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Modeling of materials flow in Supply chain with Genetic Algorithm

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ABSTRACT

From among current flows in any supply chains (Financial, Information & Materials), flow of materials has a considerable importance with regard to its share in cost price of product. This paper intends to apply genetic algorithm method for a suitable allocation of orders at different steps of the chain and with regard to minimizing considered costs. There is a comparison between presented replies based upon genetic algorithm and other common methods for searching a pattern such as Latin Hypercube, Nelder Mead with relevant proves about priority of genetic algorithm method than other methods.

KEY WORDS: Supply chain, Flow of materials, Genetic algorithm, searching a pattern.

1-INTRODUCTION

Supply Chain management is responsible for integration of all organizational units throughout the supply chain and also coordination among materials, information and financial flows for meeting the expectations of final customer with the goal of betterment the supply competition. [1]

Management of materials flow throughout the supply chain is one of the most important discussions of it. When there is a considerable logistic share in sale price of products, it seems more important than before. For instance, in U.S.A the logistic cost of a product is equal to %30 of its sale price [2]. A supply chain means a set of processes and flows inside /outside of procedures and with different compounds in order to meet all expectations of a customer. There are two different ways for performing procedural viewpoint in a supply chain as follows:

1- Cyclic viewpoint: It means all processes of a supply chain may be divided into different sets of cycles. Therefore there is transaction between two respective procedures of a chain.
2- Pressure- Tension viewpoint: It means that all processes of a supply chain will be divided into two dependant parts either by meeting customer's orders or by estimation of it [3]. Tension process will be started with a customer's order while a pressure one starts with estimation of customers' requests. [4]

There are different models for management of materials flow in supply chains up to now. Ubrain and Ghodsi Pour submitted a non-linear combined integer for solving the problem of selecting suppliers in multiple resource finding in which total logistic costs include the net price, maintenance & stock costs, transportation and ordering costs (pp 15-27). Birkenar & Sebi proposed a combined AHP model for ideal lexicography programming for solving the problem of supply chain stock.

Both qualitative & quantitative criteria included in this model in order to find finally the final result which is purchase amount of all suppliers (6, pp 395-400).

Ghahraman et al. have also applied Fuzzy AHP method for solving the problems. It is a systematic attitude in selection of options and problem solving by the use of theoretical concepts of fuzzy collection and analysis of hierarchical structure. Usually decision makers find out that it is more ensured to submit any judgment in a distance from fixed amount judgments [7, pp 382-394]. Dogan and Sahim used active programming method for solving of problems [8, pp 420-426]. By considering the order size for different stocks, Ling & Bostet presented a model for optimized stock in a supply chain [9]. Hamsfrize et al. presented a model by considering a framework for combination of environmental criterion. [10, pp 85-93].

Different & new tools and techniques have been applied in order to implement this philosophy such as mathematical programming, simulation, ultra-innovative methods and so on. In practice we need different algorithms for solving different problems with great size. The mentioned algorithms are unable to solve any problems exactly even if they are really complex. A clear method for solving these problems is accepting suitable solutions close to optimized ones instead of exact and optimized solutions. Researchers of investigating the functions have found out some innovative algorithms recently. These algorithms will provide some close replies to optimized one for great size problems within an acceptable calculation period of time and with a suitable required memory space. Since there is an increase in performance time of the program with regard to the quantity of variants and size of the sample, it is impossible to use polynomial algorithms for solving these problems. Table 1 shows this problem.

Table 1-Required time for calculation of F(N) calculation procedures

	N size		
No. of procedures of F(N)	20	50	100
1000 x N	0.02 s	0.05s	1s
1000 x N^3	0.8s	12.5s	100s
2^N	1s	35 years	$3x10^4$ centuries
3^N	5.8 s	$2x10^9$ centuries	---

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For this purpose, some innovative algorithms have been applied for solving these challenging problems such as genetic algorithm, tabo search and simulated gradual melting. Regarding the nature of non-linear functions, there is not a quick, absolute and exclusive method for solving of non-linear problems (like simplex method in linear problem solving). As it is obvious in figure 1, most of traditional methods have these major forms which may be stopped upon reaching to the first optimized partial point without any ability to exit of this point and go towards absolute point. Optimized solution is seriously depending upon the starting point and searching mechanism.

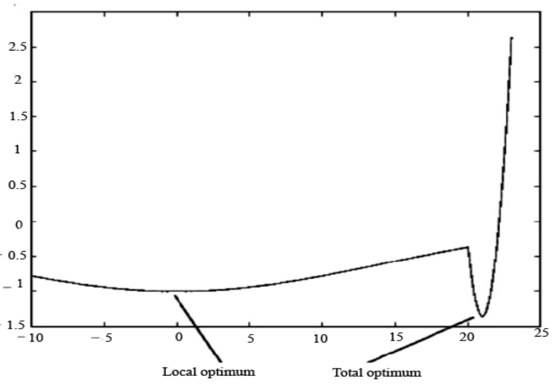

Figure 1- Absolute & local minimum

This paper intends to apply a genetic algorithm and benefits from any advantages of this method in comparison with other optimization methods for selecting convincing methods in a supply chain. Genetic algorithm is one of the most important innovative algorithms which are used for optimization of different functions. All previous information will be extracted in this algorithm and applied in searching process. One of the advantages of this method in comparison with other searching methods is lack of stoppage in optimized local points [11, pp 81-99].

This paper has been organized as follows:

A real world problem will be studied in second part. Then there is a mathematical model making and in fourth part there is a genetic algorithm for this purpose and then in sixth part we have a comparison of results with other methods and finally all findings would be presented accordingly.

2-Case study

The supply chain of agricultural machinery has been considered for model evaluation in a case study. Generally a pressure system is used in such a chain for ordering of required parts. But there is a special order with a volume of 200 multi-purpose machines have been applied for supplying of required parts of tension system. A multipurpose machine needs two power transfer systems for completion with a fundamental share in its cost price. It is possible to purchase the case in ready packs from two external suppliers with other assembling parts. Gear box is the major part in power transfer system which in itself will be supplied by three other supplies and sold to the producer of power transfer system.

A gear box includes two groups of machined parts prepared by different cutting workshops.

3-Mathematical model making

Tension system is used, from among different systems for formulation of recent problem. It means that current systems in each level request their stock from previous level and according to the received order amount from next level. Central factory will request the suppliers for all required parts in compliance with quantity and type of order received from demanding centers & BOL of product. They will also submit their demand to major suppliers as well. It is possible to have different levels in accordance with current requirements. It is true also in distribution part among retailers, distribution centers and central factories which may have profitability of the supply chain by flow the product from one level and sending directly to the next one. (It is more true for distribution part of the non-operational stations which are allocated only for distribution of the products).

Regarding the presented case study through a good understanding of governing mathematical relations, following is a model of supply chain presented in this research. The goal function of this model intends to minimize any transportation, shortage and maintenence costs accordingly. Followings are relevant symbols of this model:

X_{ijk}: It means transported goods from origin **i** to destination **j** in **K** level

($k=1,2,\ldots,P$, $j=1,2,\ldots,m_b$, $i=1,2,3,\ldots n_a$)

A: Transportation costs matrix according to the unit from origin **i** to destination **j**

S_{ik}: Maximum capacity of resources **i** at level **k**

L: Demand level of final product

L_k: Number of entering required parts to **k** level for producing an exit part unit

g_1, g_2: Relevant costs of facing with maintenance and shortage of stock

w_{ik},w_{2k}: Zero & 1 variants

All stations have maximum capacity. Therefore the exit quantity of materials from the stations should not be more than station's capacity (Limitation I). The entered quantity of materials to the stations should be at least equal to L times more than exit materials. L shows the number of entered parts for producing one unit of required exit part (Limitation II).

The quantity of transported materials from level 2 to level 1 should be at least L times more than received order (I) (Limitation III). If the amount of goal function is more than zero, we have faced with maintenance costs and then w_{ik} should be equal to one and w_{rk} should be equal to zero and vice versa. If the mentioned amount is smaller than zero, we will face with shortage costs and therefore w_{ik} should be equal to zero and w_{rk} equal to one (Limitations IV, V & VI).

$$Minf(x,w) = \sum_{i=1}^{na}\sum_{j=1}^{mb}\sum_{k=1}^{P}\left(AX_{ijk}\right) + \sum_{k=1}^{P}\left|\prod\nolimits_{k=1}^{P} L_k I - \sum\nolimits_{j=1}^{mb} X_{ijk}\right| (W_{1k}g_1 + w_{2k}g_2)$$

Subject to:

(1)

$$\sum_{I=1}^{ns} X_{ijk} \le S_{ki+1} \qquad \forall_i = 1,2,\dots n_a, k = 1,2,\dots,p$$

(2)

$$\sum_{i=1}^{ns} X_{ijk} \ge L_k \sum_{j=1}^{mb} X_{i+1jk} \qquad \forall_i = 1,2,\dots n_a, k = 1,2,\dots,p$$

(3)

$$\sum_{i=1}^{ns} X_{ij2} \ge L_1 I$$

(4)

$$w_{1K}\left(\prod_{K=1}^{P} L_k I - \sum_{J=1}^{mb} X_{ijk}\right) \ge 0 \qquad \forall k = 1,2,\dots,p-1$$

(5)

$$W_{2k}\left(\prod_{k=1}^{p} L_k I - \sum_{J=1}^{mb} X_{ijk}\right) \ge 0 \qquad \forall k = 1,2,\dots,p-1$$

(6)

$$W_{1k} + W_{2k} = 1$$

$$W_{1k} + W_{2k} = 0,1\,, \qquad X_{ijk} \ge 0$$

In this chain we have production capacity of goods equal to 250 units. It has been assumed that there is a demand for 200 units. Transported rate of goods from X_{111}&X_{121} should be at least equal to demand (200) and in next levels the entered goods to the stations should be more than exited goods from it.

All stations have special capacities therefore the collection of exit goods from a station should be lower than station capacity. Model making of the presented case study in figure 2 is as follows:

$$MinZ = 15x_{111} + 20x_{121} + 22x_{112} + 18x_{122} + 27x_{132} + 22x_{212} + 18x_{222} + 27x_{232} + 30x_{113} +$$
$$25x_{123} + 22x_{133} + 20x_{143} + 23x_{153} + 30x_{213} + 25x_{223} + 22x_{233} + 20x_{243} + 23x_{253} + 30x_{313} +$$
$$25x_{323} + 22x_{333} + 20x_{343} + 23x_{353} + \left|2400 - (x_{113} + x_{123} + x_{132} + x_{143} + x_{153} + x_{213} + x_{223} +\right.$$
$$\left. x_{223} + x_{243} + x_{253} + x_{313} + x_{323} + x_{333} + x_{343} + x_{353}) \times (W_{11} \times 500 + W_{21} \times 700)\right| +$$
$$\left|1200 - (x_{112} + x_{122} + x_{132} + x_{212} + x_{222} + x_{232}) \times (W_{12} \times 500 + W_{22} \times 700)\right| +$$
$$\left|400 - (x_{111} + x_{121}) \times (W_{13} \times 500 + W_{23} \times 700)\right|$$

Subject To:

$$x_{111} \le 300$$
$$x_{121} \le 240$$
$$x_{112} + x_{212} \le 800$$
$$x_{122} + x_{222} \le 600$$
$$x_{132} + x_{232} \le 900$$
$$x_{113} + x_{213} + x_{313} \le 1050$$
$$x_{123} + x_{223} + x_{323} \le 740$$
$$x_{133} + x_{233} + x_{333} \le 970$$
$$x_{143} + x_{243} + x_{343} \le 1200$$
$$x_{153} + x_{253} + x_{353} \le 700$$
$$x_{112} + x_{122} + x_{132} \ge 3 \times x_{111}$$
$$x_{212} + x_{222} + x_{232} \ge 3 \times x_{121})$$
$$x_{113} + x_{123} + x_{133} + x_{143} + x_{153} \ge 2 \times (x_{112} + x_{212})$$
$$x_{213} + x_{223} + x_{233} + x_{243} + x_{253} \ge 2 \times (x_{122} + x_{222})$$
$$x_{313} + x_{323} + x_{333} + x_{343} + x_{353} \ge 2 \times (x_{132} + x_{232})$$
$$x_{111} + x_{112} \ge 2 \times 200$$
$$w_{11} (2 \times 200 - (x_{111} + x_{121}) \ge 0$$
$$w_{21} (2 \times 200 - (x_{111} + x_{121}) \ge 0$$
$$w_{12} (2 \times 200 \times 3 - (x_{112} + x_{122} + x_{132} + x_{212} \; x_{222} + x_{232})) \ge 0$$
$$w_{22} (2 \times 200 \times 3 - (x_{112} + x_{122} + x_{132} + x_{212} + x_{222} + x_{232})) \ge 0$$
$$w_{13} (2 \times 200 \times 3 \times 2 - (x_{113} + x_{123} + x_{132} + x_{143} + x_{153} + x_{213} + x_{223} + x_{233} + x_{243} + x_{253} + x_{313} + x_{323} + x_{333} + x_{343} + x_{353})) \ge 0$$
$$w_{23} (2 \times 200 \times 3 \times 2 - (x_{113} + x_{123} + x_{132} + x_{143} + x_{153} + x_{213} + x_{223} + x_{233} + x_{243} + x_{253} + x_{313} + x_{323} + x_{333} + x_{343} + x_{353})) \le 0$$
$$W_{11} + W_{21} = 1$$
$$W_{12} + W_{22} = 1$$
$$W_{13} + W_{23} = 1$$

4-Presented genetic algorithm

The first idea of this method has been inspired from evolution theory of Darvin with basic application on natural genetic. John Holland et al. submitted the primary principles of genetic algorithm at Michigan University within 1962-1965. They focused on compatibility process of natural systems in their researches and endeavored for making its model in superficial systems which should bear relevant facilities of natural systems. [11, pp 81-99].

Genetic algorithm presented in this research intends to find a clear way of materials flow and quantity of it in supply chain by focusing on minimizing current costs in supply chain especially transportation costs. There are different operational algorithms for considering the efficiency of operators and accompanied with various tests on differ problems in different sizes as well. Following is the structure of genetic algorithm:

A) Chromosome : It means a set of coded bits with a possible (suitable or non-suitable) replies for the considered problem. In case of using double coding, we should assume zero or 1 for a bit. Any one of bits of considered chromosome in this problem is a potential reply for all variants of it.

B) Goal function & suitability: Goal function is for specifying that how people play their roles in the scope of the problem. Therefore suitable function is usually for exchanging the quantity of goal function to its related suitability amount. In other words, we have:

$F_{(n)}=g(f(x))$

Where f is goal function and g function will change it into a non-negative number where F is the relevant suitability amount [12].

Table II- Evaluation of intersection operators

Type of intersection operator	Size of population	Number of repetition	Quantity of goal function
Innovative	5000	100	88308.78
Distributor	5000	100	92437.14
Intermediate	5000	100	93149.77
Single point	5000	100	93864.56
Double points	5000	100	95738.43

We may measure suitability and/or non-suitability of an answer with relevant amount of suitability function. Since it is an optimized type of problem, suitability function is equal with goal function as well. The goal function of problem is minimizing the costs.

C) Population size & production quantity: The real meaning of population is the number of chromosomes. One of the advantages of genetic algorithms against traditional searching methods is using of parallel search. With above-mentioned description, both the size of population and size of searches are equal. The size of population has been considered by different tests in this research. Then there is betterment in producing methods from one generation to another for finding the best solution. The size of population in this research is 5000 chromosomes.

D) Genetic operators: In order to find a point in searching space, we should use genetic operators accordingly. Followings are two types of these operators:

1- Intersection operator: It is the major operator for producing of new chromosomes in genetic algorithm of intersection operator. This operator will produce some similar operators like itself in nature including of different parts (genes) out of its parents. There are different intersection operators such as: Single-point, Double point, Distributor, Intermediate, Innovative and …
Different methods have been applied for specifying a suitable intersection operator including single-point, double point, distributor, intermediate and innovative. Table 2 shows the results of it as well. As it is obvious, innovative method has a more suitable solution. We have a child in contact line of two parents in a small distance far from parent with a better suitability value and in a different way from a parent with worst suitability value in innovative method.

2- Mutation operator: Mutation is a random process in which the content of a gene will be replaced with another gene for producing a new genetic structure.
Mutation operator of this research is Gossin which has been selected with rate 2 along with some changes in different rates of it. Gossin operator will add a random number of Gossin distribution function with an average of zero to any vector entrance of parent. The variance of this distribution is regulated by criterion parameters and collectivity in a way that in this research we have respective changes of these variants with criterion 2 and collectivity of 1.

Suitability function of presented model is considered equal to the above-mentioned goal function with some limitations in solving of genetic algorithm. We used suitability function in order to consider all limitations and in case of applicable population variants in mentioned limitations. In case of any contrasts between population variants and limitations, probably the suitability function has been considered as a very great number. Therefore the obtained solution will be applicable in limitations of model since it is intending to minimize suitability function.
Second column of table III shows the output of genetic algorithm of variants X_{111} up to X_{253} with a population of 5000, number of repetition of 100, Gossin mutation operator and Innovative intersection operator. Figure 3 shows the betterment diagram of suitability function in continuous generations.

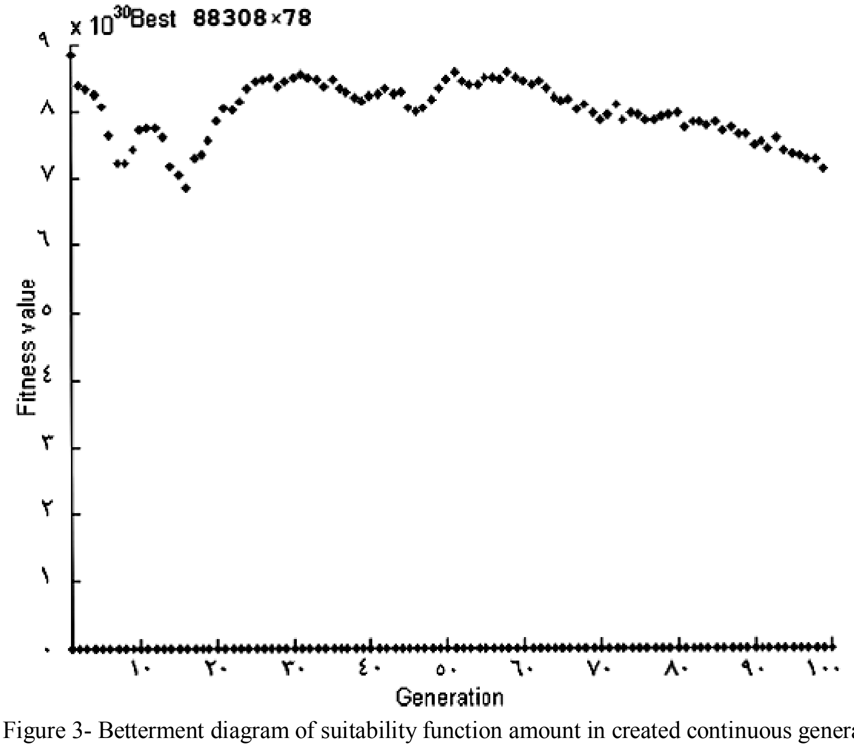

Figure 3- Betterment diagram of suitability function amount in created continuous generations

The presented model has been studied with different methods of pattern search. These methods are: Nelder –Mead method and Latin Hypercube method. This model has been solved by the use of all above-mentioned methods and by the use of MATLAB software for which table 4 shows its outputs. As it is obvious, Latin Hypercube method is better than other method among these two searching methods.

As it is obvious in table 4, there is betterment of calculated goal function about %9.4 by genetic algorithm against Nelder Mead method and about %2.27 against Latin Hypercube method. Third column of table 3 shows the output of searching method by Latin Hypercube and Nelder-Mead methods for variants x_{111} to x_{253} as well.

Table 3- Genetic algorithm output & pattern searching

Nelder-Mead	Latin Hypercube	Genetic algorithm	Variables
262.09	204.68	191.1	x_{111}
137.91	195.33	208.89	x_{121}
98.75	156.2	132.38	x_{112}
224.43	260.4	229.31	x_{122}
463.07	197.427	211.67	x_{132}
83.44	237.89	261.25	x_{212}
239.99	223.45	205.34	x_{222}
90.42	124.64	160.05	x_{232}
211.67	168.76	5.43	x_{113}
29.54	61.85	80.32	x_{123}
57.8	309.27	323.49	x_{133}
14.16	0	290.4	x_{143}
51.2	248.28	87.61	x_{153}
419.1	82.7	80.85	x_{213}
119.72	250.76	166.73	x_{223}
201.91	92.72	194.81	x_{233}
139.92	204.72	182.85	x_{243}
47.94	336.8	244.06	x_{253}
391.54	130.31	87.13	x_{313}
426.38	173.16	132.8	x_{323}
154.87	147.43	108.85	x_{333}
4.34	111.52	132.57	x_{343}
129.85	81.72	282.08	x_{353}
96618.307	90397.45	88308.78	Goal function

Table 4- Goal function quantity for different methods of pattern searching

Searching method	Goal function quantity
Genetic Algorithm	88308.78
Lain Hypercube	90297.45
Nelder-Mead	96618.207

5-Conclusion

Regarding the importance of materials flow and relevant costs in supply chain and necessary for an on-time/correct decision making for general profitability of chain, a number of ultra-innovative models have been applied in this research for genetic algorithm with a considerable priority than other previous classic models.

One of the advantages of the mentioned model is providing an acceptable solution. Therefore with considering all time limitations and other prohibitions, it is possible to make better solutions. The presented model of this research which is based upon genetic algorithm has been compared with other searching models for which obtained results show the considerable ability of genetic algorithm in solving this model of research.

It is possible to apply mentioned model for both parts supply chain and demand chain and/or on integrated bass for both parts. One of the most important advantages of this model is considering all effects of levels and part on each other and also all mentioned parts in an integrated form in order to meet general goal of the chain which is total profitability of a chain as well.

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