

## A Simulation Integrated Investment Project Ranking and Selection Approach

Ozgur YALCINKAYA and Ozgur ARMANERI

Department of Industrial Engineering, Dokuz Eylul University, Buca, Izmir - Turkey  
Email: ozgur.yalcinkaya@deu.edu.tr  
Email: ozgur.armaneri@deu.edu.tr

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**Abstract.** Enterprises are confronted with several project alternatives that they assume to gain revenue in the future, but their own economical resources are limited to carry out all alternatives. Therefore, a decision process arises to prioritize and select among alternatives according to the predetermined goals and criteria to reach the maximum utilization. On the other hand, in project evaluation, the values of project parameters are often assumed to be known with complete certainty. However, project parameters normally change during a life cycle of the project, and it is necessary to consider *uncertainty* and *risk* phenomena while evaluating projects. Simulation-based project evaluation approaches enable to make more reliable investment decision since they permit to include future uncertainty and risk in analysis process. In this article, a novel simulation-based optimal decision approach is proposed for evaluating and comparing investment projects under uncertain and/or risky environments. The phases of the proposed approach are; (a) developing the effectiveness measure formulation of a project, (b) identifying and checking all controllable project parameters that affect the measure, (c) developing simulation model for the measure, and (d) performing the project ranking and selection procedures in order to rank and select the projects. Three ranking and selection procedures, previously used for comparing performances of the different production/service systems, are embedded in the proposed approach.

**Keywords:** Project risk assessment; Investment project evaluation; Simulation; Ranking and Selection.

**AMS Classification:** 91G40, 37M05.

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### 1. Introduction

The main purpose of economic activities and economic science is to overcome the shortage between the requirements and the economic resources. In other words, the main purpose is to provide a balance between the requirements and the economic resources. From this point of view, it can be said that, the focus of the economic activities is the management of limited resources. The major problem for economy and economic activities that should provide a solution is to make a choice among many various activities for the use of economic resources. The facts that economic resources are limited and there exist

alternative opportunities of use, force economic decision units to make a decision and choice on how and where to use these resources.

The enterprises, which are one of the most important elements of the economic life, are defined as the economic units that manufacture the products with the aim of getting maximum benefit subject to legal and environmental constraints. Enterprises face various investment alternatives during their operating periods. However, the fact that economic resources are limited and there exist alternative fields to use them in, forces enterprises to make a decision and choice on how and where to use these resources. Therefore, enterprises, which are confronted with the problem of using economic resources for

many different investment alternatives, have to make a ranking and choice in order to ensure the topmost benefit among these different investment alternatives. To make this ranking and choice, investment alternatives need to be assessed in accordance with certain criteria. At this point, the evaluation process of the project alternatives requires some data for non-realized investments, i.e., total amount of investment, cash flows during the economic life of the project, discount rates, and salvage value at the end of the life. However, it is nearly impossible to know the values of these parameters with a complete certainty before the project is realized.

Because of the uncertainty and risk of the future, the parameters of projects alternatives can not be estimated with complete certainty. Any wrong value that is estimated by the decision maker will directly affect the return and the profitability of the project. In addition, sometimes the wrong alternative can be accepted and implemented because of this wrong estimation. Therefore, it is necessary to define and locate the investment decision-making problem in its real conditions that will increase the possibility of finding suitable and appropriate solutions [1-3]. The estimation of the investment efficiency is rather an uncertain problem, so the proper methods for operating in uncertainty must be used [4]. Several methods have been presented in the literature to handle the analysis of the investment projects under uncertainty or risk [5-11].

One of the practical methods, for analyzing complex, real-world decision-making situations involving risk, is simulation. Simulation is a statistics based behavioural approach that applies predetermined probability distributions and random numbers to estimate risky outcomes. Recently, the usage of simulation in investment project evaluation under uncertain and/or risky environments has been increasing. Because, simulation-based project evaluation approaches enables to make more reliable investment decision since they permit including future uncertainty and risk in analyze process. In this study, a novel approach based on simulation and post-simulation analysis is proposed for evaluating investment projects under uncertain and/or risky environment.

The paper is organized as follows; after giving the literature review for investment project evaluation and selection in second section, simulation in project evaluation process is briefly mentioned in third section. In fourth and fifth

sections, the proposed approach is explained in details and computational experiments are presented. In last section, the results of the study are discussed and suggestions for the future studies are given.

## 2. Literature on Investment Project Evaluation and Selection

Investment project evaluation and selection is the process of evaluating individual projects to choose the right one based on an analysis, so that the objectives of the company will be achieved. Investment project evaluation methods play an important role in today's competitive business environment. Shrinking profit margins and diversification require careful analysis of investments, and the decisions regarding these investments are crucial to the survival of the firm or company [9, 12].

There are several approaches in project evaluation and selection under uncertain and/or risky environment. The *first* approach in investment project evaluation is *multi-criteria or multi-objective investment evaluation and selection under uncertainty*. The process of investment project selection among different project alternatives is a complex problem due to the vagueness of the available information related with each alternative. Moreover, there are several criteria such as; market conditions, availability of raw materials, management desire, and flexibility which are involved in investment project evaluation and selection process. The selection process that takes into account several criteria for decision making is multi-criteria decision-making (MCDM) process. There are several MCDM approaches used in the literature, which seek to take explicit account of more than one criterion in supporting the decision process. Main advantage of the MCDM tools is that; they allow incorporating uncertainty of the future and the multi-objectivity.

Effective project evaluation necessitates incorporating the many conflicting objectives of decision maker(s) into decision models. Many models and methodologies for MCDM have been developed [9, 13-20]. For decisions with multiple objectives, [21] propose a method to determine "the utility function" of the decision maker in mathematical form. This utility function then represents a decision maker's level of satisfaction with different alternatives. Utility theory is a branch of decision analysis that involves the building of mathematical models to describe the behaviour of a decision maker when faced with

making a choice among alternatives in the presence of risk [22]. Among other models are statistical methods such as; Bayesian theory, fuzzy set theory, and mathematical programming. Goal programming (GP) is perhaps the oldest methodology in the field of MCDM [23-25]. According to [26], linear goal programming (LGP) formulation was first introduced by [27]. The procedure to formulate a LGP model starts with specifying a target or aspiration value for each objective, thus transforming all objectives into goals. Some survey papers that include GP methods and applications can be seen in literature [25, 28-29].

Steuer and Na [30] presented the widest review related with MCDM for economical and financial problems. However, according to the literature survey, there are not many papers related with multi-criteria or multi-objective project evaluation.

The *second* approach in project evaluation is *simulation and post-simulation analysis based investment evaluation and selection approach*. Some projects have high uncertainty, and simulation based investment project selection analysis could evaluate the projects with a greater confidence. Although, in economic analyses, it is often assumed that all factors are deterministic in nature, but in reality, some factors have stochastic properties. In some cases, where the stochastic nature of a factor is recognized, some flaws may still exist because of the simplifying approach that is used in the analysis. Two, not only common but also wrongful, practices in analytical approaches involve representing a distribution simply by its mean and using the wrong probability distribution. Simulation approach avoids these pitfalls by allowing both parametric and nonparametric factors over the range of factor values [5].

The *third* type approach in project evaluation is *spreading a fixed sum of money among possible investment policies*. The investment problem here is to determine how much money should be allocated to each possible investment policy so that the objective is minimized or maximized. In the literature, there are some studies based on this approach related with investment evaluation under uncertainty. Some of the methods used in these studies are dynamic programming [31], fuzzy logic and genetic algorithms [11].

The *fourth* and the last approach in project evaluation and selection process is *trying to evaluate the investment projects by analyzing their project risk*. For example, according to [32], the variability in the net present value (NPV) of an investment project is an indication of the project's risk. There are many methods used in investment project evaluation to identify and assess the level of perceived project risk. Mostly used methods are payback period method [33], sensitivity analysis [34], [1], probability analysis and simulation [35].

As a result of literature review, it is specified that; there are four main types of approaches recently considered and studied which have similar targets in project evaluation and selection under uncertainty or risk. The summary of these approaches is shown in Table 1.

According to the literature, the investment project evaluation methods can be classified into three main categories such as; (a) economic analysis methods, (b) strategic approaches and (c) analytic methods. The classification of the investment project evaluation and selection techniques according to these three categories, and also advantages and disadvantages of these techniques are demonstrated in Table 2. The classification table has been constructed by extending the table given in [9].

**Table 1.** The summary of the approaches recently considered in project evaluation and selection under uncertainty or risk

<b>Approaches</b>	<b>The methods used in these approaches</b>
Multi-criteria or multi-objective investment evaluation and selection approach under uncertainty	analytic hierarchy process, goal programming, multi-attribute utility models, group decision making, fuzzy multi-criteria/multi-objective programming
Simulation and post-simulation analysis based investment evaluation and selection approach	computer simulation, simulation metamodeling
Capital allocation approach (determining how much money should be allocated to each possible investment policy so that the objective is minimized or maximized)	dynamic programming, fuzzy logic, genetic algorithms
Risk assessment approach (trying to evaluate the investment projects by analyzing their project risk)	sensitivity analysis, probability analysis, computer simulation

**Table 2.** Mostly used investment project evaluation and selection techniques

	<b>Techniques</b>	<b>Advantages</b>	<b>Disadvantages</b>
<b>Economic Analysis Methods</b>	- Internal Rate of Return (IRR)	- Ease in data collection	- Do not take into account qualitative (strategic and non-economic) benefits
	- Net Present Value (NPV)	- Intuitive appeal	- Consider a single objective of cash flows, and ignore other benefits such as quality and flexibility
	- Net Present Value Ratio (NPVR)		
	- Return on Investment (ROI)		
	- Benefit-cost Analysis		
	- Simple Payback Period		
<b>Strategic Approaches</b>	- Discounted Payback Period		
	- Decision Tree Analysis		
	- Technical Importance	- Require less technical data	- Necessity to use these techniques with economic or analytic ones since they consider only long-term intangible benefits
	- Business Objectives		
<b>Analytic Methods</b>	- Competitive Advantage	- Use the general objectives of the firm	
	- Research and Development		
	- Scoring models	- Uncertainty of the future and the multi-objectivity can be incorporated	- Require more data
	- Analytic Hierarchy Process		- Usually more complex than the economic analysis
	- Outranking Methods		
	- Mathematical Programming		
	- Integer Programming	- Subjective criteria can be introduced in the modelling phase	
	- Goal Programming		
	- Data Envelopment Analysis		
	- Stochastic Methods		
	- Game Theoretical Models		
	- Multi-attribute Utility Models		
	- Fuzzy Linguistic Methods		
	- Expert Systems		
- Simulation			
- Fuzzy Set Theory			

### 2.1. Contributions of the study

In recent years, an increasing trend has been seen in project evaluation studies under uncertainty and risk. Due to possibility of a deviation in some expected project parameter values during its life cycle, it is necessary to consider uncertainty and risk phenomena while evaluating projects.

In such situations, values of the risky project parameter can be determined by probability distributions. Then project profitability is calculated by using random values of project parameters that has been generated from their own probability distributions. Hence every random value generated for a risky project parameter causes to calculate a different profitability value. By this way, the effects of the changes in the values of risky parameters on the project profitability can be determined. This fact is also the main goal of sensitivity analysis. As known, sensitivity analysis is sometimes called "what-if" analysis, which begins with a base-case situation that is developed using the most-likely values for each input. Then, the specific variable of interest is changed by several specified

percentages above and below the most-likely value, while holding other variables constant.

Although sensitivity analysis is useful, it has limitations. It is often difficult to specify precisely the relationship between a particular variable and the NPV; the relationship is further complicated by interdependencies among the variables. Holding operating costs constant while varying unit sales may ease the analysis, but in reality, operating costs do not behave in this manner. Yet, it may complicate the analysis too much to permit movement in more than one variable at a time. Here, by the simulation approach, it is possible to determine the effects of the simultaneous changes in the value of risky parameters on the project feasibility.

Due to the advantages that are introduced above, recently, the usage of simulation in project evaluation under uncertainty and risk has been increasing. The expected profitability of the project is calculated via simulation approach. It is well known that, project profitability is generally determined by checking NPV. In literature, much of the studies that use simulation approach to calculate the expected NPV of the project are

used the traditional formulation of NPV. It is as follows;

$$NPV = \sum_{t=0}^n \frac{A_t}{(1+i)^t} \quad (1)$$

where  $A_t$  is net cash flow in period  $t$ ,  $i$  is discount rate and  $n$  is the lifespan of project. In some studies net cash flows, in some discount rate, and in others, both of them are determined as probability distributions, but almost all of these studies used Monte Carlo simulation.

In these studies, it is often assumed that the effect of inflation is the same both on project inflows and outflows, so the effect of inflation on project inflows and outflows is not taken into account. But it is obvious that inflation effect will be different for cost and revenue components, and it should be considered in project evaluation process. The other important point is; in most of these studies, only the net cash flows or gross cash inflows and cash outflows are simulated in order to provide a sufficient number of NPVs and to develop the NPV distribution.

However, determining only the net cash flows or gross cash inflows and cash outflows by a probability distributions can make the calculation process easy, but not realistic. Instead of it, individual inflow and outflow components, such as sales volume, sale price, revenues, material cost, labour cost, depreciation, taxes, and any other risky parameters should be determined by probability distributions. In such a situation, the formulation of NPV will be changed. In this study, a novel NPV formulation is developed that eliminates the weakness of using the traditional formulation of NPV while evaluating the projects.

In this new situation, the number of parameters, which are defined as probability distributions, will increase. Therefore, using Monte Carlo simulation approach for modelling the new developed NPV formulation will cause some complexities. Because, when the numbers of the random variables in the mathematical model increases, providing a sufficient number of NPVs to define the NPV distribution would be more difficult by using Monte Carlo simulation. In this situation, it is needed to estimate or specify the probability distribution of each random variable in the model.

Hence, it is a necessity to develop a computer simulation model for new NPV formulation by using computer simulation software that enables to use generated random numbers for all discrete

and continuous distributions. In this study, a computer simulation model was developed by using a popular simulation language, which is aimed to be used and also widely used in complex production/service system models.

By the help of this model, all parameters affecting the NPV of the project can be defined with probability distributions if required. Moreover, with this model, it is also possible to define risky project parameters with specific distribution types such as; beta, k-erlang, exponential, gamma, johnson, lognormal, normal, poisson, triangular, uniform, weibull, etc. In this way, at each run, the simulation model will generate random values for these parameters generated from their own distributions and also the NPV of the project will be recorded as model output for each replication.

When risky investment projects are simulated, the random variables affecting the NPV of a project are generally assumed to be independent of each other. However, it must be recognized that some of the random variables affecting the NPV of a project may be related to one another. It should be emphasized that while developing the simulation models, the dependencies between some project parameters have been taken into account.

On the other hand, it is not enough checking only the expected profitability while evaluating many project alternatives at the same time. Project risk level should be considered. As known, the mostly used risk measure for each project is the standard deviation of its expected profitability. Hence, while ranking and evaluating the projects also risk levels should be checked in order to handle the uncertainty of the future.

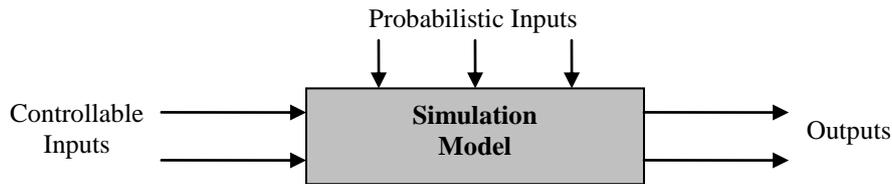
In literature, there are ranking and selection procedures used for comparing performances of the different production systems. Naturally, it can be thought the investment project as a system and project profitability as a performance measure. Hence, we embedded the ranking and selection procedures to our approach that aims to evaluate and select the projects under uncertainty and risk, and so far the authors have not confronted with such a studied in the literature.

### 3. Simulation in Project Evaluation Process

Simulation is one of the most widely used quantitative approaches in decision-making. It is a method for learning about a real system by experimenting with a model that represents the system [36-40]. The simulation model contains the mathematical expressions and logical

relationships that describe how to compute the value of the outputs given the values of the inputs. Any simulation model has two inputs; (a)

controllable inputs, and (b) probabilistic inputs. Figure 1 shows a conceptual diagram of a simulation model.



**Figure 1.** A Black-box of a simulation model

In conducting a simulation experiment, an analyst selects the value, or values, for the controllable inputs. Then values for the probabilistic inputs are randomly generated. The simulation model uses the values of the controllable inputs and the values of the probabilistic inputs to compute the value(s) of the output(s). By conducting a series of experiments using a variety of values for the controllable inputs, analyst can learn effect of the controllable inputs to the output(s) of the simulation model. After reviewing the simulation results, the analyst is often able to make decision recommendations for the controllable inputs that will provide the desired output for the real system [38].

Computers have made it both feasible and relatively inexpensive to apply simulation methods to economic decisions. Computer simulation seems to be one of the most effective tools for risky investment project appraisal. Simulation is based on repeated calculation of project effectiveness for randomly selected input parameters, and the probability distribution of the effectiveness measure thus calculated. Consequently, the probability of occurrence of unfavourable values of the effectiveness indicator and also measures of its variability can be determined. As an example, when simulation is used in the evaluation of risky investment projects, it requires that estimates be made of the probability distributions of risky project parameters. These probability distributions are then put into the simulation model, and the model is replicated several times until a sufficient number of the effectiveness measure, such as the NPV of a project, are available to define its distribution.

The results of these replications are then used to determine the probability distribution of the project's NPV and to compute the expected value and a standard deviation of returns. This information provides the decision maker with an estimate of a project's expected returns as well as its risk. Given this information, it is possible to

compute the probability of achieving a NPV that is greater or less than any particular value [41].

For evaluation and selection of investment projects, optimization and statistical techniques are commonly applied to analyze the cash flow of project; furthermore, an increasing trend can be seen in recent studies based on simulation models. Among the studies contributing this trend, using neural network as a simulation metamodel in economic analysis of risky projects by [5]; risk management of an agricultural investment utilizing simulation by [42]; the capital budgeting through random numbers and fuzzy numbers by [43]; using simulation software to solve engineering economy problems by [44]; the evaluation of investment projects optimizing multiple criteria via simulation and response surface methodology by [45-46]; project risk assessment by converting the fuzzy numbers to the near probability distributions and analyzing through simulation techniques by [7] can be examined in the literature.

In the environment of high uncertainty and risk, the project parameters such as; cash flows, discount rates, and completion time change during the life cycle of the project. Therefore, to define these parameters with deterministic values is not a rational behaviour, because they generally have stochastic nature.

Before the economics of a risky investment project can be evaluated, it is necessary to reasonably estimate the various cost and revenue components that describe the project. Investment projects may range from something as simple as the purchase of a new machine to the design and construction of very expensive process or resource recovery complex. In evaluating investment projects, we are concerned the project cash flows that result directly from the investment [47]. A generic version of a cash flow statement is shown in Figure 2, in where we first determine the net income from operations and then adjust the net income by adding any non-

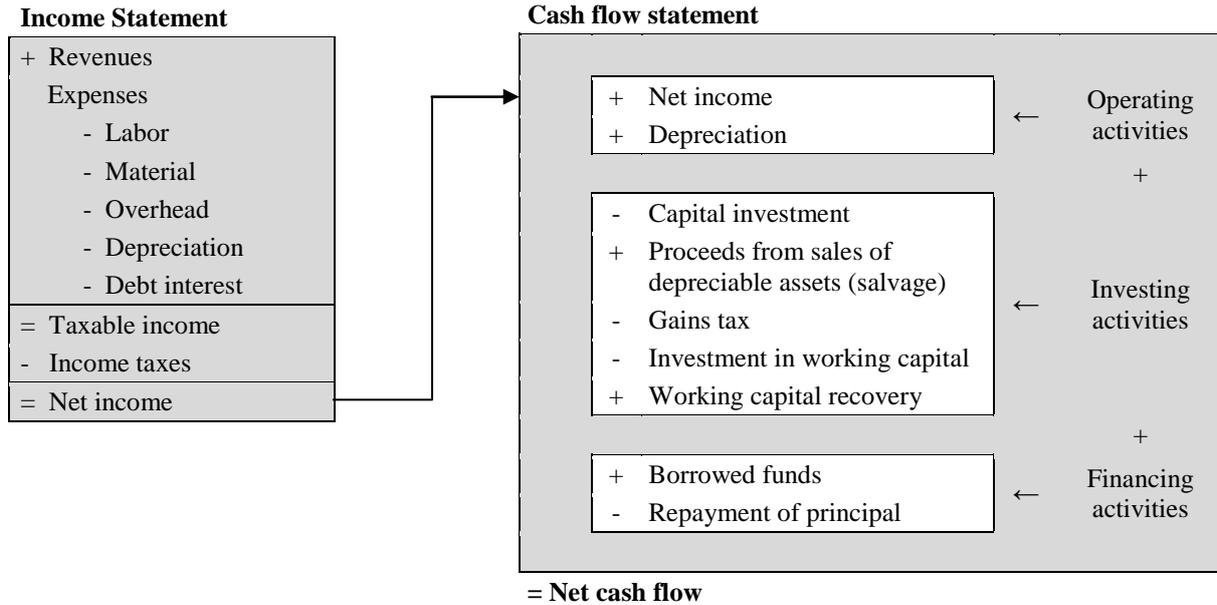


Figure 2. A popular format used for presenting a cash flow statement

cash expenses, mainly depreciation (or amortization).

In the inflation periods, price of the items that determine project gaining and expenses, will increase and also the relative prices of all items will change. Therefore, it is inevitable to make wrong decisions about investment if inflation is not taken into consideration with the matter of fact that it has important effect on the project net cash flows. To introduce the effect of inflation into our economic analysis, we need to define several inflation-related terms [47].

*Actual money units (A<sub>t</sub>):* Actual money units are estimated of future cash flows for year *t* that take into account anticipated changes in amount caused by inflationary or deflationary effects.

*Constant money units (A<sub>t</sub>' ):* Constant money units represent constant purchasing power independent of the passage of time. In situations where inflationary effects were assumed when cash flows were estimated, these estimates can be converted to constant money units (base year money units) by adjustment using accepted general inflation rate. Here, it is assumed that the base year is zero.

Since constant money units represent money unit amounts expressed in terms of purchasing power of the base year, it can be found the equivalent money units in year *t* using general inflation rate ( $\bar{f}$ );

$$A_t = A_t'(1 + \bar{f})^t \quad (2)$$

where *A<sub>t</sub>'* is constant-money unit expression for the cash flow occurring at the end of the year *t*,

and *A<sub>t</sub>* is actual-money unit expression for the cash flow at the end of year *t*. If the estimated general inflation rates are different for each year, *A<sub>t</sub>* should be calculated as follows;

$$A_t = A_t'(1 + \bar{f}_0)(1 + \bar{f}_1)(1 + \bar{f}_2)...(1 + \bar{f}_t) \quad (3)$$

$$A_t = A_t' \prod_{z=0}^t (1 + \bar{f}_z) \quad (4)$$

where  $\bar{f}_0, \bar{f}_1, \bar{f}_2, \dots, \bar{f}_t$  represent the estimated general inflation rates for year 0, 1, 2, ...*t*, respectively.

Naturally, the unit prices of the individual inflow and outflow components, such as revenues, material cost, labour cost, and overhead cost may increase with different rate from the general inflation rate. Also the increase rates for the price of inflow or outflow items can be different one another. From this point of view, [48] states that some additional arrangements should be performed on the traditional NPV formula by considering inflation, and its effect on the individual inflow and outflow components.

In order to construct the new NPV formulation that takes into account the different inflation effects on the cash flow elements, at first, inflow and outflow components should be defined separately. Let us assume that the decision maker defines the individual inflow and outflow components and their symbols as in the following;

*REV<sub>t</sub>*: Constant-money unit expression for the revenues occurring at the end of the year *t*,

$LAB_t$ : Constant-money unit expression for the labour expenses occurring at the end of the year  $t$ ,

$MAT_t$ : Constant-money unit expression for the material expenses occurring at the end of the year  $t$ ,

$OVE_t$ : Constant-money unit expression for the overhead expenses occurring at the end of the year  $t$ ,

$DEP_t$ : Actual-money unit expression for the depreciation expenses at the end of year  $t$ .

$IIC_t$ : Actual-money unit expression for the investment cost at the end of year  $t$ .

$SAL$ : Constant-money unit expression for the salvage value occurring at the end of the year  $t$ ,

$GTA$ : Actual-money unit expression for the gains tax amounts at the end of year  $t$ .

$TAX$ : Constant Income Tax Rate for every year.

As mentioned, the new NPV formulation is based on three principles; (a) the inflation effect on project inflows and outflows may be different one another, (b) the increase rates for the price of inflow or outflow items can be different each other, and (c) the inflation rates for specific cash flow element may be different for each year. Therefore, it should be define different inflation rates for each individual inflow and outflow components, such as revenues, labour cost, material cost, overhead cost, and salvage value. Also, different inflation rates should be defined for each year in the planning horizon. As in inflation rates, the discount rate may be different for each year, so discount rate should be determined for each year. As a consequence, let us assume that the decision maker defines the inflation rates, discount rate and their symbols as in the following;

$e_t$ : Inflation rate for revenues for year  $t$ .

$\gamma_t$ : Inflation rate for labour expenses for year  $t$ .

$\omega_t$ : Inflation rate for material expenses for year  $t$ .

$\tau_t$ : Inflation rate for overhead expenses for year  $t$ .

$\Omega_t$ : Inflation rate for salvage value for year  $t$ .

$i_t$ : Discount rate for year  $t$ .

Here, it is important how to express the distributions of the project parameters. For the purpose of modelling, it is assumed that each parameter will be entered into the model as follows; (a) a single deterministic value, (b) with probability distribution, and (c) with possibility distribution.

If a single deterministic value for each parameter is used, the reliability of this stage's output depends upon the accuracy of these deterministic values. A fundamental limitation of this assumption is that the various project parameters cannot be practically assumed a higher degree of certainty. The value of each parameter is affected by a myriad of risks and uncertainties which are often difficult to quantify. Because of that reason, it is necessary to express the risky project parameters as probability or possibility distributions in order to analysis of risk and uncertainty.

As mentioned above,  $REV_t$ ,  $LAB_t$ ,  $MAT_t$ ,  $OVE_t$  and  $SAL$  represent constant-money unit expression occurring at the end of the year  $t$ . We calculate actual-money unit expression for these cash flow elements at the end of year  $t$  ( $AMUE_t$ ) as follows;

$$\left. \begin{aligned} AMUE_t \text{ for the revenues} &= REV_t \prod_{z=0}^t (1 + e_z) \\ AMUE_t \text{ for the labor expenses} &= LAB_t \prod_{z=0}^t (1 + \gamma_z) \\ AMUE_t \text{ for the material expenses} &= MAT_t \prod_{z=0}^t (1 + \omega_z) \\ AMUE_t \text{ for the overhead expenses} &= OVE_t \prod_{z=0}^t (1 + \tau_z) \\ AMUE_t \text{ for the salvage value} &= SAL \prod_{z=0}^t (1 + \Omega_z) \end{aligned} \right\} (5)$$

After estimating cash flow elements and other project parameters such as inflation rates and

discount rate, net cash flow from operation determines as follows;

Taxable Income in Period  $t$  ( $TI_t$ ):

$$TI_t = REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] \quad (6)$$

Income Taxes in Period  $t$  ( $IT_t$ ):

$$IT_t = \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] \right\} TAX \quad (7)$$

Net Income in Period  $t$  ( $NI_t$ ):

$$NI_t = REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] - \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] \right\} TAX$$

$$NI_t = \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] \right\} [1-TAX] \quad (8)$$

Net Cash Flow from Operation in Period  $t$  ( $NCF_t$ ):

$$NCF_t = \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) + DEP_t \right] \right\} [1-TAX] + DEP_t$$

$$NCF_t = \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) \right] \right\} [1-TAX] + DEP_t * TAX \quad (9)$$

As a consequence, the final structure of the  $NPV_i$  formulation can be obtained as given in the equation below;

$$NPV_i = \frac{\sum_{t=u_i}^{v_i-1} \left\{ REV_t \prod_{z=0}^t (1+e_z) - \left[ LAB_t \prod_{z=0}^t (1+\gamma_z) + MAT_t \prod_{z=0}^t (1+\omega_z) + OVE_t \prod_{z=0}^t (1+\tau_z) \right] \right\} [1-TAX] + DEP_t * TAX}{\prod_{z=0}^t (1+i_z)} - \sum_{t=0}^{u_i-1} \frac{IIC_t}{\prod_{z=0}^t (1+i_z)} + \frac{SAL \prod_{z=0}^{v_i-1} (1+\Omega_z) + GTA}{\prod_{z=0}^{v_i-1} (1+i_z)} \quad (10)$$

In this equation,  $NPV_i$  represents the NPV of project  $i$ ;  $u_i$  represents the length of the project's investment period and  $v_i$  represents lifespan of the project. In simulation models, the model builder needs to estimate or specify the probability distribution of each risky project parameters in the model. For example, in order to simulate the NPV formulation, the analyst needs the probability distribution of individual inflow and outflow components. Randomly selected values of each variable of the model are then fed

into the simulation model to generate the NPV. This process is then repeated a large number of times. Each time (i.e., for each computer run), a new randomly selected value for each variable is fed into the model, and the NPV is recorded. A large number of such trials, or iterations, are conducted, so as to generate the probability distribution of the NPV. The generated probability distribution of the NPV can then be used to calculate the expected NPV, the standard deviation of the distribution of NPV, and the

coefficient of variation. The output of simulation provides an excellent basis for decision-making, because it enables the decision maker to view a continuum of risk-return tradeoffs rather than a single point estimate [49].

Monte Carlo simulation approach enables to generate a sample observation for each risky project parameters in the model. However, if the numbers of the risky project parameters in the evaluation process increases, providing a sufficient number of NPVs would be more difficult by using Monte Carlo simulation. In order to determine the random value for risky project parameter in Monte Carlo simulation, the decision maker has to generate random numbers with the help of a computer or a calculator. However, computer simulation models determine the different random values for project parameters at each run itself and calculate the NPV of the project without entailing such a necessity.

Therefore, in the scope of this study, in order to calculate the expected NPV of each project proposal and its standard deviation, a new computer simulation model has been developed by using ARENA simulation software [39] for a new NPV formulation. In other words, the  $NPV_i$  expression given in Equation (10) is executed through the ARENA simulation program. The synchronization of the random numbers is performed by using one of variance reduction techniques; common random numbers, and furthermore the verification of the models are tested through the constant numbers entered for each variable. The flowchart of the  $NPV_i$  calculation event is given in Figure 3.

By the help of this constructed model, all parameters affecting the NPV of the project can be defined with deterministic values or probability distributions if required. Moreover, with this model, it is also possible to define risky project parameters with specific distribution types such as; beta, k-erlang, exponential, gamma, johnson, lognormal, normal, poisson, triangular, uniform, weibull, etc. However, if the project parameters are defined as possibility distributions, at first, each of these distributions should be converted into the nearest probability distribution for the further detailed analysis. A practical method is proposed for data transformation from fuzzy number to uniform distribution [50].

According to this method, to construct sets, uniform random numbers are generated as the membership values and corresponding boundaries are calculated. By generating the significant number of  $\alpha$ -cut sets, then using averages, single uniform distribution is developed for this fuzzy set.

#### 4. A Simulation-Based Project Ranking and Selection Approach

The flowchart of proposed approach is depicted in Figure 4. This optimal decision approach is based on computer simulation modelling. After developing the  $NPV_i$  formulation as in Equation (10), the second step of this approach is to identify and check all controllable project parameters that affect the NPV of projects. It should be classify the project parameters into two groups; (a) the parameters whose values are known with certainty and (b) the random variables for which exact values cannot be specified at the time of decision-making. Then, it should be determined the values of certain parameters and defined the probability distributions of risky parameters for each project. After determining the probability distributions of risky parameters and the values of certain parameters for each project, the simulation model is developed. The developed simulation model should be verified and validated.

The next step is to determine the project ranking and selection goal. The proposed approach enables to perform three different procedures in order to rank and select the projects. The decision maker can select one of these three procedures for ranking and selection. In the next section, the proposed optimal decision approach is implemented on a project selection problem.

#### 5. Application of the Proposed Approach

The aim of this section is to represent the implementation of the proposed approach on a project selection problem. The problem includes ten hypothetical investment project alternatives with the objective; to decide which project alternatives will be put into practice with using limited economic sources. Investment decision will be easily taken with the proposed approach, and not only the profitability but also the risk levels of the projects will keep in view. As mentioned in the previous section, as a first step, the project parameters and their values should be defined in order to determine the profitability and risks of the project alternatives.

### 5.1. Problem description

At first, investment period lengths ( $u_i$ ) and lifespan ( $v_i$ ) are determined as depicted in Table 3, and it can be seen in the second column the highest investment period length of alternatives is determined as 3 years, and in third column the highest investment lifespan of alternatives is determined as 12 years. Also the investment costs materialized in investment period are exhibited in Table 3, which are determined as the actual-money unit. For instance, project alternative five (Pro05) has 3 years investment period length and 10 years lifespan, and investment costs are 50, 50 and 40 TL (Turkish Liras) in respectively.

As known, before the economics of a risky investment project can be evaluated, it is necessary to reasonably estimate the various inflow and outflow components that describe the project. The inflow and outflow components which appear every working periods of the related project are shown in Table 4. Note that the values of all components are estimated in constant-money units. As mentioned, constant money units represent constant purchasing power independent of the passage of time. For instance, project alternative one (Pro01) is expected to create a revenue for every working periods, that is uniformly distributed between 100 TL and 120 TL in today's monetary value. Also the project is expected to create a labour expense that is uniformly distributed between 30 TL and 40 TL, a material expense which is uniformly distributed between 20 TL and 30 TL, and an overhead expense that is uniformly distributed between 10 TL and 20 TL for every working period in today's monetary value. All these values are in constant-money units. Although here, in our case, only the uniform distribution is used, notice that the developed simulation model gives us a chance to determine the distributions of inflow and outflow components in all kind of distributions, such as; beta, k-erlang, exponential, gamma, johnson, lognormal, normal, poisson, triangular, uniform, weibull, etc.

In order to calculate the values of inflow and outflow components which include inflationary effects, determination of the inflation rate for each component for every year is needed. Inflation rates can be different for each component, and also a component may have different rates for different years. The developed novel NPV formulation, depicted in Equation (10), and simulation model permit to implement different inflation rate effects. By this way, inflow and outflow components can be determined in actual money units. After determining all components in projects' working periods as an actual money unit, we need to determine a discount rate in order to discount the expected future values to today's values. As in inflation rates, discount rates also can be determined in different values for each year. These decisions are in authorization of decision maker. The inflation and discount rates determined for each cost and revenue component is depicted in Table 5. For instance, inflation rate for revenues is uniformly distributed in 6% and 8%, and it is determined for each year. The developed simulation model will create inflation rates from this stochastic distribution for each year. However, decision maker can take a constant inflation rate for revenues. In order to calculate the profitability of the project, the base year inflation and discount rates are assumed to be zero in the simulation model.

Also annual amortization amounts, the salvage value at the end of lifespan, gains tax amounts, and income tax rate for every year should be determined in order to calculate the NPV of the project. To calculate the annual amortization amounts straight line amortization method is used in this case, and it is assumed that the whole value of the investment cost is amortized in the lifespan of the project. So, in this case, the gains tax amounts will be zero. It is also suitable to use different amortization methods while calculating the annual amortization amounts. Note that the values depicted in Table 6 are in actual-money unit, and IP is the initial letters of "investment period". Additionally, in this case, income tax rate is assumed to be 25% for each year.

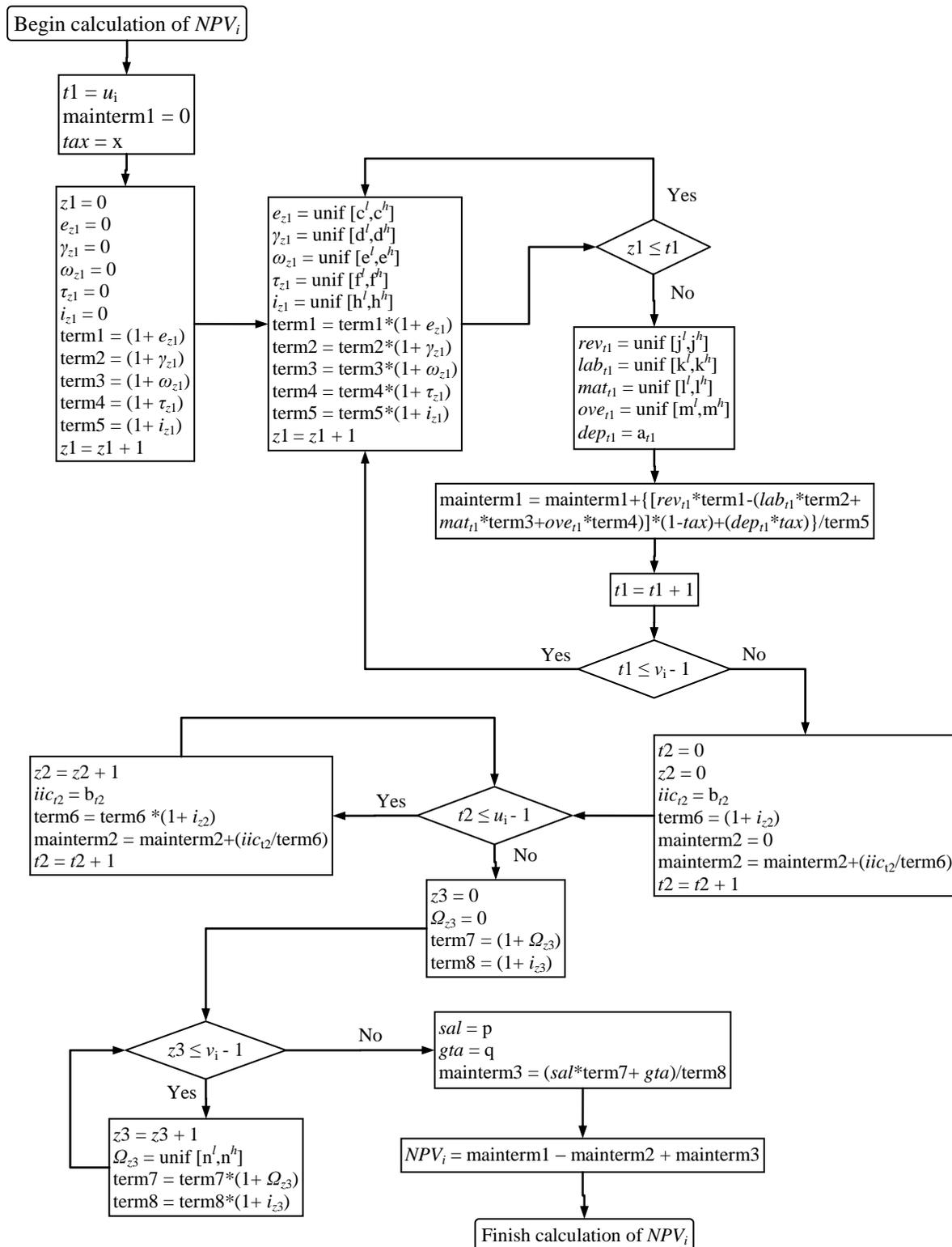


Figure 3. The flowchart of the  $NPV_i$  calculation event

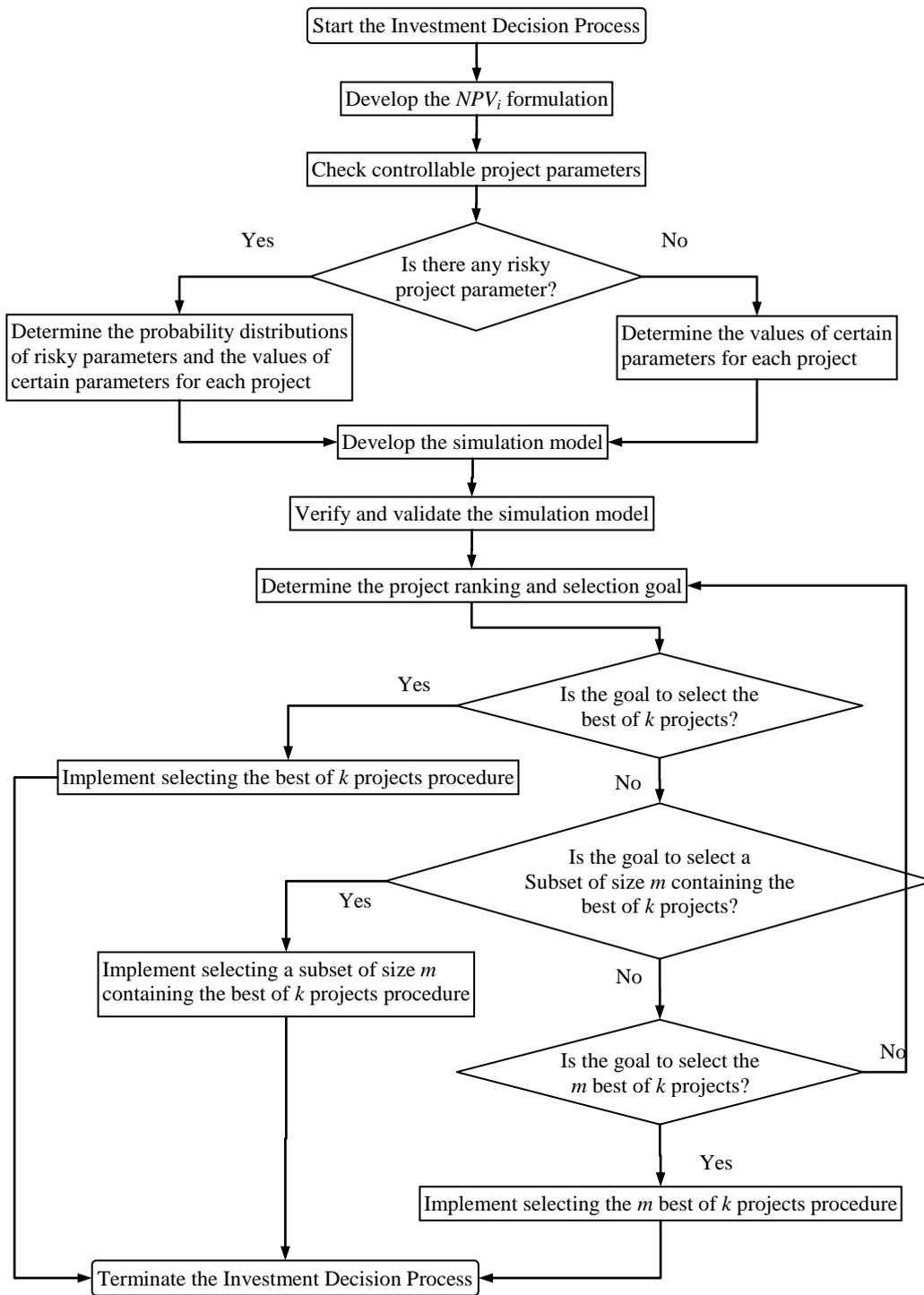


Figure 4. The flowchart of the approach

**Table 3.** The investment period length and lifespan of the project and investment costs

Project	$u_i$	$v_i$	Periods of Investment		
			0	1	2
Pro01	1	11	80	0	0
Pro02	1	12	110	0	0
Pro03	1	8	91	0	0
Pro04	2	10	60	60	0
Pro05	3	10	50	50	40
Pro06	1	10	63	0	0
Pro07	2	8	80	40	0
Pro08	3	9	40	40	40
Pro09	2	10	80	80	0
Pro10	1	8	70	0	0

**Table 4.** Cost and revenue components of the projects

Project	$REV_t$	$LAB_t$	$MAT_t$	$OVE_t$
Pro01	Unif [100, 120]	Unif [30, 40]	Unif [20, 30]	Unif [10, 20]
Pro02	Unif [90, 100]	Unif [25, 35]	Unif [20, 30]	Unif [10, 20]
Pro03	Unif [140, 160]	Unif [50, 60]	Unif [30, 40]	Unif [15, 25]
Pro04	Unif [180, 200]	Unif [40, 50]	Unif [40, 50]	Unif [20, 30]
Pro05	Unif [120, 130]	Unif [20, 30]	Unif [25, 30]	Unif [10, 15]
Pro06	Unif [80, 90]	Unif [20, 30]	Unif [15, 25]	Unif [10, 15]
Pro07	Unif [130, 150]	Unif [30, 50]	Unif [20, 40]	Unif [10, 20]
Pro08	Unif [160, 180]	Unif [40, 60]	Unif [40, 50]	Unif [20, 40]
Pro09	Unif [220, 240]	Unif [70, 80]	Unif [50, 60]	Unif [30, 40]
Pro10	Unif [100, 110]	Unif [20, 30]	Unif [20, 30]	Unif [10, 20]

**Table 5.** Multiple inflation rates and discount rate for each project

Item	Symbol	Value	Description
Inflation rate for revenues	$e_t$	Unif [0.06, 0.08]	Determine for each year (assume $e_0=0$ )
Inflation rate for labour expenses	$\gamma_t$	Unif [0.04, 0.06]	Determine for each year (assume $\gamma_0=0$ )
Inflation rate for material expenses	$\omega_t$	Unif [0.04, 0.05]	Determine for each year (assume $\omega_0=0$ )
Inflation rate for overhead expenses	$\tau_t$	Unif [0.03, 0.05]	Determine for each year (assume $\tau_0=0$ )
Inflation rate for salvage value	$\Omega_t$	Unif [0.04, 0.05]	Determine for each year (assume $\Omega_0=0$ )
Discount rate	$i_t$	Unif [0.12, 0.14]	Determine for each year (assume $i_0=0$ )

**Table 6.** Annual amortization amounts

$DEP_t$	Base year	1	2	3	4	5	6	7	8	9	10	11	12
Pro01	IP	8	8	8	8	8	8	8	8	8	8		
Pro02	IP	10	10	10	10	10	10	10	10	10	10	10	
Pro03	IP	13	13	13	13	13	13	13					
Pro04	IP	IP	15	15	15	15	15	15	15	15			
Pro05	IP	IP	IP	20	20	20	20	20	20	20			
Pro06	IP	7	7	7	7	7	7	7	7	7			
Pro07	IP	IP	20	20	20	20	20	20					
Pro08	IP	IP	IP	20	20	20	20	20	20				
Pro09	IP	IP	20	20	20	20	20	20	20	20			
Pro10	IP	10	10	10	10	10	10	10					

**5.2. Project ranking and selection**

In this section, we consider goals which are different than simply making a comparison between several alternative projects. In Section 5.2.1., a procedure whose goal is to select one of the  $k$  projects as being the best one and to control the probability that the selected project really is the best one is explained and the procedure implemented on a project selection problem. Next section, Section 5.2.2., considers a different goal, picking a subset of  $m$  of the  $k$  projects so that this selected subset contains the best project,

again with a specified probability is explained and the procedure implemented on a project selection problem. Then in Section 5.2.3., we focus on the problem of selecting the  $m$  best of the  $k$  projects. These ranking and selection procedures are widely used for comparing performances of the different production systems. In this paper, we thought the investment project as a *system* and project profitability as a *performance measure*, and we embedded this ranking and selection procedures to the proposed approach that aims to evaluate and select the

projects under uncertainty and risk. The validity of procedures is explained detail in [36].

**5.2.1. Selecting the best of k projects**

Let  $X_{ij}$  be the random variable of interest from the  $j$ th replication of the  $i$ th system, and let  $\mu_i = E(X_{ij})$ , and all  $X_{ij}$  are assumed to be independent of each other, the replications for a given alternative are independent, and the runs for different alternatives are also to be made independently. Here  $X_{ij}$  are the NPV of the  $j$ th replication of  $i$ th project.

Let  $\mu_{il}$  be the  $l$ th smallest of the  $\mu_i$ 's so that  $\mu_{i1} \leq \mu_{i2} \leq \dots \leq \mu_{ik}$ . The goal in this procedure is to select a system with the smallest expected response,  $\mu_{i1}$ . If it is aimed to find the largest mean  $\mu_{ik}$ , the procedure can be easily implemented after sign of the  $X_{ij}$ 's and  $\mu_i$ 's reversed as done in implementation part. Let "CS" denote the event of "correct selection". The inherent randomness of the observed  $X_{ij}$ 's implies that we can never be absolutely sure that we shall make the CS, but we would like to be able to pre-specify the probability of CS.

The exact problem formulation is that we want  $P(\text{CS}) \geq P^*$  provided that  $\mu_{i2} - \mu_{i1} \geq d^*$ , where the minimal CS probability  $P^* > 1/k$  and the indifference amount  $d^* > 0$  are both specified by the decision maker. The procedure for solving this problem involves two-stage sampling from each of the  $k$  systems. In the first stage we make a fixed number of replications of each system, then use the resulting variance estimates to determine how many more replications from each system are necessary in second stage of sampling in order to reach a decision. It is assumed that  $X_{ij}$ 's are normally distributed.

In the first-stage sampling, we make  $n_0 \geq 2$  replications of each of the  $k$  systems and define the first stage sample means and variances;

$$\bar{X}_i^{(1)}(n_0) = \frac{\sum_{j=1}^{n_0} X_{ij}}{n_0} \tag{11}$$

$$S_i^2(n_0) = \frac{\sum_{j=1}^{n_0} [X_{ij} - \bar{X}_i^{(1)}(n_0)]^2}{n_0 - 1} \tag{12}$$

for  $i = 1, 2, \dots, k$ . Then we compute the total sample size  $N_i$  needed for system  $i$  as;

$$N_i = \max \left\{ n_0 + 1, \left\lceil \frac{h_1^2 S_i^2(n_0)}{(d^*)^2} \right\rceil \right\} \tag{13}$$

where  $\lceil x \rceil$  is the smallest integer that is greater than or equal to the real number  $x$ , and  $h_1$  is a constant depends on  $k, P^*$ , and  $n_0$  can be obtained from [36]. Next we make  $N_i - n_0$  more replications of the system  $i$  and obtain the second-stage sample means;

$$\bar{X}_i^{(2)}(N_i - n_0) = \frac{\sum_{j=n_0+1}^{N_i} X_{ij}}{N_i - n_0} \tag{14}$$

Then weights are defined;

$$W_{i1} = \frac{n_0}{N_i} \left[ 1 + \sqrt{1 - \frac{N_i}{n_0} \left( 1 - \frac{(N_i - n_0)(d^*)^2}{h_1^2 S_i^2(n_0)} \right)} \right] \tag{15}$$

and  $W_{i2} = 1 - W_{i1}$ , for  $i = 1, 2, \dots, k$ . Finally the weighted sample means is defined;

$$\tilde{X}_i(N_i) = W_{i1} \bar{X}_i^{(1)}(n_0) + W_{i2} \bar{X}_i^{(2)}(N_i - n_0) \tag{16}$$

and select the system with smallest  $\tilde{X}_i(N_i)$ .

The choices of  $P^*$  and  $d^*$  depend on the decision maker's goals and the particular systems under study, specifying them might be tempered by the computing cost of obtaining a large  $N_i$  associated with a large  $P^*$  or small  $d^*$ , and in literature it is emphasized that  $n_0$  must be at least 20.

In our project selection case,  $P^*$  is selected to be 0.95,  $d^*$  is 1,  $n_0$  is 40,  $k$  is 10, and depending on these values  $h_1$  is read as 3.539 from table in [36, p.606]. Because our objective is to obtain largest  $NPV_i$  we reversed the simulation results to follow the procedure, and at the end we again reversed them to positive numbers. The calculated values are depicted in Table 7. As an example, after simulation values obtain for first project ( $i = 1$ ) the average of 40 runs is calculated as 172.425 TL, then it is reversed to -172.425. Then  $N_i$  calculated by using Equation (12) as 2843 which means we must have additional 2803 ( $N_i - n_0$ ) runs to calculate second stage values. Again the average of 2803 run values is reversed and -171.704 obtained. The weighted sample means is calculated as -171.715, and after reversing it to positive value 171.715 TL is evaluated for the first project. As can be seen from Table 7, the best value is calculated as 295.568 TL for the fourth project (Pro04).

**5.2.2. Selecting a subset of size m containing the best of k projects**

Here we used a procedure of selecting a subset of exactly  $m$  of the  $k$  systems so that, with probability  $P^*$ , the selected subset will contain a system with the smallest mean response  $\mu_{i1}$ . This could be a useful goal in the initial stages of a simulation study, where there may be a large number of alternative systems and we would like to perform an initial screening to eliminate those that appear to be clearly inferior. Thus, we could avoid expending a large amount of computer time getting precise estimates of the behavior of these inferior systems. Here, correct selection (CS) is defined to mean that the subset of size  $m$  that is selected contains a system with mean  $\mu_{i1}$  and we want  $P(\text{CS}) \geq P^*$  provided that  $\mu_{i2} - \mu_{i1} \geq d^*$ , and we must have  $1 \leq m \leq k-1$ ,  $P^* > m/k$ , and  $d^* > 0$ . The procedure is similar to explained in previous sub-section, Section 5.2.1. Equations (10-15) are used while calculating the related values, except that  $h_1$  is replaced with  $h_2$  in Equations (12) and (14).

In our project selection case,  $P^*$  is selected to be 0.95,  $d^*$  is 1,  $n_0$  is 40,  $k$  is 10,  $m$  is 3 and depending on these values  $h_2$  is read as 2.415 from table in [36, p.606]. We reversed the simulation results to follow the procedure, and at the end we again reversed them to positive numbers. The calculated values are depicted in Table 8. The selected subset contains projects one (Pro01), four (Pro04) and nine (Pro09).

Comparing the value  $h_2$  ( $= 2.415$ ) used here with that of  $h_1$  ( $= 3.539$ ) that the more modest goal of selecting a subset of size three containing the best system requires fewer replications on average than does the more ambitious goal of selecting the best system in previous sub-section.

**5.2.3. Selecting the m best of k projects**

A final type of selection problem considers the goal of selecting a subset of specified size  $m$  where  $1 \leq m \leq k-1$ , so that with probability at

least  $P^*$  the expected response of the selected subset are equal to the  $m$  smallest expected responses  $\mu_{i1}, \mu_{i2}, \dots, \mu_{im}$ . It is important to note that we are not saying that the  $m$  selected systems are ranked or ordered in any way among themselves, but only that the unordered set of  $m$  selected systems has expected responses that are the same as those of the unordered set of the  $m$  best systems. This particular goal might be useful if we want to identify several good options, since the best system might prove unacceptable for other reasons, such as political or environmental. Here we want  $P(\text{CS}) > P^*$  provided that  $\mu_{i(m+1)} - \mu_{im} \geq d^*$ , CS, of course, is redefined to mean that the expected responses of the selected set are equal to those of the  $m$  best systems. Also for these problem we must to have  $P^* > m!(k-m)!/k!$ . The procedure is similar to explained in Section 5.2.1. Equations (10-15) are used while calculating the related values, except that  $h_1$  is replaced with  $h_3$  in Equations (12) and (14).

In our case  $P^*$  is selected to be 0.95,  $d^*$  is 1,  $n_0$  is 40,  $k$  is 10,  $m$  is 3 and depending on these values  $h_3$  is read as 4.002 from table in [36, p.607]. Again we reversed the simulation results to follow the procedure, and at the end we reversed them to positive numbers. The calculated values are depicted in Table 9. The selected subset contains projects one (Pro01), four (Pro04) and nine (Pro09), which we claim are the three best systems but not in any particular order.

The value of  $h_3$  ( $= 4.002$ ) is larger than values of  $h_1$  ( $= 3.539$ ) and  $h_2$  ( $= 2.415$ ) resulting larger  $N_i$  values. This is reasonable since the selection problem of this section allows us to make a considerably stronger final statement than we could for either of the previous two selection problems, so that we should expect to have to supply more supporting evidence.

**Table 7.** Selecting the best of the project

Project	$i$	$\bar{X}_i^{(1)}(40)$	$S_i^2(40)$	$N_i$	$\bar{X}_i^{(2)}(N_i - 40)$	$W_{i1}$	$W_{i2}$	$\tilde{X}_i(N_i)$	$\tilde{X}_i(N_i)^*(-1)$
Pro01	1	-172.425	226.917	2843	-171.704	0.01624	0.98376	-171.715	171.715
Pro02	2	-103.228	172.828	2165	-103.018	0.02033	0.97967	-103.023	103.023
Pro03	3	-131.070	168.781	2114	-129.980	0.01988	0.98012	-130.002	130.002
<b>Pro04</b>	4	-296.975	226.538	2838	-295.545	0.01598	0.98402	-295.568	<b>295.568</b>
Pro05	5	-150.975	84.692	1061	-150.541	0.04078	0.95922	-150.558	150.558
Pro06	6	-118.135	100.526	1260	-117.679	0.03657	0.96343	-117.695	117.695
Pro07	7	-124.720	221.680	2777	-123.952	0.01611	0.98389	-123.964	123.964
Pro08	8	-106.870	247.049	3095	-106.992	0.01478	0.98522	-106.991	106.991
Pro09	9	-243.450	291.741	3654	-242.047	0.01144	0.98856	-242.063	242.063
Pro10	10	-133.825	98.199	1230	-133.280	0.03412	0.96588	-133.298	133.298

**Table 8.** Selecting a subset of size three containing the best of ten project

Project	$i$	$\bar{X}_i^{(1)}(40)$	$S_i^2(40)$	$N_i$	$\bar{X}_i^{(2)}(N_i - 40)$	$w_{i1}$	$w_{i2}$	$\tilde{X}_i(N_i)$	$\tilde{X}_i(N_i) * (-1)$
<b>Pro01</b>	1	-172.425	226.917	1324	-171.533	0.03376	0.96624	-171.564	<b>171.564</b>
Pro02	2	-103.228	172.828	1008	-103.206	0.04069	0.95931	-103.207	103.207
Pro03	3	-131.070	168.781	985	-130.292	0.04562	0.95438	-130.327	130.327
<b>Pro04</b>	4	-296.975	226.538	1322	-295.432	0.03442	0.96558	-295.485	<b>295.485</b>
Pro05	5	-150.975	84.692	494	-151.379	0.08396	0.91604	-151.345	151.345
Pro06	6	-118.135	100.526	587	-118.647	0.07689	0.92311	-118.608	118.608
Pro07	7	-124.720	221.680	1293	-123.958	0.03257	0.96743	-123.983	123.983
Pro08	8	-106.870	247.049	1441	-107.043	0.02947	0.97053	-107.038	107.038
<b>Pro09</b>	9	-243.450	291.741	1702	-242.106	0.02610	0.97390	-242.141	<b>242.141</b>
Pro10	10	-133.825	98.199	573	-134.129	0.07543	0.92457	-134.106	134.106

**Table 9.** Selecting the three best of ten project

Project	$i$	$\bar{X}_i^{(1)}(40)$	$S_i^2(40)$	$N_i$	$\bar{X}_i^{(2)}(N_i - 40)$	$w_{i1}$	$w_{i2}$	$\tilde{X}_i(N_i)$	$\tilde{X}_i(N_i) * (-1)$
<b>Pro01</b>	1	-172.425	226.917	3635	-171.741	0.01244	0.98756	-171.750	<b>171.750</b>
Pro02	2	-103.228	172.828	2769	-102.964	0.01669	0.98331	-102.969	102.969
Pro03	3	-131.070	168.781	2704	-129.943	0.01688	0.98312	-129.962	129.962
<b>Pro04</b>	4	-296.975	226.538	3629	-295.556	0.01254	0.98746	-295.574	<b>295.574</b>
Pro05	5	-150.975	84.692	1357	-150.303	0.03297	0.96703	-150.325	150.325
Pro06	6	-118.135	100.526	1611	-117.847	0.02865	0.97135	-117.855	117.855
Pro07	7	-124.720	221.680	3551	-123.962	0.01261	0.98739	-123.971	123.971
Pro08	8	-106.870	247.049	3957	-107.048	0.01093	0.98907	-107.046	107.046
<b>Pro09</b>	9	-243.450	291.741	4673	-242.104	0.00949	0.99051	-242.117	<b>242.117</b>
Pro10	10	-133.825	98.199	1573	-133.384	0.02737	0.97263	-133.396	133.396

### 6. Conclusions and Recommendations

It is obvious that investment decision-making never takes place under conditions of certainty, but only under those of uncertainty or risk. Appropriate management of all the sources of uncertainty or risk is required an efficient and effective project management. Therefore, the uncertainty and the risk of the future is the focus point of the economical decision-making process.

In traditional project evaluation methods, it is often assumed that all factors are deterministic in nature. However, in reality, factors such as initial investment cost and cash flows have stochastic properties. It is normal to observe changes on factors during a project life cycle. In literature, several methods have been presented to handle the analysis of the investment projects under uncertainty or risk. Because of the fact that, some projects have high uncertainty, simulation-based investment project selection analysis could evaluate the projects with a greater confidence. The literature search indicated that simulation models instead of analytical calculations could be used to analyze the risky project. Because, simulation-based project evaluation approaches enables to make more reliable investment decision since they permits including future uncertainty and risk in analyze process.

During the assessment of investment projects, decisions may not be rational if they are made only by considering the profitability. Because the deviations in the estimated values of project parameters will directly affect the profitability and the feasibility of the project. Thus, project risk level of the proposal should be analyzed in the assessment phase.

In this paper, a novel approach based on simulation and post-simulation analysis is proposed for evaluating and comparing investment projects under uncertain and/or risky environment. In this approach, a new NPV formulation is developed that eliminates the weakness of using the traditional formulation while evaluating the projects, and then a simulation model is constructed for the new NPV formulation by using computer simulation software that enables to use generated random numbers for all discrete and continuous distributions. By the help of this model, all parameters affecting the NPV of the project can be defined with probability distributions if required. Moreover, with this model, it is also possible to define risky project parameters with specific distribution types such as; beta, k-erlang, exponential, gamma, johnson, lognormal, normal, poisson, triangular, uniform, weibull, etc., and the expected NPV could be calculated for every combination of these risky parameters.

While developing the simulation models, the dependencies between some project parameters have been taken into account.

There are ranking and selection procedures used for comparing performances of the different production systems in literature. In this study, these procedures have been embedded to the proposed approach that aims to evaluate and select the projects under uncertainty and risk, and to the best of the authors' knowledge, this study is the first one in this research area in the literature.

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*Assist. Prof. Özgür Yalçinkaya graduated from Dokuz Eylül University in 2000, had his PhD degree in 2010, his personel web page is: <http://kisi.deu.edu.tr/ozgur.yalcinkaya/>*

*Dr. Özgür Armaneri graduated from Dokuz Eylül University in 2000, had his PhD degree in 2009, his personel web page is: <http://kisi.deu.edu.tr/ozgur.armaneri/>*