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Outline of Intelligent Support System for Development Projects

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Abstract.

The complexity of modern projects makes the proper management of them crucial. The volatile environment of the twenty-first century means that it is important to choose the right moment to start a project. Because the decision to start is irreversible, we are dealing with a real option. The paper presents a outline of Support System for choosing the right moment to start a project on the basis of multi-state real options. The system is based on knowledge of the future changes in the factors affecting the results of the project The TOPSIS method was used to choose the efficient decision.

1. Introduction

Traditional project evaluation is based on the discounted cash flow method (DCF). The main measure of effectiveness is the Net Present Value (NPV). When this value is positive, the project is approved, when negative, it is rejected, but this approach sometimes leads to the abandonment of profitable projects. The reason for this is that the DCF method does not take into account the role of managerial flexibility. The project manager has the right to take action as appropriate. This situation is called a real option. Using Real Option Valuation (ROV), we can provide a quantitative measurement for this situation. The Cox-Ross-Rubinstein model (CRR) , is commonly used for this. This approach is based on the binomial tree.

The ROV-based approach not only makes it possible to value a project, but it also can assist in the decision making process. For example, if the project is divided into phases, there is a problem of selecting the start of the next stage. The same is the case when it is possible to delay the start of the project. The right moment to begin the project and each stage has to be chosen. If the result of the project depends on some external factors that change in time, it is possible to help selection with ROV methods. The condition is that these factors can be modeled using stochastic processes.

This paper presents the outline of Intelligent Support System based on Real Option Valuation (ROV) methods for decision support in development projects. The system is based on knowledge of the future changes in the factors affecting the results of the project, which are modeled by stochastic processes.If, in the nature of the problem, there is a need to use multiple state variables, it leads to problems considered in the multicriteria analysis. The proposed solution considers two aspects, which are especially important in the context of sustainable development, namely social aspects and financial aspects. The first section presents the defer options that may arise in project management. The next section describes a multicriteria system using Real Options Valuation to support choosing the right moment to start. This system is based on the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) originally developed by Hwang and Yoon [6].

2. Related work

Project management produces an environment in which many decisions are made. If we have the opportunity to delay the start of the project, the problem of choosing the most appropriate starting point arises. If the start is planned in advance, the situation is static, the decision maker is not able to react to changes in the environment and in the same project. If extending the duration of the project is allowed and the decision maker is allowed to freely decide about the start times, a completely new situation is raised, as presented in Figure 1. The decision maker may start the project (decision *A*), then move the state ***initialization*** of project to the ***end*** of project. The decision maker may also wait (decision *W*), but then the project will remain in its starting state. After one period, the situation is repeated.

The ability to delay the project for one period of time creates a real option, expanding managerial flexibility. The project manager has the possibility to use this option freely, depending on the situation in the environment. If the current environment is favorable, the project manager will begin the project, if it is not beneficial, he or she can wait for a development in the situation. There is the problem of when to use this option - what is the best moment to start the project? Is it better to start the project now or wait for a development in the situation? Based on quantitative assessment system gives answer.

The standard approach in the valuation of real options is based on one factor, called the state variable. There have been attempts to take into account many state variables. The first attempt, on the basis of financial options, was made by Boyle [1], who took into account two assets. Mun [7] described the commercial solution for real options with many assets. In these attempts, different criteria were brought to a common financial denominator.

According to the principles of sustainable development, results of the project, depend on certain factors, which may be economic factors, social factors and environmental factors. If we consider more than one factor that leads to usability and design considerations in many areas, the problem is converted from a simple valuation to a multicriteria evaluation problem. This approach is discussed in the literature. The framework for project-level decisions, leading to more sustainable management and development, is proposed in [2]. The ecological, economic and social sources of landscape valuation are discussed in [8]. Heidkamp's paper [5], proposes a theoretical framework for the integration of economic and environmental aspects into the decision making process for sustainable development strategies.

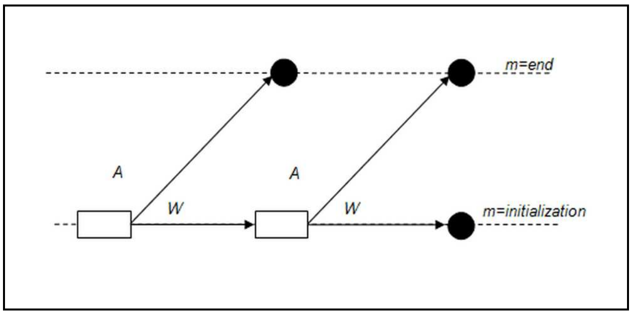

Figure 1. Considered situation

The decision maker makes his or her decisions based on changes in factors. These factors vary stochastically according to a certain random process. The idea behind the CRR method is to cover a possible future state variable binomial tree as shown in Figure 2. This is a role-specific scenario of possible changes in the value of state variables.

3. Idea of Support System for efficient decisions

The decision support system for the selection of the start moment of the project is based on the valuation of the option situations. The procedure is enriched with the TOPSIS method, which is used to select effective decisions. We assume that each state variable in one period may increase *u*-times and fall *d*-times. This assumption leads to the tree of possible state variable values, consisting of nodes marked with indices (*i, j, n*), where *i* means the number of falls in the first state variable, *j* means the number of falls in the second state variable and *n* is the number of the period . We denote state variable as $X_1(i,n)$ for first state variable and $X_2(j,n)$ for second state variable in period *n*. Connected to each node is also the present value of the project $V_s(i, j, n)$, described later. We assume that we have *N* periods, the present value of each state variable denoted by $X_k(0,0)$ and also have *u* and *d*. The value of *u* can be obtained from historical data using the calibration procedure proposed by Guthrie [4].

The proposed method, which is implemented in system, consists of several steps which include: creating a decision tree (D-tree), building possible scenarios (X-Tree), building a project value tree (V-Tree), and at the end determining efficient decisions.

Decision tree (D-Tree) is the possible states of the project are recognized. They may be different phases or specific stages. The possible decisions that could be made when considering a state are recognized. Making a decision would lead to a transition from one state to another. All possible transitions are identified. The result of this step is the creation of a D-Tree. The considered D-Tree is shown in Figure 1.

Lattice of state variables (X-Tree) which may depend on the result of the project is identified. The tree starts from a known present value of state variables. Based on the history, the values *u* and *d* can be determined in the calibration process. A tree of possible changes in state variables is formed and shows possible scenarios of the situation, presented in Figure 2. Calibration is the appropriate choice for the number of steps and the choice of parameters *d* and *u* to best meet the future value of the variable state.

The first step is to choose the model of the stochastic process. In the literature [4], the most commonly used processes are Brownian Motion (BM) and Geometric Brownian Motion (GBM). In this work we use GBM defined by the equation:

$$dX_t = \mu X_t dt + \sigma X_t dW_t \qquad (1)$$

where W_t is the Wiener process, X_t is the state variable, μ is the drift parameter, σ is the volatility parameter.

The selection of the model gives a way of generating lattice nodes. For Geometric Brownian Motion (GBM), nodes are defined by the equation (for *k*-th state variable):

$$X_k(i,n) = X_k(0,0)e^{(n-2i)\hat{\sigma}_k\sqrt{\Delta t_m}} \qquad (2)$$

where Δt_m is a part of year which for each node of tree, $\hat{\sigma}_k$ is the estimated volatility parameter for GBM. These formulas arise directly from the method of determining the parameters *u* and *d*. This is done in the model calibration process. For Geometric Brownian Motion (GBM) we have:

$$u = e^{\hat{\sigma}_k\sqrt{\Delta t_m}} \qquad (3)$$

$$d = e^{-\hat{\sigma}_k\sqrt{\Delta t_m}} \qquad (4)$$

The volatility of the process $\hat{\sigma}_k$ (for *k*-th state variable), is calculated in each case on the basis of historical data from the variability in this data:

$$\hat{\sigma}_k = \frac{\sigma_k}{\sqrt{\Delta t_d}} \tag{5}$$

where Δt_d is a part of year which represents one period in data, σ_k is standard deviation in historical data (for k-th state variable).

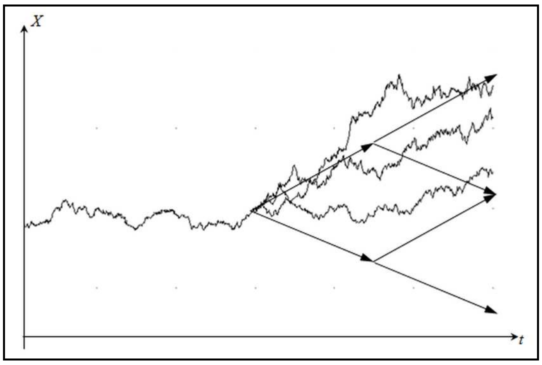

Figure 2. Binomial tree covering stochastic process

Project value tree (V-Tree) is then created. If the project evaluation is based on many state variables, it is therefore presented in a vector of values. When considering two state variables, the V-Tree grows in two dimensions:

$$\mathbf{V}^m(i,j,n) = \begin{bmatrix} f_1(X_1(i,n), V_1^m(i,j,n+1)) \\ f_2(X_2(j,n), V_2^m(i,j,n+1)) \end{bmatrix} \tag{6}$$

We denote the present value of the project, which is dependent on two state variables, as $V_k^m(i,j,n)$ - utility value of k-th state variable, the project in m-th state, period n, with i - number of falls of the first state variable and j - number of falls of the second state variable. The calculation of the value of the V-Tree starts from the end (final value). We assume that the final value of the project is a function of state variables:

$$\mathbf{V}^m(i,j,N) = \begin{bmatrix} f_1(X_1(i,N)) \\ f_2(X_2(j,N)) \end{bmatrix} \tag{7}$$

On this basis, the remaining values of the V-Tree are successively calculated. Trees are constructed for each state of the project. The calculation of value is done by backward induction. Based on the value of the project after its completion (which is usually equal to the state variable, or the right formula for this variable is calculated), the values of the project in the preceding nodes are calculated.

The present value is the discounted expected value of subsequent values:

$$\begin{aligned} V_k^m(i,j,n) = \big(&\pi_u^1\pi_u^2 V_k^m(i,j,n+1) + \pi_u^1\pi_d^2 V_k^m(i,j+1,n+1) + \\ &+ \pi_d^1\pi_u^2 V_k^m(i+1,j,n+1) + \pi_d^1\pi_d^2 V_k^m(i+1,j+1,n+1)\ \big) e^{-r\Delta t_m} \end{aligned} \tag{8}$$

Subsequent values are weighted by the probability of achieving these values. If we denote by r the risk free interest rate, we can calculate probabilities for GBM model from the formulas proposed by Seydel [9]

$$\pi_u^k = \frac{e^{r\Delta t_m} - d}{u-d} \tag{9}$$

for the growth and

$$\pi_d^k = \frac{u \quad - e^{r\Delta t_m}}{u - d} \tag{10}$$

for the fall of the second state variable.

The most important is determining efficient decisions. The values determined by the formula (8) must be calculated for each decision, so we have a superscript denoting the decision on the value achieved for the decision Act (A) and for the decision Wait (W) :

$$\mathbf{V}^A(i,j,n) = \begin{bmatrix} V_1^A(i,j,n) \\ V_2^A(i,j,n) \end{bmatrix} \tag{11}$$

$$\mathbf{V}^W(i,j,n) = \begin{bmatrix} V_1^W(i,j,n) \\ V_2^W(i,j,n) \end{bmatrix} \tag{12}$$

The selection of efficient decisions we made by TOPSIS method, originally developed by Hwang and Yoon [6], here presented by [10]. Computation are based on evaluation matrix, shown in Table 1.

Table 1. Evaluation matrix

D_l	V_1	V_2
A	$V_1^A(i,j,n)$	$V_2^A(i,j,n)$
W	$V_1^W(i,j,n)$	$V_2^W(i,j,n)$

In Table 1 we denote D_l the l-th decision (l = 1, 2), V_k is the value of the k-th state variable (k = 1, 2). Additionally we define $w_k \geq 0$ weights of assessments, which sums to one. First we normalize the matrix:

$$\mathbf{N} = \begin{bmatrix} \hat{x}_{11} & \hat{x}_{12} \\ \hat{x}_{21} & \hat{x}_{22} \end{bmatrix} \tag{13}$$

where:

$$\hat{x}_{lk} = \frac{x_{lk}}{\sqrt{\sum_{l=1}^{m} x_{lk}^{\ 2}}} \text{ , for } l = 1,2 \text{ and } k = 1,2 \tag{14}$$

and x_{jk} is an appropriate element in the evaluation matrix. Then we weigh the this matrix:

$$\mathbf{V} = \begin{bmatrix} w_1\hat{x}_{11} & w_2\hat{x}_{12} \\ w_1\hat{x}_{21} & w_2\hat{x}_{22} \end{bmatrix} = \begin{bmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \end{bmatrix} \tag{15}$$

Next we determine the worst alternative $\mathbf{A}^- = (v_1^-, v_2^-)$ and the best alternative $\mathbf{A}^+ = (v_1^+, v_2^+)$ where $v_k^- = \min_l(v_{lk})$ and $v_k^+ = \max_l(v_{lk})$ for k = 1, 2, assuming that all factors have positive impact. We calculate the distance between the target decision and the worst ($\mathbf{A}^-$) and the best ($\mathbf{A}^+$) alternatives:

$$d_l^- = \sqrt{\sum_{k=1}^{n} \left| v_{lk} - v_k^- \right|^2} \text{ , for } l = 1, 2 \tag{16}$$

$$d_l^+ = \sqrt{\sum_{k=1}^{n} \left| v_{lk} - v_k^+ \right|^2} \text{ , for } l = 1, 2 \tag{17}$$

We then calculate the similarity to the best alternative:

$$S_l = \frac{d_l^-}{d_l^+ + d_l^-}, \text{ for } l = 1, 2 \quad (18)$$

It is understood that $0 \le S_l \le 1$. A higher value of S_l means the solution is closer to the ideal solution, so decisions with the maximum value of this index should be chosen.

4. Conclusions

The complexity of modern projects forces us to new ways of looking at project management. When choosing a project, it is necessary to consider not only certain results but also the future possibilities. This holistic view, which is the basis of real options is the result of systems thinking.

This article presents a intelligent support system for development projects. It is based on the method of valuation of real options. It makes it possible to determine the best moment to start a project when there is real option to wait. In context of sustainable development, we take into account two factors, so it was necessary to employ methods of multicriteria decision making, namely TOPSIS was used.

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