Use of Evolutionary Algorithm in the Investment Project Evaluation

Hasan Durucasu*

Elif Acar**

Abstract

In the realization of infrastructure projects, the interest shown in the Build-Operate-Transfer (BOT) model is on the increase. Through the BOT projects, the risks and awards of the public in the realization of infrastructure projects are transferred to the private sector. Implementing the BOT projects successfully depends on the ability to constitute a structure which enhances the possibility of the sponsors' achievement in the BOT tender. The debt to equity ratio, the concession length and the price variables are the critical financial factors in BOT projects. Thus, these factors must be designed in the way that they will look out for the interests of the participants of the project.

In this study, a new approach regarding the project finance has been put forth by optimally integrating the major financial factors that provide financial viability for the project. The optimization equation and constraints were developed on the basis of the discounted cash flow analysis which is among the dynamic methods, and the calculations were made by utilizing the real-coded Evolutionary Algorithm for the non-linear behaviour of the objective function. In this way, a more efficient and productive support is provided for the financial decision-making process.

Keywords: Build Operate Transfer, project evaluation, optimization, Differential evolutionary algorithm

JEL Classification: C61, D22

* Professor, Department of Business Administration (Quantitative Methods) Anadolu University, Turkey, E-mail: hdurucasu@anadolu.edu.tr

**PhD, Turkey, E-mail: elifacar@anadolu.edu.tr

1- Introduction

The implementation of industrialization, which is the main objective of the developing countries including Turkey, depends on the capacity to fulfil the quite a large of scale finacial needs of the infrastructural investments. The fact that the public infrastructural investment projects required in parallel with the economic growth could not be realized in time with limited budget means brought up the use of the Public Private Partnership (PPP) models in the developing countries [Directorate General of Investment Programming Monitoring and Assessment (2012)]. The primary example of PPP project models is the Build-Operate-Transfer (BOT) model frequently used in the world and in our country.

In the BOT model, the project investment costs are covered by the project company, and thus, the construction and operation of the infrastructure facility is maintained. In return for this, the project company is supposed to meet the initial investment cost and make profit from this investment with the acquired revenues throughout the concession period. At the end of this concession period, the project company hands over the infrastructure facility to the government in a good working condition [Baser (2000)].

BOT projects, when considered as a whole process, consist of several stages: Relevant government institution arranges an invitation to tender in order to build and operate an infrastructure facility; the private corporation or the joint venture company interested in this topic prepares their feasibility reports regarding this invitation and submits their financial proposal to the government; the tendering process which is the selection process of these proposals, performed by the government; finally, the project is developed, implemented and the facility is then operated and transferred [Baser (2000)]. In general, the competitive tendering method is applied in BOT tenders [Islam et al. (2006)].

In determining the most advantageous proposal in BOT tendering, the Government considers the type, number and duration of the guarantees, the facility operation periods, costs, terms and conditions of finance, the base price and the conditions of shadow price as well. Apart from these, other important factors, such as the credibility of the project company, their experiences, technology transfer and labor employment, are carefully examined [Baser (2000)]. No matter how clear the evaluation criteria may be, it is rather difficult to make a choice among the proposals relative to the project.

It is quite important for the companies to become preferred bidder for a BOT Project due to the fact that such projects provide earning a good profit. Winning a BOT Project is associated with submitting a desirable financial offer to the government [Islam et al. (2006)]. The projects with the lowest costs, the shortest concession length, the highest equity/debt ratio and with the most acceptable prices level of the products/services are the most desirable and advantageous projects according to the government [Tiong (1996)]. In order for the project company to submit a desirable financial offer to the government, the components that can be altered within their own managerial skills, such as the length of the concession, the equity level and the unit prices/(tariff) levels of products/services, have been dealt with as critical factors (concessionary items) within the scope of the study.

The target of the project company is to maximize the expectation to win the tender by keeping reasonable level of profit. In order to be able to actualize this purpose, they need to submit an a desirable financial proposal to the government. Government intends to present product/service at a low price to consumers. Moreover, the government will intend to make profit from the facility at the end of the concession length. For such reasons, when assessing the BOT bids, the Government prefers those projects with low product/service prices and short concession length [Islam et al. (2006)]. In addition, the government requests the project company to have a reasonably high equity to debt ratio indicating that the company is economically powerful [Islam et al. (2006)]. In contrast to these, the project company prefers a higher level of product/service base-price for the profitability and a longer concession length. The company prefers a minimum equity level since the cost of equity is higher than the cost of borrowing. The expectations of the government from the project company in terms of the BOT Project are related to the adjustments of the suitable values of the concessionary items [Islam et al. (2006)].

Under a certain profit margin, a properly-balanced concession length debt to equity ratio and base prices will increase the the possibility of the project company to win the tender. From this perspective, modeling of a BOT investment project in order to increase the potential of winning the BOT tender of the project company is an optimization problem.

The motivation of this study has been related to the integration of the issues of project finance and evolutionary algorithm, as well for devising a sophisticated methodology to analyze the financial viability of BOT projects in terms of the project promoters. The focal point of this study is to develop a financial optimization model that will analyze how the probability of winning the tender could be increased by determining the optimal combination of key financial factors under a certain profit margin level that also covers all the necessary financial constraints. The model will enhance efficiency in providing quicker decisions to design a competitive financial proposal and process effectiveness in yielding more transparency to reveal financial targets [Islam et al. (2006)].

2- Financial model

The well-known discounted cash flow techniques are used to derive the financial model.

Total Project cost: According to Islam (2008), the total Project cost is the sum of annual base cost, additional cost owing to inflation of base cost, and annual debt interest during the construction period, which is to be accumulated at the end of the construction period. Eg.(1) expresses the total project cost.

$$TC = \sum_{i=1}^{CP}(BC_{i-1} + EC_{i-1} + IC_{i-1}) \qquad (1)$$

Where BC_{i-1}=portion of base cost at the beginning of the construction period; CP= length of the construction period (year); i, index for the construction period, $i \in [1,CP]$; EC_{i-1}= inflation of annual base cost; IC_{i-1}= annual debt interest during the construction period.

Acording to Ranasinghe (1996) and Islam (2008), Eq.(2) expresses additional cost owing to inflation of annual base cost, calculated at the beginning of the CP.

$$EC_{i-1} = BC_{i-1} x\left\{\left(\prod_{h=0}^{i}(1 + r_h)\right) - 1\right\} \qquad (2)$$

Where EC_{i-1}= additional cost owing to inflation of BC_{i-1} for the i^{th} year; and r_h= discrete inflation rate of debt in the h^{th} year, $r_{h=0}$=0.

Interest on debt during the construction period: In accordance with Islam (2008) ,Eq. (3) represents the debt interest for the i^{th} year, accured at the end of the CP.

$$\mathrm{IC_{i-1}} = (1 - ę)\mathrm{x}\left\{\mathrm{BC_{i-1}}\ \mathrm{x}\ \prod_{h=0}^{i}(1 + \mathrm{r_h})\right\}\mathrm{x}\left\{(1 + \mathrm{r_b})^{\mathrm{CP}-i+1} - 1\right\} \qquad (3)$$

IC_{i-1}=accured interest on debt fort he i^{th} year; r_b=interest rate of debt borrowed; and ; ę= equity level.

Accumulated debt at the end of the construction period represents the future value of debt drawings and their interests during the construction period. In line with Ranasinghe (1996) and Islam (2008), Eq. (4) expresses the accumulated debt.

$$\mathrm{ADT} = \sum_{i=1}^{\mathrm{CP}}\left\{(1 - ę)\ \mathrm{x}\ \mathrm{BC_{i-1}}\ \mathrm{x}\ \left(\prod_{h=0}^{i}(1 + \mathrm{r_h})\right)\ \mathrm{x}\ (1 + \mathrm{r_b})^{\mathrm{CP}-i+1}\right\} \qquad (4)$$

Debt repayment: Project sponsors have to pay the accumulated debt (ADT) for a specific number of years of the sponsor operation period. Using the capital recovery factor, Eq. (5) defines annual equal debt installments in accordance with Bakatjan et al. (2003) and Islam (2008).

$$\mathrm{ADI_j} = \mathrm{ADT}\left\{\frac{\mathrm{r_b x}(1+\mathrm{r_b})^{\mathrm{LRP}}}{(1+\mathrm{r_b})^{\mathrm{LRP}}-1}\right\} \qquad (5)$$

Where ADI_j= annual equal debt installment in the j^{th} year; and LRP= loan repayment period (year).

Interest on debt during the loan repayment period: Eq. (6) expresses the annual interests contained in annual equal debt installment.

$$\mathrm{INT_j} = \mathrm{ADI_j}\left\{1 - \frac{1}{(1+\mathrm{r_b})^{\mathrm{LRP}-j+1}}\right\}\ \forall j \in [\mathrm{CP} + 1, \mathrm{LRP}] \qquad (6)$$

Where INT_j= interest on debt to be paid in the j^{th} year. In addition ADI_J-INT_J= principal of debt to be paid in the j^{th} year.

Gross revenue is a function of market demand and pricing, which is determined as: Gross revenue is resultant upon product/service price and product demand (i.e., the combined effect of projected base demand and its annual growth over the operation period). Eq. (7) defines the annual gross revenue as a function of price and demand of a product/service[7].

$$\mathrm{REV_j} = \{\mathrm{P_{j-1}}\}\mathrm{x}\left\{\mathrm{Q_{j-1}}\prod_{k=0}^{j-1}\left(1 + \mathrm{g_k^Q}\right)\right\} \qquad (7)$$

Where OP= length of the operation period (year); REV_j=gross revenue in the j^{th} year; P_{j-1}= unit price of a service (such as tarif) at the start of the j^{th} year, $P_{j=0}$=base price; Q_{j-1}=product's demand at the start of the j^{th} year, $Q_{j=0}$=base demand; g_k^Q =annual growth rate of base demand in the k^{th} year, $g_{k=CP}^Q$=0; and j= index for the operation period, j ∈ [CP+1,OP].

Eq. (8) defines annual tax payable to the government during the SOP in line with Wibowo and Kochendorfer (2005) and Islam (2008).

$$\mathrm{TAX_j} = \max\left[0, \left\{r_t \text{ x } \left(\mathrm{REV_j} - \mathrm{OMC_j} - \mathrm{INT_j} - \mathrm{DEP_j}\right)\right\}\right] \tag{8}$$

Where TAX_j= tax payable to the government in the j^{th} year; r_t=annual tax rate; OMC_j= operation and maintenance cost for the j^{th} year.

Depreciation: annual depreciation rate considering total project cost will be depreciated within the operation period by using the straight line depreciation method [Islam et al, (2006)]. Eq. (9) defines the rate of annual depreciation.

$$\mathrm{DEP_j} = \frac{\mathrm{TC}}{\mathrm{SOP}} \tag{9}$$

DEP_j= depreciation in the j^{th} year; and SOP= sponsor operation period (year).

Annual profit before interests and tax, and annual net cash flow available to project promoters is defined as follows:

$$\mathrm{PBIT_j} = \left(\mathrm{REV_j} - \mathrm{OMC_j} - \mathrm{INT_j} - \mathrm{DEP_j}\right) \tag{10}$$

$$\mathrm{NCF_j^S} = \left(\mathrm{PBIT_j} - \mathrm{ADI_j} + \mathrm{DEP_j}\right) \quad \forall\, j \in [\mathrm{CP}+1, \mathrm{SOP}] \tag{11}$$

Amount of profit to project promoters by undertaking the concession project is expressed in net present value (NPV). Combining Eq.(1) through Eq.(11), the equity NPV is defined as Islam (2008):

$$\mathrm{NPV^S} = -\sum_{i=1}^{\mathrm{CP}} \left\{\frac{ę \text{ x } (\mathrm{BC_{i-1}} + \mathrm{EC_{i-1}}) + \mathrm{IC_{i-1}}}{(1+\mathrm{R})^{i-1}}\right\} + \sum_{j=\mathrm{CP}+1}^{\mathrm{SOP}} \left\{\frac{\mathrm{NCF_j^S}}{(1+\mathrm{R})^j}\right\} \tag{12}$$

Where NPV^S = net present value of sponsor's cash flow; and R= discount rate stipulated by sponsors.

The internal rate of return is the discount rate that makes the NPV zero as shown in Eq. (13).

$$\sum_{i=1}^{\mathrm{CP}} \left\{\frac{ę \text{ x } \left(\mathrm{BC_{i-1}} \text{ x } \prod_{h=0}^{i}(1+r_h)\right) + \mathrm{IC_{i-1}}}{(1+\mathrm{IRR^S})^{i-1}}\right\} = \sum_{j=\mathrm{CP}+1}^{\mathrm{SOP}} \left\{\frac{\mathrm{NCF_j^S}}{(1+\mathrm{IRR^s})^j}\right\} \tag{13}$$

DSCR is the ratio of the annual cash available (after tax) to annual total debt service [Bakatjan et al. (2003)], as defined in Eq.(14).

$$\mathrm{DSCR_j} = \left(\frac{\mathrm{REV_j} - \mathrm{OMC_j} - \mathrm{TAX_j}}{\mathrm{ADI_j}}\right) \tag{14}$$

Where $DSCR_J$= debt-service coverage ratio in the j^{th} year.

Eq.(15) defines the NPV of government cash flow discounted at the beginning of the construction period.

$$NPV^G = \sum_{l=CP+SOP+1}^{OP} \left\{ \frac{NCF_j^G}{(1+R)^j} \right\} \qquad (15)$$

3- Modelling the problem of Bid-winning

For a desired profit level, the NPV shown in the Eq. (12) can be obtained through various combinations of base prices, the concession length and the equity rate that cover all the financial constraints. The project owners should select values of the concessionary items that those selected values should provide the low values of the concession length and product/service unit price as much as possible on the desired profit level.

Maximization of a winning chance for a bid could be obtained by considering the maximization of the rate which proportions the net present values of cash flows of the unit year of the operation period into unit prices. Also, for funding the Project, a convenient level of equity rate should be selected by considering the financial strength of the project's sponsors [Islam (2008)].

The financial performance measurement referred to as Bid-Winning Index (BWI) is used to determine the lowest levels of a convenient equity level and the unit prices and concession length that is useful for maximizing the bid-winning potential of a BOT investment project. This index was developed inspired by the study of Islam (2008). It refers to the net present value of cash flows (reguired to realize a specific profit level) per unit prices and unit year of the sponsor operation period, sucject to utility of three concessionary item: base prices (2 products/services) and equity level.

The objective function of the proposed optimization model maximizes the bid-winning index for the BOT Project investment. The Eq. (16) defines the objective function.

$$Maksimum\ BWI = \left(\frac{NPV^S x\ \bar{U}}{P_{D_0}\ x\ P_{I_0}\ x\ SOP} \right) \qquad (16)$$

The Eq. (16) clearly shows the objective function depending on the convenient values of the concessionary items (sponsor operation period

(SOP), unit prices (P_D),(P_I) and the equity level (ę)). These four concessionary items, therefore, act as the decision variables of the proposed optimization model. When the objective function is analyzed from the sponsors' point of view, on one hand, while the decision variables maximizing the NPV value which can compete with other competitors are determined, on the other hand, it is being investigated to what extent the unit prices and sponsor operation period can be reduced in order to submit a tempting financial proposal to the government institution. The importance of utility $(\overline{U})$ in defining BWI is to reflect the usefulness of selecting a particular value of unit prices an equity level among a set of alternates concerning competitive tendering [Islam (2008)]. Utility is, therefore, a subjective measure, yet is a structured approach. It helps evaluate systematically the usefulness of unit prices and equity level (For more information, see Islam 2008) .

The defined BWI objective function is an improved form of Mainul Islam's (2008) study. The sponsor operation period is a discrete variable, whereas the unit prices and the equity level are continuous variables. For this reason, the reference optimization model becomes the mixed integer non-linear optimization problem. Also, with the inclusion of the utility function in the model, the problem has become a complex structure. Evolutionary algorithms are well-known in the solution of such problems.

4- Neighbourhood-based Differential evolutionary (DE) algorithm

Popular recently, the DE algorithm is a population-based, parallel evolutionary search algorithm used in the solution of optimization problems [Price et al. (2005)]. This algorithm was first introduced by K.Price in 1995. The first step of DE algorithm is to characterize the objective function through a proper coding of the chromosomes. In this sort of study, the unit prices of the services, concession length and equity rate are coded as genes in the chromosomes. The DE algorithm operates with the real-valued coding system.

In this algorithm, the initial population is formed randomly and is evaluated [Panda (2009)]. Afterwards, the algorithm performs the offspring generation and evaluation, and takes charge in the selection of the chromosomes that will provide the formation of the future generations. In DE, the reproduction operator (mutation and crossover) is used for each chromosome in the parent population to generate their own offspring. In DE algorithms, different from the genetic algorithms, a sophisticated and effective mutation operator is applied [Ozsaglam and Cunkas (2008)]. The important parameters of DE are the population size (N), crossover constant (Cr) and mutation scaling factor (F) [Eke (2011)].

The operators of DE algorithm can be identified in different ways. What operators shall be used in the frame of what rules is shown as [Aksoy (2007)] :

" algorithm / base chromosome selection/ the number of chromosome difference/ crossover type''.

In this study, a new $\bar{y}$ solution (offspring) is formed by using "DE/ri/1/bin" strategy. In order for each chromosome within the population to generate their own offspring, the $r_0 = i$ equality is ensured, and by selecting two r_1 and r_2 chromosomes randomly, a mutant chromosome is formed for each chromosome in the population [Liu et al. (2010)]. The mutation operator, as shown in the Eq. (17) for DE, is identified as the sum of the base chromosome and weighted differences of two randomly-selected chromosomes from within the population. The following Eq.(17) is used to generate a mutant chromosome.

$$v' = x^i + (F + rand(0,1) * (1 - F))(x^{r1} - x^{r2}) \tag{17}$$

The term, F in Eq. (17) is referred to as the mutation-scaling factor and has a value at the range of [0,1+). The correct choice of the mutation factor directly affects the convergence [Aksoy (2007)]. Since the mutation operator is based upon the differences of chromosomes, selecting the chromosomes is an important concern. The repetition of these chromosomes as r1 = r2 in the mutation scheme may reduce the convergence of the algorithm [Price et al. (2005)].

DE crossover operator is the process deciding that the parameters of the offspring chromosome come from the mutant chromosome "v_i" or the parent chromosome "x_i" [Panda (2009)]. Thus, offspring are produced by crossover operator. The DE algorithm binomial crossover type as shown in the Eq. (18).

$$y_i = \begin{cases} v_{i,k}, & rand_k(0,1) \leq C_r \quad \vee\, k = k_{rand} \\ x_{i,k}, & rand_k(0,1) > C_r \quad \wedge\, k \neq k_{rand} \end{cases} \tag{18}$$

The term Cr in the Eq. (18) is a real value at the user-defined Cr [0,1] range and indicates the crossover probability and is referred to as the crossover factor. During the crossover operator, if the generated random number is smaller than or equal to crossover factor, the parameter of the offspring chromosome is taken from the parameter of the mutant chromosome; otherwise, the parameter is taken from the base (xi) chromosome.

The selection operator in the neighbourhood-based DE algorithm compares the offspring chromosome with the parent chromosome and the neighbours of the parent in T number [Liu et al. (2010)]. If fitness value of offspring is better from fitness value of it's parent, offspring replaces parent chromosome in the next generation; if not so, all the parent chromosomes remain as the individuals of the population at least for one more generation. If a high-quality offspring chromosome is obtained, it will have a better fitness value than most of the neighbours of its parents and will perform replacement with the one whose neighbourhood is the closest [Liu et al. (2010)].

The selection operator for the minimization problems is shown in the Eq. (19) [Kapanoğlu (2011)].

$$x_i^{'} = \begin{cases} y_i, & f(y_i) \leq f(x_i) \\ x_i, & f(y_i) > f(x_i) \end{cases} \tag{19}$$

This denoted method is generally referred to as the greedy selection [Pak (2011)]. By this means, a significant advantage is gained in terms of convergence speed compared with the genetic algorithm [Eke (2011)]. The diversity is enhanced through the neighbourhood concept compared with classical DE algorithm [Liu et al. (2010)].

5- The financial optimization model

The objective function in Eq.(16) is subject to the following constraints:

Financial viability: Eq.(20), guarantees financial viability of a BOT

$$NPV^S \geq 0 \tag{20}$$

Financial sustainability: The negative cash flows indicate sponsor's inability to repay the debt to the full amount as committed in the loan agreement [Islam (2008)]. Therefore, Eq.(21) ensures that no negative cash flows are acceptable during each year of the SOP.

$$NCF_{j+1}^{S} \geq 0 \tag{21}$$

Profitability: Governments may not allow sponsors to dive for an excessive profit [IRR^S defined in Eq.(13)]. Therefore, Eq. (22) states that sponsor's expected profit must be within a specific upper limit of IRR^S [Islam (2008)]

$$IRR^{S} \leq IRR_{U}^{S} \tag{22}$$

IRR_U^S = upper limit of IRR^S.

Debt servicing: A BOT Project is deemed bankable if the average of annual DSCRs projected over the loan repayment period is not less than 1.5 [Bakatjan et al. (2003) and Islam (2008)].

$$DSCR_{avg} \geq \tau \tag{23}$$

Where $DSCR_{avg}$ =average of DSCRs;and τ =lower limit of average DSCR (1,5).

Financial return to governments: Government return from running the project after the concession period till the end of the economic life of the project must be positive [Islam (2008)]. Eq. (24) confirms government's concern for a positive NPV^G.

$$NPV^{G} \geq 0 \tag{24}$$

Range constraints for decision variables: Eq. (25) warrants that the values of decision variables must reside in the given bounds.

$$OP_{max} \geq SOP \geq OP_{min}\,, \quad P_{D0_{max}} \geq P_{D0} \geq P_{D0_{min}}\,, \quad P_{I0_{max}} \geq P_{I0} \geq P_{I0_{min}}\,, \quad ę_{max} \geq ę \geq ę_{min} \tag{25}$$

OP_{max} = maximum value of the operation period; OP_{min} = minimum value of the OP; P_{D0}= Domestic unit price; and P_{I0}= international unit price (per passenger)

DE algorithms cannot be directly applied to the solution of the constrained optimization problems, since the DE algorithm operates only through the objective function [Kapanoğlu (2011)]. Penalty functions are the most popular strategy for solving constrained optimization problems [Goldberg (1989)]. In this study, a penalty strategy commonly used for applications has been adopted. The fitness value of the objective function is penalized through the following Eq.(26) according the greatness of the violation of the constraints. A large negative constant value are added into the fitness value of the chromosomes which located in infeasible solutions area, there will be a negative impact on the objective function depending on distance to the feasible solutions area.

$$P(x) = \sum_{i=1}^{m}(R_i * g_i^2(x)) \quad (26)$$

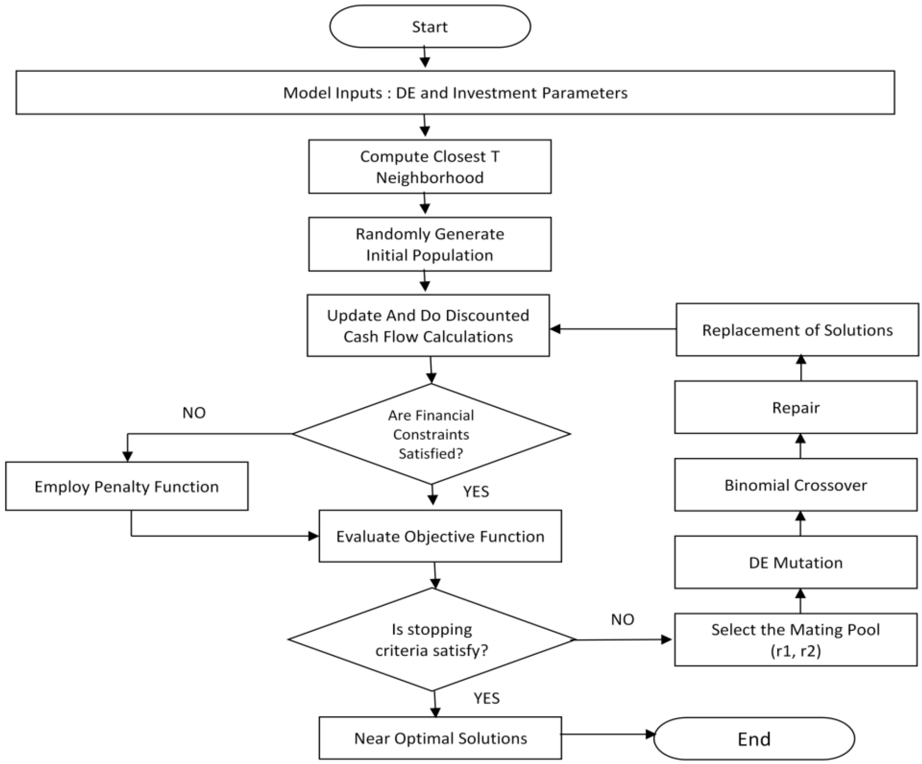
With the inclusion of the penalty term P(x) to the objective function, the BWI fitness function is defined in the Eq. (27) below:

$$Maksimum\ BWI = \left(\frac{NPV^S x\ \bar{U}}{P_{D_0}\ x\ P_{I_0}\ x\ SOP}\right) - P(x) \quad (27)$$

In the above Eq. (27), ‘’maximum BWI’’ represents the fitness value of objective function. Where P(x) = penalty function; Ri = a large constant; g_i = non-violated constraints; and m = total number of constraints. When “g_i” is negative, then, P (x) value is calculated, otherwise, P(x) is considered as zero. The advantage to this method are its flexibility of using information about the number of violated constraints, and ease of use.

The proposed algorithm is designed to maximize the chance of winning a concession agreement as stated in Eq. (16), which is therefore, considered as the objective function. The vector of decision variables consists of base prices, concession length and equity ratio. The financial constraints are shown in Eqs. (20) to (25). Note that in cases of violation of the constraints, Eq. (26) will replace the objective function, and the infeasible solutions will be graded much more poorly than the feasible ones according to the degree of violation of the constraints. The algorithm is shown in Figure 1.

Figure 1. Flow chart of BOT financial optimization model using DE



6- Results

The data of an airport BOT Project were obtained to evaluate the financial results from the viewpoint of sponsors. With these acquired data, financial models were developed by using the Eq. (1)-(15) expressed in the second section of the study. The data in Table 1 below are regarding an airport project in Turkey. The model inputs in Table 1 show the investment parameter values.

Table 1. Investment parameters

Project characteristics	Deterministic values
Max Concession Period	49 year
Construction Period (CP)	2 year
Loan Repayment Period (LRP)	15 year
Loan Interest Rate (rb)	%7
Inflation Rate (rh)	%4
Tax Rate (rt)	%11
Discount Rate (R)	%10
Initial cost (BC)	438.276.878 €
Domestic Passengers (1. year, first 6 month)	1.592.360 person
Domestic Passengers (1. year, second 6 month)	1.452.585 person
International Passengers (1. year, 1. 6 month)	430.655 person
International Passengers (1. year, 2. 6 month)	367.477 person
Price Variations	Constant
Passenger Growth Rate (Demand)	Different for each month

Sensitivity analyses were performed for the decision variables, in other words, the concessionary items. As the result of the analyses, the lower and upper threshold values, 0.20 and 0.40, were determined for the equity rate. The threshold values between € 2 and € 3 for the domestic unit price per person and the values between €10 and €15 for the foreign unit price were determined. The concession length (SOP) was ascertained between the ranges 17 years (2 year- construction and additional 15 year- loan payback) - 49 years.

Table 2. Parameter for neighborhood -based DE (BWI model)

DE algorithm parameters	Value
Population Size, N	30
Mutation Scaling Factor, F	0,5
Crossover Rate, Cr	0,5
Neighborhood Size, T	10
Penalty Coefficient, Pcoeff	10^9
Maxsimum Number of Generations, G	100

The size of the population should vary between 20 and 30 (Goldberg 1989). The population size of this model is set to 30. After successive attempts, the combination of crossover rate of 0.5 and a mutation rate of 0.5 and neighborhood size of 10 seem to produce the best result in terms of model convergence that is, producing acceptable results under stable condition. A large penalty coefficient (10^9) is adopted for using the penalty function. It was observed that 100 generations are good enough for arriving at a stable condition, and producing near optimal solutions. The algorithm is coded in the MATLAB software package. Results obtained from the model are shown in Table 3 where, for a particular level of profitability, decision-makers may choose near optimal decision vectors coupled with maximizing the probability of winning a concession agreement.

Table 3. Near-optimal decision variables

		Optimal decision vector()*			
IRR level	**Objective function (BWI)**	**Sponsor operation period (year)**	**Equity ratio (%)**	**Unit price domestic (€)**	**Unit price international (€)**
13%	1.1246	19	25	2.00	11.57
14%	1.5737	21	25	2.05	12.00
15%	2.0094	25	25	2.10	12.00
17%	2.4437	31	20	2.7	12.00

Conceptually, if the other investment parameters remain unchanged, the sponsors can gain a reasonable profit level from any string of the values of the concessionary items. Under given profit margins, an acceptable combination of concessionary items that maximize the bid-winning potential of sponsors was determined (See Table 3).

Results obtained from the model are shown in Table 3 where, for a particular level of profitability, decision-makers may choose near optimal decision vectors coupled with maximizing the probability of winning a concession agreement.

With the developed financial optimization model The Project company seeking to win the BOT tender can maximize their potential of winning the BOT tender without compromising on the profit by accepting these attractive combinations of the concession length, the equity level and unit prices.

Near-optimal values of the concession items help sponsors submit, as a whole, a competitive and financially advantageous offer to government. The deterministic DE (BWI Model) also determines the lowest value of the sponsor operation period (SOP) and unit prices.

For example, the sponsors may present a more competitive financial proposal by making profit at a rate of 15 % through utilizing these values (25 year SOP, 0.25 equity and 0.75 debt rate, domestic unit price 2.10 € and international unit price 12.00 €) . If the rate of return is selected as 13 % , such values in the Table 3 should be specified. If a higher rate of return from investment is preferred for example 17%, then these values (31 year SOP, 0.20 equity and 0.80 debt rate, domestic unit price 2.7 € and international unit price 12.00 €) should be selected.

Compared 13 % with 15% ; project company should prefer to increase the SOP instead of reducing equity rate, in order to increase profitability. Compared 15 % with 17% ; instead of increasing SOP more and more, project company should prefer to reduce equity level, in order to increase profitability. Because, more increasing SOP (concession lenght) might cause project company to lose the tender since government preference is short term project.

7- Conclusion

Simultaneous considerations of profitability as well as bid-winning prospects are vital to project promoters for evaluating the financial viability of BOT projects, particularly in order to make the financial proposal competitive. Based on the developed financial index, a deterministic, single-objective financial optimization model is proposed using neighborhood-based DE algorithms in order to find the optimal combination of key financial factors, namely: base prices of services, length of concession period, and equity ratio that would maximize the chance of winning a concession.

Despite the fact that there are numerous financial analysis models in the investment Project evaluation, these models are insufficient in undertaking the critical evaluation of bidding targets before the submission of the financial offers to the government. The private sector companies seeking to gain a competitive advantage in BOT tenders should specify the possible optimal values of the concessionary items as objectively as possible. In this way, they shall provide a financial benefit. When you want to calculate the return on investment, many analysts uses the simulation-based models. In such cases, evolutionary algorithms should be preferred as a priority.

The developed models improve the decision-making process of the private sector companies in reaching their BOT concession targets. It becomes possible to research into the combined effects of the concessionary items on the BOT project cash flows and ultimately, to determine the optimal values of the concessionary items that optimize the tender targets in the most effective and efficient ways. As the main consequence of the study, the developed optimization models are put forward as beneficial tools that the private sector companies can utilize in reaching their concessiom targets in the most effective and efficient ways.

The whole BOT process, particularly the succeeding stages of the tender/bidding stages, that is, the negotiation process was not integrated into the model. In the prospective studies, it is planned that the developed optimization models be expanded. In order for the BOT models to achieve the accurate results in terms of the private sector companies, there is the need to develop a new expertise in the fields of the management of bidding process and the follow-up of long-term agreements in particular. The BOT projects must be subjected to outstanding evaluations accompanied by qualified analysis, and necessary importances should be given to the planning stage before the implementation stage.

Attaining and maintaining such expertise continues to be an indispensable factor for the sake of being able to perform successful BOT projects.

References

Aksoy, E., 2007. Pattern Shaping in Antenna Arrays Using Differentıal Evolution Algorithm. (M.Sc. Thesis, Turkey: Gazi University).

Bakatjan, S., M. Arikan and R. L. K. Tiong, 2003. Optimal Capital Structure Model for BOT Power Projects in Turkey. ASCE, *J. Construction Enginering and Management*, 129(1), 89-97.

Baser, M., 2000. Build Operate Transfer Model as a Tool of Project Finance and Application of This Model on Izmit Municipal Water Supply Project. (Ph.D. Thesis. Turkey: Anadolu University.)

Directorate General of Investment Programming Monitoring and Assessment, 2012. Developments on The Implementation of Public-Private Partnership in Turkey and The World. (Ankara, Turkey: Ministry of Development Publication).

Eke, İ., 2011. Medıum-Term Load Forecasting by Artificial Neural Network Based Differential Evolution. *International Journal of Research and Development*, 3(1), 28-32.

Goldberg, D.E., 1989. Genetic Algorithms in Search, Optimization, and Machine Learning. (Addison-Wesley Pub. Co., Reading, Mass.)

Islam, M., 2008. Optimizing Concessionary Items' Values for Procuring Privately Financed Infrastructure Projects. (Ph.D Thesis. Australia: Griffith University).

Islam, M.M., S. Mohamed and M. Blumenstein, 2006. Towards an Optımal Fınancıal Investment Decision in Build-Operate-Transfer Projects Using Genetic Algorithms. Proceedings of the Third Joint International Conferencce on Computing and Decision Making in Civil and Building Engineering, June 14-16, Montreal, Canada, 1554-1563.

Kapanoğlu, M., 2011. Genetic Algorithm Lecturer Notes. Turkey: Osmangazi University.

Liu, B., V. Fernandez, Q. Zhang, M. Pak, S. Sipahi, and G. Gielen, 2010. An Enhanced MOEA/D-DE And Its Application to Multiobjective Analog Cell Sizing. IEEE, Congress on Evolutionary Computation, 23 July.

Ozsaglam, M.Y. and M. Cunkas, 2008. Particle Swarm Optimization Algorithm for Solving Optimization Problems. *Journal of Polytechnic,*11(4), 299-305.

Pak, M., 2011. An Enhanced Multi-Objectıve Evolutionary Algorithm (MOEA/D-DE) For The Applications of Analog Sizing With Both W/L and A Novel Operating Point Driven (Opd) Based Methods. (M.Sc. Thesis, Turkey, Istanbul: Boğazici University).

Panda, S., 2009. Differential Evolutionary Algorithm for Tcsc- Based Controller Design. *Simulation Modelling Practice and Theory*,17, 1618-1634.

Price, K.V., R.M. Storn, and J.A. Lampinen, 2005. Differential Evolution: A Practical Approach to Global Optimization. 1st Ed., Springer, Berlin, 20-182.

Ranasinghe, M., 1996. Total Project Cost: A Simplified Model for Decision Makers. *Construction Management Economics*, 14(6), 497 - 505.

Tiong, R.L.K., 1996. CSFs in Competitive Tendering and Negotiation Model for BOT Projects. *Journal of Construction Enginering And Management*, 122(3), 205-211.

Wibowo, A. and B. Kochendorfer, 2005. Financial Risk Analysis Project Finance in Indonesian Toll Roads. *Journal of Construction Engineering And Management*, 131(9), 963-972.