



Journal of Applied Sciences

ISSN 1812-5654

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>

A Genetic Approach to Optimize Mathematical Model of Facilities Relocation Problem in Supply Chain

¹B. Shirazi, ²H. Fazlollahtabar and ³D. Shafiei

¹Department of Industrial Engineering, Mazandaran University of Science and Technology, Babol, Iran

²Young Researchers Club, Islamic Azad University, Babol Branch, Iran

³Vice President of Small Industries at Mazandaran Industrial Parks Corporation, Sari, Iran

Abstract: In this study, a mathematical model is proposed for facilities relocation problem in supply chain. Facilities' location in supply chain is one of the fundamental and strategic decisions of supply chain management. As location models in supply chain take in to account more factors simultaneously, they are commonly more complicated than traditional location models, but their structures are almost resemble to the traditional models. This model can help for deciding about supply chain location changes, constructing new facilities and appropriate time for those jobs. Also Genetic algorithm is used for optimization of facilities relocation problem in supply chain.

Key words: Facility planning, optimization, genetic algorithm

INTRODUCTION

Location in any time is corresponding to that specific time conditions and a location that is appropriate for one of the facilities, because of the condition's change may not be appropriate for the same facilities after years. Location problems contained large spectrum of OR problems that were always attractive for researchers and also many varied researches been done like facility location problem where new facilities or close down already existing facilities at two different distribution levels over a given time horizon (Yapicioglu *et al.*, 2007). Facility layout problems (FLPs) concerning space layout optimization have been investigated in depth by researchers in many engineering fields. Recent advances in computing science and increased understanding of methods for developing mathematical models have helped with layout design investigations. The FLP has applications in both manufacturing and the service industry now. The FLP is a common industrial problem of allocating facilities to minimize the total cost of transporting materials or to maximize adjacency requirement (Koopmans and Beckmann, 1957) or to both minimize the cost of transporting materials and maximize adjacency requirement between the facilities (Meller and Gau, 1996).

The FLP can be classified in two categories according to the arrangement method of facilities; either an equal area layout problem or an unequal area layout problem. The unequal area layout problem can be

classified primarily into two categories depending on the plan type that the facility layout is to be drawn; either a grid-based block plan layout problem or a continual block plan layout problem. In the grid-based block plan layout problem the facility layout is constructed on the grid plan, called the grid-based block plan and divided into squares or rectangles having a unit area. In continual block plan layout problem the facility layout is constructed on the continual plan.

Relocating a production site is a difficult industrial project and companies are often reluctant to get into this kind of trouble, especially small or medium sized companies that have to go on operating with the same machines. A simple solution consists in removing the machines during paid holidays: it is then possible to close the firm for the duration of the removal process. However, a firm working on orders needs not only to be continuously present on the market but also to be highly reactive and therefore this strategy is not conceivable for this type of firms. Although similar situations are commonplace, this problem has not been dealt with yet. We considered the case of relocating the current facilities of a company to a nearby site. Two companies that were faced with the problem of removing a line of machines from one site to another without interrupting the production twice approached us. The constraints of the removal project were the same for both companies:

- The production could not be entirely stopped during the removal of the machines

- The removal process was of flow-shop type
- The budget of the removal operation was limited, which forbade any solution of flash removal type (removal of the whole of the production system overnight or over a weekend)
- The global production process remained identical, i.e., the logical chain of operations remained the same (the same machines would continue to be used one after the other)

This unusual problem is not dealt with in reference books about production organization (Heizer and Render, 1999) or facilities planning (Tompkins and White, 1984). Even the fundamental book on the methods of facilities layout (Muther, 1969) does not deal with the organization of a removal faced with such constraints. Recent study have focused on facilities relocation. In fact, these studies deal with location or layout strategies, by considering mathematical approaches (Batta and Huang, 1989; Brimberg and Wesolowsky, 2000; Huang *et al.*, 1990; Lin and Tseng, 1993) or by proposing oriented management methods (Moon and Kim, 2001; Nozick and Turnquist, 1998; Nozick, 2001; Rheault *et al.*, 1996).

However, the removal organization problem is not dealt with in these studies. In this part and as a consequence, we have elaborated an organizational method that allows production to keep on going during the removal of a flow-shop.

The true problem lies in the choice of the right parameters to balance the relocation organization. A great number of solutions can be planned to segment the totality of the production line. The use of simulations in the field of manufacturing systems to simplify the complexity and reduce the problem dimension is recognized by scientists and industrial managers. In this case, the simulation aims at determining the best combination of input parameter values, given an output criterion (Pierreval and Paris, 2003).

Relocation is relatively a new branch of location. In relocation problems, according to the changes that take place on parameters of a problem, in a time period, new locations are suggested for facilities and the time of those location changes are also determined. In this study supply chain warehouse and manufacturing facilities relocation problem and the allocation of them to customers during time periods is being studied.

Most of traditional location models are analytical and while the parameters of model are clear, the optimum answer of the problem is determinable by filling the parameters in mathematical equations related to the model.

In supply chain location problems the relationships among components become more complicated, because at the same time optimization of more components is desirable. Hence the traditional models which are based on simplifying assumptions cannot provide acceptable and correct answers for those problems. Also in such complicated problems, in general, rarely analytical optimum answer could be found. Thus, in these cases usually mathematical programming models are being used (like linear programming models, integer, mixed and ...). For finding optimum answer by those models different solver softwares are being used (like GAMS, LINGO). The new ways of solving such a complicated facility location problems are Meta heuristic solutions like polynomial algorithm (Hinojosaa *et al.*, 2006) and a single-objective particle swarm optimizer (PSO) and a bi-objective PSO are devised to solve the problem (Colebrook and Siciliaa, 2007). In this study the proposed model is a Genetic algorithm.

Recently, artificial intelligence based methods have been applied to solving facility layout problems. For example, knowledge based systems, which have been developed to provide users with problem-specific heuristic knowledge so, that facilities can be allocated accordingly (Rad and James, 1983; Tommelein *et al.*, 1991). Moreover, Yeh (1995) applied annealed neural networks to solve construction site level facility layout problems.

Although no studies of applying genetic algorithms in solving site-level facility layout problems have been reported, GAs have been applied to a diverse range of engineering and construction management searching problems, which include:

- Structural optimization (Koumoussis and Georgiou, 1994; Nagendra *et al.*, 1996)
- Resource scheduling (Chan *et al.*, 1996; Li and Love, 1997)
- Optimizing labor and equipment assignment (Li *et al.*, 1998)
- Determination of laying sequence for a continuous girder reinforced concrete floor system and Space allocation (Gero and Kazakov, 1997)

Genetic algorithm systems have also been applied to solve space layout planning problems. For example, Gero and Kazakov (1997) incorporated the concept of genetic engineering into the GA system for solving building space layout problems. Similarly, Tate and Smith compared different methods with the GA system in the application of space layout problems.

PROBLEM DESCRIPTION AND ITS ASSUMPTIONS

In the proposed problem of this study we encounter a supply chain that includes varied facilities. In the mentioned chain some factories are existed that have warehouses too i.e., each factory is a combination of two facilities: warehouse facilities and manufacturing facilities. Each factory prepares its required materials and parts whether from local provider or imports them from foreign countries. The imported parts and materials by seaports, airports, or other places of delivering imports are being sent to the factories of chain. Each factory can send the products to customers (distributors) directly from its warehouse or first send the products to transshipment points (or transshipment terminals) for sending them to costumers (retailers). Also each factory can send the products to other existed warehouses directly or by transshipment points, instead of keeping the products in its own warehouse, for delivering them to customers. A figuration of supply chain network is being shown in Fig. 1.

During programming horizon some variations happen in some of the primary conditions of the problem. These changes motivate to the possibility of supply chain facilities location replacements, because of cost reduction,

rival increase and services improvement. In any of these locations, a factory or warehouse will be built, or a warehouse is rent, or a contractor will be in charge of it. Beside, some candidate points are considered for new factories and warehouses locations. Any way, each of new locations is one of the implemental decisions. Maybe in those locations new capacities are added or the existed facilities capacity would transfer to them. But it is assumed if no decision on closing a factory or warehouse is got, no capacity would be transferred from it to other factories or warehouses. Furthermore, new facilities capacity can be created independently and there is no obligation to transfer that capacity from the existed facilities to them.

Deciding about from which transshipment terminal each customer could be serviced, is not the desired decisions of this problem; but by solving this problem the customers who are covered by each factory or warehouse will be identified. In each time period, each customer is being serviced by one factory or warehouse. The amount of customer's demands in each period, a little depends on which supply chain facilities their required goods are from; but this amount is not stochastic and it is deterministic. In this problem it is assumed that just one product is manufactured and distributed.

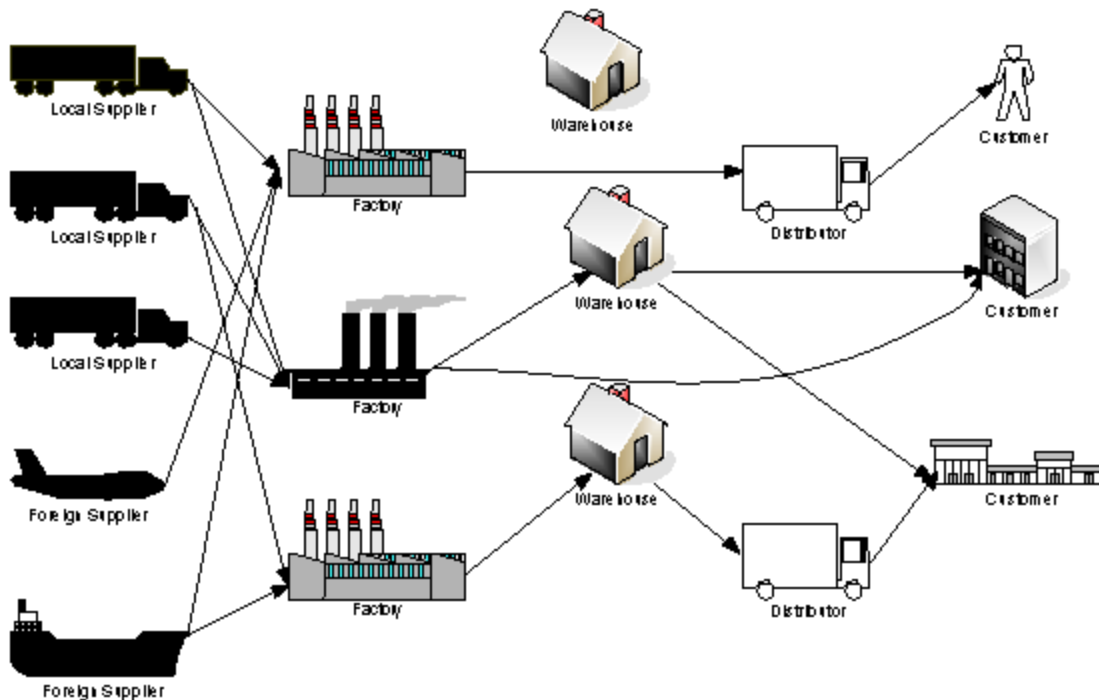


Fig 1: Supply chain network

In this problem the distance between the existed supply chain facilities and candidate locations for building facilities and also their related transportation costs are cleared. Also variable costs of inventory manufacturing and holding in each period, in both existed facilities and new facilities are identified. The fix costs of closing or opening facilities, related costs to capacity transfer from existed facilities to new one and the annual facilities operational costs are in hand. Each existed facilities is revealed and in any time period only a limited segment of each facilities capacity could be added or declined. Operational budget is limited. It is not necessary that the whole facilities locations be transferred at the end of the programming horizon.

In this problem of location, the objective is reducing the whole operational costs and investment during programming horizon.

THE PROPOSED MATHEMATICAL MODEL

In this part, it is assumed if a factory or warehouse opens during programming horizon, it won't be closed. The model is described as follows:

SUBSCRIPTIONS

- h = Existed factories locations (h = 1 ... H)
- i = New factories locations (i = 1 ... I)
- n = Existed warehouses locations (n = 1 ... N)
- p = New warehouses locations (p = 1 ... P)
- j = Customers (j = 1 ... J)
- k = Local suppliers and seaports and other import quitting locations (k = 1 ... K)
- m = Transportation facilities like transshipment terminal (m = 1 ... M)
- t = Time periods (t-1 ... T)

NOTATIONS

- D_{hj}^t = Demand of customer j in time period t, if covered by existed factory h
- D_{ij}^t = Demand of customer j in time period t, if covered by factory in new location i
- D_{nj}^t = Demand of customer j in time period t, if covered by existed warehouse n
- D_{pj}^t = Demand of customer j in time period t, if covered by warehouse in new location p
- R_h^t = Net present worth of unit income of product produced in existed factory h in period t
- R_i^t = Net present worth of unit income of product produced in factory in new location i in period t
- Q_h = Production capacity of existed factory h

- H_h = Warehouse capacity of existed factory h
- H_n = Capacity of existed warehouse n
- u_h^t = Upper bound of part of production capacity that can be transferred from existed factory h in period t
- u_i^t = Upper bound of production capacity that can be transferred to new factory i in period t
- B^t = Maximum operational budget in period t (that is spent on operational costs and facilities holding)
- S_{hj}^t = Net present worth of unit transportation cost from existed factory h to customer j in period t
- S_{ij}^t = Net present worth of unit transportation cost from new factory i customer j in period t
- S_{nj}^t = Net present worth of unit transportation cost from existed warehouse n to customer j in period t
- S_{pj}^t = Net present worth of unit transportation cost from new warehouse p to customer j in period t
- S_{hn}^t = Net present worth of unit transportation cost from existed factory h to existed warehouse n in period t
- S_{hp}^t = Net present worth of unit transportation cost from existed factory h to existed warehouse p in period t
- S_{in}^t = Net present worth of unit transportation cost from existed factory i to existed factory n in period to new warehouse p in period t
- S_{ip}^t = Net present worth of unit transportation cost from new factory i to existed factory p in period t
- c_h^t = Net present worth of production variable cost of unit product in existed factory h in period t
- c_i^t = Net present worth of production variable cost of unit product in new factory i in period t
- w_h^t = Net present worth of inventory holding variable cost of unit product in existed factory's warehouse h in period t
- w_i^t = Net present worth of inventory holding variable cost of unit product in new factory's warehouse i in period t
- w_n^t = Net present worth of inventory holding variable cost of unit product in existed warehouse n in period t
- w_p^t = Net present worth of inventory holding variable cost of unit product in new warehouse p in period t
- r_{hi}^t = Net present worth of manufacturing capacity unit location changes cost from existed factory h to new factory i in period t (contain man power, equipments, machines and ... transfer costs) (i = 1 ... I-1)
- e_i^t = Net present worth of a new manufacturing capacity unit creation variable cost in factory location i in period t
- ei_i^t = Net present worth of a new warehouse capacity unit creation variable cost in factory location i in period t

e_i^t = Net present worth of a new warehouse capacity unit creation variable cost in warehouse location p in period t

F_i^t = Net present worth of new factory creation fix cost in location i in period t

F_p^t = Net present worth of new warehouse creation fix cost in location p in period t

FR_p^t = Net present worth of new warehouse renting cost in location p in period t

F_h^t = Net present worth of existed factory h closing fix cost in period t

F_n^t = Net present worth of existed warehouse n closing fix cost in period t

$$z_p^t = \begin{cases} 1 & \text{If a warehouse is opened in location p at the beginning of period t} \\ 0 & \text{o.w} \end{cases}$$

$$zr_p^t = \begin{cases} 1 & \text{If a warehouse is rented in location p in period t} \\ 0 & \text{o.w} \end{cases}$$

$$z_h^t = \begin{cases} 1 & \text{If factory h is closed at the end of period t} \\ 0 & \text{o.w} \end{cases}$$

$$z_n^t = \begin{cases} 1 & \text{If warehouse n is closed at the end of period t} \\ 0 & \text{o.w} \end{cases}$$

π_{hi}^t = The amount of production capacity of existed factory h which transfer to new factory i in period t

ψ_i^t = Created production capacity in new factory i in period t

ψi_i^t = Created inventory holding capacity in new factory i in period t

ψ_h^t = Created inventory holding capacity in new warehouse h in period t

DECISION VARIABLES

x_h^t = No. of produced product unit by existed factory h in period t

x_i^t = No. of produced product unit by new factory i in period t

y_{hj}^t = No. of carried products unit from existed factory h to customer j in period t

y_{ij}^t = No. of carried products unit from new factory i to customer j in period t

y_{nj}^t = No. of carried products unit from existed warehouse n to customer j in period t

y_{pj}^t = No. of carried products unit from new warehouse p to customer j in period

yi_{in}^t = No. of carried products unit from existed factory h to existed warehouse n in period t

yi_{in}^t = No. of carried products unit from new factory i to existed warehouse n in period t

yi_{hp}^t = No. of carried products unit from existed factory h to new warehouse p in period t

yi_{ip}^t = No. of carried products unit from new factory i to new warehouse p in period t

$$v_{hj}^t = \begin{cases} 1 & \text{If customer j allocated to existed factory h in period t} \\ 0 & \text{o.w} \end{cases}$$

$$v_{ij}^t = \begin{cases} 1 & \text{If customer j allocated to new factory i in period t} \\ 0 & \text{o.w} \end{cases}$$

$$v_{nj}^t = \begin{cases} 1 & \text{If customer j allocated to existed warehouse n in period t} \\ 0 & \text{o.w} \end{cases}$$

$$v_{pj}^t = \begin{cases} 1 & \text{If customer j allocated to new warehouse p in period t} \\ 0 & \text{o.w} \end{cases}$$

$$z_i^t = \begin{cases} 1 & \text{If a factory is opened in location i at the beginning of period t} \\ 0 & \text{o.w} \end{cases}$$

Objective function

TP(X, Y, TI, Z, ZR, II, Ψ) Net present worth of total benefit

$$\begin{aligned} TP(X, Y, TI, Z, ZR, II, \Psi) = & \sum_t (\sum_h (R_h^t - c_h^t + w_h^t)x_h^t + \sum_i (R_i^t - c_i^t + w_i^t)x_i^t) \\ & - \sum_t \sum_j (\sum_n w_n^t y_{nj}^t + \sum_p w_p^t y_{pj}^t) + \sum_t (\sum_j (\sum_i S_{ij}^t y_{ij}^t + \sum_h S_{hj}^t y_{hj}^t \\ & + \sum_n S_{nj}^t y_{nj}^t + \sum_p S_{pj}^t y_{pj}^t) + \sum_i (\sum_h S_{hi}^t y_{hi}^t + \sum_n S_{ni}^t y_{ni}^t \\ & + \sum_p S_{pi}^t y_{pi}^t + \sum_i S_{ip}^t y_{ip}^t)) - \sum_{i=1}^I \sum_h \sum_t r_{hi}^t \pi_{hi}^t - \sum_t (\sum_i F_i^t z_i^t \\ & + \sum_h F_h^t z_h^t + \sum_n F_n^t z_n^t + \sum_p F_p^t z_p^t + \sum_p FR_p^t z_p^t) \\ & - \sum_t (\sum_i (e_i^t \psi_i^t + ei_i^t \psi i_i^t) + \sum_p ei_p^t \psi_p^t) \end{aligned} \tag{1}$$

S.t:

$$\pi_{hi}^t \leq u_h^t \cdot Q_h \cdot \sum_{\tau=1}^t z_i^\tau, \quad \forall t, i, h \tag{2}$$

$$\pi_{hi}^t \leq u_i^t \sum_{\tau=1}^T z_i^\tau, \quad \forall t, i, h \tag{3}$$

$$x_i^t \leq \sum_{\tau=1}^t (\sum_h \pi_{hi}^\tau + \psi_i^\tau), \quad \forall t, i \tag{4}$$

$$x_h^t \leq Q_h - \sum_{i=1}^I \sum_{\tau=1}^t \pi_{hi}^\tau, \quad \forall t, h \tag{5}$$

$$x_h^t = \sum_j y_{hj}^t + \sum_n y_{hn}^t + \sum_p y_{hp}^t, \quad \forall t, h \quad (6) \qquad \sum_t z_p^t \leq 1, \quad \forall p \quad (23)$$

$$x_i^t = \sum_j y_{ij}^t + \sum_n y_{in}^t + \sum_p y_{ip}^t, \quad \forall t, i \quad (7) \qquad \sum_t z_n^t \leq 1, \quad \forall n \quad (24)$$

$$\sum_j y_{nj}^t = \sum_h y_{hn}^t + \sum_i y_{in}^t, \quad \forall t, n \quad (8) \qquad \sum_{\tau=1}^t z_p^t + z_p^\tau \leq 1, \quad \forall p, t \quad (25)$$

$$\sum_j y_{pj}^t = \sum_h y_{hp}^t + \sum_i y_{ip}^t, \quad \forall t, p \quad (9) \qquad x_i^t, x_h^t, y_{ij}^t, y_{hj}^t, y_{ij}^t, y_{nj}^t, y_{in}^t, y_{ip}^t, y_{in}^t, y_{hp}^t, \pi_{in}^t, \psi_i^t, \psi_p^t, \psi_i^t \geq 0, \quad \forall i, h, t, j, n, p$$

$$\sum_j y_{hj}^t + \sum_n y_{hn}^t + \sum_p y_{hp}^t \leq H_h \sum_{\tau=1}^t (1 - z_h^\tau), \quad \forall t, h \quad (10) \qquad z_n^t, z_h^t, z_p^t, z_i^t, z_j^t, v_{ij}^t, v_{nj}^t, v_{ij}^t, v_{hj}^t \in \{0, 1\}, \quad \forall i, h, t, j, n, p$$

$$\sum_h y_{hn}^t \leq H_n \sum_{\tau=1}^t (1 - z_n^\tau), \quad \forall t, n \quad (11)$$

$$\sum_j y_{ij}^t \leq H_i \sum_{\tau=1}^t (1 - z_i^\tau), \quad \forall t, i \quad (12)$$

$$\sum_j y_{ij}^t \leq \sum_{\tau=1}^t \psi_i^\tau, \quad \forall t, i \quad (13)$$

$$\sum_j y_{pj}^t \leq \sum_{\tau=1}^t \psi_p^\tau, \quad \forall t, p \quad (14)$$

$$y_{ij}^t = D_{ij}^t v_{ij}^t, \quad \forall i, j, t \quad (15)$$

$$y_{hj}^t = D_{hj}^t v_{hj}^t, \quad \forall h, j, t \quad (16)$$

$$y_{nj}^t = D_{nj}^t v_{nj}^t, \quad \forall n, j, t \quad (17)$$

$$y_{pj}^t = D_{pj}^t v_{pj}^t, \quad \forall p, j, t \quad (18)$$

$$\sum_i v_{ij}^t + \sum_h v_{hj}^t + \sum_n v_{nj}^t + \sum_p v_{pj}^t = 1, \quad \forall t \quad (19)$$

$$\begin{aligned} & \sum_t (\sum_h (c_h^t + w_h^t) x_h^t + \sum_i (c_i^t + w_i^t) x_i^t) + \sum_t \sum_j (\sum_n w_n^t y_{nj}^t \\ & + \sum_p w_p^t y_{pj}^t) + \sum_t (\sum_j (\sum_i S_{ij}^t y_{ij}^t + \sum_h S_{hj}^t y_{hj}^t + \sum_n S_{nj}^t y_{nj}^t \\ & + \sum_p S_{pj}^t y_{pj}^t) + \sum_n (\sum_h S_{hn}^t y_{hn}^t + \sum_i S_{in}^t y_{in}^t) + \sum_p (\sum_h S_{hp}^t y_{hp}^t, \quad \forall t \quad (20) \\ & + \sum_i S_{ip}^t y_{ip}^t)) + \sum_{i=1}^{I-1} \sum_h \sum_t r_{in}^t \pi_{in}^t + \sum_t \sum_p FR_p^t z_p^t + \sum_t \sum_i (e_i^t \psi_i^t \\ & + e_i^t \psi_i^t) + \sum_p e_i^t \psi_p^t \leq B^t \end{aligned}$$

$$\sum_t z_h^t \leq 1, \quad \forall h \quad (21)$$

$$\sum_t z_i^t \leq 1, \quad \forall i \quad (22)$$

Equation 1 is the objective function which indicates the income of the products produced in existing and new factories subtracted by the costs of inventory holding, transportation, production capacity transfer, creating and closing and renting the factories and warehouses and creating new capacity in the whole facilities of the chain. Constraints (2) and (3) indicate the capacity which transfer from the existing factory to a new one in each period can not exceed the allowance. Constraint (4) necessitates the model that the amount of production in each new factory doesn't exceed the aggregation of transferred capacity and created capacity in it. Constraint (5) shows that the amount of production in existing factory in each period doesn't exceed the initial capacity subtracted by the transferred capacity. Constraints (6) to (9) are the equilibrium of inputs and outputs for existing/new factories and warehouses. Constraints (10) to (14) indicate that the amount of new/existing warehouse inputs/outputs, or new/existing factory's warehouse inputs/outputs before closing, shouldn't be more than the warehouse or the factory's warehouse capacity. Constraints (15) to (18) necessitate the model to supply all customers' demands. Constraint (19) indicates that each customer should be allocated to only one factory or warehouse. Constraint (20) guarantees that the operational costs for all chain facilities in each period won't exceed the operational budget. Constraints (21) to (24) necessitate each factory or warehouse to be opened or closed only once. Constraint (25) indicates that in each period it is forbidden to rent and create a warehouse simultaneous. The last constraints show the sign and the kind of the model variables.

Two benefits could be stated for the proposed model:

- Linear form of the whole equations that makes it possible to be solved with solver softwares

- Being applicable for rolling horizon problems i.e., all data could be updated and planning with new data is possible

OPTIMIZATION BY GENETIC ALGORITHM

Genetic algorithms are a set of optimization algorithms that seek to improve performance by sampling areas of the parameters space that are more likely to lead to better solutions. The primary advantage of GAs lies in their capacity to move randomly from one feasible layout to another, without being drawn into local optima in which other algorithms are often trapped. Genetic algorithms employ a random, yet directed, search for locating the globally optimal solution.

Typically, a set of GAs requires a representation scheme to encode feasible solutions to the optimization problem. Usually a solution is represented as a linear string called chromosome whose length varies with each application. Some measure of fitness is applied to the solutions in order to construct better solutions. There are three basic operators in the basic GA system: Reproduction (or Selection), Crossover and Mutation. Reproduction is a process in which strings are duplicated according to their fitness magnitude. Crossover is a process in which the newly reproduced strings is randomly coupled and whereby each couple of string partially exchanges information. Mutation is the occasional random alteration of the value of one of the bits in the string.

In general, a GA contains a fixed-size population of potential solutions over the search space. These potential solutions of the search space are encoded as binary, integer, or floating-point strings and called chromosomes. The initial population can be created randomly or based on the problem specific knowledge. In each evolution step, a new population is created from the preceding one using the following procedures:

- **Evaluation:** Each chromosome of the old population is evaluated using a fitness function and given a value to denote its merit
- **Selection:** Chromosomes with better fitness are selected to generate next population. Commonly used selection schemes include proportional and tournament selection
- **Recombination (crossover):** Parts of two chromosomes selected based of fitness are

swapped to generate trait-preserving off-springs. One-point, two-point and uniform crossovers are frequently seen in many GA applications

- **Mutation:** Parts of a chromosome are randomly changed to prevent the early maturity of a population. The applicable mutation operator depends on the data type of a gene. For example, with a binary gene, the gene value may be randomly flipped. For a real-coded gene, a random noise of different distribution types may be added or subtracted

The above procedures are iterated for many generations until a satisfactory solution is found or a terminated criterion is met. A pseudo-code of a standard GA is shown in Table 1.

GAs have the following advantages over traditional search methods: (i) GAs directly work with a coding of the parameter set; (ii) Search is carried out from a population of points instead of a single one as in the case of the local search or simulated annealing algorithm; (iii) Pay-off information is used instead of derivatives or auxiliary knowledge and (iv) Probabilistic transition rules are used instead of deterministic ones. GAs have been successfully applied to a diverse set of optimization problems. The flow chart of the proposed algorithm is presented in Fig. 2.

COMPUTATIONAL RESULTS

Here, an example is shown to show the efficiency of the proposed GA algorithm in two time periods. The input values are indicated in Table 2.

Based on the parameters' value and after computing in GA environment based on the stated flowchart, the optimum values of the decision variables are shown in Table 3.

Table 1: Standard genetic algorithm

Genetic Algorithm
t = 0
Initialize - population P(t)
Evaluate P(t)
While (the termination criterion is not met) do
begin
t = t+1
select P(t) from P(t-1) based on fitness
Recombine P(t)
Mutate P(t)
Evaluate P(t)
End

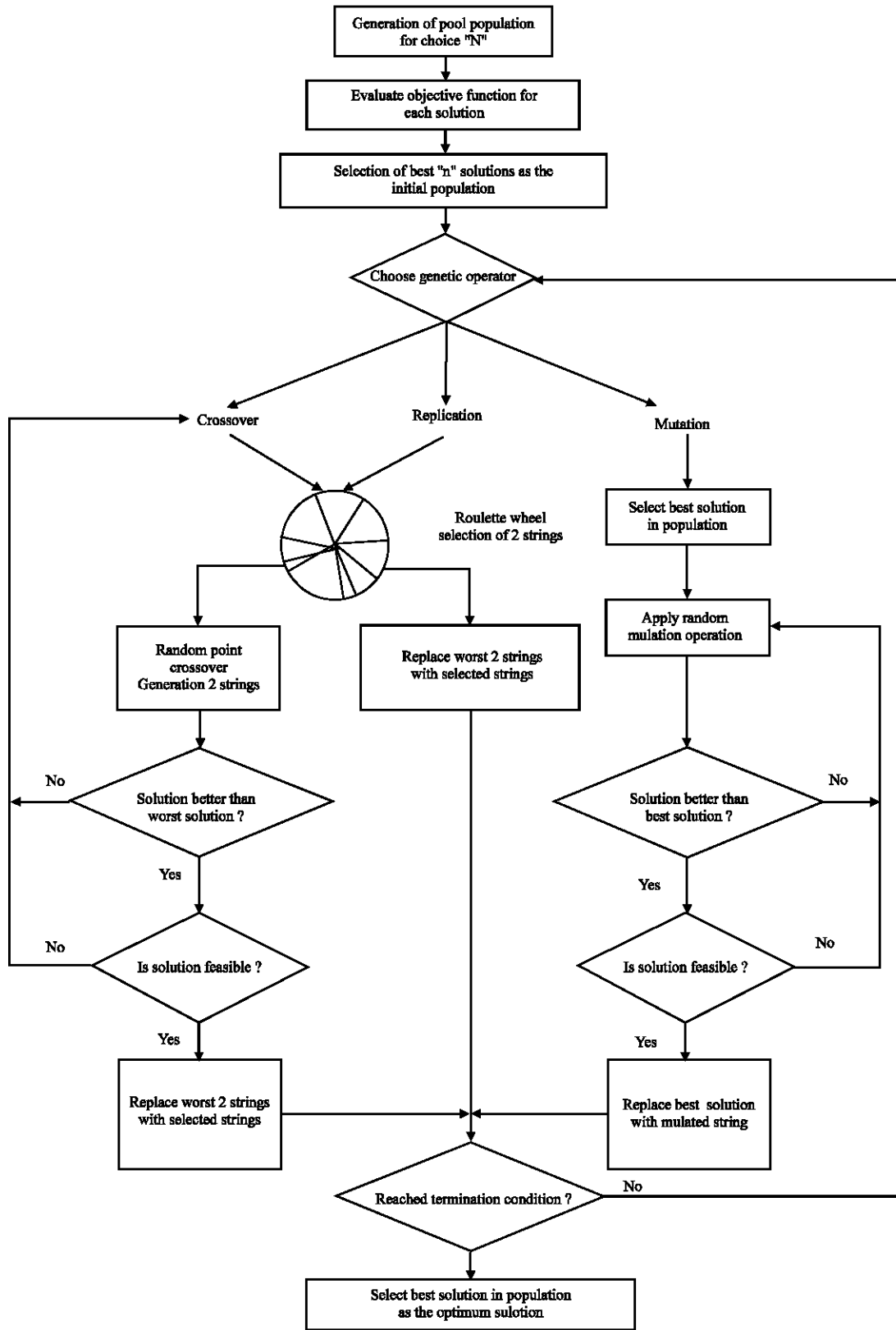


Fig. 2: The flowchart of the proposed algorithm

Table 2: Parameters with their related values

D'_{hj}	D'_h	R'_h	D'_{ij}	Q_h	H_h	H_n	B'
t = 1; h = 1; j = 1	t = 1; I = 1; j = 1	t = 1; h = 1	T = 1; p = 1; j = 1	h = 1	h = 1	n = 1	t = 1
5	3	4	3	50	25	35	40
t = 1; h = 1; j = 2	t = 1; I = 1; j = 2	t = 2; h = 1	T = 1; p = 1; j = 2	c'_h		c'_i	
7	4	4	4	t = 1; h = 1		t = 1; i = 1	
t = 2; h = 1; j = 1	t = 2; I = 1; j = 1	R'_i	T = 2; P = 1; j = 1	3		2	
6	4	t = 1; i = 1	4	t = 2; h = 1		t = 2; i = 1	
t = 2; h = 1; j = 2	t = 2; I = 1; j = 2	6	T = 2; p = 1; j = 2	4		3	
8	5	t = 2; i = 1	5	e'_i		ei'_i	
S'_{hj}	S'_{ij}	6	S'_{ij}	t = 1; i = 1		t = 1; i = 1	
t = 1; h = 1; j = 1	t = 1; I = 1; j = 1	u'_h	T = 1; n = 1; j = 1	7		6	
7	6	t = 1; h = 1	5	t = 2; i = 1		t = 2; i = 1	
t = 1; h = 1; j = 2	t = 1; I = 1; j = 2	30	T = 1; n = 1; j = 2	8		6	
6	5	t = 2; h = 1	5	F'_i		ei'_p	
t = 2; h = 1; j = 1	t = 2; I = 1; j = 1	35	T = 2; n = 1; j = 1	t = 1; i = 1		t = 1; p = 1	
8	7	u'_i	6	10		5	
t = 2; h = 1; j = 2	t = 2; I = 1; j = 2	t = 1; i = 1	T = 2; n = 1; j = 2	t = 2; i = 1		t = 2; p = 1	
7	6	40	7	11		5	
S'_{in}	S'_{hp}	t = 2; i = 1	S'_{in}	F'_p		FR'_p	
t = 1; h = 1; n = 1;	t = 1; H = 1; p = 1;	40	T = 1; i = 1; n = 1;	t = 1; p = 1		t = 1; p = 1	
3	2	w'_h	4	9		8	
t = 2; h = 1; n = 1;	t = 2; H = 1; p = 1;	t = 1; h = 1	T = 2; i = 1; n = 1;	t = 2; p = 1		t = 2; p = 1	
3	2	4	4	10		9	
S'_{ij}	r'_{hi}	t = 2; h = 1	D'_{ij}	F'_n		F'_h	
t = 1; p = 1; j = 1	t = 1; H = 1; i = 1;	4	T = 1; n = 1 j = 1	t = 1; n = 1		t = 1; h = 1	
4	12	w'_p	5	7		8	
t = 1; p = 1; j = 2	t = 2; H = 1; i = 1;	t = 1; p = 1	T = 1; n = 1 J = 2	t = 2; n = 1		t = 2; h = 1	
5	13	1	7	7		8	
t = 2; p = 1; j = 1	S'_{ip}	t = 2; p = 1	T = 2; n = 1 j = 1	w'_i		w'_n	
4	t = 1; I = 1; p = 1;	1	6	t = 1; i = 1		t = 1; n = 1	
t = 2; p = 1; j = 2	2	-	T = 2; n = 1 j = 2	2		3	
5	t = 2; I = 1; p = 1;	-	8	t = 2; i = 1		t = 2; n = 1	
-	3	-	-	2		3	

Table 3: Decision variable's values

Decision variable	x'_h	x'_i	y'_{hj}	y'_{ij}	y'_{nj}	y'_{pj}	yi'_{in}	yi'_{in}	yi'_{hp}	yi'_{ip}	v'_{hj}	v'_{ij}
Value	30	45	28	63	47	38	46	52	49	38	33	28
Decision variable	v'_{ij}	v'_{pj}	z'_i	z'_p	zr'_p	z'_h	z'_n	π'_{hi}	ψ'_i	ψ'_i	ψ'_h	ψ'_h
Value	42	55	58	61	63	59	64	68	56	49	38	

CONCLUSION

In this study, a facility relocation model in supply chain is discussed. Regarding to the specific conditions of supply chain and some assumptions in facility relocation, a mathematical model is proposed. The distinguished points of such a model are the ability of solving with softwares and also the possibility of correction in future decisions according to the changes on variable of the model. Moreover, because of the large dimensions of the model, Genetic Algorithm is proposed to decrease the solving time. An example is designed to show the efficiency of the GA approach. For future study, the same problem will be solved by other heuristics and a comparison between different approaches will be accomplished.

REFERENCES

Batta, R. and W.V. Huang, 1989. On the synthesis of advertising and relocation decisions for facility. *Comput. Ind. Eng.*, 16: 179-187.

Brimberg, J. and G.O. Wesolowsky, 2000. Facility location with closest rectangular distances. *Naval Res. Logistics*, 47: 77-84.

Chan, W.T., D.K.H. Chua and G. Kannan, 1996. Construction resource scheduling with genetic algorithms. *ASCE J. Construct. Eng. Manage.*, 122: 125-132.

Colebrook, M. and J. Siciliaa, 2007. Undesirable facility location problems on multi-criteria networks. *Comput. Operat. Res.*, 34: 1491-1514.

Gero, J.S. and V. Kazakov, 1997. Learning and reusing information in space layout planning problems using genetic engineering. *Artif. Intell. Eng.*, 11: 329-334.

Heizer, J. and B. Render, 1999. *Operations Management*. 1st Edn., Prentice-Hall, NJ. USA., ISBN: 10: 0136742432.

Hinojosaa, Y., J. Kalcsicsb, S. Nickelc, J. Puertod and S. Veltene, 2006. Dynamic supply chain design with inventory. *J. Comput. Operat. Res.*, 10.1016/j.cor.2006.03.017.

Huang, W.V., R. Batta and A.J.G. Babu, 1990. Relocation promotion problem with euclidean distance. *Eur. J. Operat. Res.*, 46: 61-72.

- Koopmans, T.C. and M. Beckmann, 1957. Assignment problems and the location of economic activities. *Econometrica*, 25: 53-76.
- Koumoussis, V.K. and P.G. Georgiou, 1994. Genetic algorithms in discrete optimization of steel truss roofs. *ASCE J. Comput. Civil Eng.*, 8: 309-325.
- Li, H. and P.E.D Love, 1997. Improved genetic algorithms for time-cost optimization. *ASCE Construct. Eng. Manage.*, 123: 233-237.
- Li, H., P.E.D. Love and S. Ogunlana, 1998. Comparing genetic algorithms and non-linear optimisation for labor and equipment assignment. *Build. Res. Inform.*, 26: 322-329.
- Lin, B.M.T. and S.S. Tseng, 1993. Generating the best K sequences in relocation problems. *Eur. J. Operat. Res.*, 69: 131-137.
- Meller, RD. and KY. Gau, 1996. Facility layout objective functions and robust layouts. *Int. J. Prod. Res.*, 34: 2727-2742.
- Moon, G. and G.P. Kim, 2001. Effects of relocation to AS/RS storage location policy with production quantity variation. *Comput. Ind. Eng.*, 40: 1-13.
- Muther, R., 1969. *Systematic Layout Planning*. 3rd Edn., VNR Company, USA, ISBN-13: 978-0-933684-09-6.
- Nagendra, S., D. Jestin, R.T. Haftka and L.T. Watson, 1996. Improved genetic algorithm for the design of stiffened composite panels. *Comput. Struct.*, 58: 543-555.
- Nozick, L.K. and M.A. Turnquist, 1998. Integrating inventory impacts into a fixed-charge model for locating distribution centers. *Transport Res. Part E*, 34: 173-186.
- Nozick, L.K., 2001. The fixed charge facility location problem with coverage restrictions. *Transport Res. Part E*, 37: 281-296.
- Pierreval, H. and J.L. Paris, 2003. From simulation optimization to simulation configuration of systems. *Simul. Modell. Practice Theory*, 11: 5-19.
- Rad, P.F. and B.M. James, 1983. The layout of temporary construction facilities. *Cost Eng.*, 25: 19-27.
- Rheault, M., J.R. Drolet and G. Abdunour, 1996. Dynamic cellular manufacturing system. *Comput. Ind. Eng.*, 31: 143-146.
- Tommelein, I.D., R.E. Levitt and T. Confrey, 1991. Sight plan experiments: Alternate strategies for site layout design. *ASCE J. Comput. Civil Eng.*, 5: 42-63.
- Tompkins, J. and J. White, 1984. *Facilities Planning*. 1st Edn., Wiley, New York, ISBN: 13: 9780471032991.
- Yapicioglu, H., A.E. Smitha and G. Dozierb, 2007. Solving the semi-desirable facility location problem using bi-objective particle swarm. *Eur. J. Operat. Res.*, 177: 733-749.
- Yeh, I.C., 1995. Construction-site layout using annealed neural network. *ASCE J. Comput. Civil Eng.*, 9: 201-208.