Iranian Int. J. Sci. ***6****(2), 2005, p.139-169*

A Model of Genetic Fuzzy Multi-Objectives Mathematical Programming for Optimizing of Research Projects Portfolio Selection

S. Khorshid[1], C. Lucas[2], M.S. Taslimi[3], A. Jafarnejad[3]
[1]*Faculty of Management-Economics, Shahid Bahonar University of Kerman, Kerman, Iran - e-mail: sed_Mar_khor@mail.uk.ac.ir*
[2]*Faculty of Engineering, University of Tehran, Tehran, Iran - e-mail: lucas@ipm.ir*
[3]*Faculty of Management, University of Tehran, Tehran, Iran.*
(*received: 30/10/2003 ; accepted: 25/4/2005*)

Abstract

Evaluation and selection of research projects are two important activities in decision making process of research and expertise panels and councils. They involved in participating a group of experts and decision-makers to evaluate the research projects with considering a set of criteria, then selecting a set of projects which better meet an organizations' objectives. On the one hand, research projects evaluation needs experts and decision-makers' judgments. In many situations, experts and decision-makers have vague and uncertain knowledge about subjects and things, so they can not express them with number values. In such situations, a realistic approach is linguistic one. According to this approach, experts can express their judgments and preferences by linguistic terms. Fuzzy set theory provides the requirement flexibility for representing uncertainty arise of subjectivity of humans and their uncertain and vague knowledge.

On the other hand, research projects portfolio selection involve using optimization models and techniques which meet multiple objectives of organization without exceeding available resources or violating other constraints. In this article, we have designed a model of mathematical programming based on integrating fuzzy set theory and Genetic algorithm optimization technique.

Keywords: *Research Projects Evaluation and Selection, Linguistic Approach, Genetic Algorithm, Optimization*

Introduction

Project evaluation and selection are the periodic activities that involved in selecting a portfolio of projects that meets the stated objectives of organization without exceeding available resources or violating other constraints. Research projects portfolio is a group of projects that perform by a specific organization. These projects compete with each other for acquiring scarce resources (human, financial and physical resources and time). In the literature, there are many methods and techniques that can be used to estimate, evaluate and choose projects portfolio, including regression analysis, monotonous regression and multi-dimensional scale analysis and mathematical programming methods (Archer and Ghasemzadeh, 2000; Oral *et al.,* 2001).

In This article, first, we describe the problem of research project evaluation and selection. After that, we solve the problem by designing a model of genetic fuzzy multi-objectives mathematical programming.

The description of the problem of research projects evaluation and selection

In this section, we outline the characteristics of research projects evaluation and selection problem and present the fuzzy and genetic definitions used in the mathematical modeling of research projects portfolio evaluation and selection. Evaluation and selection problem is an unstructured (ill-structured) and complex one following reasons: It involves several peer-reviewers and decision-makers; that is, the problem of research projects evaluation and selection is a group decision making one. Usually, a group of decision-makers initially have disagreeing opinions and judgments. Aggregating and integrating of different decision-makers opinions and judgments and agreement reaching among them is an unavailable necessity of all group decision making processes. Many researchers have used different methods and techniques for integrating and aggregating of decision makers judgments in group decision-making situations. By innovating of fuzzy set theory by Professor Zadeh, a lot of researchers have used it for integrating and aggregating of experts and decision makers' opinions and judgments under group decision making environment. We have used OWA operator for integrating and aggregating of decision makers judgments (Khorshid *et al*., 2002).

Second, the problem of evaluation and selection of research projects is a multi-criteria decision-making one. On the one hand, there is no single criterion which adequately captures the effect or impact of each project. On the other hand, research projects like other subjects and things in humane and social world represent fuzzy, qualitative and soft aspects as well as crisp and quantitative ones. Projects evaluation is sample in term of quantitative and crisp aspects, but it is difficult and problematic in term of qualitative and fuzzy ones, and is face decision-makers subjective values and judgments. Experts' and decision-makers' judgments and preferences include uncertain and vague knowledge. The uncertain and vague knowledge of decision-makers and peer-reviewers can not be stated with number values. A realistic approach to manage and capture the uncertainty and vagueness of peer-reviewers and decision-makers knowledge is linguistic one. We have used fuzzy set theory in order to model of the qualitative and fuzziness aspects of research projects. As a result, fuzzy set theory is represented interesting results on multi-criteria decision-making, multi-stage decision making, or group decision making, and measures for consensus formation in group decision making. Third, the problem of evaluation and selection of research projects is a resources allocation and optimization one. In order to solve these types of problems, the researchers of OR society have designed and used optimization techniques, and in the recent decade several, they interested to GA as an optimization technique. We have applied GA as an optimization technique in order to optimize the selection of research projects portfolio.

Objective of the study

The objective of this study is to improve the process of decision making of the research and expertise panels and councils during the evaluation and selection of research projects portfolio. The purpose is to establish how such efficient computational techniques can be applied to facilitate decision making in the area or research projects evaluation and selection and to make optimum or near-optimum decision making, the same time, to reach coincidence or agreement on made decisions.

Research projects fuzzy-linguistic assessment approach

Research projects evaluation is the first activity of the decision making process of research and expertise panels and councils. Projects evaluation provides comprehensive information about the objectives of each project, economics and social-cultural affects, etc. and required resources of each project for decision-makers. Research projects evaluation has fuzzy nature for three reasons. First, research projects represent fuzzy, qualitative and soft aspects. Therefore, the evaluation of research projects is difficult in term of fuzzy, soft and qualitative criteria. Second, research projects evaluation includes the preferences and judgments and subjective values of peer- reviewers and decision-makers that imply their uncertain and vague knowledge. In other word, the key issue in expert judgment analysis is: how should information is elicited from the experts? Usually, under such situations, peer-reviewers and decision-makers can not express their subjective values and judgments with precise and number values. A realistic approach to model the qualitative and soft aspects of research projects and manage and acquire uncertain and vague knowledge of decision-makers is linguistic one. Fuzzy set theory has proved its strengths and abilities in modeling the qualitative and linguistic aspects of things and subjects. Naturally, it is an approximate technique that represents qualitative aspects and imprecise concepts by linguistic variables instead of numerical ones, and provides the requirement flexibility for representation of uncertainty raised from decision-makers knowledge.

Linguistic approach allows a representation of the decision makers' information and knowledge in a more direct and adequate form whether they are unable of expressing that with precision. Values of linguistic variable are not numbers, but words or sentences in a natural or artificial language. In during of using linguistic approach, we need a term set defining the uncertainty granularity, that is the level of distinction among different counting of uncertainty. The elements of the terms set will determine the granularity. The semantic of the elements of the terms set is given by fuzzy numbers defined on the

[0,1] interval, which are described by membership functions. Because the linguistic assessments are just approximate ones given by the individuals, we can use the linear trapezoidal or triangular membership functions in order to capture the vagueness of those linguistic assessments.

In this study, in order to acquire the knowledge of decision makers about the weight and importance of evaluation criteria and performance value of research projects, we have defined linguistic- qualitative terms set, that their semantics are defined by fuzzy numbers on the [0,1] interval (Table 1), which are described by triangular membership function (Fig. 1).

Table 1- qualitative or linguistic terms set and semantic of their fuzzy.

Linguistic Values	Semantic of Linguistic Value
very important	(.75 1 1)
important	(.5 .75 1)
fairly important	(.25 .5 .75)
low- important	(0 .25 .5)
very-low important	(0 0 .25)

Third, research projects evaluation and selection activities are also a group of decision making activities in which more than one person participate. In other word, if several peer-reviewers and decision-makers evaluate research projects, how their judgments on a given parameter should be aggregated. In any application of the fuzzy sets based linguistic approach, particularly under environment of group decision making, the combination of linguistic values and computation of final fuzzy score of alternatives is needed.

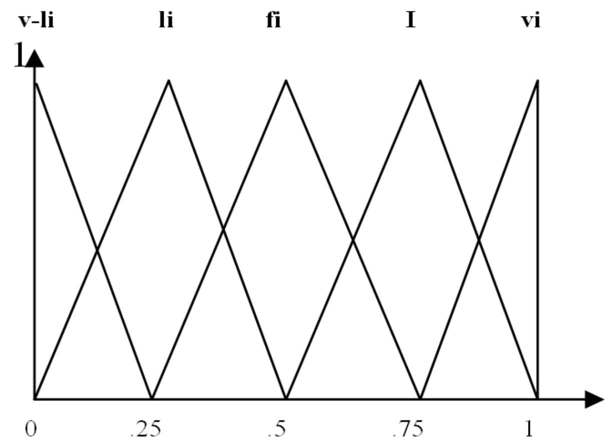

Fig.1- Linguistic terms set membership function.

Two approaches may be used to cope with this task. The first approach is based on the "Extension principle" that it allows us to aggregate and compare labels through computation on the associated membership function. The second one is the symbolic one which acts by direct computation on labels, only taking into account the meaning and properties of such linguistic assessment with independence of their semantic representation. In this article, by following from the first one, we have applied OWA operator for integrating or aggregating the experts and decision makers' judgments and preferences. This operator is introduced by R.R. Yager (Khorshid *et al*., 2002).

Fuzzy multi-attribute multi-person decision making model (FMAMPDM)

Multi criteria decision-making (MCDM) refers to making decisions in the presence of multiple, usually conflict criteria (attributes, objectives). Problem for multiple criteria decision making are common occurrences in every day life. In order to compute the final fuzzy score of research projects, we develop a model of fuzzy multi-attribute multi-person decision making. In this section, we introduce it as following:

1- Symboling

$l = \{ C_1, C_2, ..., C_l \}$ — l: projects evaluation criteria sets.

$p = \{E_1, E_2, ...E_p\}$ — p: decision maker group members sets.

$j = \{X_1, X_2, X_3, ..., X_N\}$ — N: search projects sets**.**

2-The algorithm of fuzzy multi-attribute multi-person decision making model

In this section, we present the algorithm of computing of the final fuzzy score of research projects:

2-1- Criteria fuzzy weight computation: The fuzzy weight of a criterion presents fuzzy preference degree of that criterion relative to other criteria. In multi-criteria decision-making problems, the weight of criteria should be determined, so that their sum is equal one $(\sum_i w_i = 1)$. The fuzzy weight of criteria has computed in the following.

2-1-1- Reviewers or decision-makers state their preferences and judgments about important and weight of criteria of research evaluation in the format of linguistic and qualitative terms.

$$[\, E_1C_1 , E_2C_1 ,\dots , E_pC_1 ,\dots , E_1C_l , E_2C_l \dots , E_PC_l \,] \tag{1}$$

2-1-2- Integrating and aggregating the fuzzy preferences' values of experts and decision-makers on criteria and compute social and collective fuzzy preferences values according to formula 2. We used OWA operator guided by fuzzy majority of experts for integrating individual experts' preferences values. Here, we used the concept of linguistic quantifier "most" for integrating and aggregating individual experts' preferences values. Fuzzy majority of experts used to quantify the dominance that one criterion has over all the others, according to the experts' opinions considered as a whole.

$$GO(C_l) = \phi_Q(E_1C_l ,\, E_2C_l ,\, E_3C_l ,\dots , E_PC_l) \tag{2}$$

2-1-3- Criteria fuzzy weight computation: For computing of criteria fuzzy weight and importance, we used the concept of fuzzy majority of dominance. Fuzzy majority of dominance, used to quantify the dominance that one criterion has over all the others, according to individual experts opinions. The fuzzy weight of every criterion computes according to formula 3:

$$w(C_l) = {GO(C_l)} \Big/ {\phi_Q(GO(C_1), GO(C_2), ..., GO(C_l))} \quad (3)$$

Criteria fuzzy weight is shown in the following vector (formula 4).

$$W(C) = (w(C_1), w(C_2), ...\ w(C_l)) \quad (4)$$

In order to evaluate the research projects and direct the research system toward the strategic-developmental objectives of organization and sociality, the objectives and criteria of research projects evaluation and selection is identified, that represented in the Table 2.

2-2- Research projects final fuzzy score computation

Research projects final fuzzy score been computed according to formula (5), (6), (7), (8).

2-2-1- Reviewers and decision-makers evaluate research projects with considering each criterion, and then express their preferences and judgments in the format of linguistic terms. X_{pjl} is performance value of project X_j with considering criterion C_l from each expert perspective E_P. We obtain the matrix of preference values for every expert (matrix 5).

$$E_P M = [X_{111}, X_{112}, ..., X_{11L}, ..., X_{1N1}, X_{1N2}, ..., X_{1NL}, ..., X_{PN1}, X_{PN2}, ..., X_{PNL}] \quad (5)$$

2-2-2- Integrating and aggregating the individual experts' fuzzy preferences values, and obtain group and collective fuzzy preference value. We used OWA operator for integrating of individual experts' fuzzy preferences values, and obtained GFMADMPM matrix (formula 6).

Table 2- The objectives or criteria of research projects evaluation and selection.

Row	Criteria or objectives	Sub-criteria or sub-objectives
1	**Organization and management**	Organization objectives, strategies, programs
2	**Scientific and technology**	Generating knowledge and internalizing knowledge , creativity and innovation, transmission and dissemination knowledge to scientific different fields and sociality different sections research skills development, research methodologies and tools development and enhancement, inter-disciplining research, to attend requirement sciences and techniques of sociality.
3	**The performer empowerment of project**	The relation of research subject with performer expertise, the scientific and technical ability, innovation and designation ability, the participation of researcher in the international scientific researches, ability of management and coordination of operations
4	**Social- cultural**	The enhancement of life level quality and humane-social prosperity, the enhancement of national security and country autonomy, to keep and enhance of the life environment health , to frizz and enhance country international situation, to contribute stainable development, manpower development, self-believed and self-confidence, self-dependent and self-reliance.
5	**Economics**	Enhance productivity in related section optimal use from relational advantages of related section, the money savings, to optimize resources usage, generate employment, to increase the competitive power of related section and society, to meet national needs, to enhance technological potential within industries, to enhance international standards of related section, to enhance economic structures.
6	**Feasibility**	Financial- economics, humane, technical, informational, time feasibilities.
7	**Risk**	R & D financial resources, project scheduling, business and economics unstable, external resources.

$$\begin{array}{l} GO(A_1^{c_1}) = \phi_Q(X_{111}, X_{211}, \ldots, X_{P11}) \\ \ldots. \\ GO(A_N^{C_l}) = \phi_Q(X_{1N_11}, X_{2N_2}, \ldots, X_{PNL}) \end{array} \Rightarrow \quad (6)$$

$$GFMADMPM = [GO(A_1^{c_1}), GO(A_1^{c_2}), ..., GO(A_1^{c_l}), ..., GO(A_N^{c_1}), GO(A_N^{c_2}) ..., GO(A_N^{c_l})]$$

2-2-3- Computing of the weighted matrix "WFGMADMPM":

$$W(C) \otimes GFMADMPM = [w(C_1)A_1, w(C_1)A_2, ..., w(C_1)A_N, ..., w(C_l)A_1, w(C_l)A_2, ..., w(C_l)A_N] \Rightarrow \quad (7)$$

$$WFGMADMPM = [P_{11}, P_{21}, P_{31}, ..., P_{l1}, ..., P_{12}, P_{22}, ..., P_{l2}, P_{1N}, P_{2N}, ..., P_{lN}]$$

2-2-4- Computing of the research projects fuzzy score, "PRO_j":

$$PRO_j = f(P_{1j}, P_{2j}, ..., P_{lj}) = \phi_Q(D_1, D_2, ..., D_h) \quad (8)$$

PRO_j is fuzzy score and value in every of project

The output of research projects fuzzy evaluation process is research projects fuzzy scores that are the objectives functions coefficients of the model of mathematical programming.

The model of fuzzy multi-objectives mathematical programming of research projects portfolio selection

The process of research projects portfolio selection faces with problem like potential projects subsets selection by considering of accessible resources such as money, human, financial resources, etc. and project interdependence, risk and uncertainty of projects. Optimal or near-optimal selection of research projects portfolio involve using optimization models and techniques, that meet multiple and often-conflicting objectives while satisfy existing constraints. We have formalized a fuzzy multi-objectives mathematical programming model for optimizing of research projects portfolio selection that describes some of its components in the following (Khorshid, 2002):

1- Decision variable:

The decision variables of the model are defined by:

$x_{jit} = 1$ *if project j from research group i included in the portfolio and starts in period t*
$x_{jit} = 0$ *otherwise*

2- Sets:

$i = 1, 2, \dots, M$ *i*: Research group sets.

$j = 1, 2, \dots, N_i$ *J*: Research group project sets.

$t = 1,2,\dots,T$ *t*: project start period

when the planning horizon is divided into T periods.

$z = 1, 2, 3, \dots, Z$ *Z*: Objective sets.

$r = 1,2,3,\dots, R$ *R*: research sets.

3- Objective functions:

The objective functions of model defined in the following:
a-The objective function maximum of research projects management and organization value and importance.

$$z_1 = Max \sum_{i=1}^{m} \sum_{j=1}^{N_i} \sum_{t=1}^{T} M\tilde{O}I_{ij} x_{ijt} \tag{9}$$

b- The objective function maximum of research projects science value and importance.

$$z_2 = Max \sum_{i=1}^{m} \sum_{j=1}^{N_i} \sum_{t=1}^{T} S\tilde{C}I_{ij} x_{ijt} \tag{10}$$

c- The objective function maximum of research projects economic value and importance.

$$z_3 = Max \sum_{i=1}^{M} \sum_{j=1}^{N_i} \sum_{t=1}^{T} E\tilde{C}I_{ij} x_{ijt} \tag{11}$$

d- The objective function maximum of research projects social value and importance.

$$z_4 = Max \sum_{i=1}^{M} \sum_{j=1}^{N_i} \sum_{t=1}^{T} S\widetilde{O}I_{ij}\, x_{ijt} \tag{12}$$

e- The objective function maximum of research projects feasibility.

$$z_5 = Max \sum_{i=1}^{M} \sum_{j=1}^{N_i} \sum_{t=1}^{T} \widetilde{F}_{ij}\, x_{ijt} \tag{13}$$

f- The objective function maximum of research projects performer empowerment.

$$z_6 = Max \sum_{i=1}^{M} \sum_{j=1}^{N_i} \sum_{t=1}^{T} P\widetilde{O}_{ij}\, x_{ijt} \tag{14}$$

g- The objective function minimum of fuzzy risk rate of research projects.

$$z_7 = Min \sum_{i=1}^{M} \sum_{j=1}^{N_i} \sum_{t=1}^{T} R\widetilde{I}_{ij}\, x_{ijt} \tag{15}$$

***4- Constraints*:** There are the large numbers of possible constraints which can be invoked through the constraint equations in the following:

a- Projects interdependency modeling: projects interdependency model is in the following two formats:

a-a- Constraint relate to interdependency of two projects from a research group.

$$x_{ijt} - x_{ikt} = 0 \qquad for \quad t = 1,2,3,4 \tag{16}$$

a-b- Constraint relate to interdependency of two projects from two research groups.

$$x_{ijt} - x_{hkt} = 0 \qquad for \quad t = 1,2,3,4 \tag{17}$$

b- Within every time period 't' from every research group; at least a project select.

$$\sum_{t=1}^{T} \sum_{j \in N_i} x_{ijt} \geq 1 \tag{18}$$

c- Between projects 'j' and 'k' (among of several projects) only select a project.

$$x_{ijt} + x_{ikt} = 1 \quad for \quad t = 1,2,3,4 \tag{19}$$

d- Considering projects that have already started and to ensure that ongoing projects started at time zero and to meet their requirement resource during the selection of new projects must be added to the optimization model.

$$\sum_{t=1}^{T} x_{ij1} = 1 \tag{20}$$

$$\sum_{ij \in S_o} x_{ij1} = EP \tag{21}$$

e- A guarantee that each project, if selected, will not start twice during the planning time horizon.

$$\sum_{t=1}^{T} x_{ijt} = 1 \tag{22}$$

f- All of the selected projects must be completed within the planning time horizon.

$$\sum_{i} \sum_{j} \sum_{t} (t \times k) x_{ijt} + D_{ij} \le Ph \tag{23}$$

g- Maximum number of projects that can select and implement within the planning time horizon.

$$\sum_{i} \sum_{j} \sum_{t} x_{ijt} \le T\widetilde{P}_{Ph}^{\max} \tag{24}$$

h- Minimum number of projects can select and implement within the planning time horizon.

$$\sum_{i} \sum_{j} \sum_{t} x_{ijt} \ge T\widetilde{P}_{Ph}^{\min} \tag{25}$$

The right side of the two constraints (g) and (h) are fuzzy that they should dyfuzzied before implementing GA in the following format:

$$\sum_i \sum_j \sum_t x_{ijt} \leq (TP_{Ph}^{\max^m} + (TP_{Ph}^{\max^o} - TP_{Ph}^{\max^m})$$
$$\sum_i \sum_j \sum_t x_{ijt} \geq (TP_{Ph}^{\min^m} - (TP_{Ph}^{\min^p} - TP_{Ph}^{\min^m}) \tag{26}$$

i- Finance resource constraint.

$$\sum_i \sum_j \sum_t \beta_{ij} \ x_{ijt} \leq \beta_L \qquad for \quad l = 1,2,...L \tag{27}$$

j- Other resources constraint (human resources, research space, computing resource).

$$\sum_i \sum_j \sum_t R\, r_{ij}\, x_{ijt} \leq Ar_t \tag{28}$$

k- Not to negate decision variable.

$$x_{ijt} \in (0,1) \tag{29}$$

A genetic algorithm for optimizing of research projects portfolio selection

In order to select an optimal portfolio of research projects, we need to apply a meta-heuristic technique. We have applied GA as an optimization technique according to the following reasons (Herrera *et al.*, 2001; Gen and Cheng, 2000): 1- GAs can solve hard problems quickly and reliably, 2- GAs are easy to interface to existing simulation and models, 3- GAs are extendible, 4- GAs are easy to hybridize, 5- GAs have got a great measure of success in search and optimization problems. The reason for the great part of this success is their ability to exploit the accumulated information about an initially unknown search space in order to bias subsequent searches into useful subspaces. This is their key feature, particularly in large, complex and poorly understood search spaces, where classical search tools are inappropriate; offering a valid approach to problems requiring efficient and effective search techniques. They are not guaranteed to find the global optimum solution to a problem, but they are generally good at finding acceptably good solutions to problems quickly. These reasons have caused that during the last few years, GA applications have grown enormously in many fields. In this section; we first present a short introduction of GAs and then the proposal of the multi-objective GA is introduced.

1- Genetic algorithm

GAs are general purpose search algorithms which used principle inspired by natural genetics to evolve solution to problem. The basic idea is to maintain a population of chromosomes which represent candidate solution to the concrete problem being solved which evolves overtime through a process of competition and controlled variation. Each chromosome in the population has an associated fitness to determine (to select) which chromosomes are used to form new ones in the competition process. The new ones are created by using genetic operators such as crossover and mutation. A GA starts off with a population of randomly generated chromosomes (solutions) and advances toward better chromosomes by applying genetic operators. The population undergoes evolution in a form of natural selection. During successive iterations, called generations, a new population of chromosomes is formed by using a selection mechanism and specific genetic operators such as crossover and mutation. An evaluation or fitness function must be devised for each problem to be solved; given a particular chromosome, a possible solution, the fitness function returns a single numeral fitness which is supposed to be proportional to the utility or adaptation of the solution represented by that chromosome (Herrera *et al*., 2001).

2- Multi-objective genetic algorithm for selecting the best of research projects portfolio

To solve the problem of fuzzy multi-objective mathematical programming and to optimize the selection of research projects portfolio, we propose to use a GA with following components, and at the same time, describe how it implement on research projects at Center of Telecommunication Researches of Iran as a R & D organization.

2-1- Genetic representation of solutions: The solutions to the problem are a portfolio of research projects that meet organization objectives with considering organization resources constraints within programming time horizon. Supposing X^{pq} is a solution (chromosome) for research projects portfolio selection problem.

$$X^{pq} = [x_{111}, x_{112}, \ldots, x_{11T}, \ldots x_{N_1 11}, x_{N_1 12}, \ldots, x_{N_1 1T}, \ldots, \\ x_{1M1}, x_{1M1}, \ldots. x_{1MT}, \ldots x_{N_M M1}, x_{N_M M2}, \ldots, x_{N_M MT}] \quad (30)$$

That x_{111} is research project "1" from research group "1" that likely starts in time period "1". In the designed GA, for genetic representation of problem solutions, we used binary coding that code zero represent non including of a project from a research group within the research projects portfolio and code one represent including of a project from a research group within research projects portfolio that starts in time period 't'. Then, every solution for projects portfolio selection problem consist from research projects of research groups for starting in time periods 1 or 2 or 3 or 4, that represented in format of a chromosome(string of zero or one) within population. For example, a solution of problem with considering the chromosome length (368 genes) represent in the following format:

$$X = [1010101010 \quad 1010101010 \quad 1010101010 \quad 1 \\ 0101010101 \quad 010 \ldots 1010101010 \quad 1010101010 \quad] \quad (31)$$

The first "1" on the left hand is representation including the research project "1" from the research group "1" within research projects portfolio, that starts in the period "1" , and the first "zero" is representation non including of the research project"1" from the research group "1" within research projects portfolio.

2-2- Initial population of solutions**:** Once a suitable representation has been decided on for the chromosomes, it is necessary to create an initial population to serve as the starting-point for the genetic algorithm. This initial population can be created randomly or by using specialized, problem-specific information. In this study, after coding solutions in format zero or one, we created randomly an initial population (1200 chromosomes in zero generation) from these solutions (the matrix of random numbers zero or one), that is shown in the Table 3.

2-3- Fitness evaluation: Fitness evaluation involves defining an objective or fitness function against which each chromosome is tested for suitability for the environment under consideration. As the algorithm proceeds, we would expect the individual fitness of the "best" chromosome to increase as well as the total fitness of the population as a whole. In the uni-objective problems, objective function plays role of the fitness function, but in the multi-objective problems, decision-makers face Pareto optimal solutions that should determined fitness value of solutions according to multiple objectives. In these problems, there is not a solution that optimizes all objectives, but Pareto optimal solution describe as the solution of problem. In the past decade several, many mechanism for fitness value assignment have studied and tested. In this paper, we used the weighted sum of objective functions for obtaining fitness function and utility function (Gen and Cheng, 2000). The weighted sum of objective functions for pqth chromosome in the problem of research project portfolio optimal selection is obtained in the following:

$$f_{X^{pq}} \Rightarrow evale(X^{pq}) = \sum_{z_k=1}^{6} \beta_{z_k} \frac{I_T^{\alpha}(Z_{z_k}^{(t)}(X_{pq}) - I_T^{\alpha}(Z_{z_k}^{\min(t)}) + \gamma}{I_T^{\alpha}(Z_{z_k}^{\max(t)}) - I_T^{\alpha}(Z_{z_k}^{\min(t)}) + \gamma} + \beta_{z_7} \frac{I_T^{\alpha}(Z_{z_7}^{\max(t)} - I_T^{\alpha}(Z_{z_7}^{(t)}) + \gamma}{I_T^{\alpha}(Z_{z_7}^{\max(t)}) - I_T^{\alpha}(Z_{z_7}^{\min(t)}) + \gamma} \quad (32)$$

$I_T^{\alpha}(\tilde{z}_z^{(t)}(x_{pq})$ is the normalized value of Zth objective function and β_z is the weighted coefficients of objective functions that obtain for $Z = 1,2,3,4,5,6,7$ by the two formula 33 and 34:

$$\alpha_z = \frac{I_T^{\alpha}(z_z^{max(t)}) - I_T^{\alpha}(z_z^{min(t)})}{I_T^{\alpha}(z_z^{max(t)})} \quad (33)$$

and

$$\beta_Z = \alpha_Z \Big/ \sum_{Z=1}^{7} \alpha_Z \tag{34}$$

γ is a small positive realistic value that is in the range of [0,1], and uses in order to prevent the dividing of zero and alter the behavior of selection from fitness-proportional behavior to mere random selection. When objectives functions are fuzzy, the feasible solutions of optimization problem are fuzzy.

Thereby, the fitness value of every chromosome is a fuzzy number. For selecting individuals for next generation, the fuzzy fitness value of every chromosome should be dyfuzzified. In order to dyfuzzy the fuzzy fitness value of chromosomes; researchers used the ranking functions of fuzzy numbers. Different methods for ranking of fuzzy numbers have proposed in literatures (Chen & Hwang, 1992). In this paper, we used Lius and Vang method. According to this method, total integer value of fuzzy number instead of relative value of one is computed by formula 35:

$$I_T^{\alpha}(\tilde{A}) = \alpha I_R(\tilde{A}) + (1-\alpha) I_L(\tilde{A}) = \frac{1}{2}[\alpha a + b + (1-\alpha)c] \tag{35}$$

α is in the range of [0,1]. A large α show large optimizing degree (Gen and Cheng, 2000).

The fitness value of each chromosome is computed for initial population with considering different optimization degrees $\alpha = 1, \alpha = .5, \alpha = 0$ that represented in the Table 3.

***2-4- Genetic operators*:** Genetic operators alter the genetic combination of offspring in during reproduction. GA alters initial population by using three operators of selection, crossover and mutation.

Table 3- The initial population of solutions.

The value of fitness of each chromosome				
Different optimization degree α			**Chromosomes**	**N. C.**
1	0.5	0		
.599	1	1.45	101010101010…1010101010	1-1
.83	1.39	2.15	110110011001…0011011010	2-1
.60	1.72	1.7	101101101110…1101100111	3-1
.64	2.15	1.52	111000110110…0001101010	4-1
.54	1.56	1.36	001101100110…1110001101	5-1
.81	.94	1.4	111000101001…0001110100	6-1
1.02	1.91	1.7	100101001011…1111000110	7-1
.82	1.72	2.41	100110011101…0011010101	8-1
.76	1.71	2.19	101101110011…1101011011	9-1
…	…	…	………………………	………
.70	2.22	2.38	101011101000…1110101010	1192-1
1.18	1.66	1.72	110011011011…0011111010	1193-1
1.12	1.08	2.84	111101111100…1001100110	1194-1
.77	1.04	2.61	101100110110…0101101011	1195-1
.97	1.23	2.20	011101100110…1110010101	1196-1
.76	1.04	1.68	11100101001…0101110101	1197-1
.806	1.16	1.99	100101011011…1101010110	1198-1
.803	1.65	1.86	101110010101…0011010111	1199-1
.55	1.73	2.58	1011010100101…110101101	1200-1

2-4-1- Parents selection strategy: When the fitness value of every chromosome obtains, a new population of current generation is randomly selected based on the fitness value of every chromosome. According to this operator, the most fitness of individuals select for new population. In order to select and reproduction of individuals for new generation, firstly, we compute the sum of difference of the weighted sum of the objective functions of each chromosome (1200 chromosomes) from the least of fitness value of chromosomes in current population " $f_{min} = \min_{pq} (f_{X^{pq}})$ " by formula 36:

$$\sum_{pq=1}^{1200} (f_{x^{pq}} - f_{\min}) \tag{36}$$

Then the probability of selection of each chromosome pq, $(pq = 1,2,3,...,1200)$ compute according to the formula 37:

$$pE\left(X^{pq}\right)=\frac{f_{x^{pq}}-f_{\min}}{\sum_{pq=1}^{1200}\left(f_{x^{pq}}-f_{\min}\right)} \qquad 37)$$

By computing the probability of selection for each chromosome $pE(X^{pq})$, we compute the cumulative probability $qE(X^{pq})$ for each chromosome X^{pq}. For example, the probability of selection, and also the cumulative probability of selection of the first chromosome with different optimization degrees are:

$\alpha=1, pE(X^1)=.12439, qE(X^1)=.12439;\ \alpha=.5, pE(X^1)=.007784,$
$qE(X^1)=.007784;\alpha=0, pE(X^1)=.006161, qE(X^1)=.006161$

We used the cumulative probability for selecting the most fitness of chromosome for next generation. Also, we apply a roulette wheel for the selection process. Now, we are ready to spin the roulette wheel 1200 times. Each time, we select a single chromosome for new population. In order to select a single chromosome for new population, we proceed in the following way:
1- Generating a random number "r" in the interval of (0,1). 2- If it is $qE(X^{pq})<r<qE(X^{pt})$, $pt=pq+1$, then chromosome X^{pq} is selected for the new population. Let us assume that the first random number "r" from the range (0,1) is .0255123. Since it is greater than the cumulative probability of the first chromosome $qE(X^1)=.012439$ with considering optimizing degree $\alpha=1$, and smaller than the cumulative probability of the second chromosome $qE(X^2)=.076792$; then the second chro-mosome" X^2 " is selected for the new population. 3- Repeating the stages (1) and (2), 1200 times. After the 1200th selection, a new population that consists of the selected chromosome is obtained. Here, we determine the strongest (the most fitness) individual preserved in the new population. If not, we used an elitism selection strategy. According to this strategy, if the strongest individual in the new population is not selected, an individual from

new population is randomly removed and the strongest individual adds to new population. An elitism selection strategy keeps the strongest individual from a population in a successive generation. In this way; the best solution for a previous population is not lost until outclassed by a more fitted solution.

2-4-2-Crossover operator: After selecting and reproducing a new population, we are ready to apply the recombination operator (crossover) for the individuals in the new population. Crossover operator is playing a central role in genetic algorithm. Empirical studies have shown that better results are achieved by a crossover probability between .65 and .85 (Hurley *et al*., 1995). In this paper, we compute the crossover probability with aggregating different probabilities of crossover in the range $p_c \in [.5, 1]$ by OWA operator that obtained probability crossover "$p_c = .75$". So we expect that .75 of chromosomes (900 chromosomes) will undergo crossover.

Also with considering of research projects interdependency, we use single-point crossover. Single-point crossover involves taking the two selected parents and crossing them at a randomly chosen point. Therefore, after computing the probability of crossover and determine-ing the type of crossover, we proceed in the following ways:

```
                                                        crassover point
                                                              ↓
parent 1(1010101010 01010101 ...0101001010 1011100101 010101 ...101000|10110 ...1100101010 1010)
         *******************************************| ••••••••••••••••
parent 2(1100101111 10101000 ...1100101010 1001000111 001100 ...110011|01001 ...1110001110 0011)
         ••••••••••••••••••••••••••••••••••••••••••| *****************
                                  ⇓                          ⇓
child 1  (1010101010 01010101 ...0101001010 1011100101 010101 ...101000 01001 ...1110001110 0011)
         ************************************************************
child 2 (1100101111 10101000 ...1100101010 1001000111 001100 ...1100111011 0...1100101010 1010)
         ••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
```

Fig. 2- Single-point crossover on two chromosomes and creation of two children.

1- For each chromosome in the new population, we generate a random number "r" from range (0,1). If it is $r \leq .75$, we select a given chromosome for crossover. Assume that the first random number "$r = .23784$ " is smaller than the probability of crossover "$r \leq .75$ "; then the first chromosome X^1 is selected for crossover. Also, assume the second random number $r = .84231$ is greater than the probability of crossover "$r > .75$ ", then the second chromosome X^2 is not selected for crossover, etc. After the 1200th selection, 900 chromosomes were obtained for crossover. 2- Mate the selected chromosomes randomly. For example, in our study, the chromosomes 1 and 10 are mated. 3- Determine the point of crossover. 4- The point of crossover is determined in two manners: generate a random number "r" from the range [1, l-1], l is the string length, and defining the point of crossover based on the formula 38.

Crossover point = INTEGER (*no. of genes in chromosome or the string length* crossover point*) (38)

In our study, crossover point is defined above manner. Therefore, generated random number "r" is 265 that is $r = 265$. The number point indicates the position of the crossing point (crossover point is marked by $|$). The manner of implementing single-point crossover on the chromosomes 1 and 10 represented in Fig. 2. After accomplishing crossover, the new version of current population is obtained.

2-4-3- Mutation: With mere applying crossover operator, diversity of initial population is removed and raised the problem of premature converging and jumped into point of local optimum. In order to remove this problem, a mutation operator is introduced. This attempts to introduce some random alteration of the genes.

The fitness value of genes and the average of fitness value of population is reducing by mutation operator. In order to prevent the removing of good chromosome which is resulted from crossover operator, the probability of mutation is keeping down. Researches have indicated that probability of mutation "p_m " should lie in the range defined by $\frac{1}{n} \le \; p_m \; \ge \frac{1}{l}$, where "n" is the population size and l is the string length (Ibid). In this paper, we have computed probability of mutation by formula of $\frac{1}{n} \le p_m \ge \frac{1}{l}$, that the probability of mutation is .003,($p_m = .003$). So we expect that (on average) .003 of chromosomes (four chromosomes) would undergo mutation. After computing the probability of mutation; we select four chromosomes by random process. Therefore, we generate four random numbers in the range [1,1200], that the chromosomes 100, 590, 875, and 1056 obtained, then we determine mutation local by random process and generate two random numbers in the range (1,368-1), that obtained 695 and 769 locals. Now, we are ready to use the operator of interchange mutation. According to this type of operator, two positions are randomly selected then interchanged the contents of two positions. The manner of implementing the operator of interchange mutation is shown in Fig. 3.

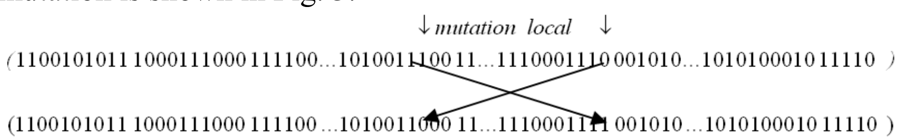

Fig. 3- Interchanging mutation on a chromosome.

2-5- Stop criterium (termination-condition)**:** GA converges in extreme. When GA used as an optimization technique, must determine stop criterium or termination-condition. Stop criterium is predefined maximum number of generation or time limit is reached. In this study, stop criterium has determined maximum number of generation (MaxGen=100 generation). The structure of designed GA is represented in Fig. 4.

Now we are ready to run the designed GA, and apply the selection process, genetic operators, evaluate the next generation, etc. This completes one iteration (one generation), that results are represented in Table 4.

When population size is 1200, crossover probability is .75, mutation probability is .003 and maxGen is 100, we used the same evaluation procedure. The final population (population in generation 100) and the best chromosome and the values of their objectives functions and fitness function with considering of the different optimum degree $\alpha = 1, \alpha = .5, \alpha = 0$ are shown in Table 5.

Begin
t : =0
initialize p(t);
calculate and evaluate the fitness value of chromosomes in p(t);
determine E(t) by handling model of Pareto solutions;
while (not termination-condition) do
begin
recombination of p(t) for producing c(t);
if (not mutation- condition) then
{mutation;}
evaluate c(t) by using fitness function;
up to date E(t) by model of handling Pareto solutions;
select p(t+1) from p(t) and c(t);
t : =t+1
end
end

Fig. 4- The structure of GA.

Table 4- The generation 1.

The value of fitness of each chromosome			
Different optimization degre α			**N. chromosome**
1	0.5	0	
.36	.949	1.59	1-1
.288	.80	1.3	2-1
.208	.78	1.35	3-1
.278	.577	1.24	4-1
.217	.480	1.24	5-1
.258	.445	1.05	6-1
.196	.320	.81	7-1
.308	.535	.67	8-1
.223	.532	.61	9-1
…	…	…	………
.133	.360	1.03	1192-1
.262	.484	.66	1193-1
.206	.528	.762	1194-1
.276	.500	.67	1195-1
.284	.480	1.13	1196-1
.234	.567	1.03	1197-1
.300	.585	1.08	1198-1
.275	.619	.74	1199-1
.252	.641	1.05	1200-1

Table 5- The generation 100.

The value of fitness of each chromosome			
Different optimization degre α			N. chromosome
1	0.5	0	1-100
.518	.547	2.1	2-100
.546	.556	2.1	3-100
.481	.547	1.95	4-100
.532	.697	1.79	5-100
.550	.540	1.16	6-100
.582	.440	1.8	7-100
.426	.490	1.08	8-100
.493	.460	1.12	9-100
.495	.486	1.24	……
…	…	…	1192-100
.478	.718	1.21	1193-100
.467	.640	1.16	1194-100
.658	.911	2.36	1195-100
.429	.373	.66	1196-100
.376	.461	1.22	1197-100
.595	.327	.951	1198-100
.427	.209	.877	1199-100
.622	.533	1.13	1200-100
.499	.585	1.51	the portfolio of research project in the hundred : "chromosome 1180"

***2.6- Research projects portfolio selection Genetic fuzzy optimization system validity test*:** We tested validity of research projects portfolio selection Genetic fuzzy optimization system in the following manners:
1- The test of the research projects portfolio selection Genetic fuzzy optimization system was carried in the context of a decision making and selection problem of research project at Iran telecommunication Research center, that results presented in the Table 6. The Genetic fuzzy optimization system begins with a set of initial population which are randomly generated. The designed system prompts the user to input the values of certain optimization parameters, such as the number of generations, the mutation probability and the crossover probability. The genetic fuzzy optimization system uses the new value of optimization parameters for generating other populations, then generates final output (the fitness of research project portfolio) and determines the time periods of start of each project.

Table 6- The obtained results from implementing the system of research projects fuzzy evaluation and genetic selection

N.project	N.research group	Start period of each project	N.project	N.research group	Start period of each project	N.project	N.research group	Start period of each project
1	1	3	12	3	2	4	7	2
1	2	4	13	3	2	5	7	3
2	2	1	1	4	1	6	7	4
2	3	2	2	4	3	1	8	1
4	3	3	1	5	3	2	8	3
3	3	3	2	5	2	1	9	1
5	3	4	3	5	1	2	9	3
6	3	1	4	5	3	3	9	2
7	3	2	5	5	4	5	9	3
8	3	3	1	6	1	6	9	4
9	3	1	2	6	3	7	9	4
10	3	4	3	6	2	4	9	4
11	3	3	3	7	1			

We measured the validity of proposed optimization system by comparing of the performance of genetic fuzzy optimization system of research projects portfolio selection by experts. Thereby, we firstly design a questionnaire containing the obtained results from performing the proposed optimization system at Iran Telecommunication Research Center. Secondly the experts and managers who involved in research projects evaluation and selection processes, have expressed their judgments on the items of questionnaire, which do project select and when do the selected project perform with considering the constraints of humane, financial, computing resources and researches space? Thirdly, we used Binominal test for analyzing the aggregated data. Fourthly, the aggregated data was analyzed using statistical package of SPSS, the obtained results from statistical analysis in significant level $\alpha = .01$ indicate that more than .75 of respondents agreed on .85-100 percent selected projects by Genetic fuzzy optimization system.

2- We designed an experiment to study the behavior of the research projects selection Genetic fuzzy optimization system to measure a set of output data of 20 test runs. Various statistical indicators were then used to measure the reliability of the system as a optimization tool to support of decisions and selections of research projects portfolio by comparing the output with the actual best solution of the problem. Also we measured the sensitivity of the system to changes in the optimization parameters (the number of generations and the mutation rate).We recorded data of minimum (worst) value, maximum (best) value, average value and exaction time in seconds. The average value measures the overall quality of the system output of 20 test runs, higher values representing improved solutions. The execution time is an indication of the computing resources consumed by the system. Because GA can search total solutions space instead of searching point to point of solutions space; the time of computation has reduced, that enhance the validity of Genetic fuzzy optimization system of the selection of research projects portfolio as a component of GDSS, as the number of decision variables and the objectives functions and the constraints of model increase. For a given set of parameters (the number of generations and the mutation rate), we execute system for 20 times, and results were recorded in all cases, then we analyze the output data by using the package of SPSS, that the result represent in Table 7. The graphs of "best", "worst" and average of fitness value were analyzed (Fig. 4).

Due to some chaotic characteristics exhibited by the statistical analysis of the output focused on determining the level of replication of the output for different input parameters. The range of values, frequency distribution, and the proportion of results that satisfy a certain range are the indices that can be used to determine the reliability of the genetic fuzzy optimization system of research project portfolio. The solutions for which the maximum output lie across the range of 85-100 percent of the best solutions, were also measured (Fig. 5).

Table 7- Performance data of 20 test runs.

For optimum degree: $\alpha = 0.5$					
Probability mutation: $p_m = 0.003$					
No. of generation / Statistic	100	200	300	400	500
Avg. fitness value	1.659	1.4623	1.8345	1.635	1.6932
Maximum fitness value	1.91	1.91	1.91	1.91	1.91
Minimum fitness value	.2093	.2093	.2093	.2093	.2093
Probability mutation: $p_m = 0.002$					
No. of generation / Statistic	100	200	300	400	500
Avg. fitness value	1.1359	1.345	1.4745	1.567	1.6932
Maximum fitness value	1.91	1.98	1.91	1.98	1.91
Minimum fitness value	.2093	.2093	.2093	.2093	.2093
Probability mutation: $p_m = 0.001$					
No. of generation / Statistic	100	200	300	400	500
Avg. fitness value	1.23	1.37	1.278	1.67	1.478
Maximum fitness value	1.98	2.76	1.957	2.45	2.76
Minimum fitness value	.2093	.2093	.2093	.2093	.2093

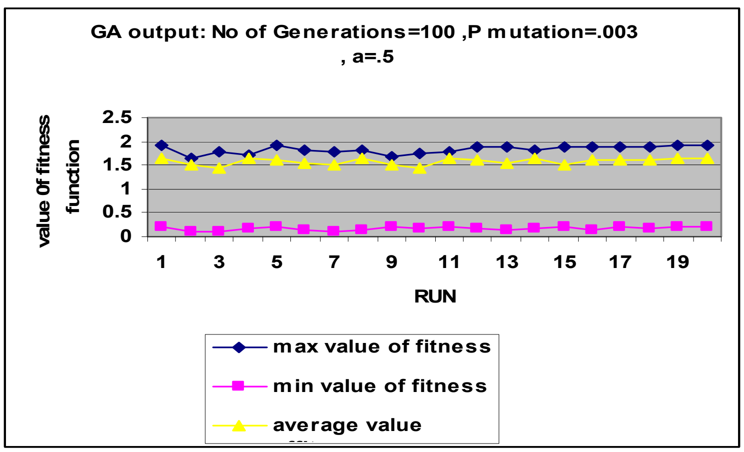

Fig. 4- Graph of GA output for 20 test runs.

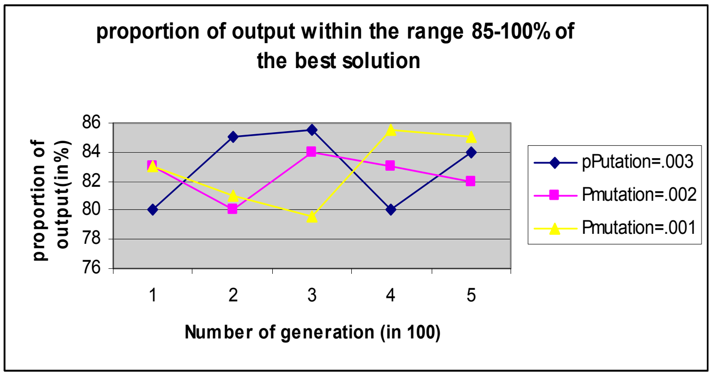

Fig. 5- Proportion of output within the range 85-100% of best solution.

Conclusions and Recommendation

In this article, we gave a genetic fuzzy system for evaluation and selection of research projects portfolio with purpose to help expertise and research panels in during the evaluation and selection of research projects and assignment of resources to them. From the results of the experiments, the following observations are made:

1. Combining fuzzy sets theory and genetic algorithm provide decision-makers with a realistic approach for evaluating and selecting of research projects. On the one hand, applying fuzzy sets theory in process of evaluating of research projects allow decision-makers that express linguistic preferences and subjective judgments about the proposed research projects. On the other hand, genetic fuzzy optimization system search more large space of solution and provide best solutions for decision makers. Because GA can search total solutions space instead of searching point to point of solutions space; the time of computation has reduced. The advantage of GA increase as an optimization technique related to other techniques with increasing the numbers of decision variables and objective functions and constraints (to be larger solutions space). As a result, the computational results demonstrate that integrating the GA algorithm and fuzzy approach can be a promising for research projects evaluation and selection.

2. Defining and applying different optimum degrees for ranking fuzzy numbers in order to select the most fitness of chromosomes for

next generation was enabled decision-making team to take better, satisfactory, consensual and flexible decisions and choices under uncertainty situation.

3. To Structure the ill-structure and complexity process of evaluation and selection of research projects by capturing uncertainty raised from decision-makers subjectivity by modeling qualitative aspects of research projects.

4. A cross-impact analysis was carried out to study the effects of changes in the optimization parameters on the output generated by the system during the different runs. It was observed that keeping one of the optimization parameters constant and varying the value of the other, did not result in a predictable output pattern.

In this article, we used a linguistic approach for acquiring the experts' knowledge and substituted the linguistic information of experts with triangular fuzzy numbers, then, we used OWA operator for integrating and aggregating of experts' knowledge and formalized a fuzzy fitness function for evaluating the fitness of solutions. For future researchers and to guide them to do more researches, we give the recommendation in the following description: 1- use LOWA operator for integrating and aggregating of experts' knowledge within future researches on research projects portfolio evaluation and selection process in order to be more near to human world and to make more realized decisions; 2- use propose methodology under situations that resources of organization are fuzzy; 3- researchers formalize linguistic objective functions and also linguistic fitness function in order to evaluate and select of the most fitness of research projects portfolio; 4- develop the model of fuzzy evaluation and genetic selection for evaluating and selecting of capital projects; 5- order to overcome the chaotic behavior of GA, were suggested that GA integrated with other techniques of AI.

References

Archer, N.P., and Ghasemzadeh, F. (2000) *Project portfolio selection through decision support*, Decision Support System, **29**, 73-88.

Gen, M., and Cheng, R., (2000) *Genetic algorithms and engineering optimization*, John Wiley & Sons, New York.

Herrera, F., Lopez, E., Mendana, C., and Rodriguez, M.A. (2001) *A linguistic decision model for personnel management solved with a linguistic biobjective genetic algorithm*', Fuzzy Sets and Systems, **118**, 47-64.

Chen, S. and Hwang, C. (1992) *Fuzzy multiple attribute decision making*, Springer-Verlag, Stuttgart.

Hurley, S., Moutinho, L., and Stephens, N.M. (1995) *Solving marketing optimization problems using genetic algorithms*, European Journal of Marketing, **29**(4), 39-56.

Khorshid, S., Lucas, C. and Mamariani, A. (2002) *A fuzzy approach for integrating experts judgment in MCDM*, In: Proceeding of the 4th Seminar on fuzzy sets and its' applications (ed. by Ameri, R.), University of Mazandaran, Babolsar, Iran, pp. 55-69.

Khorshid, S. (2002). *Design a model of fuzzy genetic for enhancing of the effectiveness of decision making teams decisions based on GDSS*, *Ph. D. Dissertation:* Faculty of Management, University of Tehran, Iran.

Oral, M., Kettani, O., and Cinar, U. (2001) *Project evaluation and selection in a network of collaboration: a consensual disaggregation multi-criterion approach*, European Journal of Operational Research, **130,** 332-346.

Robert, F. (1996) *OWA operator in decision making*. In: Exploring the limits of support system, (ed. by C. Carlsson), TUCS general publication, No. 3, Turku Centre for Computer Science, Abo, pp 85-104.