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Research Article

A Fuzzy Approach for Generalized Project Selection and Scheduling Problem with Resource Management

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Abstract

In this study, the problem of project selection and scheduling with resource management is considered project setup times, dynamic project arrivals, priorities and relationship between projects. A fuzzy multi-objective mixed integer linear programming (MILP) model is proposed for the solution of the problem. The classic two-phase fuzzy goal programming (FGP) approach is modified to solve the proposed multi-objective MILP model. The addressed problem is defined over the project selection and scheduling problem of a construction company. The effect of resource management on the project selection and scheduling problem is demonstrated over the generated test problems. Modified two-phase FGP and classic two-phase FGP approaches are compared over test problems. With the use of the modified two-phase FGP approach, additional alternative solutions are found for the problem.

Keywords

Project selection and scheduling, Modified two-phase fuzzy goal programming, Fuzzy multi-objective mathematical model, Resource management, Dynamic project arrivals

1. INTRODUCTION

Project selection and scheduling (PSS) is an important decision problem for organizations. Due to limited resources, it is not possible for an organization to carry out all its projects in a certain period of time [1]. Organizations have to choose and schedule the project portfolio that will optimize their objective(s) among set of projects [2-3].

By the project selection problem, projects to be realized in a certain time period are selected from among all projects. By the project scheduling problem, starting period of selected projects

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are determined [4]. Addressing PSS problems independently or sequentially causes sub-optimal solutions and inefficient resource utilization [5]. The problem of PSS has begun to be taken into account simultaneously [6-7].

The problem of PSS is a resource constraint optimization problem. In other words, the current resource amount of the organization can not be exceeded for each periods. By the PSS problem the obtained results are optimal according to available amount of resources, but it is not sufficient for the organization to get optimal results in terms of resource management (RM) [5]. If RM is not considered, the amount of resources in each period is considered constant and equal to initial resource amount. As a result of ignoring the RM, it is possible to say that the organization keeps the unnecessary resources in some periods or it is not possible to increase the amount of income by increasing the amount of resources in certain periods. With the RM, it is decided the amount of pre-determined resources for each period. RM should also be considered in the problem of PSS in order to optimize the objectives of the organizations and optimal resource utilization. By the solution of the PSS with RM problem, the projects are selected, starting times of the projects are determined and the amount of resources in each period are identified.

In this study, PSS with RM problem is addressed. The problem is generalized by taking into account real-life constraints. Dynamic project arrivals, project setup times, priorities and relationships between projects and fuzzy nature of the problem are considered.

This study is different and original from the literature with the following features:

i. The problem of PSS with RM is generalized by taking into account dynamic project arrivals, project setup times, project priorities, relationships between projects and fuzzy nature of the problem. There is no study dealing with all these aspects of the problem.

ii. The importance of RM on PSS problem is demonstrated through test problems.

iii. Two-phase FGP approach is modified for the solution of the problem. The comparison of the classic and modified two-phase FGP approach is conducted over the test problems.

The article consists of five sections. The first section is the introduction. In the second section, literature review is given. In the third section, the proposed mathematical model and modified two-phase FGP model are presented. Section four is the results and discussion section. The last section is the conclusion section.

2. LITERATURE REVIEW

Studies considering PSS problem are examined. Coffin and Taylor (1996), addressed a heuristic algorithm for PSS problem [8]. Ghasemzadeh et al. (1999), proposed a mathematical model for the PSS problem. Interdependencies between projects were taken into account [9]. Gutjahr et al. (2008), discussed the problem of project selection. Then, they examined project scheduling and staff assignment problems as sub-problems. They have followed a sequential approach. Heuristic algorithm was proposed to solve the problem [10]. Carazo et al. (2010), addressed the problem of PSS with different relationships between projects. Multi-objective scatter search algorithm was proposed for the problem [11]. Liu and Wang (2011), considered time-dependent resources for PSS problem. Constraint programming was used to solve the problem. Priorities and relationships between projects were taken into consideration. The objective function was maximization of the profit [12]. Shou et al. (2014), addressed a two-step heuristic algorithm for the PSS problem. In the algorithm, projects were selected and later scheduling was carried out [13].

Hassanzadeh et al. (2014), addressed the problem of PSS for pharmaceutical drug research and development projects. Robust optimization was used for the problem [14]. Huang and Zhao (2014), considered fuzzy parameters for the PSS problem. Different relationships between projects and flexible project beginning time were taken into account. Genetic algorithm was proposed for the problem. A numerical example was given [15]. Pajares and Lopez (2014), examined the importance of inter-project relationships for determining the project portfolio [16]. Tofighian and Naderi (2015), proposed an optimization model and heuristic for the multi-objective PSS problem [17]. Hosseininasab and Shetab-Boushehri (2015), applied the PSS problem for road construction projects. They proposed optimization models and algorithms [18]. Huang et al. (2016), took into account uncertainty of the PSS problem. New algorithms were used to solve the problem [19]. Amirian and Sahraeian (2017), proposed a multi-objective mathematical model with grey parameters. They proposed heuristic algorithms for the problem [20]. Shariatmadari et al. (2017), considered PSS with RM problem. A heurisitc algorithm was applied for the problem. The problem addressed by a single objective function, cost minimization [5]. Kumar et al. (2018), applied a Tabu Search algorithm to PSS problem with single objective function. Interdependencies between projects were considered [21]. Shafahi and Haghani (2018), addressed PSS problem with phases. Maximization of the net present value is the objective function. The dependency of the phases was considered. Optimization models and algorithms were proposed for the problem [22].

Perez et al. (2018), addressed PSS problem with a fuzzy approach. They considered relationships between projects. An application was made in Spanish state university [23]. Song et al. (2019), assumed weights of the criteria as uncertain. They addressed multi-objective PSS problem. Stochastic multi-criteria acceptability analysis method was used. An application was conducted in a hospital [24]. Nemati-Lafmejani et al. (2019), used a heuristic algorithm. They addressed PSS problem with multi-mode. Minimization of the makespan and total cost are the objective functions of the addressed problem [25]. Sarnataro et al. (2020), considered PSS problem by urban planning projects with a multi-objective optimization model [26]. Miralinaghi et al. (2020), used bi-level programming for the problem of urban road PSS problem[27].

Although there has been studies about PSS problem, a few studies are taken into account RM on PSS problem. This study is first to address generalized PSS problem with RM. Different features from the literature are taken into account such as, dynamic project arrivals, project setup times, project priorities, relationships between projects and fuzzy nature of the problem. The addressed problem is defined with a real case problem. A fuzzy multi-objective optimization model is proposed for the solution of the problem. The proposed mathematical model is solved with the modified two phase fuzzy goal programming model. In this study, the classic two phase fuzzy goal programming model is modified. The comparison of the classic and modified two-phase FGP approach is conducted over the test problems. As a result, with the modified two-phase FGP approach higher total weighted satisfaction degrees are obtained than the classic two-phase FGP approach in 13 of the 24 test problems.

3. METHODOLOGY

3.1. Definitions on Fuzzy Logic

Definition 1: In fuzzy sets, the membership function of a set is represented by a number between 0 and 1, as in Eq. (1) [28]. $\mu_{\tilde{a}(x)}$ denotes the membership function of triangular fuzzy number (TFN) $\tilde{a}$.

$$\mu_{\tilde{a}(x)} \rightarrow [0,1] \quad (1)$$

The number 0 indicates that the related object is not a member of the set, and the number 1 indicates that the related object is a full member of the set (see Fig. 1).

Definition 2: For a TFN as $\tilde{a}=(a_1, a_2, a_3)$, $\mu_{\tilde{a}(x)}$ is calculated by the following Eq. (2) [29].

$$\mu_{\tilde{a}(x)} = \begin{cases} \frac{x-a_1}{a_2-a_1}, & if \quad a_1 \leq x \leq a_2 \\ \frac{a_3-x}{a_3-a_2}, & if \quad a_2 \leq x \leq a_3 \\ 0 & otherwise \end{cases} \quad (2)$$

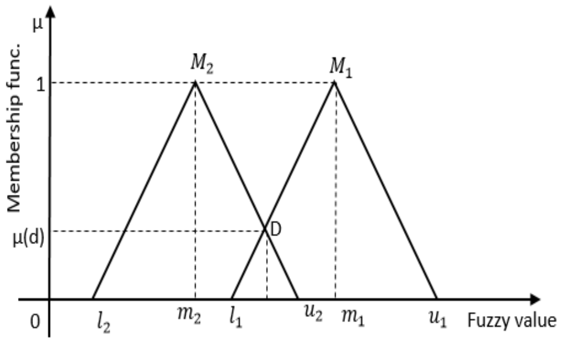

Figure 1. Representation of fuzzy numbers

Definition 3: A and B can be showed as (a_1, a_2, a_3) and (b_1, b_2, b_3). Basic fuzzy operators for fuzzy number A and B are given below:

$\tilde{A}(+)\tilde{B}=(a_1+b_1, a_2+b_2, a_3+b_3)$; $\tilde{A}(-)\tilde{B}=(a_1-b_3, a_2-b_2, a_3-b_1)$

$\tilde{A}(\times)\tilde{B}=(a_1b_1, a_2b_2, a_3b_3)$;

$\tilde{A}(\div)\tilde{B}=(\frac{a_1}{b_1}, \frac{a_2}{b_2}, \frac{a_3}{b_3})$;

$(\tilde{A})^{-1}=(\frac{1}{a_3}, \frac{1}{a_2}, \frac{1}{a_1})$

3.2. Fuzzy Multi-Objective Mixed Integer Linear Programming Model

In this study, project selection and scheduling problem is generalized considering resource management, dynamic project arrival times, project setup times, priorities and relationship between projects.

With dynamic project arrival time, projects may arrive during the planning period. Thus, not only projects that are ready beginning of the scheduling period, but also projects that arrive after the beginning of the scheduling period are also taken into account.

In real life, projects require setup before starting time. During the setup phase, activities such as planning the project, completing permit procedures and preparing the technical infrastructure are carried out. During the setup phase, the resources involved in the setup are used. The current setup resource amount of the company can not be exceeded. Setup time of the projects should also be taken into account in order to reflect the real life problem.

In this study, the relationship between projects has been considered in 3 ways. These are defined as priority relationship between projects, complementary projects and exclusive projects.

Considering the priorities between projects, some projects can start after priority projects are completed. In complementary projects, if a particular project is complementary to the other project and one of these two projects is chosen, the other must be chosen as well.

If two projects are defined as exclusive projects, projects can not be selected simultaneously. With the solution of the mathematical model

- Selection of projects
- Scheduling of selected projects
- Determination the optimum amount of resources for each period

are made simultaneously.

The model has three objectives. Objective functions are maximization of the total expected profit and preference of the projects and minimization of total cost.

Due to imprecise aspiration levels of the decision maker for each objective function a fuzzy approach is necessary for the solution of the problem.

The proposed model is given below:

Sets and Indices

P: Set of projects, P={1,2,…, N}

M: Set of periods, M= {1,2,…,T}

I: Set of resources, I={1,2,…,R}

i, h, e: Project indices, where i, h, e ∈ P

j, t: Period indices, where j, t∈ M

k: Resource indice, where k ∈ I

Parameters

O_{it}: Expected profit of project i that is started in period t

d_i: Duration of project i

r_{ik}: Resource requirement of project i for resource k

$E_{ie}: \begin{cases} 1; If\ project\ i\ and\ e\ are\ mutually\ exclusive \\ 0; \quad o.w. \end{cases}$

$H_{ih}: \begin{cases} 1; If\ project\ i\ and\ h\ are\ complementary\ projects \\ 0; \quad o.w. \end{cases}$

$Pr_{ih}: \begin{cases} 1; If\ project\ i\ can\ be\ started\ after\ project\ h \\ 0; \quad o.w. \end{cases}$

L_k: Cost of decreasing resource k by one unit

PR_i: Preference level of project i

C_k: Cost of processing resource k by one unit

U_k: Cost of increasing resource k by one unit

a_i: Arrival time of project i

s_i: Setup time of project i

rs_i: Setup resource requirement of project i

RS_t: Amount of setup resource availability in period t

RI_k: Initial amount of resource k

Decision Variables

$x_{it}: \begin{cases} 1; If\ project\ i\ starts\ in\ period\ t \\ 0; \quad\quad\quad\quad\quad\quad\quad\quad\quad\quad o.w. \end{cases}$

R_{kt}: Amount of resource k in period t

I_{kt}: The amount of increased resource of k for period t compared to (t-1)

D_{kt}: The amount of decreased resource of k for period t compared to (t-1)

Model

$$\text{Max } Z_1 \cong \sum_i \sum_t^{(T-d_i+1)} [O_{it} x_{it}] \quad (3)$$

$$\text{Min } Z_2 \cong \sum_k \sum_t [U_k I_{kt} + C_k R_{kt} + L_k D_{kt}] \quad (4)$$

$$\text{Max } Z_3 \cong \sum_i \sum_t^{(T-d_i+1)} SU_i x_{it} \quad (5)$$

$$\sum_{t>0}^{(T-d_i+1)} x_{it} \leq 1 \qquad \forall\ i \quad (6)$$

$$\sum_i \left(\sum_{j=\max(1,t-d_i+1)}^{\min(t,T-d_i+1)} x_{ij} \right) r_{ik} \leq R_{kt} \qquad \forall\ k, t > 0 \quad (7)$$

$$\sum_{t>0}^{T-d_i+1} x_{it}(t + d_i) Pr_{hi} \leq \sum_{t>0}^{(T-d_h+1)} t\ x_{ht} \qquad \forall\ i, h \quad (8)$$

$$\left(\sum_{t>0}^{(T-d_i+1)} x_{it} + \sum_{t>0}^{(T-d_e+1)} x_{et} \right) E_{ie} \leq 1 \qquad \forall\ i, e \quad (9)$$

$$\sum_{t>0}^{(T-d_i+1)} x_{it} H_{ih} = \sum_{t>0}^{(T-d_h+1)} x_{ht} H_{ih} \qquad \forall\ i, h \quad (10)$$

$$\sum_{t\geq 0}^{t<a_i} x_{it} = 0 \qquad \forall\ i \quad (11)$$

$$\sum_i \left(\sum_{j=\max(1,t-s_i+1)}^{\min(t,T-s_i+1)} x_{ij} \right) rs_i \leq RS_t \qquad \forall\ t \quad (12)$$

$$I_{kt} \geq R_{kt} - R_{k(t-1)} \qquad \forall\ k, t > 0 \quad (13)$$

$$D_{kt} \geq R_{k(t-1)} - R_{kt} \qquad \forall\ k, t > 0 \quad (14)$$

$$R_{k0} = RI_k \qquad \forall\ k \quad (15)$$

$$I_{k0} = 0 \qquad \forall\ k \quad (16)$$

$$D_{k0} = 0 \qquad \forall\ k \quad (17)$$

$$R_{kt}, I_{kt}, D_{kt} \geq 0\ and\ x_{it} \in \{0,1\} \qquad \forall\ i, k, t \quad (18)$$

(3), (4) and (5) are the fuzzy objective functions, maximizing total expected profit, minimizing total cost and maximizing preference level of the projects, respectively. Constraint (6) ensures that each project is assigned to at most one period. With the constraint (7), the amount of resources required in each period is calculated. Constraint (8) ensures that priorities between projects are taken into account. With the constraint (9), selecting certain projects together is prevented. With constraint (10) complementary projects are considered. Constraint (11) ensures that the dynamic arrival of projects is taken into account. Constraint (12) prevents exceeding the amount of setup resources for each periods. Constraint (13) calculates the amount of resource increases in each period. Constraint (14) calculates the amount of resource decreases in each period. With the constraint (15), the initial resource amount is determined. Constraints (16) and (17) ensure that the initial amount of increasing and decreasing resources are considered zero. Constraint (18) is sign constraint.

3.3. Modified Two-Phase FGP

Due to imprecise aspiration levels of the DM for each objective function a fuzzy approach is necessary for the solution of the FMOMILP model. Modified two-phase FGP model is proposed due to the simultaneous optimization of conflicting objective functions and imprecise aspiration levels. The two-phase FGP approach is applied to supplier selection problem [30], the project management problem [31], the assembly line balancing problem [32], and the order allocation problem [33]. In the first phase, a solution is obtained so that the satisfaction degree value of the objective function with the smallest value is maximized. First phase can be called as max-min phase. The output of the first phase is first phase satisfaction degree (FPSD) values for the objectives. In the 2nd phase, the obtained solution is improved by taking into account the weights of the objective functions. In the second phase, it is aimed to achieve a greater satisfaction degree for each objective function than the FPSD values . The objective function of the second phase is the maximization of the total weighted second phase satisfaction degree (SPSD) values. However, in this case, the result obtained in the first stage does not change in most cases [30]. For this reason, within the scope of the study, the FPSD value of the least important objective is updated. The new updated value should be smaller than the old FPSD value. Thus, it is aimed to increase the satisfaction degree value of more important objectives. The procedure is applied until a satisfactory solution is obtained.

The two-phase FGP approach is described below.

Phase 1 (Max-Min Approach)

In FGP, each objective function is defined by its membership function. Membership function shows the degree of satisfaction of the decision maker in achieving the goal.

The linear membership function is formulated as Eq. (19) for minimization and Eq. (20) for maximization type objective function [34].

$$\mu_{Z_k}=\begin{cases}1; & Z_k < Z_k^l\\ \frac{Z_k^u-Z_k}{Z_k^u-Z_k^l}; & Z_k^l < Z_k < Z_k^u\\ 0; & Z_k > Z_k^u\end{cases} \tag{19}$$

$$\mu_{Z_k}=\begin{cases}0; & Z_k < Z_k^l\\ \frac{Z_k-Z_k^l}{Z_k^u-Z_k^l}; & Z_k^l < Z_k < Z_k^u\\ 1; & Z_k > Z_k^u\end{cases} \tag{20}$$

Linear membership function is graphically shown in Fig. 2 according to the objective function type.

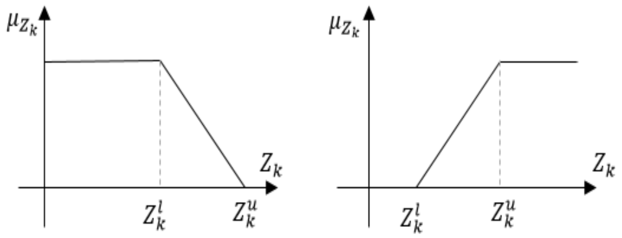

Figure 2. Membership functions for minimization and maximization objectives

μ_{Z_k} denotes the membership function of objective Z_k and Z_k^l denotes lower bound of objective Z_k and Z_k^u denotes upper bound of objective Z_k.

The values of Z_k^l and Z_k^u are obtained by solving each objective function as a single objective. In the first phase, a solution was obtained with objective function maximization of the minimum FPSD value. In other words, the threshold satisfaction degree (THSD) is maximized. The relevant mathematical model is named as "Model X" and given below:

Max THSD (21)

s.t.

THSD ≤ FPSD_k $\forall\ k$ (22)

and Constraints (6)-(18)

Phase 2 (Weighted Sum Approach)

In the 2nd phase, objective is the maximization of the total weighted 2nd Phase Satisfaction Degree (SPSD) values. The SPSD value of each objective function is at least equal to the related FPSD value. The aim is to increase the satisfaction degree values obtained in the first phase. The relevant mathematical model is named as "Model Y" and given below:

Max TWSD= $\sum_{k=1}^{K} w_k * SPSD_k$ (23)

s.t.

$SPSD_k \geq FPSD_\text{k}$ (24)

and Constraints (6)-(18)

In most cases, there is no improvement in satisfaction degree values in the 2nd phase. Therefore, within the scope of the study, the DM determines the desired satisfaction degree (DSD) value for the least important objective function. The specified value must be less than the THSD value. Equation 24 should be provided for other objective functions. In this case, the FPSD value of the least important objective function is slightly reduced and it is aimed to increase the satisfaction degree value of the important objective functions. If the obtained solution is a satisfactory solution, the algorithm is terminated, otherwise the DSD value is updated again. The modified two-stage FGP approach is given in Fig. 3.

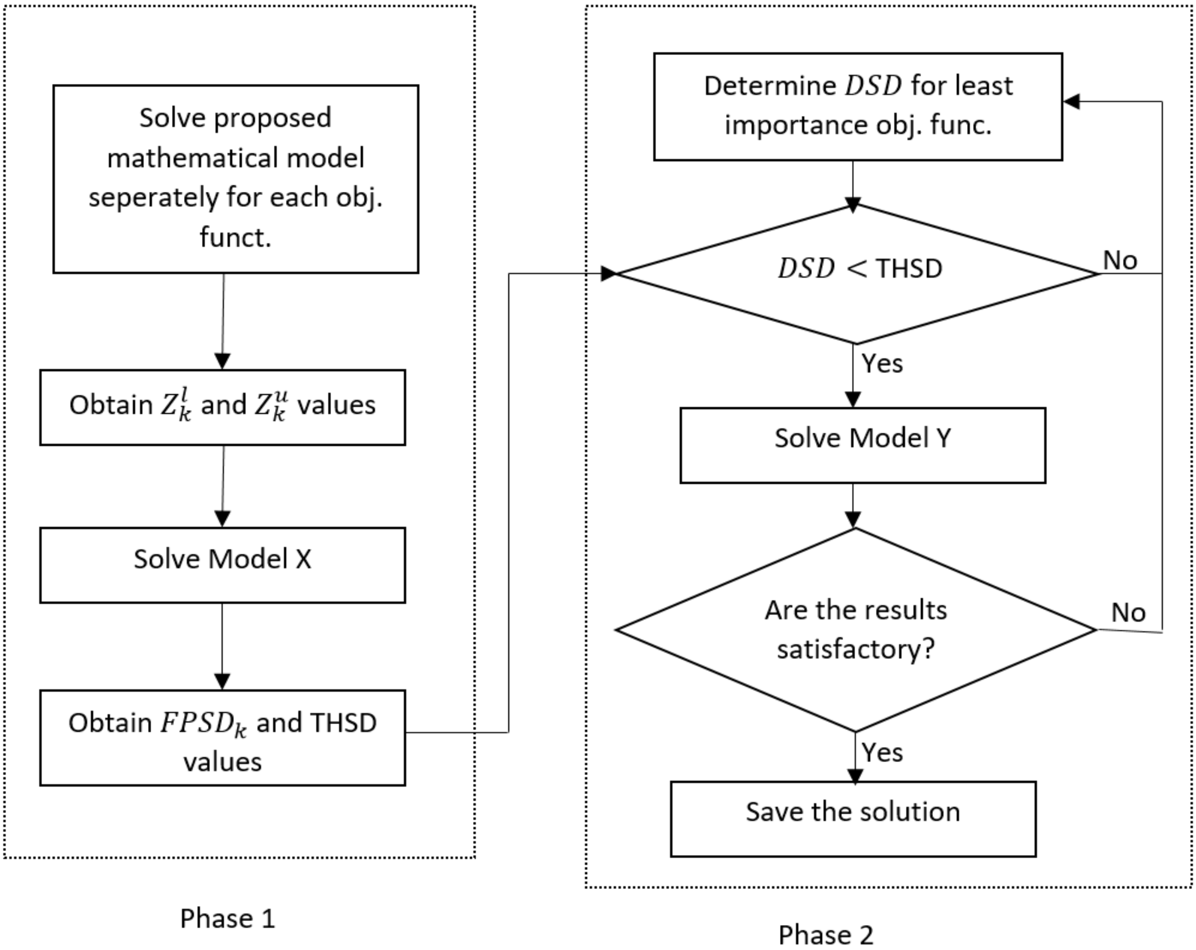

Figure 3. Modified Two-Phase FGP approach

4. RESULTS AND DISCUSSION

The model is coded in GAMS program and CPLEX is used as a solver. The properties of the computer are i7-5500 U CPU, 2.40 GHz and 12 GB.

4.1. Test Problems

The properties of the generated test problems are given in this section. Number of projects is 7, period number is 8, number of resources is 2. Expected profits are derived from a uniform distribution between 200 and 500. Duration of projects is considered U (2, 6). Resource requirements are derived in accordance with the U (1, 5). The E_{ie}, H_{ih} and Pr_{ih} parameters are derived as 0 with a probability 90% and 1 with a probability 10%. The preference level of the projects are randomly generated between 0 and 1. Arrival times are derived from a uniform distribution between 0 and 4. Setup times and setup resource requirement of the projects are equal to 1. Amount of setup resource availability is 4. Initial amount of resources are considered at three levels: 1, 2, 3, or 4 for PSS with RM problem. Six different situations have been taken into consideration for increasing, decreasing and processing costs: $L_k>C_k>U_k$, $L_k>U_k>C_k$, $U_k> L_k> C_k$, $C_k> L_k> U_k$, $C_k> U_k> L_k$ or $U_k> C_k> L_k$. Total number of generated test problems is 24.

4.2. Comparison

4.2.1. Effects of RM on PSS problem

In this section, the PSS with RM problem and the PSS without RM problem are solved using both the classic and modified two-phase FGP approaches.

After solving PSS with RM problem the proposed mathematical model is modified to solve PSS problem. Thus, the amount of resources in each period is considered constant. The following Eq. (25) and Eq. (26) have been added to solve the problem.

$$I_{kt} = 0 \qquad \forall\, k, t \tag{25}$$

$$D_{kt} = 0 \qquad \forall\, k, t \tag{26}$$

This section shows the effect of considering RM for the problem of PSS on the test problems. PSS problem is considered with and without RM. In PSS problem the amount of resources is constant for each period and equal to initial resource amount. The average resource amount of PSS with RM problem is taken as initial resource amount for PSS problem. Therefore, if resource management is not taken into account and the amount of resources is considered constant in each period, the initial resource amounts are taken as average amount of resource of the result of PSS with RM problem. The results obtained by using the modified two-phase FGP approach for PSS with RM and PSS are given in Table 1. The first and third objective function (total expected profit and total preference level) deteriorates when resource management is not taken into account. But the second objective function (total cost) got a better value. The total cost value is dependent on the initial resource amount. As a result, expected profit and sustainability score was improved by taking into account resource management. Non-dominated solutions are obtained by both PSS with RM problem and PSS problem. The obtained solutions of these problems can be presented to DM as alternative solutions. The objective function values of the test problems are given in Table 6. The best values of objective functions are given as bold. Accordingly, in all test problems, objective 1 and 3 got better values with the solution of PSS with RM problem. On the other hand, considering the average amount of resources obtained in the PSS with RM problem, Objective 2 got better value with the solution of the PSS problem. Objective function values of test problems for the PSS with RM and PSS.

Table 1. Objective function values of test problems for the PSS with RM and PSS

No		RI_k	PSS with RM			PSS		
1	$L_k > C_k > U_k$	1	**2280**	866	**1.265**	1545	**600**	1.233
2		2	**2631**	628	**3.387**	1999	**640**	3.237
3		3	**1683**	647	**2.141**	859	**448**	1.035
4		4	**1592**	600	**1.121**	791	**440**	0.984
5	$L_k > U_k > C_k$	1	**2081**	358	**2.166**	1635	**208**	1.633
6		2	**1586**	1045	**2.972**	758	**728**	1.512
7		3	**918**	557	**0.958**	498	**448**	0.7985
8		4	**1325**	137	**0.401**	978	**80**	0.2553
9	$U_k > L_k > C_k$	1	**1902**	280	**2.196**	1717	**104**	2.1961
10		2	**2086**	772	**2.398**	1711	**448**	2.4954
11		3	**2305**	871	**3.56**	1791	**440**	2.351
12		4	**1825**	577	**2.234**	1284	**360**	1.99
13	$C_k > L_k > U_k$	1	**1055**	485	**1.529**	955	**392**	1.529
14		2	**2734**	1111	**2.844**	1684	**800**	1.495
15		3	**1682**	1354	**3.143**	1447	**1152**	2.6443
16		4	**1390**	574	**1.593**	438	**320**	0.6493
17	$C_k > U_k > L_k$	1	**1620**	886	**1.596**	795	**560**	0.3902
18		2	**1820**	486	**1.176**	499	**336**	0.7914
19		3	**2857**	622	**4.334**	1895	**440**	2.771
20		4	**1254**	715	**0.595**	430	**576**	0.4086
21	$U_k > C_k > L_k$	1	**2023**	492	**1.82**	1128	**312**	1.38
22		2	**1562**	678	**2.099**	821	**320**	1.804
23		3	**3629**	1615	**5.833**	2537	**1080**	4.173
24		4	**2101**	684	**2.419**	1349	**528**	1.8795

4.2.2. Comparison of classic and modified two-phase FGP model

In this section, classic and modified two-phase FGP approaches are compared over test problems for PSS with RM problem. The results of the test problems according to the methods are given in Table 2. Table 2 shows the TWSD values and objective function values for each test problem. A higher TWSD value was obtained with the modified two-phase FGP approach in 13 of the 24 test problems. In other words, better results were obtained with the modified two-phase FGP considering the objective function weights. Modified and classical approaches gave the same solutions in the remaining 11 test problems. The obtained TWSD values are given graphically in Fig. 4.

Table 2. Solution of test problems according to classic and modified two-phase FGP approaches

No	Cost	RI_k	Classic two-phase FGP				Modified two-phase FGP			
			Z_1	Z_2	Z_3	TWSD	Z_1	Z_2	Z_3	TWSD
1	$L_k > C_k > U_k$	1	2137	788	1.265	0.94324	2280	866	1.265	**0.96786**
2		2	2548	598	3.387	0.97299	2631	628	3.387	**0.98574**
3		3	1584	566	2.141	0.96303	1683	647	2.141	**0.98528**
4		4	1592	600	1.121	0.98666	1592	600;	1.121	0.98666
5	$L_k > U_k > C_k$	1	1965	344	2.166	0.88342	2081	358	2.166	**0.904**
6		2	1586	1045	2.972	0.99471	1586	1045	2.972	0.99471
7		3	918	557	0.958	0.99747	918	557	0.958	0.99747
8		4	1325	137	0.401	0.99931	1325	137	0.401	0.99931
9	$U_k > L_k > C_k$	1	1866	223	2.196	0.9888	1902	280	2.196	**0.99241**
10		2	2086	772	2.398	0.976	2086	772	2.398	0.976
11		3	2116	761	3.56;	0.956	2305	871	3.56	**0.98505**
12		4	1825	577	2.234	0.992	1825	577	2.234	0.992
13	$C_k > L_k > U_k$	1	955	385	1.529	0.976	1055	485	1.529	**0.983**
14		2	2734	1111	2.844	0.984	2734	1111	2.844	0.984
15		3	1682	1354	3.143	0.981	1682	1354	3.143	0.981
16		4	1299	464	1.593	0.973	1390	574	1.593	**0.983**
17	$C_k > U_k > L_k$	1	1620	886	1.596	0.98693	1620	886	1.596	0.98693
18		2	1808	456	1.176	0.99062	1820	486	1.176	**0.9931**
19		3	2857	622	4.334	0.991	2857	622	4.334	0.991
20		4	1254	715	0.595	0.99	1254	715	0.595	0.99
21	$U_k > C_k > L_k$	1	1959	472	1.82	0.97805	2023	492	1.82	**0.991**
22		2	1275	568	2.099	0.913	1562	678	2.099	**0.98528**
23		3	3399	1429	5.203	0.91044	3629	1615	5.833	**0.971**
24		4	2028	558	2.419	0.97564	2101	684	2.419	**0.988**

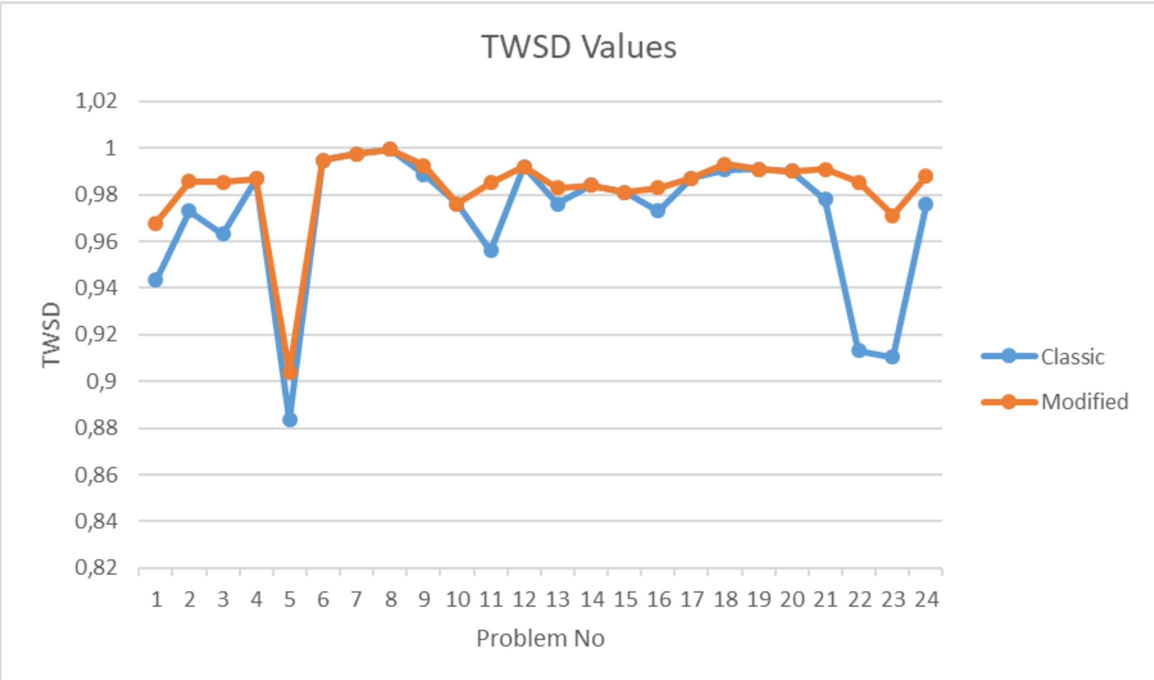

Figure 4. TWSD values for test problems according to classic and modified two-phase FGP approaches

5. CONCLUSIONS

In this study, the PSS with RM problem is considered. Project setup times, dynamic project arrival times, priorities and relationship between projects are handled in a fuzzy approach. Fuzzy optimization method is used to solve the problem. In the proposed methodology, classic two-phase FGP approach is modified to improve the solution of the first phase considering objective function weights. The modified and classic two-phase FGP approaches are compared over genereated test problems and a case study. With the modified two-phase FGP approach higher total weighted satisfaction degrees are obtained than the classic two-phase FGP approach in 13 of the 24 test problems. The importance of RM is demonstrated over the test problems. By considering RM total expected profit and total sustainability scores are improved. When the initial resource amounts in PSS problem are taken as average resource amount in the solution of PSS with RM problem the total expected profit and total sustainability score deteriorates, whereas the total cost is getting better. As a result, alternative solutions are derived for the decision maker. The methodology can be applied by other companies facing the problem of project selection and scheduling. In future studies, a heuristic algorithm is planned for the solution of large scale problems.

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