



## A stochastic-fuzzy multi agent model for scheduling and portfolio selection of project by considering environmental and economic resilience

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### Abstract

Aim of this research is to provide a stochastic fuzzy model for scheduling and selection of project portfolio in multi model sustainable and resilience condition. In real environments projects are executed in multi modes and the aim of sustainability maximization and resilience in project portfolio are pursued. For this goal librarian studies have been done based on this, a stochastic fuzzy programming model was implemented that aim to schedule and select sustainable and resilience project in multimode situation. Model was validated and was solved in small dimension. Then it was analyzed by two algorithms NSGAI and MOPSO. Results indicate that NSGAI has better performance than MOPSO and is more efficient. The most of influencing is on current value and then sustainability and resilience and sustainability is influenced by reinvestment similarly. But influencing current value from reinvestment rate is significant. Impact of loan interest on objective function is totally descending. It means if loan interest is increased all objective function can be decreased that resilience most of others and then sustainability and finally current value is decreased. It seems this function are decreased between 17 to 23 percent in 50 percent increase of loan interest.

**Keywords:** scheduling, portfolio selection, economic resilience, environmental resilience

**Paper Type:** Original Research

### 1. Introduction

The complexities of business environment have been led to increase in number of influencing factors in selection of project. Companies should make decision in a multi objective environment in order to optimize profit and risk in a multi period time horizon (Liu et al, 2019). Generally, managers encounter with some limitations in adoption of decisions about implementation of projects including prioritization and multi resource limitations. In addition, project has a significance impact on cash flow and flow of non-financial resource. Thus for decision makers, merging scheduling problems and selection is fruitful. If projects can be executed in multi-mode each mode create a net cash flow (Auoam and Venhok, 2019; Ayough et al. 2022). Multi modes project can be implemented in multi modes since using from technical methods, equipment's and resource in time horizon. Problem of selection and scheduling of project portfolio with multi-mode projects provide more options and can expand the feasible solution space. But project selection and scheduling problem has uncertainty space that in several research's the space is considered in scheduling and project selection problems. But dominant approach generally focusses on fuzzy approach and seldom focus on stochastic approaches that due to high uncertainty in such problems, combination of both techniques meaning using from stochastic and fuzzy hybrid approaches can cover uncertainty better and more and consider it. This concept is important since in the portfolio selection the uncertainty always exists and thus in order to encounter with uncertainty the various approaches of uncertainty should be used that fuzzy stochastic approach because of using from two approaches is more complete than fuzzy or stochastic approach single (Shafahi and Haghani, 2018; Ayough et al. 2023). The other subject that generally is considered in portfolio selection problem is sustainability one. but it is seldom observed that in hybrid of scheduling and selection the suitability is considered. This is while sustainability that is based on economic, environmental and social goals play the main role in scientific and application problems and various research and can create the better and more suitable condition for projects. Despite high attention to sustainable supply chain, in project issues it has not been considered too much (Wee et al, 2020) Another main note that is reviewed among literature just in one article is project resilience that

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like sustainability issue is more considered in supply chains and converse to sustainability concepts in project literature it is less considered. In other word we can say that there is less researches that consider both sustainability and resilience concepts in the literature of selection and project scheduling and this can be considered as a research gap. Resilience emphasize on the way of treating and coping projects with risks and consequences that can be very important in the subject of project portfolio selection (Tavana et al, 2019) Due to noted gaps the current research aims to model for scheduling and selecting multi model project portfolio by considering sustainability and resilience synchronically. For this goal a multi objective programming model is provided that its solution can be led to resilient and sustainable project selection. Optimization of project portfolio in current research is about oil projects. It is attempted to select best oil project in portfolio based on determined measures and also objectives and parameters in the research. Selection of projects based on sustainability and resilience will be done that each project that Is in highest level from the social responsibility and resilience and also to be in lowest level from the cost and environmental level is selected as optimized project in portfolio. Finally, research aim to respond to key question that how is the stochastic and fuzzy model for scheduling and selection of project portfolio with sustainability and resilience in multi-mode situation? All of above notes can explain the motivation of the research from scientific and applicable terms. The current research provides a model for portfolio selection using stochastic fuzzy approaches in order to contribute to literature and pave way for more research in this field and from the application view it can provide a model for project managers in order to select resilience and sustainable projects. The current paper is organized so that firstly literature review is done and based on this the research gap is extracted. Then the mathematical model is designed and after that findings analysis is done. In the end conclusion is provided.

## 2. Literature Review

In this section literature review during 5 recent years from 2019 until now is provided. The articles have similar concept to current research. Ma et al. (2019) adopt a 3 pillars of economic, environment and social responsibility for measurement and exploration of sustainability. Novak and Trezskalik (2020) consider a process of stochastic discrete multi objective programming by limited number of stages. Li et al (2020) studies a selection problem between cost and time for multi projects in which resource allocation decision and project scheduling is distributed so that project managers can optimize project and it is subject to a total budget for all projects. Diskit and Tiwari (2020) consider a case from a diary firm and include financial risks in the form of project uncertainty cash flows and evaluate strategic alignment scores and risk scores for organizational-legal and political of projects using a AHP process. Bi et al (2021) provide a methodology based on complex network theory in order to select a robust project portfolio under strategic goals. Fu and Zhu (2021) create a multi agent system in order to consider project scheduling problem because of private information concerns and independent nature of project factors. Bi et al (2022) propose a methodology for system dynamic model by considering dynamic strategies in order to predict strategic perception value through implementation of project portfolio. Mahmoodi et al (2022) propose a conceptual framework for project-based organization in order to select the most suitable portfolio based on the organizational resilience strategy. Panadro et al (2022) analyze the stochastic model of project portfolio selection. The aim of the research is to maximize the net current value while considering cash flows and discount rate in the future periods and also the strong set of limitations including maximal risk. Harisson et al (2022) proposes an applicable categorization of scheduling and project portfolio selection that including multi groups of proposed projects through various section of an organization. Harrison et al (2022) propose a new optimization model for scheduling and project portfolio selection as a part of army force process in the future in development of defense force capability development of Australia. Mohagheghi et al (2022) proposes a new mathematical model for selection of project sustainability. Ranjbar et al (2022) consider the portfolio selection among set of projects that should be scheduled from the contractor view. Mary and Omlin (2022) proposes a new utility function with sharp ratio that indicate risk and sustainability with governance, social and environmental scores. Tavakolan et al (2023) try to schedule and select project portfolio simultaneously from contractor perspective, Bai et al (2023) optimize project portfolio by considering cascading failure among projects. Forouzeshnejad (2023) optimize a hybrid data driven model for project portfolio selection problem based on sustainability and strategic dimensions: Vieira et al (2024) aim to review of terminology and approaches of project portfolio selection by considering interdependencies. Ramedani et al (2024) provide a two stage sustainable uncertain multi objective portfolio selection and scheduling considering conflicting criteria. Ayough et al. (2024), study addresses the Critical Chain Project Scheduling (CCPS) problem, emphasizing the feeding buffer's role alongside the project buffer – a less explored area. Researchers use a Mixed-Integer Nonlinear Programming (MINLP) model to identify the critical chain and analyze the feeding buffer's impact on activity criticality. Lingo software solves small instances, while a Genetic Algorithm (GA) tackles large-scale problems. The findings demonstrate how considering the feeding buffer leads to different critical chains and enables optimal management of activities and resources. Based on above literature review we can see that there is less research explores resilience and sustainability in selection and scheduling project portfolio synchronically that

can be contribution of current research. On the other hand, uncertainty in selection and scheduling problem generally is limited to using from fuzzy or stochastic approach that current research use from hybrid of fuzzy and stochastic approach. Other note that is considered as contribution of current research is paying attention to multi-mode situation in projects. Fourth contribution is to consider the combination of scheduling and selection of projects that despite in some researches is considered but they are not in the framework of sustainability and resilience and also the situation of multi-mode is seldom considered it can be the difference of current research and similar ones. It should be noted that current research considers the scheduling and project portfolio selection in multi agent's situation that is another contribution of current research.

### 3. Model

Project scheduling problem is one of the main problems in the field of industrial engineering, civil engineering and other branches based on project that is very popular among researchers and also is applicable very much. Such kind of modeling during the time have been changed too much and is enhanced so that there are the various forms of project scheduling on the models that are implemented. One of the approaches is sustainable one the despite conducted researches in the field it is observed that has many applications. In such scheduling there are 3 objectives of sustainability: minimizing costs, minimizing environmental issues and maximization of social responsibility in project scheduling model. In the other work researcher in such model only does not attempt to minimize time but other objectives are considered by him too. Beside sustainability problem, being multi modes for a project can be important too. Usually in project scheduling we can see that multi modes of activities are considered this is while in optimization problem for project portfolio because of existence multiple projects we can consider the multi modes activities. It means a project can be executed in multi modes. On the other hand, resilience issue about project is another subject that can help to literature since as the sustainability and sustainability of projects can be a criterion for selection of a project in portfolio resilience and coping level of a project against risk can be a criterion for selection of project in portfolio. Project multi agency is considered as a main criterion. A project may be implemented by the various agents and each one due to his or her managerial methodology impose the different cost and time to project. Due to the fact that multi agency can be observed in some works but about sustainability and resilience and also selection of project portfolio and scheduling this subject is considered less. Finally, the uncertainty is proposed that can be existed in time and cost parameters. Due to the fact that stochastic and fuzzy models because of perfection and uncertainty can be suitable models about project scheduling and project portfolio thus such models can be provided about project scheduling and sustainable project portfolio. The current research due to above items try to propose a model with above characteristics. Parameters of execution time and project construction time are both stochastic and fuzzy since they have high uncertainty and in order to consider this uncertainty they are considered both stochastic and fuzzy. assumptions are in as following:

1. Parameter of execution time and project execution is uncertainty and from stochastic style
2. Model is multi periodic
3. Model is 3 objectives that first and second objectives is related to sustainability and third one include resilience
4. Each project can be executed in the various modes
5. Each mode has its time and cost of execution
6. Economic parameters for calculation of project net current value are considered
7. Wastes are categorized to inert active and sellable wastes

$i = 1 \dots N$	projects
$t = 1 \dots T$	Monthly periods
$y = 1 \dots Y$	Yearly periods
$k = 1 \dots K$	Inert wastes
$h = 1 \dots h$	Active wastes
$a = 1 \dots A$	Sellable wastes
$l = 1 \dots L$	load

$m = 1 \dots M$	Project mode
$ag = 1 \dots AG$	agent
$r^1$	Discount rate
$r^2$	Reinvestment rate
$r^3$	Loan interest rate
$r^{re}$	Tax rate
$r^e$	Tax on carbon rate
$r_{ia}^w$	Selling price of waste a produced by project i
$Lr$	Tax on landfill rate for each tone of inert waste
$Sr$	Tax on landfill rate for each active tone
$pLr$	Increasing rate in LR
$pSr$	Increasing rate in SR
$pe$	Increasing rate in Re
$\delta_{ikm}^1$	Level of inert waste k produced by project I under mode of m in each period from execution stage
$\delta_{ihm}^2$	Active waste level of h produced by project I under mode m in each period of execution stage
$\delta_{iam}^3$	Level of sellable waste a produced by project I under mode m in each period in execution stage
$Y_{im}$	Level of pollution emission produced by project I under mode of m in each time period
$\tilde{d}_{ism}^1$	Project stage time under mode m under scenario of s
$\tilde{d}_{ism}^2$	Project execution stage time during under mode m under scenario s
$Cf_{iag}$	Project net cash flow attained by agent ag in each period of execution
$C_{iag}$	Project cash flow cost I in each period from stage by agent ag
$SV_i$	Scrap value of project i
$De_i$	Project depreciation cost in each time of execution phase
$IO_i$	Required time for starting project phase
$\beta$	Available primary budget
$D_l$	Available loan level for each project
$Q_{il}$	Repayment time duration for each loan
$\psi_l$	Number of periods after construction phase of each project until repayment of loan can be deferrable
$SP_{im}$	Project sustainability score under mode m
$RES_{im}$	Project resilience under mode m
$ST_i$	Start time for project i

$FN_i$	Finnish time for project i
$R_t$	Received net cash flow in period t
$EX_{tag}$	Total cost in period t by agent ag
$E_t$	Surplus money in period t invested in period t+1
$DC_{it}$	Depreciation cost of project I in period t
$\tau_{iy}^{re}$	Tax on income paid by project I in year y
$\tau_y^e$	Tax on carbon paid in year y
$\tau_y^w$	Tax on deletion in year y
$TM_{it}$	Total level of repaid loan for project I in period t
$TI_{it}$	Total repaid loan interest for project I in period t
$X_{itm}$	If project I in period t under mode m is started 1 and else zero
$Y_{imag}$	If project I under mode of m is selected by agent ag 1 and else zero
$\beta$	Total allocated budget
$F_{ilt}$	Level of received loan for each project I in period t

$$\max z1 = \left( E_T \left( \frac{P}{f} \cdot r^1 \cdot T \right) \right) - \beta' \quad (1)$$

Above formula indicate the first function that aim to maximize the net current value of final wealth in the last programming horizon

$$\max Z2 = \sum_{i=1}^N \sum_{m=1}^M SP_{im} Y_{im} \quad (2)$$

Above formula indicate second function that aim to maximized sustainability score of selected portfolio from project

$$\max Z3 = \sum_{i=1}^N \sum_{m=1}^M RES_{im} Y_{im} \quad (3)$$

Above formula aim to maximize resilience of selected portfolio

$$TM_{it} = \sum_{l=1}^L \sum_{\theta} \frac{F_{il\theta}}{Q_{il}} \quad (4)$$

Above formula calculate principal repaid loan for each project in each period under each scenario

$$TI_{its} = \sum_{l=1}^L \sum_{\theta} \frac{(1+r_l^2) \cdot F_{il\theta}}{Q_{il}} - TM_{it} \quad (5)$$

Above formula calculate the level of repaid loans by each project in each period and under each scenario

$$R_t = \sum_{l=1}^N \sum_{\theta} CF_{iag} X_{i\theta m} \quad (6)$$

Above formula calculate cash flow retained by implementation projects in time period under each scenario

$$\sum_{t=0}^T X_{itm} \leq 1 \quad (7)$$

Above formal ensure that if a project is selected it just scheduled once

$$\sum_{m=1}^M Y_{imag} = 1 \quad (8)$$

Above formula indicate that each project can be executed under one mode

$$\sum_{ag=1}^M Y_{imag} = 1 \quad (9)$$

Above formula indicate each project can be executable just by one agent

$$ST_i = \sum_{t=0}^T t X_{itm} \quad (10)$$

Above formula determine the starting time of a project

$$FN_i = \sum_{t=0}^T (t + \tilde{d}_{im}^1 + \tilde{d}_{im}^2) X_{itm} \quad (11)$$

Above formula determine finish time of a project

$$FN_{is} \leq T \quad (12)$$

Above formula ensure that finish time of a project under each scenario is before the end of planning horizon

$$\tau_y^e = \sum_{i=1}^N \sum_t \sum_{\theta} (Y_{imag} r^e p e^{(y-1)} X_{i\theta m}) \quad (13)$$

Above formula calculate the level of tax on carbon paid in each year under each scenario

$$EX_t = \sum_{i=1}^N \sum_{\theta}^{t-1} C_{iag} X_{i\theta m} \quad (14)$$

Above formula calculate the implementation cost for selected projects in each period under each scenario

$$\sum_{i=1}^N \sum_{l=1}^L F_{ilt} \beta' = \sum_{i=1}^N IO_i X_{itm} E_t \quad (15)$$

Above formula balance input and output flows under each scenario

$$\sum_{i=1}^N \sum_{l=1}^L F_{ilt} + R_t + E_{(t-1)}(1+r^3) + \sum_{i=1}^N SV_i X_{itm} - E_t + \sum_{a=1}^A \sum_{i=1}^N \sum_{\theta} (\delta_{iam}^3 r_{ia}^w) X_{i\theta m} = EX_{tag} + \sum_{i=1}^N DC_{it} \quad (16)$$

$$+ \sum_{i=1}^N IO_i X_{itm} + \sum_{i=1}^N (TM_{it} + TI_{it})$$

Above formula balance input and output flows in all periods except zero period and last month of each year under each scenario

$$\sum_{i=1}^N \sum_{l=1}^L F_{ilt} + R_t + E_{(t-1)}(1+r^3) + \sum_{i=1}^N SV_i X_{itm} \quad (17)$$

$$+ \sum_{a=1}^A \sum_{i=1}^N \sum_{\theta}^t (\delta_{ia}^3 r_{ia}^w) X_{i\theta m} - E_{ts}$$

$$= EX_{tag} + \sum_{i=1}^N DC_{it} + \sum_{i=1}^N IO_i X_{itm}$$

$$+ \sum_{i=1}^N (TM_{it} + TI_{it}) + (\tau_{12}^e + \tau_{12}^w)$$

$$+ \sum_{i=1}^N \tau_{it/12}^{re}$$

Above formula balance input and output flows of last month each year under each scenario

$$DC_{it} = \sum_{\theta}^t De_i X_{i\theta m} \quad (18)$$

Above formula calculate depreciation cost of each project in each period under each scenario

Above formula calculate the level of paid tax for deletion of wastes that cannot be usable in each year under each scenario

$$\tau_{iys}^{re} = \sum_t^y \sum_{\theta}^t \sum_m ((cinf_{iag} - De_i) X_{i\theta m}) r^{re} \quad (19)$$

$$- \sum_t^y TI_{it} r^{re}$$

Above formula calculate tax on income level paid by each project in each year under each scenario

$$F_{ilt} \leq D_l X_{itm} \quad (20)$$

Above formula indicate that loan received by each project in each period under each scenario cannot be higher than certain value

$$\sum_{t=0}^T X_{itm} = Y_{im} \quad (21)$$

Above formula ensure only selectable project can be schedulable

$$' \leq \beta \beta \quad (22)$$

Above formula ensure that investment amount in zero period should be less or equaled with available budget

### 3.1 Stochastic fuzzy model

Current research aims to propose a fuzzy stochastic model that construction time and project execution time in the various modes in uncertainty condition are considered. For this goal we use from stochastic and fuzzy approach for handling uncertainty. Due to the fact that one constrains include uncertain parameters and it calculate finish time of project the limitation can be converted to another formula

$$FN_i = \sum_{t=0}^T (t + \tilde{d}_{im}^1 + \tilde{d}_{im}^2) X_{itm} \quad (23)$$

For de-fuzziation the above formula based on stochastic fuzzy model use from below formula

$$FN_{i1} = \sum_{t=0}^T (t + d_{im1}^1 + d_{im1}^2) X_{itm} \quad (24)$$

$$FN_{i2} = \sum_{t=0}^T (t + d_{im2}^1 + d_{im2}^2) X_{itm} \quad (25)$$

$$FN_{i3} = \sum_{t=0}^T (t + d_{im3}^1 + d_{im3}^2) X_{itm} \quad (26)$$

$$d_{imn+1.1}^1 \geq d_{im1}^1 \quad (27)$$

$$d_{imn+1.2}^1 \geq d_{im2}^1 \quad (28)$$

$$d_{imn+1.3}^1 \geq d_{im3}^1 \quad (29)$$

$$d_{imn+1.1}^2 \geq d_{im1}^2 \quad (30)$$

$$d_{imn+1.2}^2 \geq d_{im2}^2 \quad (31)$$

$$d_{imn+1.3}^2 \geq d_{im3}^2 \quad (32)$$

### 4. Solution methodology

In current paper for solution of model NSGAI algorithm has been used. NSGAI is considered as one of the most applicable and strong algorithm for solution of multi objective optimization problem and its efficiency has been proved in several problems. In 1995 NSGA optimization method has been introduced for solution of optimization problems that has multi objective characteristics. The main notes that can be referred about such optimization method include following items

The answer that no other answer is not better than it, has more score. Answers are sorted based on the fact that there is multiple answer better than this. Fitness for answers are allocated based on their ranking and not domination on other answers. The fitness sharing method is used for closed answers in order to regulate answers disperse desirably and the answers uniformly are diffused in search space.

Due to high sensitivity that performance and quality of NSGA algorithm indicate toward fitness sharing parameters and other ones, the version 2 of NSGA with metaheuristic algorithm of NSGA-II in 2000. Beside all efficiencies of metaheuristic NSGAI we can consider this as a formation model for several multi objective optimization algorithm. The algorithm and its exclusive methodology in treating with multi objective optimization is used more by various people in order to create newer optimization algorithm. No doubt the algorithm is one of the most fundamental members of evolutionary multi objective algorithm collection that we can consider them as the second generation of such methodologies. The significant characteristics of such algorithm include

- 1- Definition of compression distance as a replaced characteristic for methodologies like fitness sharing
- 2- Using from tournament selection operator
- 3- Storage and archiving the non-dominated answers that are achieved in pervious stages of algorithm

In fact, NSGAI algorithm is a multi-objective genetic algorithm on based which the no dominated answers are designed so th at in single objective genetic algorithm the only one objective function is considered as fitness function and its decision variable are entered as gene to chromosome and form the primary population. But in NSGAI algorithm we are faced with multi objective and the algorithm are designed for solution of multi objective problems. In this algorithm the comparison between 2 or more answers for each chromosome are done and the best one can be gained. The answers can be led to pareto front or pareto curve. In this curve or front the best answers that are considered as dominated answers and no other answer can dominate them are put and there is no difference among gained points in this front. The difference of the algorithm with classic genetic algorithm is that in this algorithm the multi objective operation that include non-dominated sorting and also formation of pareto front and comparison among answers will be shaped. While in classic genetic algorithm there is no such situation.

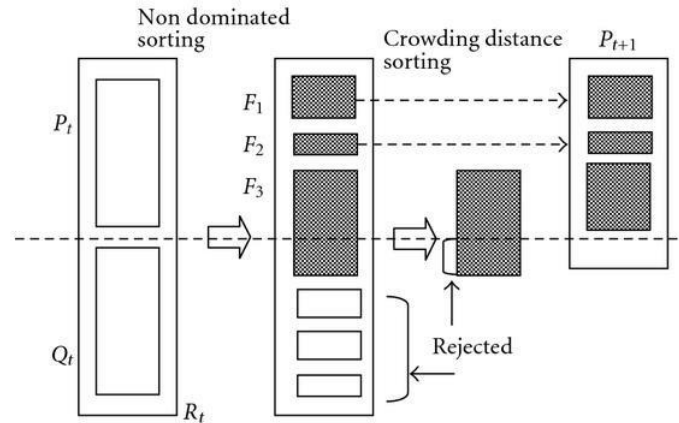


Figure 1. total schematic of NSGAI

In this research a binary chromosome is defined for binary variable and an integer chromosome is defined for integer variables . example of binary chromosome is as following:

1	0	1	1	0	0	1	0	1	1
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Firstly, a random solution is defined for binary chromosome then by using from updating process the binary chromosome will be changed. Two operations of updating process include crossover and mutation. For binary chromosome we use from single point operation for both crossover and mutation.

Another chromosome type is integer one that is shown as following:

241	321	159	188	211	257	333	451	179	201
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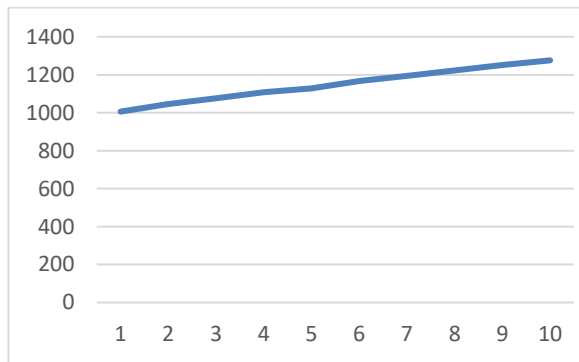
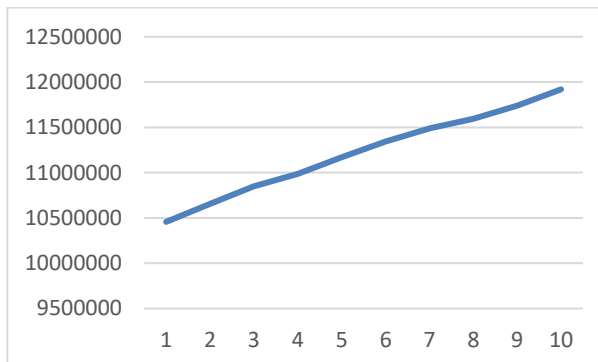
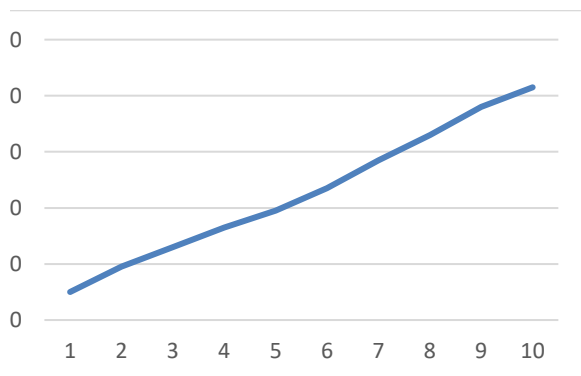
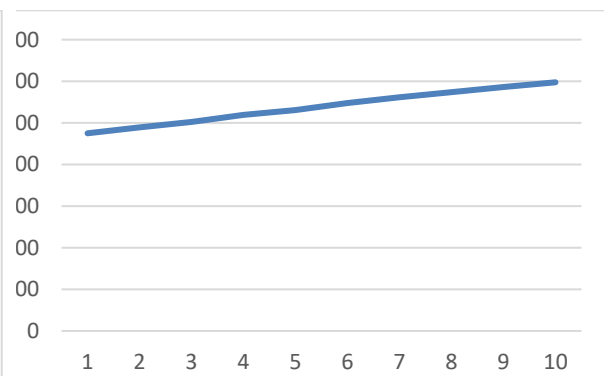
### Finding analysis

In this section we explore the validation of model. Validation is considered as one of the most important part of optimization model which on based the model validity is confirmed. For this goal, the model is solved in various dimensions and if the value of calculation time and functions are increased, we can say that model has required validity. Firstly, the problem dimensions are introduced.

**Table 1.** problem dimensions

NO	projects	Monthly pe- riods	Yearly peri- ods	Inert wastes	Active wastes	Sellable wastes	loan	Project modes	agent	scenario
1	5	5	1	1	1	1	1	1	1	1
2	7	5	1	1	1	1	1	1	1	1
3	9	6	2	2	2	1	1	1	2	1
4	10	7	2	2	2	1	2	2	3	1
5	12	8	3	3	3	2	2	2	4	2
6	14	9	3	3	3	2	2	2	4	2
7	15	10	4	4	4	2	3	3	5	2
8	17	11	4	4	4	2	3	3	5	2
9	19	12	5	5	5	3	3	3	5	3
10	20	12	5	5	5	3	4	4	6	3
11	22	13	6	6	6	3	4	4	6	3
12	23	14	6	6	6	3	4	4	6	3
13	25	15	6	6	6	3	4	4	7	3
14	27	17	7	7	7	3	5	5	7	3
15	28	18	7	7	7	4	5	5	7	4
16	30	20	7	7	7	4	5	5	8	4
17	32	22	8	8	8	4	5	5	8	4
18	33	23	8	8	8	4	5	5	8	4
19	35	25	8	8	8	4	5	5	8	4
20	40	30	8	8	8	4	5	5	8	4

As we can observe 20 examples are introduced in which the problem dimension are increased than pervious problem therefore we can say that objective function values in each problem than pervious problem should be increased and this is the logical result of solution. For testing the procedure, the problem is solved in 20 examples and the results is shown as following:

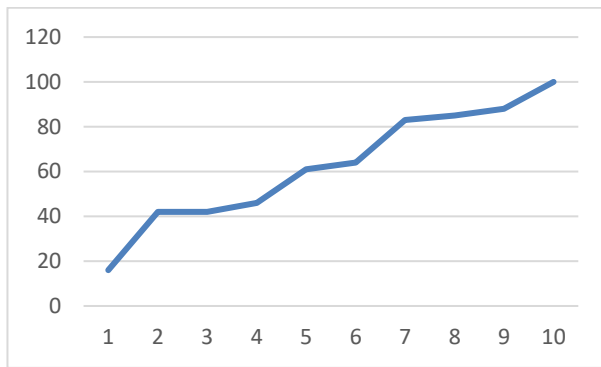
**Figure 2.** increasing the second function after dimension increasing**Figure 1.** increasing the first function after dimension increasing**Figure 4.** increasing the calculation time after dimension increasing**Figure 3.** increasing the third function after dimension increasing

As we see by increasing dimension both objective function and calculation time is increased thus we can say model is valid since the logical result of model solution in various dimension is to increase the time and objective function values. This can be seen about 10 problems that can be solvable with exact method. We use from metaheuristic algorithm for model solution. Due to defect of exact methodology in model solution the metaheuristic algorithm is used. The NSGAI algorithm is used for removal of defect. We explore the gap analysis and comparison between to used solution methodology based on table and figures.

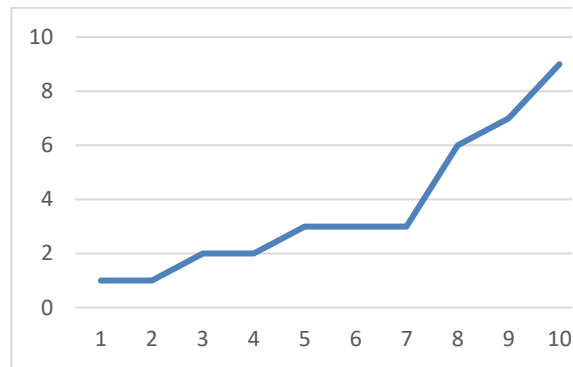
**Table 2.** analysis of gap between genetic algorithm and exact method

NO	epsilon constraint			Genetic algorithm				Gap analysis				
	Current value of final wealth	sustainability	resilient	Calculation time	Current value of final wealth	Sustainability	resilient	Calculation time	Current value of final wealth	sustainability	resilient	Calculation time
1	10456852	1006	950	10	10456836	1005	949	10	16	1	1	0
2	10654245	1045	978	19	10654203	1044	975	18	42	1	3	1
3	10849883	1076	1005	26	10849841	1074	1001	24	42	2	4	2
4	10987582	1109	1038	33	10987536	1107	1034	30	46	2	4	3
5	11169699	1129	1061	39	11169638	1126	1057	36	61	3	4	3
6	11345172	1168	1096	47	11345108	1165	1092	43	64	3	4	4
7	11488647	1194	1123	57	11488564	1191	1118	53	83	3	5	4
8	11595257	1223	1148	66	11595172	1217	1141	62	85	6	7	4
9	11740892	1251	1172	76	11740804	1244	1164	71	88	7	8	5
10	11920000	1276	1195	83	11919900	1267	1186	78	100	9	9	5
11	.....	.....	.....	low memory	12091078	1302	1224	85	.....	.....	.....	.....
12	.....	.....	.....	low memory	12250103	1325	1247	90	.....	.....	.....	.....
13	.....	.....	.....	low memory	12390741	1365	1286	99	.....	.....	.....	.....
14	.....	.....	.....	low memory	12496964	1398	1318	104	.....	.....	.....	.....
15	.....	.....	.....	low memory	12631295	1426	1354	114	.....	.....	.....	.....
16	.....	.....	.....	low memory	12794010	1458	1382	123	.....	.....	.....	.....
17	.....	.....	.....	low memory	12987762	1491	1407	128	.....	.....	.....	.....
18	.....	.....	.....	low memory	13097069	1523	1434	134	.....	.....	.....	.....
19	.....	.....	.....	low memory	13278743	1559	1456	143	.....	.....	.....	.....
20	.....	.....	.....	low memory	13385529	1581	1494	153	.....	.....	.....	.....

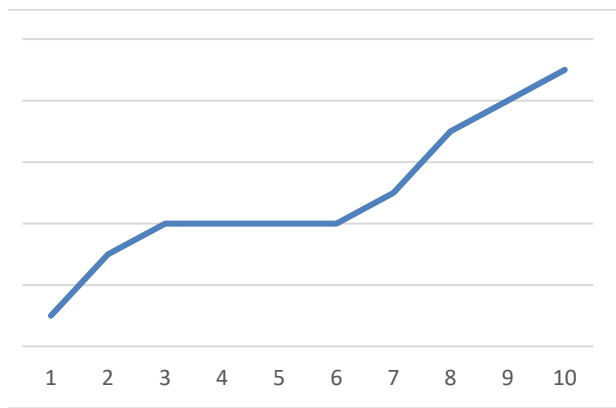
As we observe NSGAI is able to solve model in higher dimension and the error of exact method is tackled by the algorithm. Gap between 2 methodologies is depicted in following figures.



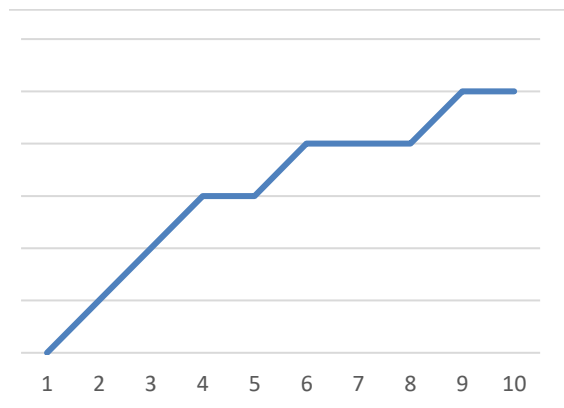
**Figure 5.** gap analysis between genetic algorithm and exact methodology about objective function 1



**Figure 6.** gap analysis between genetic algorithm and exact methodology about objective function 2



**Figure 7.** gap analysis between genetic algorithm and exact methodology about objective function 3



**Figure 8.** gap analysis between genetic algorithm and exact methodology about calculation time

As we see in above figures by increasing dimensions, gap between 2 algorithms of exact and NSGAI is increased and this indicate the better efficiency of NSGAI algorithm in achieving to optimal solution specially while increasing model dimensions

In order to better selection of algorithm the MOPSO algorithm is used beside NSGAI. The algorithm is considered as a strong one like NSGAI algorithm that is formed based particle intelligence. In following table, the performance of both algorithm is compared based on four measures of pareto front, distance to ideal point, congestion distance and calculation time. The analysis is as following.

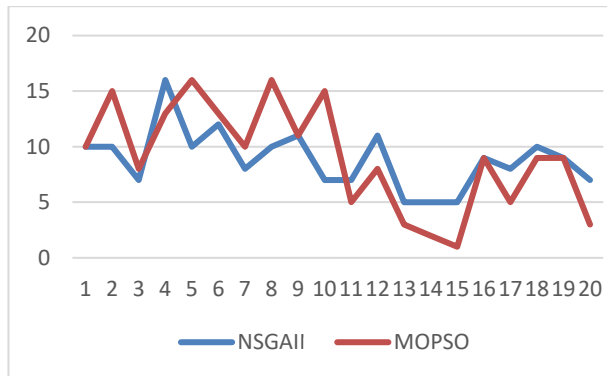


Figure 9. comparison of NSGAI and MOPSO based on pareto front

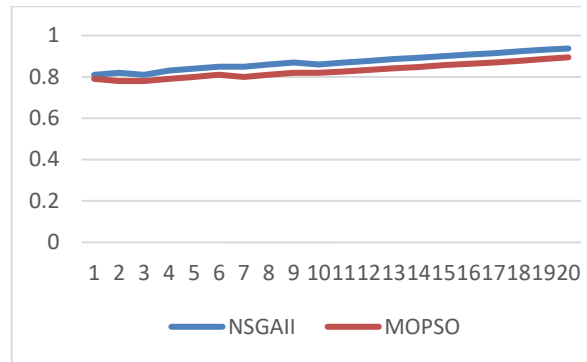


Figure 10. comparison of NSGAI and MOPSO based on distance to ideal point

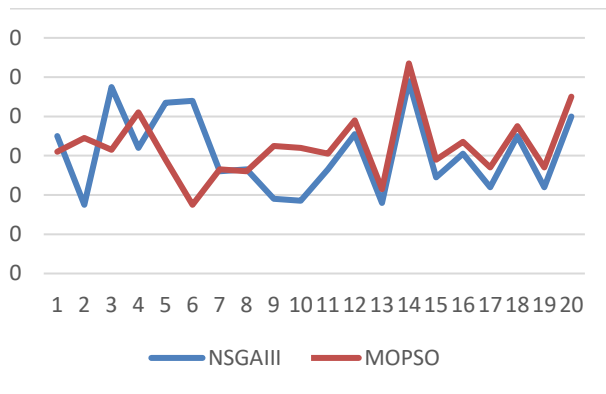


Figure 11. comparison of NSGAI and MOPSO based on congestion point

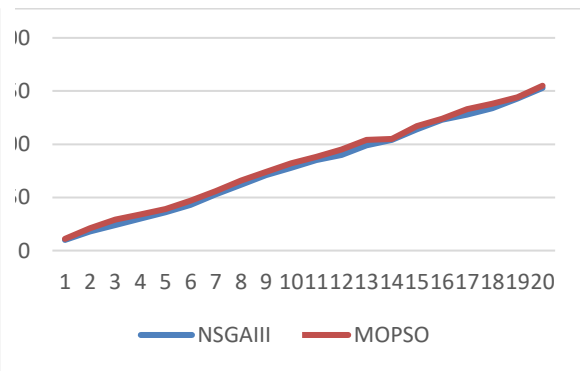


Figure 12. comparison of NSGAI and MOPSO based on calculation time

As we can observe from figure 9 blue chart in high dimension and final examples produce more pareto points than MOPSO that indicate the superiority of algorithm. Since in production of pareto points NSGAI has better performance from production of pareto points. About distance to ideal point we can see that MOPSO in all examples is in better situation and is superior than NSGAI. Therefore we can say that from the distance to ideal point, MOPSO is more efficient. In figure 11 we can see that NSGAI algorithm is better than MOPSO because congestion distance is created less in most of the examples and for this reason efficiency about this criterion is in better position. About congestion distance each algorithm that has lesser congestion distance is superior. Therefore, from congestion distance NSGAI is superior than MOPSO. In figure 12 we can observe calculation time for NSGAI is less than MOPSO. Therefore, we can say that NSGAI is more efficient. Although by increasing dimensions' calculation time for both algorithms are increased but NSGAI totally is superior than MOPSO. The results show that except distance to ideal point, in 3 other criteria NSGAI algorithm is more efficient than MOPSO and is considered as superior algorithm in this research that analysis can be done based on this. While we can tackle the defect of exact algorithm.

### 4.1 Sensitivity analysis

In this section parametrical sensitivity analysis is conducted. In sensitivity analysis some parameters that has direct impact on model is explored and model response to them is analyzed. In this section some main parameters are analyzed. Results are indicated in following figures:

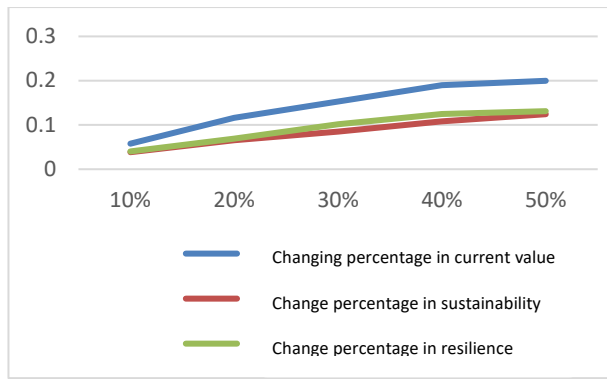


Figure 13. sensitivity analysis of discount rate

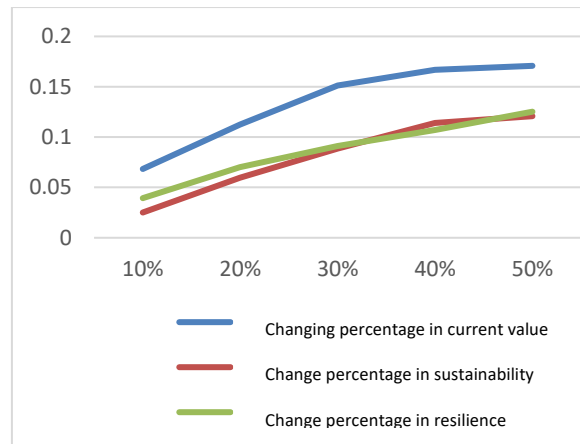


Figure 14. sensitivity analysis of reinvestment rate

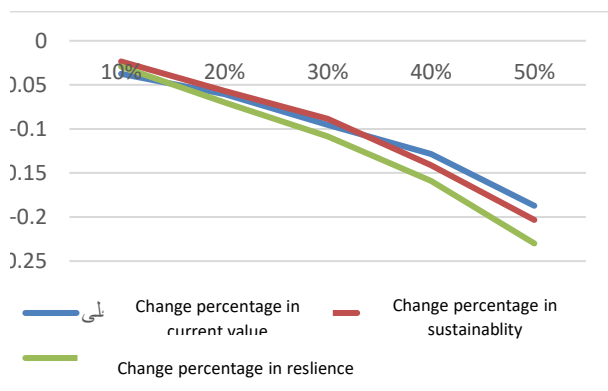


Figure 15. sensitivity analysis of loan interest rate

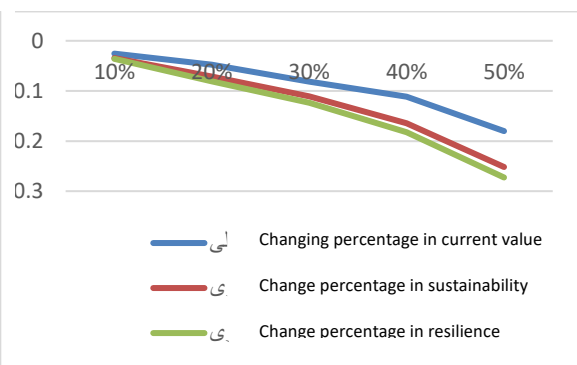


Figure 16. sensitivity analysis of income tax

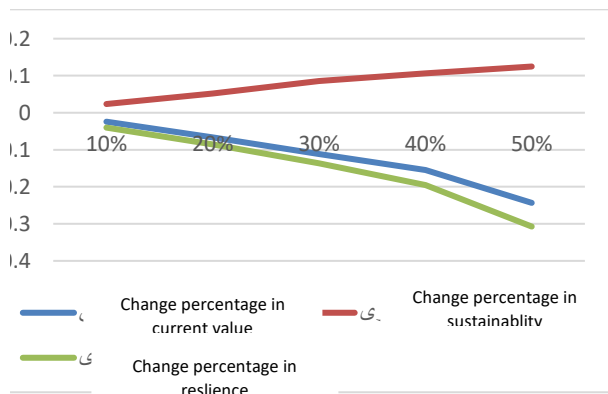


Figure 17. sensitivity analysis of carbon tax

In this section impact of discount rate on objective function are explored. Results indicate that increasing discount rate has the highest impact on current value and can increase the current value while increasing 50 percentage of discount. It impacts on resilience and sustainability too. This is while influencing on sustainability is more than resilience. The interesting note is that pattern of influencing is descending. It means firstly influencing patters is ascending than it become flat. About reinvestment rate we can see the positive impact of it on objective function. It should be noted that most of influencing is on current value and then sustainability and resilience. Of course resilience and sustainability is influenced by reinvestment similarly. But influencing current value from reinvestment rate is significant In figure 15 we can see that impact of loan interest on objective function is totally descending. It means if loan interest is increased all objective function can be decreased that resilience most of others and then sustainability and finally current value is decreased. It seems this function are decreased between 17 to 23 percent in 50 percent increase of loan interest. Therefore, rate of loan interest is among parameters that can be led

to decrease objective function. In figure 16 we can observe that tax on income rate has the negative impact like interest rate on objective function so that resilience is decreased more than 2 other objective function from tax on income rate. Sustainability and finally current value of projects are influenced. In figure 17 we can see that tax on carbon has the negative impact on resilience and current value but it can increase sustainability too since tax on carbon influence on environment and reduction of population and thus it can increase the resilience score of project. Therefore, some projects can be selected that has lower carbon and finally lower tax on carbon. Uncertainty analysis is done. Due to 3 scenarios in current research and due to the fact that duration of each project is defined under various scenario in this part we explore that increasing duration time have what kind of influencing on objective function in various scenario. Results are as following:

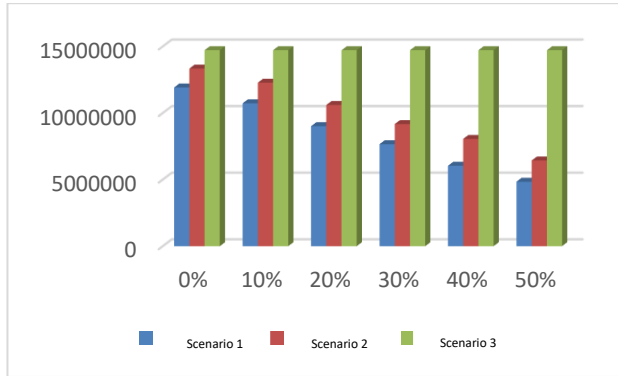


Figure 18. analysis of duration uncertainty of each project about objective function one

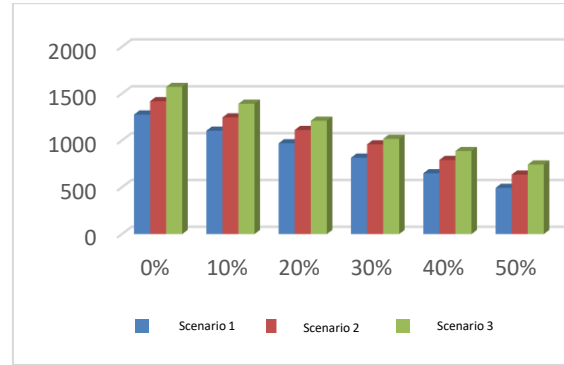


Figure 19: analysis of duration uncertainty of each project about objective function two

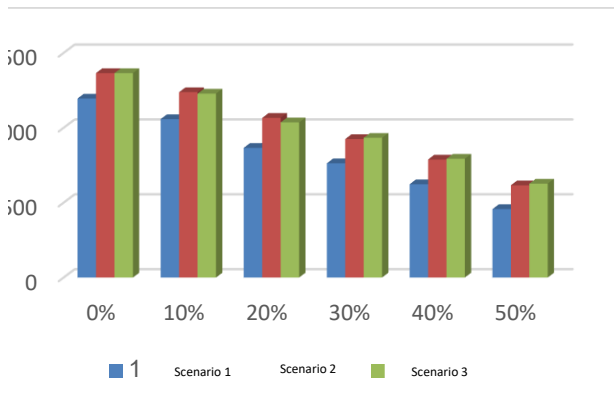


Figure 20. analysis of duration uncertainty of each project about objective function three

As we can observe in figure 18 scenario 3 is the best one fore objective function one since highest level of current value is attained under the scenario. While scenario 2 indicate middle mode and scenario 1 is the weakest one since lowest level of current value is gained. This affair indicates that increasing duration of project can influence on current value function in the various scenario. As we observe in figure 19 similar to current value mode about sustainability, by increasing duration of project the best scenario is scenario 3 and worst one is scenario 1. It means highest level of sustainability in scenario 3 and lowest one is in scenario 1. About resilience it seems there is a difference than 2 pervious figure so that scenario 2 , 3 is almost same and even in some cases scenario 3 is weaker than scenario 2. Therefore, about resilience we cannot say exactly scenario 3 is in the best mode but scenario 1 is in weakest mode among existed scenario.

### 5. Conclusion

Fuzzy stochastic model in the current research by considering construction time of project in uncertainty condition is provided and aim to selection projects that has higher sustainability and resilience and also they are done in various modes. Therefore, a 3 objective function model was designed that first one was maximization of current value and in fact it seeks to an economic objective and 2 other objectives include sustainability and resilience. The hybrid model of scheduling and sustain able portfolio project selection in current research despite aim to minimize the duration of project in portfolio they put some project in portfolio that have highest sustainable indicate meaning

environmental and social aspects. Therefore, both duration of all project in current research can be minimized and project with highest sustainability can be selected. The hybrid model of scheduling and portfolio project selection for resilience can act as sustainability so that projects that are selected are ones that have highest score of sustainability and of course scheduling of all projects in portfolio are minimized. It means duration of projects can be reached to lowest level. In fuzzy stochastic approach in current research construction and execution duration of project are considered as uncertain and in order to handle the mode, the fuzzy stochastic approach is used. Therefore, limitations that include construction and execution duration of project are converted to deterministic limitation based on fuzzy stochastic model in current research In multi-mode model it is assumed that project can be done in various modes. Of course multi-mode model exists for doing activities in various modes in which it is assumed each activity may have 2 modes of machine or hand. But in current research it is assumed there are multi modes for execution of projects and not activities and such modes influence on cost and duration of projects. As a result, it is tired to select some modes for doing each project that can optimize duration, cost, sustainability and resilience. Duration and cost should be minimized and sustainability and resiliency should have maximized. About multi agency it should be noted that in current research there are several agents for each project and thus each agent can have its managerial methodology that can impost various duration and const. since the goal of project portfolio is considered some projects should be selected that is optimal from agent point of view. It means the way of agent management should be so that selection of them can be led to optimization of project portfolio. In current research an agent can be allocated to each project and based on this some parameters can be changed Based on finding of current research, there are some proposes for future research

- 1- Development of stochastic fuzzy model to other parameters like cost parameters
- 2- Adding other components to model
- 3- Using from other metaheuristic algorithm beside existed algorithm and comparison of results
- 4- Using from 2 staged approach in solution of model like using from hybrid of DEA and mathematical programming in order to analysis project efficiency and then selection of portfolio based on this

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