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Location and Allocation in Multi-Level Supply Chain Network of Projects

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***Abstract** – This research aims to optimize cost and demand-satisfaction in a 3-level supply chain management for a portfolio of projects at EPC companies, including vendors (for product procurement), warehouses as distribution centers, and projects as demand zones. In contrast, it reduces the costs of transporting and warehousing and increases demand satisfying for projects. We utilize the Multi-objective Particle Swarm Optimization (MOPSO) meta-heuristic algorithm to solve this model and the decision-making of vendors and warehouses. Besides, it leads to demand and storage allocation and monitoring of product flow between these levels of the portfolio supply chain.*

***Keywords**– Location-allocation; Cost Optimization; MOPSO Algorithm; 3-Level Supply Chain Management; Project Procurement.*

I. INTRODUCTION

Location and allocation of the supply chain are some of the subjects that have played a pivotal role in structure design which is studied under more general headings as logistics management study (Wang et al., 2011). In projects, supplier as projects vendors is a place where the raw materials, equipment for processing, and human resources come together to produce the final product for satisfying the demand of projects. An optimized location decision for the unit results in the overall effectiveness of the system (Ahmadi-Javid & Hoseinpour, 2015). In allocation problems, it is assumed that the number of vendor's factories and warehouses and their locations are already known and attempts to explain how the products are transferred to each of the projects as distribution centers. In other words, by assuming that amount of demanded items by each project, storing capacity and unit production and service cost of each demand zones (projects) from each distribution center (warehouses) are known, the allocation problem determines how many products that distribution centers must send to each of the demand centers. Location-allocation problems not only determine how many products each project as demand zones receives but also defines the number of warehouses and vendor's factories and their location and capacity (HA et al., 2016). The location problems can be classified as unit or multi-unit matters. As the name implies, the single unit location problems determine an optimal location for a unit, and multi-unit location problems simultaneously determine the optimal locations for multi-units (Haux and Candia, 1984). The aim of this article is to study designing a supply chain network for projects portfolio of substations construction. In this single product network, three levels include vendors' production factories, distributors or warehouses, and finally, demand zones which are substations of EPC projects. The proposed model minimizes supply chain network costs and

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maximizes the rate of satisfying the project demand considering model constraints. Finally, the proposed model is optimized using a multi-objective meta-heuristic method (Eskandarpour et al., 2017). In addition, cost management is one of the significant knowledge areas in PMBOK[1] for each kind of project. As a result, by optimization the cost of the portfolio supply chain, one fundamental strategic goal for EPC companies is obtained. The sophisticated 3-level portfolio supply chain structure with constrained particles for this research can be shown in the following figure 1.

The innovation of this paper is applying and integrating supply chain management and project and portfolio management. Schedule and cost management are two critical knowledge are in project and portfolio management in PMBOK. Another significant knowledge area is procurement management for purchasing needed equipment in the erection phase and satisfying the demands of projects in equipment cause optimizing schedules based on the critical path. On the other hand, optimizing the cost of supplying equipment such as procurement price, transportation, storing and etc., cause decreasing and optimization costs—moreover, allocation and selection of best vendors for supplying equipment cause to carry out procurement project management processes. Based on the aforementioned reasons, the innovated view is applied for procurement knowledge areas of similar projects by defining supply chain levels. Figure 1 shows the complexity of this real case study for the corporation. In the figure, factories, warehouses, and projects have been illustrated as nodes. Moreover, flows between nodes have been illustrated between factories-warehouses and warehouses-projects. For portfolio management of substations construction projects, an integrated view is vital and necessary.

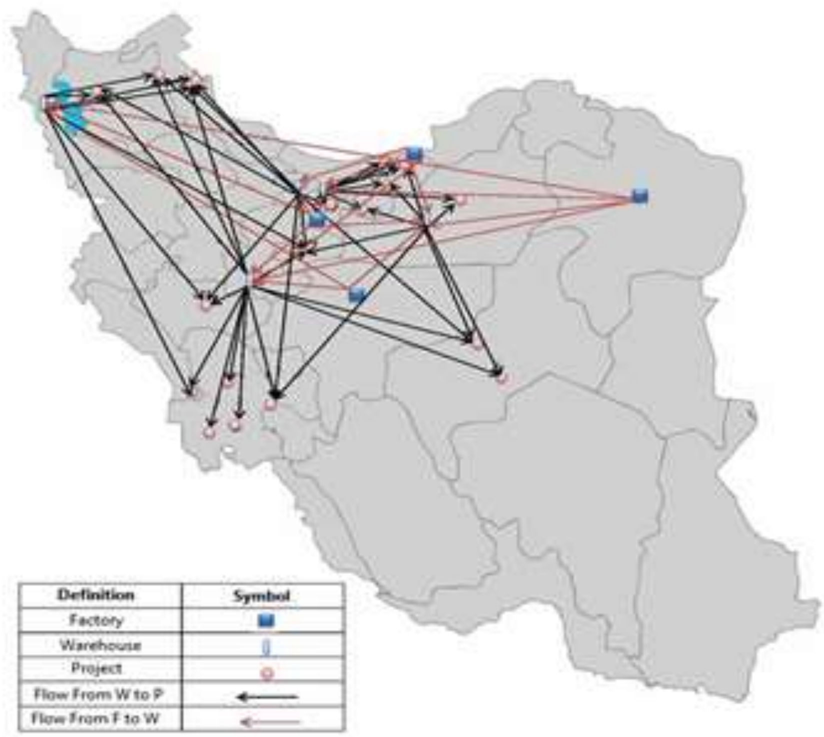

Figure 1- Map of projects portfolio supply chain network (Case Study)

١ . Project Management Body Of Knowledge-Edition 6th

In the following, the first literature review based on location and allocation problems will be described. Afterward, the problem conditions of this case study and all assumptions and requirements will be described. The next step will illustrate the numerical model and applying an algorithm for solving the model. Finally, the three best scenarios that resulted from solving problems will be described.

II. LITERATURE REVIEW

A. Researches on location and allocation problems

In this study, past related researches according to location, allocation, and multi-objective optimization using PSO algorithm are mentioned. (Warszawski & Peer, 1973) was one of the first researchers that began researching multi-item location problems (Mousavi et al., 2015). These models include fixed costs of location, linear transportation costs, and the assumption that each warehouse can be allocated to more than several items. Geoffrion and Graves (1974) raised issues of location multi-item with capacity and presented a model for solving the problem of designing a distribution system with the optimal location for median distribution centers between factories and demand centers (Hajipour et al., 2014).

Another category of problem is presented as facilities location with fixed costs in which the fixed cost of location-allocation are considered to each of the candidates (Tancrez et al., 2012). There are two types of facility allocation problems, one with capacity and the other without capacity. Models with capacity are mentioned as models with limited factory production capacity and models without capacity as no-limit in factory production capacity. Location models for factories with capacity and without capacity are studied mainly by Islet and Discyn (2008), while the location model for factories with capacity is studied by Sridharen (1995).

There is a new trend for basic facilities location with the combined method. Researchers pay attention to this new approach because of the recognition of the fact that location decisions cannot achieve the optimal solution without taking into account inventory costs and transportation. Location problems are developed by allocating the costs such as production, inventory, and distribution costs (Sadeghi et al., 2014). Combined decision models have a particular focus on the coordination of choosing two of the three important decisions in the supply chain: 1) routing-location models, 2) inventory-routing models 3) location-inventory models. These models have been widely studied by (Shen, 2007). (Fathollahi Fard, & Hajaghaei-Keshteli, 2018) firstly have addressed the tri-level location-allocation design problem, which considers the forward and reverses network simultaneously. The proposed problem is formulated on the static Stackelberg game between the Distribution Centers (D.C.s), Customer Zones (C.Z.s), and Recover Centers (R.C.s) in the framework. (Ebrahimi, 2018) has designed a closed-loop supply chain network taking into consideration sustainability aspects and quantity discounts under uncertainty. To this end, a stochastic multi-objective optimization for supplier selection and location-allocation-routing problems is formulated. In (Ehtesham Rasi et al.,, 2020), authors have presented a new form of the location-routing problem of facilities under uncertainty in a supply chain network for deteriorating items through taking environmental considerations, cost, and procurement time, and customer satisfaction into account, to simultaneously minimize total system costs, maximal delivery time and emissions across the entire network and maximize customer satisfaction.

B. Researches on project procurement supply chain

(Genovese et al., 2020) have provided new insight into current and emerging supply chain approaches and related power relations deriving from public procurement processes within Local Authorities (L.A.s). (Wuni et al., 2020) has identified and prioritized the CSFs which may help MiC project managers and stakeholders in the appropriate allocation of limited resources. These shared CSFs may constitute forecasting and diagnostic tools for progressively measuring success along with the MiC project lifecycle phases. In (Owusu et al., 2020), the authors have examined procurement irregularities as one of the most unexplored threats in the procurement process of construction projects. It also tests the suppositions associated with the contributions of irregularities to corruption in construction procurement. (Kamoni,

2020) has entailed a census of all the 47 mega projects under the various public procuring entities in the energy sector. The unit of observation was the procurement managers in the procuring entities dealing with mega projects. (Wang, 2020) in his paper, the evaluation index, which is different from the traditional supplier selection of engineering projects, is established to select reliable suppliers, which can improve the overall performance of the supply chain of engineering projects and achieve the goal of rapidly responding to customer demands by promoting the interaction between logistics and information flow. (Gosling et al., 2020) have summarized the findings of a research project which is focused on developing the principles required for procurement excellence and structuring the possible contractual choices in engineer-to-order supply chains.

C. Researches on PSO

PSO is one of the simultaneous multi-function computational techniques, and population search algorithms that begins from a set of random solutions called a particle. Speed is given to each particle(Mousavi et al., 2016). A number of researchers in 2009 developed an inventory model for a supply chain network in which supply chain performance is evaluated by applying two criteria, total cost and demand satisfaction rates, using a fuzzy system. The author considered a multi-objective optimization algorithm and simulation to solve this two-criterion model (Maghsoudlou et al., 2016).

Yueyue Liu (2019)compare MOPSO-LS with the well-known multi-objective optimization algorithm NSGA-II. The experimental results have verified the effectiveness of the proposed algorithm. The work of this paper shed some light on the fast-growing research related to sustainable production scheduling (Liu, Xiaoya et al., 2019).

Mentioned literature review shows that little researches are done for implementing supply chain network algorithm. (Shukor et al., 2016) On the other hand it is a novel research in proposing a locating and allocating supply chain network especially in station posts in which are one of the country's strategic projects in power generation and transmission.(Ghodratnama et al., 2015) The aim of this article is to formulate and analyze a locating and allocating factory strategic model in 3-level supply chain network of station projects with the purpose of minimizing total supply chain cost including production costs, transportation and distribution costs and also maximizing demand satisfying rate using MOSPSO algorithm. This case study that integrate portfolio management and supply chain management is new work and there is not similar works for substation projects. It means that we will optimize both cost and time as two main knowledge areas of project management by applying splly chain model.

The remainder of this paper is organized as follows. The problem conditions are defined in section 3. Section 4 presents the MOPSO algorithm steps to optimize the location-allocation problem based on a case study. Section 5 provides the computation results, and finally, Section 6 outlines the conclusion and some suggestions for future researches.

III. PROBLEM DEFINITION

This article includes a supply chain with three different levels. The first level of the final stage of this supply chain network includes demand centers that determine which items must be transported to demand centers in a way that meets lower satisfaction bounds. This level includes substation projects scattered around the country based on figure 1. The main demand for these projects is equipment. Equipment is needed for erection and finalizing the construction part before pre-commissioning and commissioning. It means that the prerequisite of completing the projects is procuring equipment from vendors or suppliers. The second level supply chain network includes distribution centers (warehouses), specifies which products should be transferred from the warehouse to demand centers (Dey et al., 2016). The main point is that warehouses are limited and have different prices for renting. The locations of warehouses must be optimized for all projects. The third level consists of suppliers and manufacturers. The suppliers are various for supplying the equipment of substation projects. The decision-making supplier is very critical for cost optimization. Moreover, the production capacity of the supplier must be considered too. In the supply chain, the net income includes the sale of items, and supply chain costs include facilities, labor, transportation, raw materials, and inventories.

(Schuster Puga & Tancrez, 2017) in addition, in this article, the station project supply chain network is studied. The product range includes panels required for the project, which is one of the most important station items for different parts of the project construction (Govindan, et al., 2015).

A. Problem assumptions

For modeling the problem, the below assumptions are considered:

- Candidate sites for factories and distribution centers (warehouses) are specified.
- Costs of production in factories are fixed.
- Cost of transportation from the factory to the warehouse is identified and fixed.
- Cost of transportation from the distribution centers to demand centers (projects) identified and fixed.
- The minimum rate of satisfying demand should be considered.

B. Problem input data

- The number of candidates for factories and distribution centers and each capacity of them
- Production costs for each factory
- Distribution cost for each shipped from factories to distribution centers
- Operating costs for any goods distribution centers and transportation costs from the distribution centers to demand centers
- The number of distribution centers and demand
- Minimum rate of satisfying the demand (a fraction of satisfying the demand) should be considered.

C. The decision variables

- Number and location of factories.
- Product flows from localized factories to distribution centers
- Number and location of distribution centers
- Demand centers allocation to distribution centers

D. Objective functions

1. Minimizing all costs of the supply chain, including:

- Factory production Expenses
- Items distribution Expenses from factories to distribution centers (warehouses)
- Warehouses rent Expenses
- Costs of distribution from distribution centers to demand centers

2. Maximizing the satisfaction rate of demand

E. Mathematical modeling

In this paper, location and allocation of 3-level post construction projects in supply chain network with the constraint of capacity for factories and warehouses are considered. The problem is modeled as an integrated model as the following equation:

Objectives:

$$Objective1: Min \sum_{i=1}^{n} P_i X_{ie} y_i + \sum_{e=1}^{t} f_e y_e + \sum_{i=1}^{n} \sum_{e=1}^{t} C_{ie} X_{ie} + \sum_{e=1}^{t} \sum_{j=1}^{m} C_{ej} X_{ej} \ , \quad (1)$$

$$Objective2: Max \frac{\sum_{e=1}^{t} \sum_{j=1}^{m} X_{ej}}{\sum_{j=1}^{m} D_j} \ , \quad (2)$$

Subject to:

$$\sum_{e=1}^{t} X_{ej} \le D_j \qquad for \ \ j = 1,2,\ldots,m \ , \quad (3)$$

$$\sum_{e=1}^{t} X_{ie} \le K_i Y_i \qquad for \ \ i = 1,2,\ldots,n \quad (4)$$

$$\sum_{j=1}^{m} X_{ej} \le K_e Y_e \qquad for \ \ e = 1,2,\ldots,t \ , \quad (5)$$

$$\sum_{i=1}^{n} X_{ie} - \sum_{j=1}^{m} X_{ej} \ge 0 \qquad for \ \ e = 1,2,\ldots,t \ , \quad (6)$$

$$0.8 \le \frac{\sum_{e=1}^{t} \sum_{j=1}^{m} X_{ej}}{\sum_{j=1}^{m} D_j} \le 1 \quad (7)$$

$$Y_i, Y_e \in \{0,1\} \qquad for \ \ i = 1,2,\ldots,n \quad e = 1,2,\ldots,t \ , \quad (8)$$

$$X_{ie} \in \{Integer\} \qquad for \ \ i = 1,2,\ldots,n \quad e = 1,2,\ldots,t \ , \quad (9)$$

$$X_{ej} \in \{Integer\} \qquad for\ e = 1,2,\ldots,t \quad j = 1,2,\ldots,m, \tag{10}$$

where the notations of this model are as follows:

Table I- Notations of mentioned location-allocation problem

Index	***Definition***
m	Number of distribution centers
t	Number of warehouses locations
n	Number of candidates for factories locations
D_j	Average demand in demand centers
K_i	Potential capacity *i*th factory
K_e	The potential capacity of *e*th warehouse
P_i	Production cost in factory *i* per one unite of production
f_e	Total costs of warehouse *e* being open
C_{ie}	Operational and Transportation costs of an item from factory *i* to warehouse *e*
C_{ej}	Operational and Transportation costs of an item from warehouse *e* to distribution center *j*

In addition, decision variables of this model are defined as the following table:

Table II- Decision variables of mentioned location-allocation problem

Index	***Definition***
Y_i	If factory *i* is open then it takes value 1 otherwise, 0
Y_e	If warehouse *e* is open then it takes value 1 otherwise, 0
X_{ie}	Amount of items that are transported from factory *i* to warehouse *e*
X_{ej}	Amount of items that are transported from warehouse *e* to demand center *j*

In the above multi-objective model:

The objective function (1) minimizes total variable and fixed operating and start-up costs. The objective function (2) indicates maximizing demand satisfying function. Constraint (3) of the model makes the model maximize satisfying demand in each region of the demand centers. Constraint (4) indicates that factories cannot produce more than their capacity. If factory *i* do not be selected, its capacity equals 0, and if it is selected, its capacity equals to K_i . Constraint (5) indicates that warehouses cannot have outputs toward distribution centers more than their capacities. Constraint (6) indicates that warehouse outputs cannot be more than warehouse input. Constraint (7) indicates that the demand satisfying rate changes between 80% and 100%. Note that this range has been set based on expert judgment. The project managers assert that if this range fulfills for procurement phase, the risk of delays for the project completely decreases.

Decision variables that are in the solution represent the supply chain network configuration. There are two types of variables in the model: 1) binary variables 2) continuous variables. Binary variables indicate factories and warehouses' existence or absence. Continuous variables indicate the flow of materials from factories to warehouses and allocating the number of demand centers to warehouses. In the next section, the MOPSO algorithm to optimize the mentioned location-allocation model is discussed.

IV. MOPSO ALGORITHM

In this section, we propose a model solving method based on the MOPSO algorithm. These algorithm models set of potential problem solutions as a group of particles that move in virtual seeking space. In the PSO algorithm, each component suggests a solution in *n*-dimensional space. In addition, each component has its own and the group's best past experience (Rezaei et al., 2017).

A. Multi-objective optimization with MOPSO

Generally, multi-objective optimization can be introduced as two or more inconsistence function simultaneous optimization process considering special constraints. Since the multi-objective optimization problem has multiple objective functions, the solution's aim is to find several interactive solutions instead of finding only one solution (Harris et al., 2014). Multi-objective optimization algorithm uses dominance concept to achieve the optimum solutions. In this algorithm, two solutions are compared with each other based on the fact that which one prevails over the other solutions (Shankar et al., 2013).

B. MOPSO algorithm

In this subsection, we propose the pseudo-code of MOPSO to solve the proposed location-allocation model in the following figure.

Step 1: Generate *n* random particles for making population; speed initialization is performed for particles in a way that particle speed in k^{th} dimension is limited by the maximum value (V_{max})

Step 2: Define Counter set equal to zero

Step 3: Calculate particles appropriate values using two objective functions

Step 4: Calculate *pbest* and *gbest*

Then run the following calculation loop:

Loop 1: Calculate new speed and direction using *pbest* and *gbest* values

Loop 2: The position of each particle is updated by new speed and direction

Loop 3: New values are calculated

Loop 4: If the new *pbest* value is better than the current value, it will be updated

Loop 5: If the new *gbest* value is better than the current value, it will be updated

Loop 6: Identify particles that lead to the dominant solution according to presented *gbest* and saving them in an archive named dominant solution list, and the final solution that is not dominant is cleared for limiting the list

Loop 7: Calculate density distance for each particle

Loop 8: Sort all dominant particles in descending order and select the best of them with minimum result counting for the next iteration

j=j+1,

this loop is repeated until achieving maximum iteration.

V. NUMERICAL EXAMPLE BASED ON CASE STUDY

In this research, power transmission projects have been studied for factories' locations and warehouses, as well as their allocation. Hence, the data set related to this case study is presented in appendix (A) section. This information includes tables of demand centers, board making factories candidate for project boards supply, maximum area for candidate warehouses, average production price for board making factories, maximum storage capacity for distribution area, renting cost of distribution centers, the distance between factories and candidate warehouses, the distance between candidate warehouses and demand centers and the number of boards demand.

Average costs of transportation are calculated by asking trade experts and obtaining transportation data from freight firms using the following equation:

$$T_{total} = T_{fixed} + (T_{\mathrm{variable}} * X_{ij}), \tag{11}$$

Where X_{ij} is the distance between points *i* and *j*, in addition, T_{fixed} and T_{variable} represent transport fixed cost per any distance of transportation and variable cost of transport per kilometer, respectively. In this study, T_{fixed} = 1,500,000 Rials and T_{variable} = 11,000 Rials/Km has been set.

A. Computational solution

Based on the above data includes the cost of production in each factory, the cost of transportation in 3-level of supply chain network, the costs of distribution centers (warehouses), the production capacity of factories, and storage capacity, the mathematical model is provided. Note that the determination of demand amount is based on projects. For instance, one project needs three of equipment, and the other project needs five of the same equipment. This needs completely based on the engineering documents of each project. In this model, four candidate factories, five candidate distribution centers (warehouses), and 20 demand points (projects) have been considered in the special one-grade company that implements EPC[2] electrical projects. One of the significant problems in substation projects portfolio, the allocation of warehouses to projects for storing equipment based on selected vendors or suppliers. An integrated view for solving this problem must be considered that by defining this problem as a mathematical problem. As a result and sample, for one significant piece of equipment, four potential vendors that can supply this equipment are considered. Moreover, five candidate warehouses that the company rent them for their projects are considered. Finally, 20 similar substation projects are considered as the last level of supply chain structure. By considering these parameters as input data, the quantitative solving problem was initiated.

Considering the above data, 129 decision variables for this model have considered which 120 variables are integer, and nine variables are binary. The proposed model is coded in MATLAB software under different functions. The total number of 200 iterations for the algorithm are considered. In addition, all of needed input data are reported in Table A-1 to A-10 in the Appendix section.

Now, according to mentioned cost function and related distance tables, the transportation costs between factories and warehouses and also transportation costs between warehouses and demand points are calculated, and results are shown in Tables 3 to 5.

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٢ . Engineering, Procurement and Construction

Table III- Transportation cost of each product between factories and distribution centers

Cost (Rial)	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Mazandaran board making	3,491,000	5,108,000	7,572,000	4,569,000	12,951,000
Yam board making	8,606,000	6,901,000	5,174,000	6,461,000	12,896,000
Khorasan Phishro board making	8,782,000	11,884,000	14,139,000	11,268,000	19,727,000
Pars Novin Tarh Niroo board making	4,129,000	2,171,000	4,327,000	1,819,000	10,003,000

Table IV- Transportation cost between distribution centers and demand centers

Cost (Rial)	*Daboo project*	*Oshib project*	*Amol project*	*Rineh project*	*Aslandooz project*	*Ahar project*	*Ardabil project*	*Taghidizaj project*	*Alborz project*	*Shadegan project*
Semnan warehouse	3,755,000	3,425,000	3,755,000	3,491,000	13,303,000	11,653,000	10,454,000	10,806,000	3,502,000	13,952,000
Karaj warehouse	4,074,000	4,415,000	4,074,000	3,227,000	10,564,000	8,639,000	7,451,000	4,525,000	6,538,000	12,060,000
Bakhtar warehouse	6,582,000	6,923,000	6,582,000	5,735,000	12,115,000	10,201,000	9,002,000	9,354,000	8,837,000	8,694,000
Kan warehouse	3,524,000	3,854,000	3,524,000	2,666,000	11,125,000	9,211,000	8,012,000	8,364,000	5,933,000	11,862,000
Niroogah warehouse	11,906,000	12,247,000	11,906,000	11,059,000	6,219,000	4,305,000	5,383,000	3,128,000	14,381,000	14,172,000

Table V- Transportation cost between distribution centers and demand centers

Cost (Rial)	*Ramshir project*	*Maroon project*	*Behbahan project*	*Meybod project*	*Sadoogh project*	*Vardavard project*	*Firooz bahram project*	*10 Feeders project*	*Petrochemical project*	*Cheshmaekhosh project*
Semnan warehouse	13,721,000	12,676,000	14,425,000	10,058,000	10,641,000	4,272,000	4,085,000	5,229,000	9,013,000	12,379,000
Karaj warehouse	11,840,000	10,784,000	12,533,000	8,364,000	8.958,000	1,808,000	2,006,000	3,612,000	7,165,000	10,476,000
Bakhtar warehouse	8,463,000	7,407,000	9,167,000	7,935,000	8,529,000	4,690,000	4,547,000	3,029,000	3,788,000	7,110,000
Kan warehouse	11,631,000	10,586,000	12,335,000	7,968,000	8,551,000	1,830,000	1,775,000	3,227,000	6,967,000	10,234,000
Niroogah warehouse	13,952,000	12,896,000	14,656,000	16,196,000	16,779,000	9,640,000	9,871,000	11,445,000	9,640,000	11,675,000

In the MOPSO algorithm, 20 particles and 6 points, which are model scenarios, have been considered. The aim of the problem is to select three factories out of four candidate factories and four warehouses out of 5 candidate warehouses. Coding of planning is in a way that has the ability to change the number of factories or distribution centers. Number 1 is considered in the allocation row if the allocation is done and 0 if the allocations among allocation are not done. The results and graphs of the best results obtained in three scenarios of six scenarios are described in Table VI t0 XVII.

B. Performance evaluation of the proposed solution algorithms

Results of the algorithm lead to the location and allocation in the proposed model. In the three following scenarios, solution tables are presented in detail. Location in factories and warehouses are expressed as binary variables. Therefore in locating a part, points that are assigned by number 1 are presented as a selected point in solution, and points that are assigned by number 0 mean that they are not selected in locating and consequently are not allocated. In the next step, selected points and demand points are allocated. It should be noted that first locating points is done in model solving algorithm and then allocate items flow. Location and allocation are done in such a way that it satisfies all the problem constraints. Finally, points are selected that can satisfy the objective functions better.

The first scenario

In this scenario, three factories are considered as a supplier of equipment for substation projects except " Yam board making". Moreover, four warehouses are allocated to factories and projects as the second level of supply chain network except " Kan warehouse". The equipment flows between three levels of the procurement network of projects are shown in table VIII and VIX.

Table VI- Factories allocation in the first scenario

Factory	*Mazandaran board making*	*Yam board making*	*Pishro Khorasan board making*	*Pars Novin Tarh Niroo board making*
Allocation	1	0	1	1

Table VII- Warehouses allocation in the first scenario

Factory	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Allocation	1	1	1	1	0

Table VIII- Goods flow between factories and warehouses in the first scenario

	Allocation	*1*	*1*	*1*	*1*	*0*
Allocation	*Goods flow*	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
1	*Mazandaran board making*	27	75	31	40	0
0	*Yam board making*	0	0	0	0	0
1	*Khorasan Phishro board making*	149	49	33	7	0
1	*Pars Novin Tarh Niroo board making*	1	98	69	66	0

Table IX- Goods flow between warehouses and projects in the first scenario

Goods flow	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Daboo project	23	0	0	0	0
Oshib project	23	0	0	0	0
Amol project	0	14	0	0	0
Rineh project	0	0	0	0	0
Aslandooz project	0	15	0	0	0
Ahar project	0	8	0	0	0
Ardabil project	0	32	0	0	0
Taghidizaj project	2	0	0	9	0
Alborz project	47	0	0	0	0
Shadegan project	0	34	0	0	0
Ramshir project	0	0	0	48	0
Maroon project	14	23	0	0	0
Behbahan project	32	0	0	0	0
Meybod project	0	14	0	0	0
Sadoogh project	0	15	0	0	0
Vardavard project	0	14	0	0	0
Firoozbahram project	36	0	0	0	0
10 Feeders project	0	0	133	8	0
Petrochemical project	0	43	0	0	0
Cheshmekhosh project	0	0	0	48	0

In this scenario, three factories are considered as a supplier of equipment for substation projects except " Pishro Khorasan board making ". Moreover, four warehouses are allocated to factories and projects as the second level of supply chain network except " Karaj warehouse ". The equipment flows between three levels of the procurement network of projects are shown in table XII and XIII.

The second scenario

Table X- Factories allocation in the second scenario

Factory	*Mazandaran board making*	*Yam board making*	*Pishro Khorasan board making*	*Pars Novin Tarh Niroo board making*
Allocation	1	1	0	1

Table XI- Warehouses allocation in the second scenario

Factory	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Allocation	1	0	1	1	1

Table XII- Goods flow between factories and warehouses in the second scenario

	Allocation	*1*	*0*	*1*	*1*	*1*
Allocation	*Goods flow*	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
1	*Mazandaran board making*	34	0	49	7	96
1	*Yam board making*	52	0	24	55	19
0	*Khorasan Phishro board making*	0	0	0	0	0
1	*Pars Novin Tarh Niroo board making*	91	0	60	51	18

Table XIII- Goods flow between warehouses and projects in the second scenario

Goods flow	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Daboo project	0	0	0	0	23
Oshib project	0	0	23	0	0
Amol project	14	0	0	0	0
Rineh project	0	0	0	0	15
Aslandooz project	0	0	0	0	15
Ahar project	0	0	18	0	0
Ardabil project	0	0	0	0	32
Taghidizaj project	11	0	0	0	0

Continue Table XIII- Goods flow between warehouses and projects in the second scenario

Goods flow	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Alborz project	47	0	0	0	0
Shadegan project	0	0	9	25	0
Ramshir project	0	0	0	0	48
Maroon project	0	0	37	0	0
Behbahan project	0	0	0	0	0
Meybod project	0	0	14	0	0
Sadoogh project	0	0	14	0	0
Vardavard project	0	0	14	0	0
Firoozbahram project	0	0	3	0	0
10 Feeders project	105	0	0	40	0
Petrochemical project	0	0	0	0	0
Cheshmekhosh project	0	0	0	48	0

In this scenario, three factories are regarded as a supplier of equipment for substation projects except "Yam board making ". Further, the equipment flows between three levels of the procurement network of projects are shown in Table XVI and VXII.

The third scenario

Table XIV- Factories allocation in the third scenario

Factory	*Mazandaran board making*	*Yam board making*	*Pishro Khorasan board making*	*Pars Novin Tarh Niroo board making*
Allocation	1	0	1	1

Table XV- Warehouses allocation in the third scenario

Factory	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Allocation	1	0	1	1	1

Table XVI- Goods flow between factories and warehouses in the third scenario

	Allocation	***1***	***0***	***1***	***1***	***1***
Allocation	***Goods flow***	***Semnan warehouse***	***Karaj warehouse***	***Bakhtar warehouse***	***Kan warehouse***	***Niroogah warehouse***
1	***Mazandaran board making***	52	0	51	23	91
0	***Yam board making***	0	0	0	0	0
1	***Khorasan Phishro board making***	53	0	59	17	33
1	***Pars Novin Tarh Niroo board making***	72	0	23	73	52

Table XVII- Goods flow between warehouses and projects in the third scenario

Goods flow	***Semnan warehouse***	***Karaj warehouse***	***Bakhtar warehouse***	***Kan warehouse***	***Niroogah warehouse***
Daboo project	6	0	0	17	0
Oshib project	0	0	0	23	0
Amol project	14	0	0	0	0
Rineh project	15	0	0	0	0
Aslandooz project	0	0	10	0	5
Ahar project	0	0	0	0	0
Ardabil project	0	0	0	0	11
Taghidizaj project	47	0	0	0	0
Alborz project	0	0	0	0	0
Shadegan project	34	0	0	0	0
Ramshir project	0	0	0	0	48
Maroon project	0	0	0	37	0
Behbahan project	32	0	14	0	0
Meybod project	0	0	0	0	0
Sadoogh project	15	0	0	0	0
Vardavard project	14	0	0	0	0
Firoozbahram project	0	0	0	0	36
10 Feeders project	0	0	109	36	0
Petrochemical project	0	0	0	0	43
Cheshmekhosh project	0	0	0	0	33

The results of the three mentioned scenarios in the first and second objective function values are as follows:

Table XVIII- Objective function values in different solution scenarios

Scenario	*Cost function value*	*Demand satisfying function value*
1	135,005,535,341	0.9714
2	121,331,622,770	0.8373
3	128,025,991,169	0.9021

According to objective functions values, we can conclude contradictions of the objective function because the cost objective function increases by increasing the rate of satisfying demand. The diagram of applying the algorithm is presented in detail as following figure 2. In this diagram, in one dimension, the first objective function values, and in another dimension, the second objective function values are placed.

The demand satisfaction rate range in constraints is defined between 0.8 and 1. This reflects the fact that if we tightened the demand satisfaction rate range, it leads to an increase in the average cost function in the obtained solution. Obtained scenarios let managers find the best scenario toward corporate objective by a tradeoff between objective functions and according to corporate strategies.

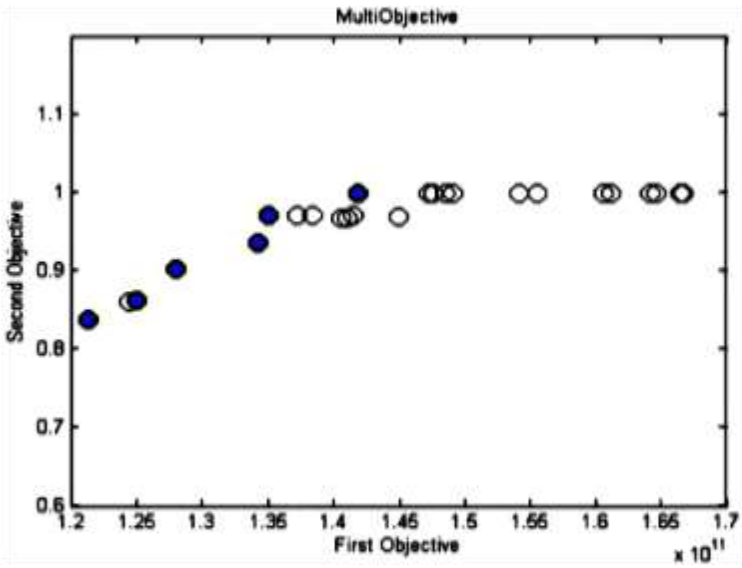

Figure 2- Top spots solutions diagram based on objective functions

Since the first objective function minimizes costs and the second objective function maximizes demand satisfaction rate and these two objective functions are in contradiction with each other. They have vantage points that can uphold this situation better, so the top and left sides of the graph have this effect. Results obtained from 3 scenarios which include points 1, 3, and 5 of the diagram left side, are presented in detail.

Based on experiences studies on this scope of work as electrical projects and expert's judgment, the results of this solving problem method are verified and validated. Since the defined objective functions are critical and vital for all project and portfolio managers, simultaneous optimization can be presented best scenarios for project future path selection. In this special and significant real case, all costs and potential supply chain node choices are considered real. As a result, the scenarios have been considered for decision-making managers in this company.

VI. CONCLUSION AND FUTURE RESEARCH

In this paper, a location-allocation model of 3-level projects portfolio supply chain network is proposed to select supply chain superior suppliers and warehouses. In addition, determination to optimize products flow between each level of supply chain structure is another aspect of this model. To this aim, the costs related to the opening of warehouses, production costs in each vendor's factory, and transportation costs are considered. We used a real case with two objective functions, including minimization of the total cost of projects portfolio supply chain and maximization of demand satisfying rate for one product. In addition, the MOPSO algorithm is applied to optimize the proposed model, and three strategic scenarios are presented to the portfolio manager. It means that the managers can analyze their scenarios and, by considering the organizational strategy, initiate decision making. Moreover, this model does not have any limitations for the level of supply chain structure, number of suppliers, number of warehouses, and finally, the number of projects. By altering some variables, we can add others cost variables and indicators to this model. Furthermore, the results of this paper could be used as a logistic management system for strategic designing of supply chain and monitoring flow of materials. A number of suggestions can be expressed as future researches. For example, we can consider demand as an uncertain and probable variable. This will be closer to a realistic model and lead to system dynamics and optimization in supply chain network functions. In addition, risk assessment with considering fuzzy logic can be considered for future research. Furthermore, the mixture of routing and scheduling of projects by considering the Critical Chain Method can be considered for the new researcher. On the other hand, we can develop this model for program management. It means that several programs and several projects can be considered with their cost variable, client indicators, requirements, and consumptions of agreement or contract.

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Appendix A: Input data based on real case

Table A-1- Demand points

Project description	*City*
Construction of 63.20 KV station of Daboo	Amol
Construction of 63.20 KV station of Oshib	Babol
Construction of 63.20 KV station of Daboo and development of 63 K.V. line of Amol I and Amol III	Amol
Designing, equipment supply, structural operations, installation, testing and commissioning of the 63.20 KV posts of Rineh (E.P.C)	Rineh
Construction of 63.20 Kv post of Aslandooz	Aslandooz
Structural operations, installation and commissioning of the 63.20 KV post of Ahar	Ahar
Construction of 63.20 KV post of central Ardabil	Ardabil
Construction of 63.20 KV post of Taghi Dizaj	Taghi Dizaj
Equipment supplying and executive operations of 63.20 KV post of Alborz	Shahrood
Construction of 400KV power post and transfer line for Shadegan Steel prpject	Shadegan
Power system improvement of booster units 1 and 2 of Omidiyeh and Ramshir complex in Aghajari in form of PC	Ramshir
Optimizing of Phase II power system of Maroon (3)	Ahvaz
Designing, equipment supply, structural operations, installation, testing and commissioning of the 63.20 KV posts of Kheibar-Behbahan (E.P.C)	Behbahan
Designing, equipment supply, structural operations, installation, testing and commissioning of the 63.20 KV posts of Meybod-Ardakan (E.P.C)	Meybod
Designing, equipment supply, structural operations, installation, testing and commissioning of the 63.20 KV posts of Sadoogh-Yazd (E.P.C)	Yazd
Improvement of 400.230 KV post of Vardavard	Vardavard
Optimizing of 400.230 KV post of Firoozbahram	Tehran
Development of 10 Feeders of Tehran 63 KV	Qom
Designing, equipment supply, structural operations, installation, testing and commissioning of the 63.20 KV posts of Lorestan Petrochemical and Foundation, tower installation, wiring of 63.20 KV line for electrification to Lorestan Petrochemical complex	Khorramabad
Designing, commodity supply, installation, tests, engineering services launching and power grid of oilfield of Cheshmehkhosh	Dehloran

Table A-2 – Candidate factories with maximum production capacity

Factory	*City*	*Maximum production capacity (unit)*
Mazandaran board making	Sari	300
Yam board making	Esfahan	350
Khorasan Phishro board making	Mashhad	270
Pars Novin Tarh Niroo board making	Eslamshahr	220

Table A-3 – Maximum space of candidate warehouse

Warehouse	*City*	*Space (m^2)*
Semnan warehouse	Semnan	400
Karaj warehouse	Karaj	500
Bakhtar warehouse	Arak	300
Kan warehouse	Tehran	255
Niroogah warehouse	Oroomieh	500

Table A-4 – Unit price of factory product

Factory	*Unit price (Rial)*
Mazandaran board making	207, 426,845
Yam board making	216,686,972
Khorasan Phishro board making	192,610,642
Pars Novin Tarh Niroo board making	185,202,540

Table A-5 – Maximum storage capacity of distribution center

Warehouse	*Space (m^2)*	*Maximum number of cell*
Semnan warehouse	400	177
Karaj warehouse	500	222
Bakhtar warehouse	300	133
Kan warehouse	255	113
Niroogah warehouse	500	222

Table A-6 – Renting cost of distribution center (Annual)

warehouse	*Cost (Rial)*
Semnan warehouse	192,000,000
Karaj warehouse	390,000,000
Bakhtar warehouse	350,000,000
Kan warehouse	500,000,000
Niroogah warehouse	425,000,000

Table A-7- Road distance between factories and distribution centers (Km)

Distance (Km)	*Semnan warehouse*	*Karaj warehouse*	*Bakhtar warehouse*	*Kan warehouse*	*Niroogah warehouse*
Mazandaran board making	181	328	552	279	1041
Yam board making	646	491	334	451	1036
Khorasan Phishro board making	662	944	1149	888	1657
Pars Novin Tarh Niroo board making	239	61	257	29	773

Table A-8- Road distance between distribution centers and demand centers (Km)

Distance (Km)	*Daboo project*	*Oshib project*	*Amol project*	*Rineh project*	*Aslandooz project*	*Ahar project*	*Ardabil project*	*Taghidizaj project*	*Alborz project*	*Shadegan project*
Semnan warehouse	205	175	205	181	1073	923	814	846	182	1132
Karaj warehouse	234	265	234	157	824	649	541	572	458	960
Bakhtar warehouse	462	493	462	385	965	791	682	714	667	654
Kan warehouse	184	214	184	106	875	701	592	624	403	942
Niroogah warehouse	946	977	946	869	429	255	353	148	1171	1152

Table A-9- Road distance between distribution centers and demand centers (Km)

Distance (Km)	*Ramshir project*	*Maroon project*	*Behbahan project*	*Meybod project*	*Sadoogh project*	*Vardavard project*	*firoozbahram project*	*10 Feeders project*	*Petrochemical project*	*Cheshmekhosh project*
Semnan warehouse	1111	1016	1175	778	831	252	235	339	683	989
Karaj warehouse	940	844	1003	624	678	28	46	192	515	816
Bakhtar warehouse	633	537	697	585	639	290	277	139	208	510
Kan warehouse	921	826	985	588	641	30	25	157	497	794
Niroogah warehouse	1132	1036	1196	1336	1389	740	761	905	740	925

Table A-10- Demand number of projects

Projects	***Daboo project***	***Oshib project***	***Amol project***	***Rineh project***	***Aslandooz project***	***Ahar project***	***Ardabil project***	***Taghidizaj project***	***Alborz project***	***Shadegan project***
Demand number	23	23	14	15	15	18	32	11	47	34
Projects	Ramshir project	Maroon project	Behbahan project	Meybod project	Sadoogh project	Vardavard project	Firooz bahram project	10 Feeders project	Petrochemical project	Cheshmekhosh project
Demand number	48	37	32	14	15	14	36	145	43	48