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Utility Function Evaluation on Economic Variables

—Construction Bidding Portfolios for Contractor Project Management

Lin, Chih-Hsien
Ph.D. Student, Dept. of Architecture
National Cheng Kung University
Tainan, Taiwan
shenshen630606@hotmail.com

Chen, Yao-Kuang
Associate Professor, Dept. of Architecture
National Cheng Kung University
Tainan, Taiwan
ykchen@mail.ncku.edu.tw

***Abstract*—The work of contractors mainly comes from bidding strategy, they take this as the main process of the construction project life cycle. And also, it is the most important part to be discussed in the construction management field. This case study considers the economic environment changes, objectively uses the economic analysis of financial management and further subjectively evaluates the utility function to get the optimal return rate and the bid price at the maximum expected utility increasing under interest rate, inflation rate, reinvestment rate and other economic environment variables, to help decision-makers can make the most suitable and competitive bidding decision.**

Keywords—bidding strategy; economic analysis; utility function

I. INTRODUCTION

There are four stages in bidding decision-making process of construction plant, such as bidding, decision-making, bidding decision-making and price decision [1]. The bidding and price decision are the most important stages for the construction company because of the input to the bid price, the opportunity cost and the actual project cost, and also the influence of the success or failure of the operation of the company. At present, the bidding works of domestic construction plants are mainly based on the estimation of project cost only, and then supplemented by the subjective intuition judgment and experience of decision-makers, whether to participate in bidding or bidding price decision [2]. Empirical law and subjective intuition to determine the biggest problem is that personnel training is not easy and liquidity, when the company scale expansion, and the assessment of large-scale project and the increase in the number of individuals such a huge amount of information, thus, decisions based on experience and intuitive judgment increase the risk of decision making [3]. Carr's bidding probability model in 1982, although validated for winning probability, is still flawed as a firm's bidding decision. It takes the highest expected profit as the basis for selecting the bid profit value, ignoring the investor's risk-oriented attitude, different engineering groups, the value of the currency and other factors.

The main purpose of this study is to explore the change of economic environment, the objective economic analysis of financial management and the subjective assessment of utility function to explore the maximum expected utility return under different rates of the optimal return rate and bid price. It is expected that this case study will provide an effective reference in engineering practice, which will help decision-makers to make more competitive bidding decisions and achieve sustainable development.

II. LITERATURE REVIEW AND METHODOLOGY

Before the bidding, it is necessary to select the financial risk which can be reduced in the early stage of the project according to the concept of financial management, and analyze the cash flow of the existing project, the construction in progress and the possible new construction project with combination characteristics. The initial screening of the company is to undertake the project portfolio, followed by the new case of the cost estimates, the probability distribution and profitability analysis. The benchmark probability model is mainly based on the statistical probability model [4], which evaluates the profit rate and the probability of winning of the new case. Then, considering the influence of economic factors and risks, using the cost of capital and inflation to the economy profit analysis, the last reference to the utility function of decision-making assessment[5,6], analysis of the structure shown in Fig. 1.

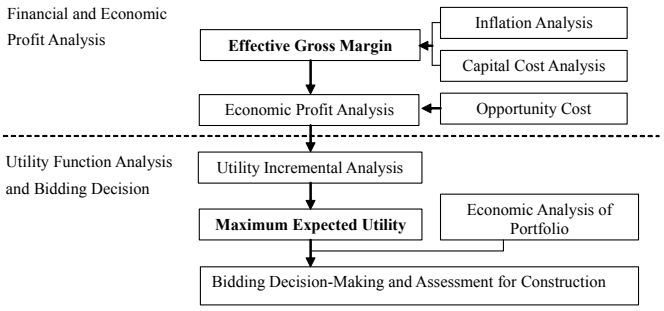

Fig. 1. Bid decision making scenario assessment process

A. Winning Probability P (W), Lowest Bid-Cost Ratio (LBC) and Carr Expected Maximum Value (EMV)

The Carr regression model includes the independent variables, such as the number of bidders, the size of the project, the market and the reference coefficient obtained in the last two years, into the regression equation, according to the bid price

(*BP*) of the project's direct cost (*DC*). Another by the bid-cost (*FBC*) can calculate the bid rate and the expected value of the tender, as shown in Equations (1) and (2), where the standard error (*SD*) is the estimated or probable actual cost (C).

$$P(W) = 1 - P\left[\frac{(FBC - LBC)}{SD}\right] \quad (1)$$

$$EMV = P(W)(FBC - 1)C \quad (2)$$

The reliability of the direct cost estimation can be calculated from the statistical data of each project. If the data are subdivided as much as possible, the more relevant operations can be easily integrated, and the cost estimate and variation of each independent item can be obtained. The direct cost can be expressed by Equation (3) to Equation (5)[7]. In the formula, $E(J)$ is the estimated median direct cost of the project case, $E(O_i)$ is the estimated cost of each project (i) in the project case, $V(J)$ is the variance of the estimated direct cost of the project case, and $V(O_i)$ is the variance of the estimated cost of each work item n in the project case of work items, $CV(O_{ij})$ is the variance of work items (i) and work item (j) and $\rho(i, j)$ is their correlation coefficient, $SD(O_i)$ and $SD(O_j)$ are the standard deviation of estimated cost of work item (i) and work item (j), respectively.

$$E(J) = \sum_{i=1}^{n} E(O_i) \quad (3)$$

$$V(J) = \sum_{i=1}^{n} V(O_i) + 2\sum_{i=1}^{n}\sum_{j=1}^{n} CV(O_{ij}) \quad (4)$$

$$CV(O_{ij}) = \rho(i, j)SD(O_i)SD(O_j) \quad (5)$$

B. Loss Probability

The probability of loss of the project, *P(L)*, can be calculated from the bid price (*FBC*), the estimated cost (*C*) or the possible actual cost *E(J)* and its standard error *SD(J)*, as shown in Equation (6).[7]

$$P(L) = 1 - \Phi\left(\frac{FBC * C - E(J)}{SD(J)}\right) \quad (6)$$

C. The Impact of Inflation on Gross Margin

Construction factory contracted projects to the owners obtains the actual payment period, prices continue to produce changes. As the duration of the construction work is often very long, ranging from one year as many as three to five years to complete, so the value of inflation has a great impact. Inflation for the nominal rate of reduction as the Equation (7), where *rm* is nominal discount rate, *f* is inflation rate, *r* real interest rate.

$$rm = f + r + f * r \quad (7)$$

In the absence of utility theory as the basis for evaluation decision-making, the past decision-making analysis is mostly based on economic "monetary value" as the criteria refer to a fast and clear decision-making reference data under the premise that the investment amount is not large. However, in a large-scale, high-value and long-term investment assessment, the attitude of the construction industry for investment risk becomes a decisive factor. Some projects, while the high interest rates, but the risk is great, the industry may not be willing to go forward to fight for the right to contract. The substitution of the utility value for the monetary value is the basis for decision making, reflecting the risk orientation of the industry. Three basic risk orientations are shown in Fig. 2 [8].

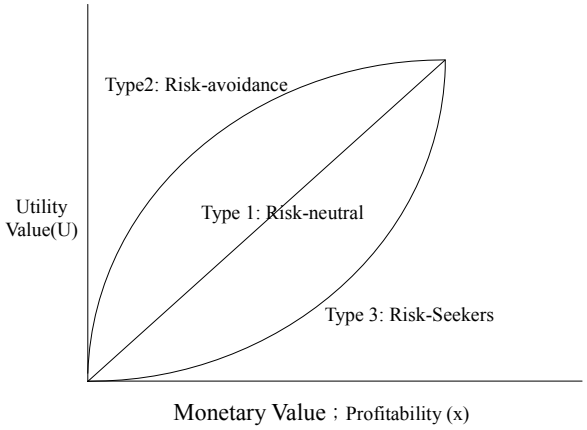

Fig. 2. Three basic types of utility functions

The three types of investors in all lines tend to prefer higher profit values, but the marginal utility increases from the three point along the curve cut point, the Type 1 of those who do not attach much importance to risk, as long as the amount of capital invested can be matched to the degree of satisfaction. The Type 2 of those who are risk aversion, which means that the investment amount to a certain extent, there must be greater profit increment in order to improve a little satisfaction. The Type 3 is risky, in the amount of investment and profit in a small number of increments has a greater incremental satisfaction. In the integrated bidding strategy model, the maximum utility increment obtained from the effective profit rate modified by the capital operation cost and the inflation rate is the best bidding price [9]. The utility function, *U(x)*, the income (or loss) of the construction-in-progress (or loss) of the decision-maker in a construction factory is shown in Equation (8), where *x* is the amount of income (or loss) (New Taiwan dollars, NT. 10 thousand). In other words, if the utility value of existing construction in a construction plant as a base, you can bid according to the price of the combination of the utility

of incremental changes in the situation, to assess the different gross margin under the utility value, multiplied by the utility increment The probability of winning the bid can be calculated the expected incremental utility, then the maximum expected incremental utility to obtain the best possible gross margin as a bidding decision-making reference[5,6].

$$U(x) = 100 - 100e^{-0.0015x} \tag{8}$$

According to objective economic analysis for cash flow, financial cost, estimated profit, financial ratio and profit rate, and then by the subjective utility analysis of decision-makers to obtain the probability of winning bid. The maximum expected utility increment of the bidding strategy at different return rates could be suitable bid price. Assuming that there are five caseworks in progress, and tenders intend to bid a new case NJ , as shown in Tables I and II respectively. The direct cost $E(Jj)$ of the project case, the direct cost standard deviation $SD(Jj)$ of the project case estimate, the bid price $B(Jj)$ and the completion ratio of the project case are the set data, and further probability of loss, $P(L)$. From Table I, the total amount of the project contracted is NT. 2,855 million and the estimated direct cost of the five projects is NT. 2,491 million. The probability of loss in the second case is about 24.01%, which is due to the low profit margin of the bid price and the large deviation of the estimated error. The probability of the loss in the fourth case is the smallest and almost zero, which is mainly due to the estimated error very small. Therefore, the probability of loss in the case depends on the accuracy of the bid decision-making and the price of the profit margin. According to utility theory, the maximum value of utility increment is the best choice of object. This is based on the utility value of the existing works of the plant, and the optimal gross profit margin is estimated based on the incremental utility of the utility price at the price to be tender. The median expected profit for a construction-in-progress project is 94 million (258,500-249,100), with a variance of:

$$V(P) = \sum_{j=1}^{5} V(Jj) + 2\sum_{j=1}^{5}\sum_{\substack{k=1 \\ (j\neq k)}}^{5} \rho(j,k)SD(Jj)SD(Jk) = 9.7219*10^{6}$$

TABLE I. DATA FOR CONSTRUCTION IN PROGRESS(UNIT: 10 THOUSAND)

Case	$E(Jj)$	$SD(Jj)$	$B(Jj)$	$P(L)$	Completion ratio%
1	17,500	1,800	19,800	10.07	85%
2	62,400	2,550	64,200	24.01	50%
3	92,000	2,600	94,500	16.81	10%
4	46,500	350	48,000	0.00	35%
5	30,700	800	32,000	5.21	90%
Total	**249,100**	**3,118**	**258,500**	**0.13**	

TABLE II. CHARACTERISTICS OF BIDDING (UNIT: TEN THOUSAND)

New case	$E(Jj)$	$SD(Jj)$	LBC	$SD(LBC)$	year
NJ	43,500	400	1.18	0.053	1.5

The new case *NJ* to be bid is NT. 43.5 million between NT. 17.5 million and NT. 92 million of the five existing cases under construction. Table III shows the change in utility increment (Δ U(X) = 13.57), the most appropriate bid amount is 1.14 times of the estimated direct cost, where gross profit is 14(%). However, if the best bid price according to Carr's bidding model is FBC* =1.13 (E(V)max =0.1079). In addition, a construction company chooses to bid only set by the return rate of 4% or more, the probability of its loss will be minimal, mainly due to *LBC* value as high as 1.18 in Table II, presenting good market competitiveness.

In the simulation of economic environment variables, such as interest rate (r), inflation rate (s), and reinvestment rate (h), the following three scenarios are set: (1) r = 0%, s = 0%, h = 0%, (2) r = 14.4%, s = 1.2%, h = 9.6%, (3) r = 12%, s = 6.0%, h = 9.6%.

TABLE III. RESULTS OF UTILITY INCREMENT EVALUATION UNDER DIFFERENT ECONOMIC ENVIRONMENT VARIABLES

Gross Profit(%)	ΔU(X)	Economic Scenarios			P(L)	E(V)
		(1)	(2)	(3)		
1	-2.69	1.69	-5.92	-7.13	13.79	0.0099
2	-0.45	3.59	-3.45	-4.57	1.46	0.0198
3	1.64	5.36	-1.13	-2.17	0.06	0.0297
4	3.58	7.01	1.02	0.06	0	0.0396
5	5.38	8.55	3.02	2.14	0	0.0495
6	7.05	9.95	4.87	4.06	0	0.0594
7	8.57	11.23	6.57	5.82	0	0.0686
8	9.93	12.35	8.10	7.41	0	0.0776
9	11.11	13.31	9.44	8.81	0	0.0864
10	12.29	14.08	10.58	10.01	0	0.0930
11	12.84	14.62	11.49	10.97	0	0.1001
12	13.33	14.91	12.13	11.67	0	0.1044
13	13.54	14.92	12.49	12.09	0	**0.1079**
14	13.57	14.65	12.95	12.78	0	0.1078
15	13.17	14.09	12.64	12.50	0	0.1065
16	12.49	13.26	12.04	11.93	0	0.1040
17	11.56	12.19	11.20	11.10	0	0.0969
18	10.43	10.94	10.14	10.06	0	0.0900
19	9.17	9.56	8.94	8.88	0	0.0817
20	7.85	8.15	7.67	7.62	0	0.0700
21	6.53	6.75	6.40	6.36	0	0.0609
22	5.28	5.44	5.18	5.16	0	0.0506
23	4.14	4.26	4.07	4.06	0	0.0391
24	3.15	3.23	3.11	3.09	0	0.0312
25	2.33	2.38	2.30	2.29	0	0.0225
26	1.67	1.70	1.65	1.64	0	0.0182
27	1.16	1.18	1.14	1.14	0	0.0108
28	0.78	0.79	0.77	0.77	0	0.0084
29	0.50	0.51	0.50	0.50	0	0.0058
30	0.32	0.32	0.31	0.31	0	0.0030
Financial Ratios(%)	1.6	0	2.4	2.6	-	-
Profitability(%)	12.4	13	11.6	11.4	-	-
Financial Cost[a]	687	0	1,050	1,143	-	-
Estimated Profit[a]	5,403	5,655	5,194	5,733	-	-

[a.] Unit: NT.10 thousand

The effect of the effective gross margin on the expected utility of the bid *NJ* shown in Table III can be seen that the expected utility increment of the portfolio is greatest when the interest rate, reinvestment rate of return and inflation rate are all zero in scenarios (1), without the burden of financial costs; the lower interest rate (r) and reinvestment rate (h) will decrease utility in scenarios (2), however, higher inflation rate (s) will worse, shown in Fig.3.

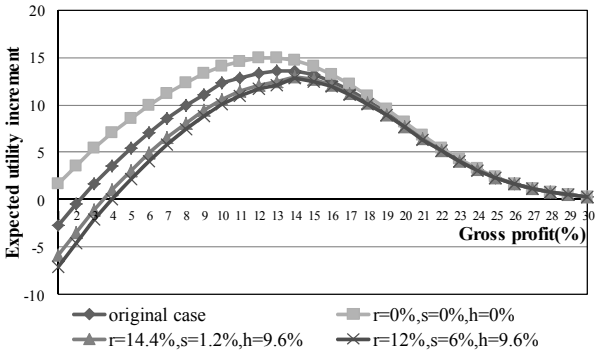

Fig. 3. Effect of incremental utility on the expected gross margin

III. Discussion and Conclusion

The bidding decision can be divided into two parts. The first part is the result of objective economic analysis. From the calculation results of engineering economy, the optimal wool return rate, cash flow, financial cost, estimated profit and financial ratio And profitability analysis results for decision makers to assess the reference. The second part is the subjective utility analysis of the decision-maker, which can get the bid winning probability of the bidding combination, the utility increment under the different gross return rate, and the expected utility of the bid strategy with different returns And then the maximum expected utility increment under the different reward rate is chosen to analyze the optimal wool return rate and the bid price according to the bidding strategy.

A. Utility function evaluation result.

For example, when the utility function of the decision maker is changed to $100-100*e^{-0.0001}$, the original utility value is reduced to 55.07, and the maximum expected utility increment of the bid is slightly increased . When the utility function of the decision maker is changed to $100-100*e^{-0.0002}$, the original utility value increases to 74.27, but the maximum expected utility increases slightly.

B. Simulation of economic environment variables

The maximum expected utility increment obtained at r = 0%, s = 0% and h = 0% is higher than the original case, but in the case of r = 14.4%, s = 1.2%, h = 9.6% and r = 12%, s = 6.0% and h = 9.6%, the maximum value of the decision-maker's utility expected utility increment are lower than the original case, thus, we can see that the high financial costs will reduce the decision-maker utility value; the latter by the high inflation rate of the maximum expected utility increment is the lowest, reducing the utility assessment of policy makers. In economic environment such as interest rate, reinvestment rate of return and inflation rate will affect the financial cost that the construction company must bear, and will also change the actual profit rate and the maximum expected utility increment. Bidding strategy in construction management has a great impact on the formulation. So the bidding strategy need to be considered by the financial cost of capital in order to get the right decision basis. The correlation coefficient between cases, the utility function of the decision maker and the change of the confidence interval will affect the risk assessment and maximum expected utility increment.

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