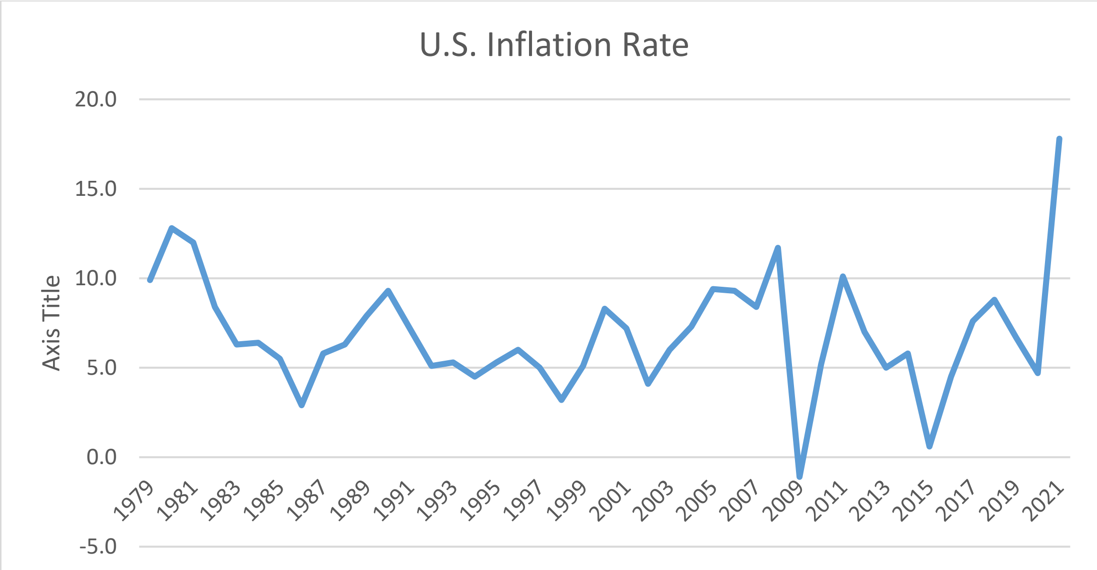

Figure 1: Inflation Rates Over Time

Source: https://www.bls.gov/cpi/research-series/r-cpi-u-rs-home.htm

2. Literature Review

One of the significant reasons for public-private partnership infrastructure project cancellation is the price increase, reflected by the soaring inflation rate (Rostami & Oduoza, 2017). When material prices increase, for example, the actual cost of construction materials increases. This external shock is classified as a risk. Strategies that contractors can take to hedge against inflation include managing the negative impact of increasing inflation. Measures include adjustment of discount rate to adapt to the inflation increase. Usually, they use the nominal inflation rate to adjust the discount rate.

The basic formula to compute a present value is as follows:

$$P = F\left[\frac{1}{(1+r)^n}\right] \tag{1}$$

Where
P = the present value cost or value
F = the future value
r = the discount rate per period
n = the number of discount periods

More accurately, the real discount rate is derived as:

$$r^* = \frac{i-f}{i+f} \tag{2}$$

Where
r^* = the real discount rate, used to remove the effect of inflation
i = the nominal interest rate
f = inflation rate

Cady (1983) suggested using the "pseudo-inflation rate" or synthetic inflation rate for the discount rate in NPV calculations.

$$f^* = \frac{f'-q}{1+q} \tag{3}$$

$$i^* = \frac{(1+i)(1+q)}{(1+f')} - 1 \quad (4)$$

Where
f^* is the "pseudo-inflation rate" or synthetic inflation rate (Cady, 1983); f' is the inflation rate of the highway construction sector; q is the change rate in highway fund; and i is the nominal interest rate. However, Cady's inflation rate was not recommended because of its inconsistent results. Instead, the general inflation rate released by the Highway Administration (SHA) was suggested to compute present values more accurately (Jawad & Ozbay, 2006).

Inflation creates an external macro shock in a business environment, and its variation widens the dispersion of the expected returns of an investment project (Higgins, 2009). That is, a project with a broader spread of the expected returns is riskier than the one with a narrower one. Inflation risk concerns project lenders and contractors (Antonio J et al., 2011). This type of risk has the most significant rank in a survey of construction contractors in Kuwait because financial shortage delays construction work (Antonio J et al., 2011).

Project contractors should employ a strategy to mitigate the negative impact of inflation on net present value, such as a contingency budget (Table 1).

Table 1 – Allowable Contingency Percentage or Types of "Guestimates"

Rough order of magnitude (ROM) or Order of Magnitude	- 25% to 75%
Budgetary	-10% to 25%
Range of estimate (used as an alternative to ROM)	±35%
Approximate estimate (somewhat informational)	±15%
Definitive (based on detailed information)	±5%

Source: Project Management Institute

Although the types of “guestimates” to deal with price increases in Table 2 are helpful for cost estimators, they do not provide a model for the present values under changing inflation. This paper proposes a model with two changing variables, inflation and cash flow, for NPV calculation.

3. Methodology

We used the Life Cycle Cost Analysis for an infrastructure project (Jawad & Ozbay, 2006) following the following process: (i) identifying the project cost; (ii) estimating the net cash flows; (iii) discounting the net cash flows to obtain the project’s NPV (deterministic model); (iv) identifying the risks of project’s cash flows through its standard deviation; (v) discounting the stochastic cash flows to the present values (stochastic model); (vi) compare the NPVs between the deterministic and stochastic models; (v) conducting Monte Carlo simulation to estimate the probability of NPV in the stochastic model. The stochastic model uses uncertain input parameters, including inflation rate, to generate simulated results (e.g., NPV) while a deterministic model assumes constant input parameters (Jawad & Ozbay, 2006). The Monte Carlo simulation generates possible present values of the project life cycle costs.

The two input measures of interest are inflation rate and annual net cash flow. First, the inflation rate assumes triangular distribution. These three estimates are optimistic, most likely and pessimistic values of the inflation rate. Meredith and Mantel (2011) pointed out that changes in supply time in the upstream of a supply chain could cause cost changes, such as a change in the production method. In this model, we suggest that a change in supply (e.g., material or equipment supply) leads to a change in annual costs.

The second stochastic variable is the annual net cash flow, which assumes a normal distribution, as Meredith and Mantel (2011) suggested.

The forecast output is NPV:

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+k+p)^t}$$

Where NPV is the net present value of the future cash flows; C_t is the annual net cash flow; k is the discount rate; and p is the inflation rate.

I analyze the NPVs for the following models:

(i) Model 1: NPV with the deterministic net cash flow and inflation rate.
(ii) Model 2: NPV with stochastic cash flows and without inflation.
(iii) Model 3: NPV with stochastic cash flows and inflation.

We employ the Monte Carlo simulation technique that randomly samples the distributions of the inflation rate and the annual net cash flows. The forecast output from the simulation is the NPV. We estimate the probability that the forecast NPV is greater than zero. We use Crystal Ball Software for the simulation.

4. Result and Discussion

A community receives a $100,000 fund to build a new bridge to substitute the existing bamboo bridge. The project life cycle is five years. The community offers three alternatives for payments to the project bidder: (i) annual fixed payment of 20,000$ for the construction contractor during the project life cycle; (ii) stochastic cash flow with no inflation; (iii) stochastic cash flow with inflation. Assume that the discount rate is 12% and the annual inflation rate has a mean of 3% and a standard deviation of one-third of 1 percent (or 0.003), as suggested by Meredith & Mantel (2011). Table 2 shows the three cost estimates for the triangular distribution of the project cash flows during the project life cycle.

Table 2: Three Cost Estimates During the Project Life Cycle

Year	***Minimum Cash Flow***	***Most Likely Cash Flow***	***Max Cash Flow***
Y0	90,000	100,000	110,000
Y1	-18,000	-20,000	-22,000
Y2	-18,000	-20,000	-22,000
Y3	-18,000	-20,000	-22,000
Y4	-18,000	-20,000	-22,000
Y5	-18,000	-20,000	-22,000
Total	$ -	$ -	$ -

4.1 Simulation Results

Table 3 shows the NPV results of the deterministic model and stochastic models. Specifically, Model 1 returns zero NPV, Model 2 NPV of $10,714 and Model 3 NPV of $32,957. The positive NPVs of Models 2 & 3 suggest that the community (i.e., the project owner) still have a cash balance of $10,714 (Model 2) and $32,957 at the end of the project (Model 3). These differences are equivalent to an 11% and 33% increase from the available fund of $100,000 for Model 2 and Model 3, respectively. It suggests that if the project owner (i.e., the community that receives the fund of $100,000) signed a construction contract with fixed annual payments of $20,000 for five times to the construction contractor, the project owner should benefit some cash balance, according to Table 4 because of the theory of time value of money.

In addition, the simulation results show that the probability of achieving positive NPV is 100%.

Table 3: Net Present Values

	Deterministic Model	Stochastic Models	
Year	**Discounted Cash Flow with No Discount (Model 1)**	**Discounted Three-Estimate Cash Flows with No Inflation (Model 2)**	**Discounted Three-Estimate Cash Flows with Stochastic Inflation (Model 3)**
Y0	100,000	100,000	100,000
Y1	-20,000	-17,857	-17,391
Y2	-20,000	-17,857	-15,123
Y3	-20,000	-17,857	-13,150
Y4	-20,000	-17,857	-11,435
Y5	-20,000	-17,857	-9,944
NPV	0	10,714	32,957
Probibility (NPV>=0)	N/A	N/A	100%
Change from the fund (%)	0%	11%	33%

The range of NPV deviation from the original fund in Table 4 is between 11% and 33%, which is relatively close to the PMI's allowable range for the contingency of 35% for a project budget, also called as a "guestimate" type (Project Management Institute, 2013).

In addition, suppose that a contractor accepts a contract, he must invest a one-time lump sum of $100,000 at the beginning of the project life cycle (Year 0) and receives a fixed annual payment of $20,000 from Year 1 to Year 5. A simulation with Crystal Ball Software shows that there is zero probability that this investment is profitable in terms of NPV on the side of the contractor (Figure 2). However, on the side of the project owner, this scheme of contract payments generates a 100% probability of positive NPV (Model 3).

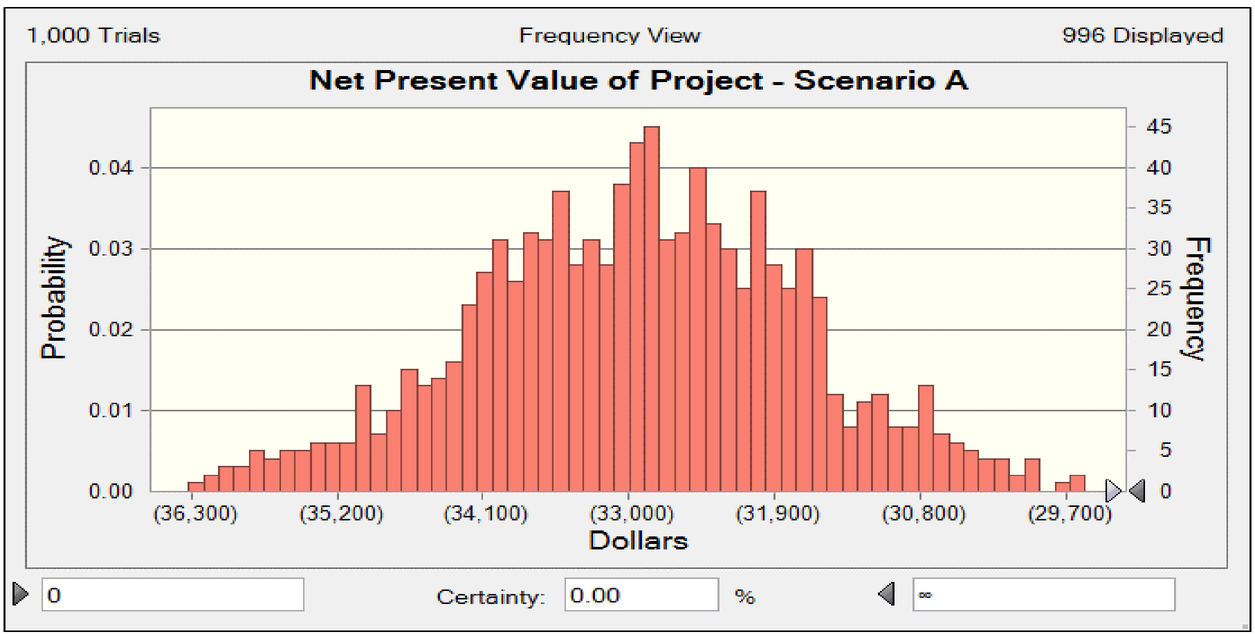

Figure 2: Crystal Simulation Results for NPV

Note: The probability distribution shows zero probability that the contractor will have a positive NPV.

5. Conclusion

Budget or cost-effectiveness is crucial in projects with budget constraints. It refers to achieving the project objectives at minimal costs (Visconti, 2012). However, when the annual project costs and inflation increase, the budget is insufficient to complete the project within the life cycle. Specifically, suppose the project customer has planned an annual payment of $20,000 for a project contractor. In that case, a reserve fund of $100,000 for the project is insufficient due to changes in yearly cost flows and inflation rate. The simulation results in this paper indicate that three-estimate costs (min, most likely, max costs) and stochastic inflation rates, assumed to have a normal distribution (i.e., mean of 3% with 0.003 standard deviation) increase the total project cost by 33%. This result is close to the allowable contingency of 35% as suggested by Project Management Institute. This finding is helpful for a contract estimator in hedging against inflation and cost changes. Alternatively, the project owner should add more cash to the future annual payments to adjust for increasing inflation rate instead of planning a fixed annual payment for the contractor. The cost estimator should also consider the pessimistic scenario of maximum annual costs due to any uncertainty of input prices.

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Biography

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