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Optimisation Methods for a three-asset Capital Investment Portfolio Problem

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Abstract: Decision making has never been an easy task, especially where capital funding of an investment portfolio is concerned. This has been the case at Selfless Investments PVT (Ltd) where the organisation has a three asset portfolio namely; Madzimbabwe Asphalt, Seagwick Farm and Thabo's Farm. The sole purpose of this study was focused on this organisation's capital budgeting problem; where there has not been a clear allocation of funds to each of the three assets in the portfolio. The researcher furthermore had to incorporate the stochastic nature of the road-construction bidding and awarding process. On setting the objectives of the research, we applied binomial logistics regression using SPSS to calculate the probability of obtaining the tender award, which resulted to 14.6% ceteris paribus. Thus we would expect the organisation to develop a competitive edge when bidding, inclusive of the job characteristics considered by the tenderer. We deduced, using Microsoft Excel, the Markowitz Portfolio Optimisation in order to calculate the weights which should be allocated to each of the assets in the portfolio. Madzimbabwe Asphalt was found to be more stable of the other assets in the portfolio in terms of return. Of our available capital, allocate 59.83% to Madzimbabwe Asphalt, 33.06% to Seagwick farm and 7.11% to Thabo's farm. Moreover, the researcher calculated the efficient frontier, which would aid the decision maker as to which portfolio combination to opt for. The optimal portfolio combination had a total portfolio risk of 872.74 and expected return of 66,609.89. Thus we concluded that the more diverse a portfolio is, the less risky it is, hence, one should not place their eggs in one basket, since placing them in one basket would mean that dropping the basket results in all eggs breaking at once.

Keywords: Capital budgeting; portfolio; risk; Markowitz Portfolio Theory, optimisation, return.

1. Introduction

Project selection is a major problem in managerial decision making. The resource allocation problem is in determining the distribution of limited budgetary resources among competing alternative projects. Capital budgeting narrows the view of the investor by considering mainly the benefits or costs to the company and not to the society. Since the company may be viewed as the sum of its investments, the future development of the company depends on the efficient choice of these investments. Decision makers should therefore use judgement and mathematical modelling tools to assess the projects to see if the project justifies investment. The results obtained must be analysed by the decision makers based on their experiences of similar situations in the past and their intuition about the future.

Selfless Investments Pvt (Ltd) is an entity that employs multiple budgets, operating budget, cash budget and capital budgets in the day to day running of the organisation. Early identification and subsequent effective management of risk are fundamental skills that lead to sustainability and improved predictability of performance of construction, as well as for the livestock and poultry production. Three projects that have varying capital requirements and risks have been invested in over the past few years and hence the most profitable return from all three projects is desired. The three investments in the portfolio are;

- Madzimbabwe Asphalt (road construction) which is the backbone of Selfless Investments.
- Thabo's Farm (chicken poultry production).
- Sedgwick Farm (cattle ranching).

A capital structure is a mix of a company's long-term debt, specific short-term debt, common equity and preferred equity. The capital structure is how a firm finances its overall operations and growth by using different sources of funds (Investopedia).Since capital is expensive for small businesses, it is particularly important for business owners to determine a target capital structure for their firms (Encyclopaedia).

The organisation has relied on calculated project's future accounting profit by period, the cash flow by period, the present value of the cash flows after considering the time value of money, the number of years it takes for each project's cash flow to pay back the initial cash invested, an assessment of the risks and other factors that may affect the profitability of the projects. The financial progressions serve as benchmarks for measuring and evaluating the performance and growth of the organisation as a whole.

This research presents a study on the usefulness of portfolio optimisation to determine what proportion of each of the investment projects should be in the portfolio, combining the considerations of the expected value of the portfolio's rate of return as well as measures of financial risk and how it might aid in more realistic approaches to decision analysis of the firm.

2. Capital Budgeting: An Overview

Each organisation has an array of major goals. At a superficial look, they seem coordinated but when managers break them down into smaller goals and try to allocate the budget of each of them, multiple conflicting goals pop up and make budget planning seriously challenging. Conflict among organisational goals is a common feature of multi-objective entities and causes an imbalance in achievement of the set of goals. Namely, one goal is achieved at the expense of deviation or less achievement of another goal.

The imbalanced achievement of goals has a very dysfunctional effect on organisation's performance. To avoid this, all budgeters and resource allocators should beware of efficient techniques for budget planning in multi-objective systems. Since the multi-objective nature of organisational systems endogenously brings about an amount of imbalance over achieving the goals, reducing this imbalance is always regarded as a very important problem for Operations Research experts. Generally, many techniques and models have been formulated for this purpose.

2.1. Review of financial methods used in capital budgeting

According to The Journal of Finance (Vol.7), the process of selecting a portfolio may be divided into two stages. The first stage starts with observation and experience and ends with beliefs about the future performances of available securities. The second stage starts with the relevant beliefs about the future performances and ends with the choice of portfolio. One type of rule concerning choice of portfolio is that the investor does (or should) maximise the discounted value of future returns. Expected discounts should be discounted because we do not know the future with certainty. The expected returns could include risk allowance or we could vary returns with risk. The hypothesis that the investor does maximise discounted return must be rejected. If we ignore imperfections the foregoing rule never implies that there is a diversified portfolio which is preferable to all non-diversified portfolios. Diversification is both observed and sensible.

Wellington (1877) was concerned with the most cost effective location of railways, and the application of economic choices to other engineering design questions, such as the grade and the gauge of the railway. For example, he demonstrated that light rail was false economy using his analysis techniques. Wellington described the application of present value techniques for the allocation of capital within a company. Present value techniques, also called discounted cash flow techniques, account for the time value of money. It is necessary to account for the time value of money in the evaluation of projects that last for more than a few years.

2.2. Review of mathematical models used in capital budgeting for multiple investment goals

Bisschop and Meeraus (1982) state that models are used as a framework for analysis, for data collection, and for discussion. They also state that models are created to improve the conceptual understanding of a problem. Models can further be used as moderators to guide discussions when there are several decision makers who are involved in the final decision making and recommendations. Goal programming has been frequently used in Capital budgeting. Some authors have proven integer programming to be the better choice when dealing with allocating funds for investment in projects that will bring future profits for the organisation. In evaluating capital budgeting decisions, quantitative approaches, such as traditional discounted cash flow modelling and real options valuations are useful when there is a presumed probability distribution for the future forecasted outcomes or for when there are lower levels of uncertainty. As uncertainty increases and forecasting becomes difficult, the value of financial modelling techniques decreases. Alessandri *et al.* (May 2004) argue that it may be useful to employ a qualitative approach to evaluate capital projects when faced with high levels of uncertainty.

Determining if investment decisions add value to a firm represents a research focus for both strategic management and finance scholars. Both disciplines strive to identify patterns of decisions that lead to the creation of shareholder wealth (Alessandri *et al.*, 2002).

Two primary perspectives relevant to the impact of risk and uncertainty on strategic decision-making are economic rationality and behavioural theory. The rationality side is traditionally aligned with a finance/economics approach, where analyses are undertaken under the basic market assumptions of perfect, or close to perfect information and complete markets (Eisenhardt and Zbaracki, 1992). The traditional discounted cash flow (DCF) valuation algorithm was originally derived from, and justified by valuing passive investments in bonds and known cash flows. This model assumes the expected values of the future uncertain cash flows are acceptable proxies for the cash flows' distributions, and that the expected values are given. Courtney et al (1997) go on to suggest that specific decision tools are more appropriate and more useful for some levels of uncertainty but not for others. In general, as the level of uncertainty increases, managers should employ more qualitative approaches to manage uncertainty in the decision process. According to Ignizio (1978), Goal Programming is a tool that has been proposed as a model and approach for analysis of problems involving multiple conflicting objectives. He pointed out that actual real world problems invariably involve nondeterministic system for which a variety of conflicting non commensurable objectives exist.

Charnes *et al.* (1959) were the first to formulate a linear program to solve a capital budgeting problem. According to Romero and Rehman (2003) both Lexicographic Goal Programming (LGP) and Weighted Goal Programming (WGP) are best known and widely used as goal programming variants. However, the variants lie heavily on the great amount of information that this goal targets, weights as well as pre-emptive ordering of preferences. These requirements can cause possible weakness if the decision makers are not confident of the value of these parameters. Contini (1968) proposed stochastic goal programming (SGP) model. He considered the goals as uncertain variables with normal distribution, that the model maximizes the probability that the consequence of the decision will belong to a certain region encompassing the uncertain goal. Keown and Taylor (1980) proposed an adoption of the chance constrained for stochastic goal programming model and transforms the model to a non-linear program, and applied it to budget allocation production problem. Basu and Pal (2006) used a goal programming model for allocating the budget within the existing academic units in a university in future planning period.

Multi attribute utility analysis (MAUT) is a more rigorous methodology for how to incorporate risk preferences and uncertainty into multi criteria decision support methods (Loken, 2007). Canbolat *et al.* (2007) applied a MAUT model to assist in selecting the location of a global manufacturing facility. Ananda and Herath (2005) also used MAUT in a real-world application to analyse risk preferences with regards to forest land-use in Australia. Gomez-Limon, Arriaza, and Riesgo (2003) utilised multi-criteria decision making analysis in regards to risk aversion.

Zabeo *et al.* (2011) assessed the risk and vulnerability of soil contamination in Europe by selecting a vulnerability assessment framework. They did this by combining multi-criteria decision analysis techniques (MAUT/MAVT) and spatial analysis. Khadam and Kaluarachchi (2003) addressed the use of cost-benefit analysis as the primary method for decision analysis when addressing environmental projects.

2.3. *Markowitz portfolio theory*

There are several authors, for example Markowitz (1991), Elton and Gruber (1997) that discuss the main issues that an individual face when investing, one issue is how to allocate the resources among alternative assets. When selecting a portfolio, the Markowitz Portfolio Theory (MPT) states that risk as well as return must be considered according to Elton and Gruber (1997).

Markowitz (1959) argues that risk can be minimized but not eliminated, and this without changing a portfolios return. According to Marling and Emanuelsson (2012) the Markowitz Portfolio Theory provides a method to analyse how good a given portfolio is based on only the means and the variance of the returns of the assets contained in the portfolio.

Most investors desire to maximise the expected return with the least risk. Markowitz model is thus a theoretical framework for analysis of risk and reward and their interrelationship. Markowitz used the statistical analysis for measurement of risk and mathematical programming for selection of assets in a portfolio in an efficient manner.

2.4. Binary logistic regression

A company bidding by sealed tender needs to know the relationship between their bid price and their chances of winning the contract. The bidders have to identify the factors influencing the probability of winning in public procurement procedures and to assess the strength of their impact. Binary logistic regression is the primary research instrument used to describe the influence of several (quantitative or qualitative) on one dependant binary variable. It allows us to estimate the probability of the occurrence of an event.

3. Methodology

The method that we used to predict how much to invest in each of the assets in the portfolio; incorporating risk and return is the Markowitz Portfolio Optimisation method using the mean-variance optimisation technique. Moreover, the chances of success or failure of obtaining a tender is determined with the use of Binary Logistics Regression.

3.1.1. Markowitz portfolio optimisation

We have to select the portfolio weighting factors optimally, that is, in Markowitz Portfolio Theory, the optimal set of weights is one in which the portfolio achieves an acceptable baseline expected rate of return with minimal risk. We compute the monthly means and covariance of the returns using the 60 historical monthly data-sets. These are referenced as the input data in the portfolio. The expected return for each asset, risk for each asset and correlation between these assets are input for the MPT technique.

3.1.2. Mean variance optimisation

The modern portfolio theory by Markowitz assumes that investors will undertake their decision based on risk and return. We will consider the objective of minimising the portfolio risk mathematically expressed as the portfolio variance. The variables of the problem are the portfolio weights (investment asset allocations), optimising the problem will give us the optimal weights that will minimise the portfolio variance (risk). We obtain the full optimisation problem as follows:

Minimise Z = $W^T \Sigma W$

Subject to:

$$\sum_{i=1}^{p} W_i E(R_i) \geq R$$

$$\sum_{i=1}^{p} W_i = 1$$

$$W_i \geq 0$$

We solve the quadratic programming problem in order to obtain the weights $W'_i s$ that minimise the portfolio risk and maximises the investors targeted return.

3.1.3. Efficient frontier

A combination of assets is said to be efficient if it has the best possible expected level of return for its level of risk. Every possible combination of risky assets can be plotted in risk and expected return space, and the collection of all such possible portfolios defines a region in this space. In the absence of the opportunity to hold a risk-free asset, this region is the opportunity set (the feasible set).The positively sloped (upward-sloped) top boundary of this region is a portion of a hyperbola and is called the efficient frontier. Portfolios that lie below the efficient frontier are sub-optimal, because they do not provide enough return for the level of risk. Portfolios that cluster to the right of the efficient frontier are also sub-optimal, because they have a higher level of risk for the defined rate of return.

3.2. Binary logistic regression

Logistic regression is based on the method of expressing a probability in terms of odds. The odds are calculated as the ratio of the number of successes to the number of failures.

$$\text{Logit}\ (p) = \ln \frac{P}{1-P} = \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k$$

Where;

p denotes the likelihood of occurrence of an event such that p is an element of (0,1) and β is the vector of unknown parameters $\beta = (\beta_1, \beta_2, ..., \beta_k)^T$.

We test the significance of the independent variable using the Wald test. We calculate the odds of obtaining the tender and calculate the exponent of the value to obtain a probability.

The Hosmer-Lemeshow goodness of fit test was used to find out how well the model fit the data.

4. Data Analysis and Interpretation of Results

We analyse the data on Excel because we have used a large dataset ad it can be tedious to calculate manually the expected return and risk of each asset. The results obtained imply that Madzimbabwe Asphalt is a steadier investment of the two asset investments individually, that is, standing alone Madzimbabwe Asphalt would sustain the organisation better than the other two investment assets separately.

Table 1: Covariance Matrix

	Madzimbabwe Asphalt	*Livestock*	*Poultry*
Madzimbabwe Asphalt	1459116.20	-479598.98	663870.52
Livestock	-479598.98	3184450.17	-58113.49
Poultry	663870.52	-58113.49	5398409.06

The results tabulated are a reflection that the three assets are moving inversely. Madzimbabwe Asphalt and Seagwick Farm have a negative covariance. Cattle sales returns and chicken sales return also have a negative covariance as shown in Table 1. Their returns are moving inversely hence diversity and reduction in risk. Madzimbabwe Asphalt and Thabo's Farm have a positive covariance. This means that their returns have a move together and they have a higher risk. The covariance matrix is symmetric along the diagonal. The values in the main diagonal represent the respective variances of the assets. That is, for example, the variance which is as a result of investing in Madzimbabwe Asphalt ó11=1459116.202, et cetera. The off-diagonal entries are the covariances of the corresponding pairs of counters shown in the table above. For example between Madzimbabwe Asphalt and Seagwick Farm ó12="479598.9833. The risk is found by calculating the square root of the main diagonal, that is, the risk for Madzimbabwe Asphalt is 1207.9388. This means that the organisation can suffer a loss or gain of 1207.9388. The covariances do not clearly show how two assets move together, however a correlation matrix was used which interprets better than the covariance matrix because correlation scales between -1 and 1. The covariance matrix is a very essential component in this study and it shall continue to be used later on in the portfolio optimisation model. However, covariance does not interpret the relationship between assets clearly, hence the need for a correlation matrix as shown in Table 2.

4.1. Correlation

Table 2: Correlation matrix

	Madzimbabwe Asphalt	*Livestock*	*Poultry*
Madzimbabwe Asphalt	1	-0.22	0.24
Livestock	-0.22	1	-0.01
Poultry	0.24	-0.01	1

The correlation matrix shows that there is a weak positive correlation between Madzimbabwe Asphalt and Thabo's Farm. This could be due to the fact that construction business requires more capital compared with poultry business. An investor may decide to put in a higher percentage of his investments into construction, meaning that a lesser percentage will be available for investment for poultry. However, the poultry line of business does not require huge amount of capital to guarantee good positive returns. As a result even if construction draws out many funds from the portfolio, poultry business can still produce positive returns.

There is a weak negative correlation between Madzimbabwe Asphalt and Seagwick farm. This shows that choosing to invest in either of the two assets in the portfolio, it would affect the perfomance of the other. Both assets require more capital for investment, however construction requires even more funding than cattle farming. Therefore investing in Madzimbabwe Asphalt means there are fewer resources to put towards the Seagwick farm and vice versa. Hence the weak negative correlation.

There is a weak negative correlation between Seagwick farm and Thabo's farm. This could be due to the fact that their products are substitute goods according to consumer theory. Beef and chicken, the main products of cattle rearing and poultry farming respectively, are products that a consumer perceives as similar or comparable, so that having more of one product makes them desire less of the other product. Formally, beef and chicken are substitutes if, when the price of beef rises, the demand for chicken rises. Hence the weak negative correlation between them.

4.2. Mean variance optimisation

The Mean Variance Optimisation model is used to determine the highest expected return with the minimum risk for an asset invested in. In this case, we calculated the weights using Excel Solver and obtained the following result:

Table 3: Mean Portfolio Weights

Asset	*Weight*
Madzimbabwe Asphalt	59.8%
Seagwick Farm	33.1%
Thabo's Farm	7.1%
Sum	100%

Table 2 shows the minimum risk portfolio weights which add up to 100% satisfying the full investment constraint in the Markowitz model. Asset Weight Madzimbabwe Asphalt 59.83% Seagwick Farm 33.06% Thabo's Farm 7.11% Sum 100%. These weights mean that an investor will invest 59.83% of his/her wealth to Madz imbabwe Asphalt, 33.06% to Seagwick Farm and 7.11% to Thabo's Farm. Furthermore, we need to calculate the expected return and variance of the portfolio. The expected return is calculated as the weighted average of the likely profits of the assets in the portfolio, weighted by the likely profits of each asset. When we plug the weights into the formulae in the equation we got the expected return as 66609.89 and the portfolio variance is 761670.79 resulting in a portfolio risk of 872.74. We should note that diversification does not guarantee high return but it reduces risk significantly.

The mean variance optimisation determines the highest expected return with the minimum risk for an asset invested in. We obtained the following optimal weights which show the percentage capital to be allocated to each investment asset, summing up to 100%, therefore satisfying the full investment constraint in the Markowitz Portfolio Theory Model.

4.3. Efficient frontier

The Markowitz model allows us to evaluate trade-offs between risk and return. By running the model for a series of different levels of return, one can see how portfolio risk must increase as desired return increases. According to Markowitz, for every point on the efficient frontier, there is at least one portfolio that can be constructed from all available investments that has the expected risk and return corresponding to that point.

The return/risk trade-off may be graphed, and this graph is known as the efficient frontier. The best possible project portfolios for a given amount of risk lie on the Efficient Frontier curve. These are also called the optimal project portfolios. Figure 1 show the efficient frontier produced from our data. The efficient frontier shall be explained in two parts.

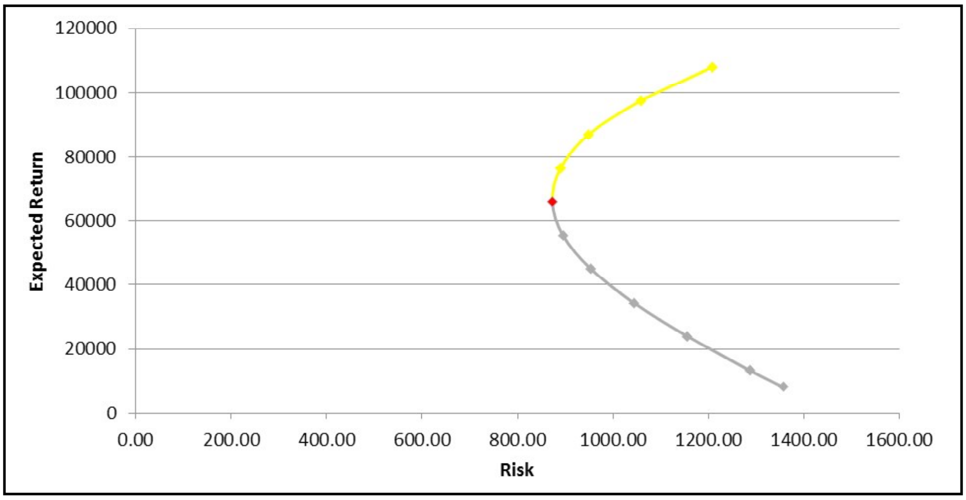

Figure 1: Efficient Frontier

The first part is one where the investor is risk averse. One would prefer to take the portfolio option where there is the maximum return at the lowest risk possible. As shown in our graph, the point with a red marker is the most efficient portfolio option. This is the portfolio combination that gives a high portfolio return at the minimum risk. The area below the graph (grey line) shows portfolios which are undesirable. There is low return for high risk. No investor would opt for a portfolio which is very risky and yet has a minimum return; it would result in huge losses.

The second part is for a risk taker who would definitely opt for the most risky portfolio (yellow line region on Figure 1 as they would have high return. The risk taker is speculative in nature; they are not afraid of having massive losses when their high expectations of a high return do not come to pass. The more risk an investor is willing to accept, the higher the expected return of the investment. However, choosing a risky asset portfolio would mean either of two possibilities; either a high risk-high return scenario or a high risk-low return scenario. We see these impacts (compare yellow and grey lines) on Figure 1 where the same value of risk can either produce high expected return or low expected return.

The optimal portfolio is the point on the graph where there is a red dot Expected portfolio return = 66,609.89 and risk = 872.74 can be interpreted as the optimal portfolio return at the minimum risk possible. This implies that diversification does not guarantee high return, but reduces portfolio risk significantly.

4.4. Binary logistic regression

A Binary Logistics Regression was conducted to predict the chances of winning a tender. 60 tender results from previous bids were used. The dependant variables where win=1 and lose=0; the independent variables were

x_1 = *amount bidded by Selfless Investments,*

x_2 = *The highest amount offered for the tender,*

x_3 = *Lowest amount offered for the tender,*

x_4 = *duration of completing the scope of work,*

x_5 = *number of companies bidding for the tender.*

All the variables were found to be significant as their p-value was below 0.05.

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Priceoffered byorganisation	1.705	.172	97.648	1	.000	5.493	3.918	7.700
	LowestBid	.098	.025	15.199	1	.000	1.103	.270	.995
	HighestBid	.660	.270	5.867	1	.015	1.068	.790	1.650
	Declaredduration indays	-1.013	.444	5.212	1	.022	.363	.993	1.005
	No.OfCompanies	-.112	.344	.102	1	.039	.892	2.710	5.126
	Constant	-1.765	2.679	.502	1	.009	.171	0.865	1.260

Figure 2: Variables in the equation

The resulting logit model from the tabulated results in Figure 2 is as follows:

$$\text{Logit }\{P(x)\} = \ln \frac{p}{1-p} = -1.765 + 1.705x_1 + 0.098x_2 + 0.660x_3 - 1.013x_4 - 0.112x_5.$$

Each of the regression coefficients describes the size of the contribution of that risk factor to the dependant variable ceteris paribus. A positive regression coefficient means that, that risk factor increases the probability of the outcome, while a negative regression coefficient means that, that risk factor decreases the probability of that outcome. However, in the case of the duration in days of the project, the more negative this value is, the more the chances of obtaining the tender because no employer would want the duration of a project to be long. In the case of the number of competitors for the same tender, an increase in the number of competitors implies the lesser the chances of obtaining the tender. Thus we would prefer this value to be most negative so that the fewer the competitors, the better the chances of obtaining a tender.

5. Conclusion

Madzimbabwe Asphalt got the most allocation from the results (from solving the mean variance portfolio problem), this may be due to its stability i.e. lower variance, compared with Seagwick farm and Thabo's farm. When the assets were combined to give an overall portfolio risk, this resulted in lower risk than that of each individual asset. That is, one should not put all their eggs in one basket.

The results also showed that when diversifying, optimizing the portfolio will give weights that yield a better risk-return relative to the efficient frontier. Depending on risk aversion of an investor, the choice of a portfolio and allocation of funds to the assets will be done with the help of the efficient frontier. An investor may opt for higher returns and an investor close to retirement might prefer low risk portfolios. Any deviation from the efficient frontier may lead to sub-optimal/ inefficient portfolios.

We calculated the probability of obtaining a tender, ceteris paribus. The probability was low (close to zero), hence a sign that the organisation should develop a competitive edge because projects vary so much in so many areas. Taking into account the results obtained, the next stage of work could therefore be a scenario analysis for future tenders, which could enable the assessment of chances of winning a tender according to the different strategies used by competitors.

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