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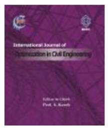

OPTIMIZATION OF MULTI PERIOD - MULTI LOCATION CONSTRUCTION PROJECTS CONSIDERING RESOURCE POOL AND BATCH ORDERING

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ABSTRACT

During the past two decades, some industries have been moving towards project-centered systems in many modern countries. Therefore, managing simultaneous projects with considering the limitations in resources, equipment and manpower is very crucial. In the real world, project-based organizations are always facing with two main important features. First, the construction projects are decentralized and their distances are long, and second, there are several construction projects undertaken at different time periods. Therefore, appropriate selection of projects with regard to the capabilities of the organization may lead with increasing an expected profitability. This paper investigates the multi-period decentralized multi construction-project and scheduling problem subject to resource constraints, optimal resource pool location, deterioration and batch ordering of nonrenewable resources altogether, for the first time in the literature. In order to describe the problem under consideration in this paper and obtaining the optimal solutions, a mixed integer linear programming model is developed. Finally, the impact of decision integration on the profit profile of an organization is comprehensively investigated by solving numerical examples and through developing some heuristic methods.

Keywords: project selection; construction scheduling; resource pool location; batch ordering; multi-period planning.

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1. INTRODUCTION

According to development of industry in recent decades, technology and urban life, the

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nature of the construction projects has also been changed. On the other hand, the modern world has been moving toward project-centered system that has raised the importance of project management systems. Project-based organizations are facing with a large number of small and large construction projects at each year. The organizations should manage these projects in the most cost-effective way, given the limited human resources, equipment, financial resources and available nonrenewable resources. Due to resource constraints as well as permanent business changing environments, selecting the optimal project portfolio for such organizations would be of great importance.

One of the most important factors affecting selection of projects is limited availability of resources. An organization must select projects that have sufficient financial, human, equipment and consumable resources in order to successfully implement them. If a project is selected that the organization does not have the enough capabilities to carry out, then it will face with heavy delay penalties.

Another important factor in choosing project is the distances between the selected projects. This factor plays a key role in shortening the project's completion times as well as reducing the logistic costs imposed by the organization. Those groups of organizations can select more decentralized projects in a portfolio that have strong operational infrastructure, vast resources and equipment, and numerous financial capabilities.

Since project-driven organizations are continuously involved in the implementation of construction projects, investment management is also very important for them to take into consideration. One of the important capital assets of such organizations is the warehouses and central workshops of projects. In the literature, the so-called resources pool refers to these warehouses and workshops. Choosing an appropriate location for resources pool, its capacity and the concentration of equipment and services can reduce the time of implementation of projects undertaken, as well as reduce costs and thus lead to higher profits. Generally, organizations try to establish resources pool at the best possible location with regard to current projects as well as projects that are being scheduled to implement in the future.

1.1 The literature on decentralized projects scheduling problems

In literature, the decentralized multi-project scheduling problem has been considered recently, and rare researches can be found in this area. In the decentralized projects, the transfer time of resources between activities and between projects should have to be taken into account because they affect the completion times of projects. The decentralized projects scheduling problem was examined by Yang and Sum [1] for the first time. They considered equal times for resources transferring between all activities. In fact, these times are only between resource pools and activities, and no transferring time was considered among activities. By considering resources transfer between two activities, Krüger and Scholl [3,2] examined this problem by developing a mathematical model. By considering priority rules, they categorized projects according to their priorities and allocated limited resources can be assigned to the projects. Significant weakness of their heuristic algorithm was related to prioritizing project implementation at the beginning of the algorithm. To tackle this weakness, Adhau et al. [4] with assisting of the multi agent system tried to provide the appropriate solutions for decentralized multi-project scheduling problem. They divided the resources used in projects into two categories. There are a number of resources that can be locally available due to the abundance. Other category of resources is scarce and should be transferred between projects as global resources. Fink and Homberger [5] have also addressed this problem considering the auctioning and negotiation model. They have taken the negotiation between the planning managers of each local project and the resource allocation manager. But the decision about the resource pool location has so far been considered only by Rostami et al. [6]. They considered decentralized multi-project scheduling problem taking into account the periodic services. This problem was solved by a hybrid artificial bee colony algorithm. In the special case of the above problem, Rostami and Bagherpour [7] solved the problem without considering periodic service using a lagrangian relaxation algorithm.

2.1 Literature review on portfolio selection problems

Unlike the decentralized project scheduling problems, portfolio selection problems have been studied by many researchers. For example see research conducted by Dos Santos [8], Archer and Ghasemzadeh [9], Meade and Presley [10], Huang et al. [11] and Dutra et al. [12]. All of them have tried to identify the optimal project portfolio by providing different techniques.

It should be also noted that all of the above mentioned research studied portfolio selection problem without considering multi-period planning. By considering multi-period planning, Khalili-Damghani et al. [13] investigated a fuzzy multi-objective project selection problem with assisting TOPSIS method. Other research that studied project selection problem with respect to multi-periodic planning pointed to Khalili-Damghani et al. [14], Liu [15], and Khalili-Damghani and Sadi- Nezhad [16]. In recent years, the decision integration of portfolio selection with other problems has been considered by many researchers. Decision integration between project selection and scheduling has been considered by Shariatmadari et al. [17]. By providing a heuristic method, as well as the development of the Gravitational Search Algorithm (GSA), they have tried to solve various instances as well. In their study, the decision-making axis is resource management. Also, Wu et al. [18] examined the problem of maximizing profits in selecting a project portfolio. This problem was solved by providing a combinatorial method.

3.1 Literature review on resource batch ordering

In recent years, researchers have been focused on resource management in the projects have to be carried out. Considering the batch order is visible in research in recent years due to the cost of purchasing materials, logistics costs and holding costs have increased. Aquilano and Smith [19] examined the batch ordering and project scheduling problem by presenting a hybrid critical paths method. Thereafter, research was carried out on this subject, including the Dodin and Elimam [20] research that during of activities is variable and prizes are foreseen in the purchase. Also, the same problem was solved by Sajadieh et al. [21] with the help of genetic algorithm. With regard to batch ordering system for resources purchasing, Fu [22] developed a hybrid genetic algorithm for project scheduling problem. Finally, Zoraghi et al. [23] investigated a multi-mode resource-constrained project scheduling problem with material ordering under bonus–penalty policies. The focus of their model is to provide a schedule satisfying time and resource availability, as well as a material ordering plan, such that the total holding and ordering costs along with the penalty or bonus of project implementation are minimized.

As mentioned above, in recent years, some features have been added to study the project scheduling problems which can reduce costs and thereby lead to higher profitability of the organization. Based on the literature review, the decentralized multi-project selection and scheduling problem has not been addressed so far with respect to multi-period planning, resource pool location, batch ordering and non-renewable resources deterioration. In this paper, this problem is introduced for the first time. Hence, in this paper, the revenue of projects, fixed ordering and buying costs of materials are considered as a function of time. This matter has been underestimated in previous researches. Then, by defining the appropriate parameters and decision variables, a mixed-integer linear programming (MILP) model is developed for solving this kind of problems. Since the resource constrained multi-project scheduling problem is NP-hard class(Salewski, Schirmer and Drexl [24]), the developed version of this problem that presented in this paper still remains NP-hard. The importance of this problem is in the integrated management of project planning and implementation protocol. Organizations should pay attention to the fact that, if they do not pay attention to this matter, the negative impact on project revenues might be significant. The impact of the lack of decision integration on reducing earnings is examined in this paper.

The rest of this paper is organized as follows. Section 2 defines the proposed problem and the assumptions are clearly explained. By defining the appropriate parameters and variables, section 3 present a mixed integer linear programming model. In section 4, by generating random instances, the computational results are evaluated and the impact of decision integration on increasing the organization's profitability is studied. Finally, Section 5 concludes and proposes future studies.

2. PROBLEM DEFINITION

It is assumed that there is a project-based organization that is going on at the beginning of planning process. In the planning horizon of this organization, different projects are introduced at different times, different places which all information about these projects is specified at the beginning of the planning process. This information includes the projects release times, the location of the project, the funding required for each project, the project revenue based on its completion time and the amount of required renewable non-renewable resources. In order to maximize its profitability, the organization selects and implements a portfolio of projects based on budget and renewable resources constraints. In order to implement these projects, a resource pool should be established in a specific location that is selected from the potential places available. This pool is a place to store non-renewable resources that are to be purchased with a batch order system. Due to the fact that non-renewable resources are purchased locally, these kinds of resources are known unlimited. Also, the resource pool is used for maintenance of renewable resources and equipment. These resources are constrained due to their global nature. Also, these resources require periodic services. The time table of periodic services is identified at the beginning of the planning. It is assumed that at the time specified for the periodic service, if the resource is in during of processing an activity, the resource will continue the processing of current activity and then refer to the resource pool as well.

It should be noted that each type of resources has a unique feature. The renewable resources, due to the limitation, should be transferred between activities, so the time it takes to transfer these resources between activities will affect the completion time of the projects. Also, non-renewable resources are stored after the purchase in the resource pool. Due to sufficient facilities in the pool, the stored resources in pool are not deteriorated. These types of resources start to deteriorate after dispatching to activities, which cause the cost of deterioration based on the linear time function.

In addition to the costs of construction and deterioration, other costs are imposed by the organization during projects implementation. As mentioned, the non-renewable resources are supplied with a batch ordering system. Therefore, based on the ordering time, the fixed cost of each batch and the variable costs of purchasing each unit of resource are imposed by the organization. Due to the fact that in order to prevent their deterioration, they should be holed in the pool, so holding costs will be imposed on the organization.

3. PROBLEM FORMULATION

In this section, a Mixed Integer Linear Programming (MILP) model is proposed to obtain a global optimal solution for small-size problems. To simplify, each activity is assigned to a specific number. For example, Activity # 5 of Project # 2 represents a single number, e.g. 9 (there is no specific rule in numbering). Also, a dummy activity e is considered for the completion of all projects where the activity durations, distances and required non-renewable resources are zero and the renewable resources required is R.

Also, in order to facilitate selection of the projects portfolio, a set called K is defined, which includes the last activity number of all projects. Differentiating of projects is done through these activities. Table 1 shows the parameters and variables of the model.

Table 1: Parameters and decision variables

Section	Notation	Description
Sets	I	Set of project's activities
	$P_D(i)$	direct predecessors of the ith activity
	$P_I(i)$	direct/indirect predecessors of the ith activity
	$SP(i)$	Activities that are assigned to a same project with activity i
	L	the potential centers of the resource pool
	K	Set of the last activity of projects
	T	the time horizon of the projects
Indexes	i, j	activity number
	e	dummy activity
	l	centers of pool
	k	last activity number related to each project
	t, u	time

Parameters	D_{ij}	distance between i and j
	b_k	amount of funding required for each project (the project related to activity k)
	F_l	fixed cost of the establishment resource pool in the center l
	r_i	renewable resource needed for the i^{th} activity
	r_i'	nonrenewable resource needed for the i^{th} activity
	R	capacity of the renewable resources
	B	total financial resources
	d_i	duration of the i^{th} activity
	A_i	release time of each project (the project related to activity i)
	α_i	deterioration coefficient for the i^{th} activity
	η_t	Equals to 1 if the periodic service occurs at time t
	P_{kt}	revenue of completion of each project at time t
	CF_t	fixed cost of each ordering at time t
	CB_t	buying cost of each nonrenewable resource in time t
	CH	holding cost of each nonrenewable resource at each unit time
	CD	deterioration cost of each nonrenewable resource at each unit time
	M	A large positive number
Decision Variables	x_{ij}	amount of renewable resource transfer from activity i to j ($x_{ij} = integer$)
	E_l	Equals to 1 if resource pool constructed in the center l ($E_l \in \{0,1\}$)
	z_{ij}	Equals to 1 if renewable resource transferred from i to j ($z_{ij} \in \{0,1\}$)
	y_{it}	Equals to 1 if processing of activity i finishes at time t ($y_{it} \in \{0,1\}$)
	λ_{it}	Equals 1 if processing of activity i starts before t ($\lambda_{it} \in \{0,1\}$)
	Y_k	Equals 1 if project related to activity k is selected ($Y_k \in \{0,1\}$)
	Q_t	amount of nonrenewable resource ordered at time t ($Q_t = integer$)
	I_t	inventory of nonrenewable resource in resource pool at time t ($I_t \geq 0$)
	γ_t	Equals to 1 if a batch of nonrenewable resources is ordered at time t ($\gamma_t \in \{0,1\}$)
	θ_{it}	Equals to 1 if the nonrenewable resource is sent to activity i at time t ($\theta_{it} \in \{0,1\}$)

Based on the defined parameters and decision variables, the linear mathematical model is defined as follows:

$$Max \sum_k \sum_t P_{kt}.y_{kt} - \sum_l F_l.E_l - CD.\sum_i r_i'\alpha_i \left(\left(\sum_t t y_{it} - d_i \right) - \sum_t t\theta_{it} \right) - CH\sum_t I_t - \sum_t CF_t\gamma_t - \sum_t CB_t Q_t \quad (1)$$

S.t:

$$\sum_{l} E_l = 1 \tag{2}$$

$$\sum_{t} y_{kt} = Y_k \qquad \forall k \in \mathrm{K} \tag{3}$$

$$\sum_{k} Y_k . b_k \le B \tag{4}$$

$$M\left(1-\sum_{t} y_{k+1,t}\right)+\sum_{t}\left(t-d_{k+1}\right).y_{k+1,t} \ge A_{k+1} \qquad \forall k \in \mathrm{K},\ \mathrm{k} \ne \mathrm{n} \tag{5}$$

$$z_{lj} \le E_l \qquad \forall l \in L,\ j \in I \tag{6}$$

$$z_{ij} \le \sum_{t} y_{jt} \qquad \forall i \in \{I \cup L\},\ j \in I \tag{7}$$

$$\begin{aligned} &x_{ij} \le z_{ij} r_i \quad \forall i \in \{I \cup L\}\ (r_l = R),\ j \notin P_I(i) \\ &x_{ij} = 0 \qquad \forall i \in I \ \text{and}\ j \in P_I(i) \end{aligned} \tag{8}$$

$$\sum_{j \in \{I \cup L\}} x_{ji} = \sum_{j} x_{ij} \qquad \forall i \in I \ \text{and}\ i \ne e \tag{9}$$

$$\sum_{j \in \{I \cup L\}} x_{ji} = r_i \times \sum_{t} y_{it} \qquad \forall i \in I \tag{10}$$

$$\sum_{l}\sum_{j} x_{lj} = R \tag{11}$$

$$\sum_{t}\left(t-d_i\right).y_{it} \ge \sum_{t} t y_{jt} \qquad \forall i \in I,\ j \in P_D(i) \tag{12}$$

$$\sum_{t} y_{it} = \sum_{t} y_{kt} \qquad \forall i \in I, k \in SP(i) \tag{13}$$

$$\begin{aligned} &M\left(2 - z_{ji} - E_l\right) + \sum_{t} t y_{it} - d_i \ge \sum_{t} t y_{jt} + D_{ji} + 2D_{jl}\left(\sum_{t} \eta_t\left(\lambda_{jt} - \lambda_{it}\right)\right) \\ &\forall j \in \{I \cup L\}\,(d_l = 0, y_{l0} = 1), i \in I, l \in L \end{aligned} \tag{14}$$

$$\left(\sum_{t}\left(t-d_j\right).y_{jt} - \sum_{t}\left(t-d_i\right).y_{it}\right) + M\left(1-z_{ij}\right) \ge 0 \qquad \forall i, j \in I \tag{15}$$

$$\lambda_{it} = \sum_{u \le t + d_i - 1} y_{iu} \qquad \forall i \in I, t \in T \ \text{and}\ \lambda_{i1} = 0 \tag{16}$$

$$M\left(1-\sum_{t} y_{it}\right)+\sum_{t}\left(t-d_i\right) y_{it} \ge \sum_{t} t\theta_{it} + \sum_{l} D_{li} E_l \qquad \forall i \in I \tag{17}$$

$$\sum_{t} \theta_{it} = \sum_{t} y_{it} \qquad \forall i \in I \tag{18}$$

$$I_t = I_{t-1} + Q_t - \sum_{i} r_i' . \theta_{it} \qquad (I_0 = 0) \quad \forall t \in T \tag{19}$$

$$Q_t \le \gamma_t M \qquad \forall t \in T \tag{20}$$

$$\sum_t Q_t \geq \sum_i r_i' \sum_t y_{it} \tag{21}$$

$$\begin{cases} E_l,\, Y_k,\, z_{ij},\, y_{it},\, \lambda_{it},\, \theta_{it} \ and \ \gamma_t \in \{0,1\} \\ \quad x_{ij} \ and \ Q_t \in Integer \\ \qquad I_t \geq 0 \end{cases} \tag{22}$$

The objective function (1) maximizes profit of the organization. In this regard, the company's profits will be earned from the completion of selected projects as soon as possible. In addition, the costs of resource pool construction, deterioration, holding and buying of non-renewable resources reduce the organization's profits. In equation (1), it should be noted that the income parameter P_{kt} will be decreased over time. Due to the definition of specific penalties in the contract, if the completion of a project is postponed, the project's revenue will be reduced. Constraint (2) forces that only one point must be selected as the location of the resource pool from among potential points became available. The equation (3) determines the selected projects. A project is selected when the last activity of the project is completed at a time such as *t*. Given the financial limitation, the total funding of the selected projects should not exceed the amount of the budget, which is controlled by constraint (4). Constraint (5) states that a project (first activity of a project) cannot be implemented earlier than its release time. Constraint (6) forces that if the resource pool is not constructed in the location *l*, the resource should not be get out of this location. Also, constraint (7) states that if an activity is not included in a selected project, then the renewable resources should not be transferred to it. Constraint (8) states that not more than the required resource for activity *i* should be transferred from *i* to *j*. Also, no resource is to be moved from *i* to activities which are its direct or indirect predecessors. Constraint (9) states that the total resources inputs to an activity must be equal to the total resources of the output. According to Constraint (10), the total of the input renewable resources for each activity must be equal to the needed resource for that activity if the related project is selected. Constraint (11) states that the total output of renewable resources from the pool should not be greater than its total capacity. Constraint (12) states that an activity cannot start earlier than the completion of all its predecessors. Constraint (13) forces that an activity must only be completed at a time if the related project is selected.

Constraint (14) states that an activity can start to be implemented when the required renewable resource is completely received. The sweep time between activity and pool should be added to the arrival time, if the related resource needs periodic services. It is also necessary to restrict the transfer of resources from an activity to activities that have an earlier start time that is controlled by constraint (15). To calculate the sweep time, an auxiliary variable λ_{it} is used which can be calculated by equation (16). Constraint (17) states that an activity can be started to be implemented when non-renewable required resources receives from the resource pool. Constraint (18) forces that the non-renewable resources only are sent to the activities which the related projects have been selected. Equation (19) calculates the amount of inventory at time *t*. Constraint (20) forces that the variable Q_t should not get a positive value if the resource is not ordered at time t. Also, constraint (21) states that the total purchased resources should not be less than the total required non-renewable resources related to active projects. Finally, equation (22) introduces the model decision variables.

With regard to the objective function and defined constraints, it is clear that the above mathematical model is a linear programming model that can obtain an optimal global solution for the problems. But due to the complexity of the problem and its NP-hardness, the Avg. solving time is increased exponentially with increasing problem size.

4. EXPERIMENTAL RESULTS

In this section, in order to evaluate the impact of the proposed integrated model on the profitability of project-driven organizations, different instances are generated by assisting the benchmark problems published in the literature. The benchmark problems generated by Kolisch and Sprecher [25] here is used to determine activities, precedence relationships, durations, the amount of resources required, and the total amount of available renewable resources. Other parameters defined in this paper are generated randomly through the relations presented in Table 2.

Table 2: Random generation of parameters

Parameters	Random generation formula
D_{ij}	Integer from uniform [0,5] for one project Integer from uniform [5,15] for different projects
b_k	Integer from uniform [100,300]
F_l	Integer from uniform $[50, 200]$
r_i'	Integer from uniform [0.10]
B	Integer from uniform $\left[\min\{b_k\}, \sum b_k\right]$
A_i	Integer from uniform $\left[0, T-\sum d_i\right]$
α_i	Uniform [0,0.3]
η_t	Periodic every 15 time units (i.e. $\eta_{15}=\eta_{30}=\eta_{45}=...=1$)
P_{kt}	Uniform $[800,1400]-\max\{0,(t-A_k)\}\times[1,5]$
CF_t	Uniform $[10, 20]$
CB_t	Uniform $[1, 3]$
CH	Uniform $[0.3, 1.2]$
CD	Uniform $[0.3, 1.2]$
The number of potential location	3
The number of activities	30
The number of projects (*npr*)	3, 5

Considering that the most important contribution of this paper is to create decision integration in selecting projects, choosing the optimal location for pool construction and procurement policies for material purchases, so in this section the impact of providing such an integrated model on the overall profit achieved by a project-driven organization is being investigated. Since the problem is NP-hard, the proposed linear mathematical model cannot solve the large-size problems at logical CPU running time. For this reason, only benchmarking instances with 30 activities are evaluated in this section. To this end, 15 benchmark instances in literature are chosen and unspecified parameters are generated randomly. Then, the effect of decision integration is examined for each of the decision-making sectors.

The first subject in the proposed model which is integrated with other subject is selecting the optimal portfolio of projects. There are several methods in the context of being decided without regard to the integrated model for choosing a portfolio of projects. The first method is the selection based on the most profitable projects (MPP). At first, projects are sorted based on profitability. Then the projects are put in the basket so that the overall budget of the organization is not violated. The second approach is to select the project based on the lowest project funding (LPF). Finally, the third approach is based on the earliest release time (ERT). Based on the above approaches of portfolio selection, regardless of decision integration and the number of projects, Tables 3-8 show the results of solving instances with and without the decision integration to select the optimal portfolio of projects.

Table 3: Comparative results with /without decision integration about project selection (MPP method and 3 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	1,653	628.47	1,024.53	1,555	499.47	1,055.53	3.03%
2	1,076	394.89	681.11	958	274.75	683.25	0.31%
3	950	289.28	660.73	950	289.28	660.73	0.00%
4	1,709	611.31	1,097.69	1,613	468.90	1,144.10	4.23%
5	2,031	777.67	1,253.33	1,677	417.57	1,259.43	0.49%
6	833	253.07	579.93	833	253.07	579.93	0.00%
7	916	303.65	612.35	883	266.58	616.42	0.67%
8	1,106	389.98	716.02	1,072	335.54	736.46	2.85%
9	943	339.95	603.05	907	299.49	607.51	0.74%
10	1974	591.02	1,382.98	1829	427.80	1,401.20	1.32%
11	1,109	316.73	792.27	1,109	316.73	792.27	0.00%
12	1587	523.08	1,063.92	1417	350.14	1,066.86	0.28%
13	1,632	559.45	1,072.55	1,495	378.68	1,116.32	4.08%
14	814	302.97	511.03	783	254.16	528.84	3.48%
15	1936	562.99	1,373.01	1936	562.99	1,373.01	0.00%
Avg.	**1,351**	**456**	**895**	**1,268**	**360**	**908**	**1.47%**

Table 4: Comparative results with /without decision integration about project selection (LPF method and 3 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	1,555	499.47	1,055.53	1,555	499.47	1,055.53	0.00%
2	819	194.10	624.90	958	274.75	683.25	9.34%
3	912	264.94	647.06	950	289.28	660.73	2.11%
4	1,690	569.70	1,120.30	1,613	468.90	1,144.10	2.12%
5	1,677	417.57	1,259.43	1,677	417.57	1,259.43	0.00%
6	769	239.08	529.92	833	253.07	579.93	9.44%
7	916	303.65	612.35	883	266.58	616.42	0.67%
8	893	240.31	652.69	1,072	335.54	736.46	12.83%
9	907	299.49	607.51	907	299.49	607.51	0.00%
10	1955	593.15	1,361.85	1829	427.80	1,401.20	2.89%
11	784	159.31	624.69	1,109	316.73	792.27	26.83%
12	1587	523.08	1,063.92	1417	350.14	1,066.86	0.28%
13	1,495	378.68	1,116.32	1,495	378.68	1,116.32	0.00%
14	750	232.88	517.13	783	254.16	528.84	2.27%
15	1802	432.84	1,369.16	1936	562.99	1,373.01	0.28%
Avg.	**1,234**	**357**	**878**	**1,268**	**360**	**908**	**3.49%**

Table 5: Comparative results with /without decision integration about project selection (ERT method and 3 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	1,653	628.47	1,024.53	1,555	499.47	1,055.53	3.03%
2	958	274.75	683.25	958	274.75	683.25	0.00%
3	950	289.28	660.73	950	289.28	660.73	0.00%
4	1,690	569.70	1,120.30	1,613	468.90	1,144.10	2.12%
5	2,031	777.67	1,253.33	1,677	417.57	1,259.43	0.49%
6	833	253.07	579.93	833	253.07	579.93	0.00%
7	883	266.58	616.42	883	266.58	616.42	0.00%
8	893	240.31	652.69	1,072	335.54	736.46	12.83%
9	943	339.95	603.05	907	299.49	607.51	0.74%
10	1955	593.15	1,361.85	1829	427.80	1,401.20	2.89%
11	1,109	316.73	792.27	1,109	316.73	792.27	0.00%
12	1574	525.87	1,048.13	1417	350.14	1,066.86	1.79%
13	1,632	559.45	1,072.55	1,495	378.68	1,116.32	4.08%
14	783	254.16	528.84	783	254.16	528.84	0.00%
15	1936	562.99	1,373.01	1936	562.99	1,373.01	0.00%
Avg.	**1,322**	**430**	**891**	**1,268**	**360**	**908**	**1.88%**

Table 6: Comparative results with /without decision integration about project selection (MPP method and 5 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	4,349	935.04	3,413.97	4,259	689.96	3,569.04	4.54%
2	1,239	328.95	910.05	1,147	229.86	917.14	0.78%
3	3,357	813.07	2,543.93	3,202	617.67	2,584.33	1.59%
4	2,455	518.99	1,936.01	2,455	518.99	1,936.01	0.00%
5	1,312	341.38	970.62	1,312	341.38	970.62	0.00%
6	2,886	640.40	2,245.60	2,830	553.27	2,276.74	1.39%
7	2,892	665.74	2,226.26	2,820	480.53	2,339.47	5.09%
8	2,013	485.94	1,527.06	1,948	392.72	1,555.28	1.85%
9	2,159	419.71	1,739.29	2,159	419.71	1,739.29	0.00%
10	948	228.66	719.34	967	203.46	763.54	6.14%
11	4,214	917.39	3,296.61	4,143	697.27	3,445.73	4.52%
12	3,006	694.39	2,311.61	2,854	500.88	2,353.12	1.80%
13	2,227	424.02	1,802.98	2,227	424.02	1,802.98	0.00%
14	3,757	757.04	2,999.96	3,715	634.15	3,080.85	2.70%
15	1,133	290.05	842.95	1,090	243.07	846.93	0.47%
Avg.	**2,530**	**564**	**1,966**	**2,475**	**463**	**2,012**	**2.36%**

Table 7: Comparative results with /without decision integration about project selection (LPF method and 5 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	4,049	627.60	3,421.41	4,259	689.96	3,569.04	4.32%
2	1,597	711.46	885.54	1,147	229.86	917.14	3.57%
3	2,800	538.16	2,261.84	3,202	617.67	2,584.33	14.26%
4	2,508	601.92	1,906.08	2,455	518.99	1,936.01	1.57%
5	1,113	228.17	884.84	1,312	341.38	970.62	9.69%
6	2,830	553.27	2,276.74	2,830	553.27	2,276.74	0.00%
7	2,654	451.71	2,202.29	2,820	480.53	2,339.47	6.23%
8	1,873	374.60	1,498.40	1,948	392.72	1,555.28	3.80%
9	1,921	332.33	1,588.67	2,159	419.71	1,739.29	9.48%
10	948	228.66	719.34	967	203.46	763.54	6.14%
11	3,706	655.96	3,050.04	4,143	697.27	3,445.73	12.97%
12	2,683	431.96	2,251.04	2,854	500.88	2,353.12	4.54%
13	2,227	424.02	1,802.98	2,227	424.02	1,802.98	0.00%
14	3,671	623.70	3,047.30	3,715	634.15	3,080.85	1.10%
15	1,090	243.07	846.93	1,090	243.07	846.93	0.00%
Avg.	**2,378**	**468**	**1,910**	**2,475**	**463**	**2,012**	**5.37%**

Table 8: Comparative results with /without decision integration about project selection (ERT method and 5 projects)

instances	Without decision integration	With decision integration	Increase in

	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	profit (%)
1	4,259	689.96	3,569.04	4,259	689.96	3,569.04	0.00%
2	1,147	229.86	917.14	1,147	229.86	917.14	0.00%
3	3,354	832.46	2,521.54	3,202	617.67	2,584.33	2.49%
4	2,093	418.60	1,674.40	2,455	518.99	1,936.01	15.62%
5	1,002	180.56	821.44	1,312	341.38	970.62	18.16%
6	2,830	553.27	2,276.74	2,830	553.27	2,276.74	0.00%
7	2,883	591.02	2,291.99	2,820	480.53	2,339.47	2.07%
8	2,013	485.94	1,527.06	1,948	392.72	1,555.28	1.85%
9	1,897	341.46	1,555.54	2,159	419.71	1,739.29	11.81%
10	967	203.46	763.54	967	203.46	763.54	0.00%
11	4,143	861.74	3,281.26	4,143	697.27	3,445.73	5.01%
12	2,982	644.11	2,337.89	2,854	500.88	2,353.12	0.65%
13	2,097	412.69	1,684.31	2,227	424.02	1,802.98	7.05%
14	3,671	623.70	3,047.30	3,715	634.15	3,080.85	1.10%
15	1,090	243.07	846.93	1,090	243.07	846.93	0.00%
Avg.	**2,429**	**487**	**1,941**	**2,475**	**463**	**2,012**	**3.66%**

As shown in Tables 3-8, considering the decision integration regarding the selection of the optimal portfolio and the project scheduling will increase the profit. The results show that the decision integration in comparison with MPP method increases the profit of organization on average 1.47% and 2.36% for problems with 3 and 5 projects, respectively. Also, the decision integration in comparison with LPF method increases the profit of organization on average 3.49% and 5.37% for problems with 3 and 5 projects, respectively. Finally, the decision integration in comparison with ERT method increases the profit of organization on average 1.88% and 3.66% for problems with 3 and 5 projects, respectively.

The second subject in the proposed model that is integrated with other subject is selecting the optimal location of resource pool. There are several methods in the context of being decided without regard to the integrated model for choosing location of resource pool. One of these methods is selecting the location with the lowest cost of construction (LCC). Another method is selecting the location of construction based on the P-median model, where equation (23) can be used to select a location that has a minimum weighted distance from all activities:

$$Arg\min_{l\in L}\left\{\sum_i r_i D_{li}\right\} \tag{23}$$

Based on the above approaches of resource pool location, regardless of decision integration and the number of projects, Tables 9-12 show the results of solving instances with and without the decision integration to select the optimal location of resource pool.

Table 9: Comparative results with /without decision integration about resource pool location (LCC method and 3 projects)

instances	Without decision integration				With decision integration				Increase in profit (%)
	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	
1	1,510	82	416.60	1,011.40	1,555	103	396.47	1,055.534	4.36%
2	958	91	183.75	683.25	958	91	183.75	683.25	0.00%
3	908	79	224.73	604.27	950	95	194.28	660.73	9.34%
4	1,634	90	429.12	1,114.88	1,613	137	331.90	1,144.10	2.62%
5	1,624	68	318.51	1,237.49	1,677	125	292.57	1,259.43	1.77%
6	833	77	176.07	579.93	833	77	176.07	579.93	0.00%
7	883	83	183.58	616.42	883	83	183.58	616.42	0.00%
8	1,013	68	229.82	715.18	1,072	81	254.54	736.46	2.98%
9	890	73	220.70	596.30	907	102	197.49	607.51	1.88%
10	1,807	94	312.58	1,400.43	1,829	175	252.80	1,401.20	0.06%
11	1,037	59	216.43	761.57	1,109	114	202.73	792.27	4.03%
12	1,393	66	281.69	1,045.31	1,417	94	256.14	1,066.86	2.06%
13	1,430	101	277.66	1,051.34	1,495	128	250.68	1,116.32	6.18%
14	783	74	180.16	528.84	783	74	180.16	528.84	0.00%
15	1,890	76	473.61	1,340.39	1,936	180	382.99	1,373.01	2.43%
Avg.	**1,240**	**79**	**275**	**886**	**1,268**	**111**	**249**	**908**	**2.52%**

Table 10: Comparative results with /without decision integration about resource pool location (P-median method and 3 projects)

instances	Without decision integration				With decision integration				Increase in profit (%)
	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	
1	1,537	114	378.15	1,044.85	1,555	103	396.47	1,055.534	1.02%
2	958	91	183.75	683.25	958	91	183.75	683.25	0.00%
3	950	95	194.28	660.73	950	95	194.28	660.73	0.00%
4	1,564	122	327.96	1,114.04	1,613	137	331.90	1,144.10	2.70%
5	1,677	125	292.57	1,259.43	1,677	125	292.57	1,259.43	0.00%
6	819	85	172.00	562.00	833	77	176.07	579.93	3.19%
7	880	90	184.47	605.53	883	83	183.58	616.42	1.80%
8	1,083	110	251.72	721.28	1,072	81	254.54	736.46	2.11%
9	873	91	197.09	584.91	907	102	197.49	607.51	3.86%
10	1,829	175	252.80	1,401.20	1,829	175	252.80	1,401.20	0.00%
11	1,085	78	224.28	782.72	1,109	114	202.73	792.27	1.22%
12	1,393	66	281.69	1,045.31	1,417	94	256.14	1,066.86	2.06%
13	1,502	136	257.22	1,108.78	1,495	128	250.68	1,116.32	0.68%
14	783	74	180.16	528.84	783	74	180.16	528.84	0.00%
15	1,886	149	414.54	1,322.46	1,936	180	382.99	1,373.01	3.82%
Avg.	**1,255**	**107**	**253**	**895**	**1,268**	**111**	**249**	**908**	**1.46%**

Table 11: Comparative results with /without decision integration about resource pool location (LCC method and 5 projects)

t a r	Without decision integration	With decision integration	Increase

	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	in profit (%)
1	4,193	82	673.58	3,437.42	4,259	114	575.96	3,569.042	3.83%
2	1,096	91	124.69	880.31	1,147	100	129.86	917.14	4.18%
3	3,136	79	543.50	2,513.50	3,202	95	522.67	2,584.33	2.82%
4	2,435	90	440.10	1,904.90	2,455	122	396.99	1,936.01	1.63%
5	1,312	68	273.38	970.62	1,312	68	273.38	970.62	0.00%
6	2,741	77	481.62	2,182.38	2,830	85	468.27	2,276.74	4.32%
7	2,687	83	459.51	2,144.49	2,820	122	358.53	2,339.47	9.09%
8	1,926	68	313.35	1,544.65	1,948	81	311.72	1,555.28	0.69%
9	2,100	73	376.40	1,650.60	2,159	102	317.71	1,739.29	5.37%
10	909	94	83.26	731.75	967	127	76.46	763.54	4.35%
11	3,920	59	668.55	3,192.45	4,143	114	583.27	3,445.73	7.93%
12	2,689	66	430.39	2,192.61	2,854	134	366.88	2,353.12	7.32%
13	2,187	101	325.03	1,760.97	2,227	128	296.02	1,802.98	2.39%
14	3,613	74	665.22	2,873.78	3,715	97	537.15	3,080.85	7.21%
15	1,090	76	167.07	846.93	1,090	76	167.07	846.93	0.00%
Avg.	**2,402**	**79**	**402**	**1,922**	**2,475**	**104**	**359**	**2,012**	**4.70%**

As shown in Tables 9-12, considering the decision integration regarding the resource pool location and the project scheduling will increase the profit. The results show that the decision integration in comparison with LCC method increases the profit of organization on average 2.52% and 4.70% for problems with 3 and 5 projects, respectively. Also, the decision integration in comparison with P-median method increases the profit of organization on average 1.46% and 2.64% for problems with 3 and 5 projects, respectively. It is obvious the P-median method can obtain the better solutions than LCC in without decision integration situation. The results also show that the decision integration model will have more effectiveness in improving the solutions with increasing number of projects.

Finally, the third subject in the proposed model that is integrated with other subject is purchasing non-renewable resources with batch order system. Indeed, in the proposed model, supply chain management is integrated with project management. In the absence of decision integration, the project scheduling is accomplished regardless of purchasing non-renewable resources, and assuming they are ready at the start of any activity. Then the determined scheduling is catch as an input to supply chain management and this unit decides about procurement policy based on fixed and variable purchasing costs and holding costs.

Table 12: Comparative results with /without decision integration about resource pool location (P-median method and 5 projects)

instances	Without decision integration				With decision integration				Increase in profit (%)
	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	Projects revenue	Resource pool construction cost	Other imposed Costs	Total profit	
1	4,259	114	575.96	3,569.04	4,259	114	575.96	3,569.042	0.00%
2	1,106	91	137.72	877.28	1,147	100	129.86	917.14	4.54%
3	3,202	95	522.67	2,584.33	3,202	95	522.67	2,584.33	0.00%
4	2,455	122	396.99	1,936.01	2,455	122	396.99	1,936.01	0.00%
5	1,282	125	264.47	892.53	1,312	68	273.38	970.62	8.75%
6	2,830	85	468.27	2,276.74	2,830	85	468.27	2,276.74	0.00%

7	2,734	90	407.31	2,236.69	2,820	122	358.53	2,339.47	4.60%
8	1,956	110	355.53	1,490.47	1,948	81	311.72	1,555.28	4.35%
9	2,127	91	342.91	1,693.09	2,159	102	317.71	1,739.29	2.73%
10	979	175	84.44	719.57	967	127	76.46	763.54	6.11%
11	4,045	78	632.30	3,334.70	4,143	114	583.27	3,445.73	3.33%
12	2,789	66	448.85	2,274.15	2,854	134	366.88	2,353.12	3.47%
13	2,221	136	327.74	1,757.26	2,227	128	296.02	1,802.98	2.60%
14	3,652	74	600.16	2,977.84	3,715	97	537.15	3,080.85	3.46%
15	1,114	149	179.18	785.82	1,090	76	167.07	846.93	7.78%
Avg.	**2,450**	**107**	**383**	**1,960**	**2,475**	**104**	**359**	**2,012**	**2.64%**

To do this, first, the mathematical model is implemented by eliminating the purchase and holding costs from the objective function. Then the time taken to dispatch non-renewable resources to activities is considered as the input of the heuristic algorithm presented below. This heuristic algorithm, which is a kind of greedy search algorithm, tries to minimize the total buying and holding costs. In this algorithm, at the first step, the objective function is calculated via equation (24):

$$ff(0) = \sum_i \sum_t \theta_{it} CF_t + \sum_i \sum_t \theta_{it} CB_t r_i' \tag{24}$$

In the above equation, θ_{it} is equivalent to the dispatching time of resources obtained from the mathematical model. This objective function means that it is initially assumed that the non-renewable resources required for each activity is purchased separately at the required time. Therefore, the number of batches is equal to the number of activities and also their purchasing times are equal to the dispatching times. In this case, holding costs will be zero. Then, the batches are sorted based on purchasing time. The first batch is considered as *basic batch*. Then it is examined if the purchased resources related to the second batch are purchased at the same time as the *basic batch* would reduce costs ($ff(s)$ less than $ff(s-1)$) or not? If such a change would reduce costs, then this change will stabilize and we will go to the third batch. Otherwise, the situation returns to the previous state, and then the comparison occurs between the *basic batch* and the third batch. If the last batch is reached, the *basic batch* is updated and is equivalent to the next batch. This process continues until the last comparison. In order to model this process, the parameter *s* is equivalent to the step number, the binary variable $\gamma_t(s)$ is equivalent to the purchasing times in step *s*, the integer variable $Q_t(s)$ is the equivalent of the purchasing values at time *t* in step *s*, and finally the variable $\Delta CH(s)$ is defined equivalent to the changes in holding costs in step *s* comparison to step *s -1*. In this case, the objective function in step *s* will be equivalent to equation (25):

$$ff(s) = \sum_t \gamma_t(s) CF_t + \sum_t Q_t(s) CB_t + \Delta CH(s) \tag{25}$$

At the end of the algorithm, the obtained solution is considered as the optimal solution for supply chain management, and this cost is deducted from the total profitability calculated from the mathematical model. Based on the heuristic algorithm for determining batch order policy, regardless of decision integration and the number of projects, Tables 13 and 14 show the results of solving instances with and without the decision integration to determine batch order policy.

As shown in Tables 13 and 14, considering the decision integration regarding the batch order policy and the project scheduling will increase the profit. The results show that the decision integration in comparison with the proposed greedy search algorithm increases the profit of organization on average 3.85% and 4.32% for problems with 3 and 5 projects, respectively.

Table 13: Comparative results with /without decision integration about batch ordering (3 projects)

instances	Without decision integration				With decision integration				Increase in profit (%)
	Projects revenue	Batch ordering cost	Other imposed Costs	Total profit	Projects revenue	Batch ordering cost	Other imposed Costs	Total profit	
1	1,568	426.50	118.75	1,022.75	1,555	392.67	106.80	1,055.534	3.21%
2	963	213.79	102.37	646.84	958	181.36	93.39	683.25	5.63%
3	950	191.90	98.19	659.91	950	190.12	99.16	660.73	0.12%
4	1,619	393.42	129.55	1,096.03	1,613	325.11	143.79	1,144.10	4.39%
5	1,683	348.38	127.84	1,206.78	1,677	289.21	128.36	1,259.43	4.36%
6	849	194.42	78.12	576.46	833	170.14	82.93	579.93	0.60%
7	883	196.03	86.15	600.82	883	181.52	85.06	616.42	2.60%
8	1,085	284.27	89.33	711.40	1,072	251.09	84.45	736.46	3.52%
9	923	242.75	107.87	572.38	907	192.14	107.35	607.51	6.14%
10	1,849	403.08	159.22	1,286.70	1,829	247.50	180.30	1,401.20	8.90%
11	1,136	245.38	119.56	771.06	1,109	198.49	118.24	792.27	2.75%
12	1,419	286.64	97.34	1,035.02	1,417	253.32	96.82	1,066.86	3.08%
13	1,507	302.91	133.90	1,070.19	1,495	246.52	132.16	1,116.32	4.31%
14	794	200.09	75.48	518.43	783	175.11	79.05	528.84	2.01%
15	1,942	440.83	159.08	1,342.09	1,936	379.71	183.28	1,373.01	2.30%
Avg.	**1,278**	**291**	**112**	**874**	**1,268**	**245**	**115**	**908**	**3.85%**

Table 14: Comparative results with /without decision integration about batch ordering (5 projects)

instances	Without decision integration				With decision integration				Increase in profit (%)
	Projects revenue	Batch ordering cost	Other imposed Costs	Total profit	Projects revenue	Batch ordering cost	Other imposed Costs	Total profit	
1	4,279	731.71	116.83	3,430.46	4,259	569.29	120.67	3,569.042	4.04%
2	1,155	155.93	112.30	886.78	1,147	125.98	103.88	917.14	3.42%
3	3,208	571.02	97.29	2,539.69	3,202	516.28	101.39	2,584.33	1.76%
4	2,460	435.42	118.36	1,906.22	2,455	393.93	125.06	1,936.01	1.56%
5	1,319	309.97	73.46	935.58	1,312	268.57	72.81	970.62	3.75%
6	2,843	605.56	80.29	2,157.15	2,830	465.37	87.90	2,276.74	5.54%
7	2,827	545.61	89.47	2,191.92	2,820	355.06	125.47	2,339.47	6.73%
8	1,955	373.41	85.58	1,496.02	1,948	307.99	84.73	1,555.28	3.96%
9	2,162	374.03	91.76	1,696.21	2,159	311.82	107.89	1,739.29	2.54%
10	969	109.50	133.56	725.94	967	72.27	131.19	763.54	5.18%
11	4,162	761.65	79.91	3,320.44	4,143	579.23	118.04	3,445.73	3.77%
12	2,867	541.86	137.04	2,188.10	2,854	361.68	139.20	2,353.12	7.54%
13	2,246	422.25	109.53	1,714.22	2,227	292.83	131.19	1,802.98	5.18%
14	3,726	696.76	99.13	2,930.11	3,715	530.50	103.65	3,080.85	5.14%
15	1,090	198.38	79.68	811.94	1,090	162.70	80.37	846.93	4.31%

Avg.	**2,485**	**456**	**100**	**1,929**	**2,475**	**354**	**109**	**2,012**	**4.32%**

It should be noted that so far, all the studies carried out on the impact of decision integration on increasing profits have only been based on the elimination of one dimension of decision integration. If all three decision dimensions, i.e. selecting the optimal portfolio, choosing the optimal location of the resource pool, and determining the best batch order policy, are determined without decision integration, then the significance of the model presented in this paper will be better demonstrated. For this reason, Tables 15 and 16 show the results of solving instances with and without the decision integration in all aspects of decision making. In the absence of decision integration, the best methods presented in this section are used. In order to select the optimal portfolio the MPP method is used. For choosing the optimal location of the resource pool the P-median method is applied. Finally, the greedy search algorithm is used for determining the best batch order policy.

Table 15: Comparative results with /without decision integration (3 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	1,653	679.55	973.45	1,555	499.47	1,055.53	8.43%
2	1,076	429.32	646.68	958	274.75	683.25	5.66%
3	950	292.13	657.88	950	289.28	660.73	0.43%
4	1,709	652.15	1,056.85	1,613	468.90	1,144.10	8.26%
5	2,031	830.48	1,200.52	1,677	417.57	1,259.43	4.91%
6	833	271.72	561.28	833	253.07	579.93	3.32%
7	916	323.07	592.93	883	266.58	616.42	3.96%
8	1,106	426.03	679.97	1,072	335.54	736.46	8.31%
9	943	383.42	559.58	907	299.49	607.51	8.57%
10	1974	705.51	1,268.49	1829	427.80	1,401.20	10.46%
11	1,109	340.68	768.32	1,109	316.73	792.27	3.12%
12	1587	570.69	1,016.31	1417	350.14	1,066.86	4.97%
13	1,632	608.41	1,023.59	1,495	378.68	1,116.32	9.06%
14	814	311.11	502.89	783	254.16	528.84	5.16%
15	1936	626.88	1,309.12	1936	562.99	1,373.01	4.88%
Avg.	**1,351**	**497**	**855**	**1,268**	**360**	**908**	**6.27%**

As shown in Tables 15 and 16, considering the decision integration in all aspects considered in this paper will increase the profit. The results show that the decision integration increases the profit of organization on average 6.27% and 7.85% for problems with 3 and 5 projects, respectively. In order to facilitate the conclusion, Table 17 shows all the results presented in this section.

Table 16: Comparative results with /without decision integration (5 projects)

instances	Without decision integration			With decision integration			Increase in profit (%)
	Projects revenue	Imposed Costs	Total profit	Projects revenue	Imposed Costs	Total profit	
1	4,349	1,022.02	3,326.99	4,259	689.96	3,569.04	7.28%

2	1,239	378.51	860.49	1,147	229.86	917.14	6.58%
3	3,357	846.64	2,510.36	3,202	617.67	2,584.33	2.95%
4	2,455	548.78	1,906.22	2,455	518.99	1,936.01	1.56%
5	1,312	433.22	878.78	1,312	341.38	970.62	10.45%
6	2,886	776.05	2,109.95	2,830	553.27	2,276.74	7.90%
7	2,892	810.34	2,081.66	2,820	480.53	2,339.47	12.38%
8	2,013	586.59	1,426.41	1,948	392.72	1,555.28	9.03%
9	2,159	493.12	1,665.88	2,159	419.71	1,739.29	4.41%
10	948	282.69	665.31	967	203.46	763.54	14.77%
11	4,214	1,085.95	3,128.05	4,143	697.27	3,445.73	10.16%
12	3,006	874.75	2,131.25	2,854	500.88	2,353.12	10.41%
13	2,227	559.42	1,667.58	2,227	424.02	1,802.98	8.12%
14	3,757	899.80	2,857.20	3,715	634.15	3,080.85	7.83%
15	1,133	364.26	768.74	1,090	243.07	846.93	10.17%
Avg.	**2,530**	**664**	**1,866**	**2,475**	**463**	**2,012**	**7.85%**

Table 17: The conclusion of the obtained results

The subjects that have not been considered in decision integration	Heuristic method for the subject	The increase in profit by using decision integration model (%)	
		Instances with 3 projects	Instances with 5 projects
Project selection	MPP	1.47%	2.36%
	LPF	3.49%	5.37%
	ERT	1.88%	3.66%
Resource pool location	LCC	2.52%	4.70%
	P-median	1.46%	2.64%
Resource batch ordering	Greedy search algorithm	3.85%	4.32%
All subjects	MPP, P-median, Greedy search algorithm	6.27%	7.85%

5. CONCLUSION AND FURTHER RESEARCH

This paper investigated the multi-period decentralized multi-project and scheduling problem with regard to resource constraints, optimal resource pool location, deterioration and batch ordering of nonrenewable resources, for the first time. Initially, a mixed-integer linear programming model was developed that could solve the global optimal problems. The most important contribution in this paper is the integrated decision-making model for project portfolio management in a project-driven organization. For this reason, the impact of decision integration on increasing organizational profit was examined in computational results section. The results showed considering the decision integration regarding the selection of the optimal portfolio and the project scheduling will increase the profit on average 3.04% (the average increase in profits by different methods and different number of project). Also, the results showed considering the decision integration regarding the optimal resource pool location and the project scheduling will increase the profit on average 2.83%. Finally, considering the decision integration regarding the optimal batch order policy and the project scheduling will increase the profit on average 4.09%. Another important result is that considering the decision integration in all aspects considered in this paper will increase the profit on average 6.27% and 7.85% for problems with 3 and 5 projects, respectively. Further study can be elaborated on applying fuzzy logic and stochastic model for the problem under consideration in this paper in order to deal with uncertain conditions which might be happened in batch delivery and resource location.

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