A Hybrid Genetic Algorithm for Supplier Selection and Network Optimization

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Abstract
The practicality of novel network optimization models based on innovative combination of financial and market-based factors such as price, cost, quality, and supplier's contribution background is irrefutable. In this study a hybrid approach (Fuzzy Analytic Network Process and Genetic Algorithm) is applied to provide more efficiency in the decision-making process.

Keywords: Supply chain configuration, Hybrid real and binary GA, FANP

Introduction
Present competitive market has imposed heavy pressure on the enterprises. Many industries like automotive which have been founded on the basis of part assembly and production of other firms are well-informed that in highly technology and contribution based economy, the importance of designing supply chain is irrefutable. In this study, since not only the supplier selection issue, but also the optimization of the whole supply network is investigated, we use a combination of the most applicable supplier evaluation factors in network modeling. According to a well-known survey done by Dickson, 23 important and practical criteria have been identified out of 50 separate factors in supplier selection. Accordingly, product quality, on time delivery, product's appropriate function, product's guarantee, product's cost and its technical capabilities and production capacity were identified as most important factors (Dickson 1996). Weber and his colleagues later showed that supplier selection problem is fundamentally a multi-objective model (Weber et al. 2001). Swift also examined 21 supplier selection factors for purchase managers (Swift 1995). On the other hand, Buta and Hook utilize 4 criterions for supplier evaluation: manufacturing and production cost, quality, technology, and services (Bhutta and Huq 2002). In another comprehensive review of selection criterions in supply chains, quality, lead time, cost, service production capability, management, technology, research and development, financial matters, flexibility, communication, risk and security, and environmental issues were considered most, respectively (William et al. 2010). However, factors like cost, quality, delivery, and vendors' capacity are more applicable. Criterion selection for vendor evaluation depends on the product type and problem conditions (Dahel 2003, Lehman and O'Shaughnessy 1982).

According to the past studies in this context, supplier evaluation factors were never studied comprehensively and based on yielding to an operational and applicable functionality. Applied approaches are devoid of capability for precise or reasonably practical estimation. In addition, proposed approaches for optimizing supply chain configuration models and supplier selection could rarely include both factors of solution simplicity and yielding to an ideal solution. In this regard, supplier selection criteria in this study are determined to be product price (dynamic through the network), transportation cost, quality, and suppliers' contribution background. Accordingly, since FANP approach is an efficient tool in conditions where elements' inter-relations make a networked structure system, it is used to estimate the contribution background factor more accurately (Saaty 1996). The FANP approach has been studied by many researchers to solve complex decision-making topics (Najafi et al. 2011).

Furthermore, an extensive literature review of the field proves a discernible gap for a concrete methodological approach in dealing with supplier selection and supply chain configuration. Although this area has attracted several researchers, very few efforts focused on the most practical factors in supplier selection while considering accurate estimation of the fuzzy qualitative and quantitative aspects. Also, to the best of our knowledge, it is difficult to find an efficient integrated approach to handle this problem in a fast yet effective manner. In an effort to fulfill this gap, we developed an inclusive mixed integer non-linear programming (MINLP) model and an integrated real and binary Genetic Algorithm which is proven to be rapid and reliable. Presented model in this study is one of the multiple sourcing models in which multiple purchasers buys an identical product from more than one vendor where the total demand is segregated between vendors. This viewpoint that sometimes one of the suppliers cannot fulfill its allocated demand due to various reasons like price discount, and constraints like capacity, quality, lead time etc. is remarkable. Since the computational complexity of our problem grows exponentially in accordance with dimension growth, it should be classified as an NP-hard question. Hence, considering its appropriate efficiency, logical structure and a moderate complexity, we proposed a refined Genetic Algorithm for solving the developed model.

Literature review

Configuration of supply chain is regarded as one of the most crucial aspects in supply chain management where the ultimate goal is to improve the whole network. In the competition arena, a supply chain should act efficiently at least in some areas like price, quality, and lead time (Stadtler 2005). The literature is highly rich in the design and arrangement of supply chain, and many scientists are absorbed by this scope. In 2006, Ding et al' examined the supply chain issues using an optimization method which was based on multi-criterion simulation (Ding et al. 2006). In another article in that year, this problem was considered with the emphasis on environmental issues using multi-objective optimization and graph theory (Dotoli et al. 2006). Selim and Ozkarahan offered and interactive Fuzzy goal programming to address optimum numbers, locations and capacity levels of plants and warehouses in a distribution network problem (Selim and Ozakarahan 2008). Of other studies in this subject would be the non-linear model which was presented by Links and Vandal where they tackled their model with a Genetic algorithm, considering the uncertainty in demand issue (Lieckens and Vandaele 2007).

Generally, the approaches used in supplier selection problems can be classified into general divisions like Data Envelopment Analysis (DEA), Cluster Analysis (CA), mathematical programming, AHP, Artificial Intelligence (AI), Analytic Network Process (ANP), Fuzzy theory and integrated approaches (Garfamy 2006, Hinkle et al. 1969, Sadrian and Yoon 1994, Sung and Krishnan 2008, Weber et al. 2000). With the improvement of Fuzzy applications and technics in problem analysis and real-life problems, Fuzzy approaches were commonly used in supplier selection field. In this approach which uses mathematical logic for precise modeling of some stochastic criterions, stochastic and uncertain aspects in supplier selection are more noticeable. In

2006, a hierarchical model based on Fuzzy theory was presented to solve supplier selection problem which had the ability to consider quality and quantity criterions (Chen et al. 2006). Highly applicable nature of Fuzzy issues made them more practical among other approaches in supplier selection area. In one of the surveys, Fuzzy zero-one programming was used for supplier selection (Vinodh et al. 2011). Also, regarding the solution making process for complex models which were developed through literature, several heuristic approaches have been proposed where Genetic Algorithm has received more attentions (Chan and Chung 2004, Kaplan and Norton 2006, Kim et al. 2008).

Problem definition

In this survey, in order to obtain an efficient supply network design, highly applicable and vital factors are considered including the backgrounds of the suppliers' contribution, dynamic price, transportation cost, and product quality. The background of the supplier's contribution is regarded as a value between zero and one, where, the smaller this value is, the more the customer is inclined to bargain with the desired supplier based on the last contributions. We can calculate and determine this value regarding many factors like; delay in the product lead time in each order, flexibility for order change, Technological capability of the supplier, environmental issues related to the supplier, innovations of the supplier, production capacity, policies and principles related to the sale in the suppliers' organization, permissiveness and stricture of the supplier in the process of receiving the purchased product's money, and etc. In order to calculate this factor regarding the considerable efficiency of FANP approach in network structures under uncertainty, we apply this technique. Furthermore, the product price in the second layer assumed to be different from the first layer. It is calculated considering the amount of profit and added value at the supplier's place in that layer; this price is determined by means of a cumulative coefficient. This coefficient is weighted average of the purchased products' price including the profit margin parameter. We present a minimization objective function in which the model seeks to find an optimum assortment to minimize the costs; product price in each layer, transportation cost and cost of placing an order on selected suppliers. Also, the difference between the purchasers' demanded quality and the suppliers' offered quality is added to the minimization objective function as a penalty, where in this case the objective function will search for the suppliers having higher or at least equal quality to the purchasers' demanded quality. In addition, some parameters are defined to increase the utility and practicality of the problem. We are studying the problem in a situation that only required numbers of plants are going to be selected. In this case, the required indices and resulted model will be presented below.

A. *Variables:*
   - X_{ij} The amount of products transported from plant i to warehouse j
   - Y_{jk} The amount of the products transported from warehouse j to retailer k
   - Z_i The zero-one variable for determining the use or disuse of plant

B. *Parameters:*
   - P_i Product price in the plant i
   - P'_j Product price in the warehouse j
   - C_{ij} Product's transportation cost from plant i to warehouse j
   - C_{jk} Product's transportation cost from the warehouse j to retailer k
   - S_{ij} Difference between warehouse j's demanded and plant i's presented quality
   - S_{jk} Difference between retailer k's demanded and warehouse j's presented qualities
   - φ_j Added-value and profit's determination factor in the second layer by warehouse j

Q_j Demanded product quality of warehouse *j*
Q'_k Demanded product quality of retailer *k*
q_i Quality presented by plant *i*
q'_j Quality presented by warehouse *j*
R_k Ultimate demand by retailer *k* in the third layer
$Pmin_i$ Least acceptable production amount for plant *i*
$Pmax_i$ Maximum production capacity in plant *i*
a_{ij} Plant *i*'s credit from the warehouse *j*'s point of view
b_{jk} Warehouse *j*'s credit from the retailer *k*'s point of view
M A large amount
α_i Cost of placing an order on plant *i*

C. *Model:*

$$\text{Min} \quad \sum_{i=1}^{n}\sum_{j=1}^{m}\left(1-a_{ij}\right)X_{ij}+\sum_{j=1}^{m}\sum_{k=1}^{o}\left(1-b_{jk}\right)Y_{jk}+\sum_{i=1}^{n}\sum_{j=1}^{m}P_i X_{ij}+\sum_{j=1}^{m}\sum_{k=1}^{o}P'_j Y_{jk}$$
$$+\sum_{i=1}^{n}\sum_{j=1}^{m}c_{ij}X_{ij}+\sum_{j=1}^{m}\sum_{k=1}^{o}c'_{jk}Y_{jk}+\sum_{i=1}^{n}\sum_{j=1}^{m}S_{ij}X_{ij}+\sum_{j=1}^{m}\sum_{k=1}^{o}S'_{jk}Y_{jk}+\sum_{i=1}^{n}\alpha_i.Z_i \qquad (1)$$

Subject to:

$$\sum_{i=1}^{n}X_{ij}=\sum_{k=1}^{o}Y_{jk} \qquad \forall j \qquad (2)$$

$$\sum_{j=1}^{m}Y_{jk}\geq \mathrm{R}_k \qquad \forall k \qquad (3)$$

$$\sum_{j=1}^{m}X_{ij}\leq Z_i.\mathrm{Pmax}_i \qquad \forall i \qquad (4)$$

$$\sum_{j=1}^{m}X_{ij}+M.(1-Z_i)\geq \mathrm{Pmin}_i \qquad \forall i \qquad (5)$$

$$\sum_{i=1}^{n}Z_i\leq S \qquad (6)$$

$$P'_j.\sum_{i=1}^{n}X_{ij}=(1+\varphi_i).\sum_{i=1}^{n}P_i.X_{ij} \qquad \forall j \qquad (7)$$

$$\mathrm{Q}_j-\mathrm{q}_i=\mathrm{S}_{ij} \qquad \forall i,j \qquad (8)$$

$$\mathrm{Q}'_k-\mathrm{q}'_j=\mathrm{S}'_{jk} \qquad \forall j,k \qquad (9)$$

$$X_{ij}\geq 0 \qquad \forall i,j \qquad (10)$$

$$Y_{jk}\geq 0 \qquad \forall j,k \qquad (11)$$

$$Z_i\in\{0,1\} \qquad \forall i \qquad (12)$$

Equation (1) illustrates the objective function. Constraint (2) assures that the distributed amount of goods from plants to warehouses is equal to the amount of goods distributed from warehouses to retailers. Constraint (3) declares that the amount of goods distributed to retailer k should meet its demand. Constraint (4) indicates that total amount of goods distributed from plant i should not surpass its maximum production capacity. Constraint (5) defines that total ordered goods to plant *i* should exceed its minimum applicable production rate. Constraint (6) ensures that the number of selected suppliers is less or equal to our preferable number. Constraint (7) defines the relation between first and second layer price. Equation (8) and (9) affirms the penalty for not meeting the quality requirements of each layer. Finally, constraints (10), (11) and (12) enforce the binary and non-negativity restrictions on the corresponding decision variables.

Solution approach

In order to start the solution process it is required for all the coefficients of objective-function to be definite; hence, coefficients of a_{ij} (plant i's credit from the warehouse j's point of view) and b_{jk} (warehouse j's credit from the retailer k's point of view) must be calculated by FANP approach. Considering the existing dependence of objectives and criterions, the Matrix Cloud approach is used like below (Kahraman et al. 2006).In this condition, if we let W_1 be objectives' weighted vector toward the general goal, W_2 will be the matrix showing the effect of each goal on criterions. W_3 and W_4 will be the matrixes indicating the internal dependence of goals and internal dependence of criterions.

In this stage experts will perform pair to pair comparisons. Since uncertainty lies in decisions, they will present their opinions using linguistic data, based on the table 1 (Chang 1996). Then this algorithm will be performed:

Table 1 – Linguistic scales and their degree of significance

Degree of significance	Fuzzy triangular	Fuzzy recursive triangular
Just equal	(1, 1, 1)	(1, 1, 1)
Equally	(1/2, 1, 3/2)	(2/3, 1, 2)
Important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very Strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

1st stage: Determining goals' degree of significance, assuming no dependence between goals, calculating W_1.

2nd stage: Determining criterions' degree of significance in proportion to each goal, assuming no dependence between criterions, calculating W_2.

3rd stage: Determining goals' internal dependence matrix in proportion to each goal, calculating W_3.

4th stage: Determining criterions' internal dependence matrix in proportion to each criterion, calculating W_4.

5th stage: Determining the mutual priority of goals, calculating $W^A=W_3*W_1$.

6th stage: Determining the mutual priority of criterions, calculating $W^B=W_4*W_2$.

7th stage: Determining general priorities of criterions, calculating $W^{ANP}=W^B*W^A$.

A. Applying Genetic Algorithm:

Genetic algorithm is one of the approaches applied to solve a NP-Hard problem which tries to optimize a developing structure of stochastic assortment of the first and feasible solutions of the problem based on the survival of the bests' theory, derived from the Nature.

B. Parameters set-up:

In the first phase of solution method, we need to define our GA parameters which play a crucial role in solution quality and algorithm rapidity. These parameters are as follows:

- Maximum number of iteration: this number determines the stop condition.
- Population size: the number of generated chromosomes.
- Cross-over percentage: the rate by which new solutions are produced using cross-over operator.
- Mutation rate: the rate by which new solutions are emerged using mutation function.
- Selection pressure: this operator increases the use of elitism whenever better solutions are generated.

C. Solution representation:

In the proposed method we solve the problem from the last nodes (retailers) backwards to the primary nodes (plants). The algorithm consists of binary and real chromosomes. The variable definitions as well as parse solution representation and violations are as follows:

Chromosomes definitions:

$$Z_i = \{0,1\} \qquad \forall i \tag{13}$$

$$\hat{Y}_{\min} \le \hat{Y}_{jk} \le \hat{Y}_{\max} \qquad \forall j,k \tag{14}$$

$$0 \le \hat{Y}_{jk} \le 1 \qquad \forall j,k \tag{15}$$

$$\hat{Y}_{jk} \sim uniform(0,1) \qquad \forall j,k \tag{16}$$

$$\hat{X}_{\min} \le \hat{X}_{ij} \le \hat{X}_{\max} \qquad \forall i,j \tag{17}$$

$$0 \le \hat{X}_{ij} \le 1 \qquad \forall i,j \tag{18}$$

$$\hat{X}_{ij} \sim uniform(0,1) \qquad \forall i,j \tag{19}$$

Parsing solutions:

$$Y_{jk} = \frac{\hat{Y}_{jk}.R_k}{\sum_{j=1}^{m} \hat{Y}_{jk}} \qquad \forall j,k \tag{20}$$

$$X_{ij} = \frac{\hat{X}_{ij}.\sum_{k=1}^{o} Y_{jk}}{\sum_{i=1}^{n} \hat{X}_{ij}} \qquad \forall i,j \tag{21}$$

$$PSV = Plant\ Selection\ Violation \tag{22}$$

$$PSV = \max\left(\frac{\sum_{i=1}^{n} Z_i}{S} - 1, 0\right) \tag{23}$$

$$POPV_i = Placing\ Order\ on\ Plant_i\ Violation \tag{24}$$

$$MPOPV = Mean\ \text{of}\ Placing\ Order\ on\ Plant\ Violation \tag{25}$$

$$PMaxCV_i = Plant_i\ Max\ Capacity Violation \tag{26}$$

$$MPMaxCV = Mean\ \text{of}\ Plant\ Max\ Capacity Violation \tag{27}$$

$$PMaxCV_i = \max\left(\frac{\sum_{j=1}^{m} X_{ij}}{P\max_i} - 1, 0\right) * Z_i \qquad \forall i \tag{28}$$

$$MPMaxCV = \sum_{i=1}^{n} PMaxCV_i \tag{29}$$

$$PMinCV_i = Plant_i \;\; Min \;\; CapacityViolation \tag{30}$$

$$MPMinCV = Mean \text{ of } Plant \;\; Min \;\; CapacityViolation \tag{31}$$

$$PMinCV_i = \max\left(1 - \frac{\sum_{j=1}^{m} X_{ij}}{P\min_i}, 0\right) * Z_i \qquad \forall i \tag{32}$$

$$MPMinCV = \sum_{i=1}^{n} Plant_i \;\; Min \;\; CapacityViolation \tag{33}$$

$$TV = Total \;\; Violation \tag{34}$$

$$TV = \frac{PSV + MPOPV + MPMaxCV + MPMinCV}{4} \tag{35}$$

D. Cross-over:

This process includes both uniform and arithmetic cross-over functions:

Uniform cross-over: first, the binary vector $\vec{\alpha}$ is generated (with probability 0.5 which is known as the mixing ratio). Then, this vector decides which parent will contribute each of the gene values in the offspring chromosomes.

Arithmetic cross-over: first, an arbitrary γ is given which is a number less than one. Then, the vector α is generated where each of its entities are derived from the uniform function of ($-\gamma$, γ). Thereafter, previous processes are repeated.

$$\gamma = Arithmitic \;\; Cross \;\; Over \;\; \text{Arbitrary} \; Parameter \tag{36}$$

$$\alpha_{ij} = Arithmitic \;\; Cross \;\; Over \;\; Parameter \;\; for \;\; \hat{X}_{ij} \tag{37}$$

$$\alpha'_{jk} = Arithmitic \;\; Cross \;\; Over \;\; Parameter \;\; for \;\; \hat{Y}_{jk} \tag{38}$$

$$-\gamma \le \alpha_{ij}, \alpha'_{jk} \le \gamma \qquad \forall i, j, k \tag{39}$$

$$\alpha_{ij}, \alpha'_{jk} \sim uniform(-\gamma, \gamma) \qquad \forall i, j, k \tag{40}$$

$$\vec{X} = \left[X_{ij}\right]_{n*m} \tag{41}$$

$$\vec{Y} = \left[Y_{jk}\right]_{m*o} \tag{42}$$

$$\vec{\alpha} = \left[\alpha_{ij}\right]_{n*m} \tag{43}$$

$$\vec{\alpha}' = \left[\alpha'_{jk}\right]_{m*o} \tag{44}$$

$$\vec{X}_1' = \vec{\alpha}.\vec{X}_1 + (1 - \vec{\alpha}).\vec{X}_2 \tag{45}$$

$$\vec{X}_2' = \vec{\alpha}.\vec{X}_2 + (1-\vec{\alpha}).\vec{X}_1 \quad (46)$$

$$\vec{Y}_1' = \vec{\alpha}'\vec{Y}_1 + (1-\vec{\alpha}')\vec{Y}_2 \quad (47)$$

$$\vec{Y}_2' = \vec{\alpha}'\vec{Y}_2 + (1-\vec{\alpha}')\vec{Y}_1 \quad (48)$$

E. Mutation:

Binary mutation: this operator, using mutation percentage, determines the probability of changing a zero-entity of a chromosome to a one-entity and vice versa.

Real mutation: this operator, first, using mutation percentage, determines whether a solution (e.g. X_{i0}) should be changed. Then, through mutation rate specifies the change volume where the mutation rate is not fixed. This rate will be increased whenever the mutation results in 20% improvement of the solution. Also, there is a condition to avoid generating solutions out of the predetermined range (e.g. (X_{min}, X_{max})). The process can be noticed below:

$$\sigma_{\hat{X}} = Step\ Size\ for\ \hat{X} \quad (49)$$

$$\sigma_{\hat{X}} = \frac{1}{20} * \left(\hat{X}_{\max} - \hat{X}_{\min}\right) \quad (50)$$

$$N_{\vec{X}}(0,1) = \text{Standard}\, Normal\ \text{Mutation Coefficient}\ \vec{X} \quad (51)$$

$$\vec{X}' = \min\left(\max\left(\vec{X} + \sigma_{\hat{X}} * N_{\vec{X}}(0,1), \hat{X}_{\min}\right), \hat{X}_{\max}\right) \quad (52)$$

$$\sigma_{\hat{Y}} = Step\ Size\ for\ \hat{Y} \quad (53)$$

$$\sigma_{\hat{Y}} = \frac{1}{20} * \left(\hat{Y}_{\max} - \hat{Y}_{\min}\right) \quad (54)$$

$$N_{\vec{Y}}(0,1) = \text{Standard}\, Normal\ \text{Mutation Coefficient}\ \vec{Y} \quad (55)$$

$$\vec{Y}' = \min\left(\max\left(\vec{Y} + \sigma_{\hat{Y}} * N_{\vec{Y}}(0,1), \hat{Y}_{\min}\right), \hat{Y}_{\max}\right) \quad (56)$$

F. Stop condition:

In order to deliver a fast yet comprehensive and reliable search the maximum number of iteration is set to be 700.

G. Selection:

In this study, to generate offspring from a combination of weak and strong solutions, Roulette Wheel Selection approach is employed. Also, through this section, the selection pressure enhances the generation of better solutions.

H. Fitness evaluation:

After parsing the solutions, primary fitness of the answers is derived by the objective function. Thereafter, the final fitness value of each solution is resulted by adding related violations considering their weights. Following equations are applied in this section:

$$OFV_1 = Objective\ Function\ Value \quad (57)$$

$$OFV_2 = Objective\ Function\ Value\ considering\ Violations \quad (58)$$

$$\beta = Violation\ Penalty\ Coefficient \quad (59)$$

$$OFV_2 = (OFV_1) * (1 + \beta * TV) \quad (60)$$

In order to deliver a better understanding of the proposed integrated Real and Binary GA, the flowchart of our methodology is given as figure 1.

Numerical Example

Total number of plants at the beginning of selection process is considered to be 4, where at most, we want to choose two of them. In addition, 4 warehouses and 5 retailers exist. Population number is considered 50 and the break criterion is 50. Besides, other required information of the problem except the background factor, will be produced randomly and with a defined limit. First we should extract the background factor of suppliers in the third layer using FANP approach. Hence, since we should perform this technique 5+4 times in this example, we will only clarify one of them and others can be calculated similarly. First, In order to determine W1, the table 2 will be given to experts so that they could perform pair-comparison between 4 crucial perspectives without considering any dependence between them. These perspectives were decided to be sustainability, vulnerability, flexibility and technological capabilities of the suppliers. Let the table 2 be completed like below:

Table 2 – Pair comparison

	Sus.	Vuln.	Flex.	Tech.
Sustainability		WMI	WMI	WMI
Vulnerability			VSMI	VSMI
Flexibility				SMI
Technology				

After normalization and related calculations, W_1= (0.33, 0.43, 0.17, 0.07) will be resulted. And after performing the same calculations, W_2 and W_3 will be gained. In order to derive W_4 we should use the existing connection between the 4 plants in the first layer.

Now, dependence priorities of the four perspectives will be calculated by this equation:

$W^A=W_3*W_1$= (0.1848, 0.2784, 0.2067, 0.3303)

Dependence priorities of the four plants are presented in the following tables. Finally, we derive the weight of each four plants of the first layer from the first warehouse's point of view by multiplying W^B and W^A matrixes like this:

Table 3 - W^B

	Sus.	Vuln.	Flex.	Tech.
First factory	0.1427	0.0622	0.2605	0.2345
Second factory	0.0797	0.0986	0.3816	0.2399
Third factory	0.1498	0.1848	0.5698	0.3955
Fourth factory	0.1591	0.1370	0.4670	0.3367

Table 4 - W^{ANP}

W^{ANP}	$1-a_{i1}$
First factory	0.81
Second factory	0.79
Third factory	0.67
Fourth factory	0.72

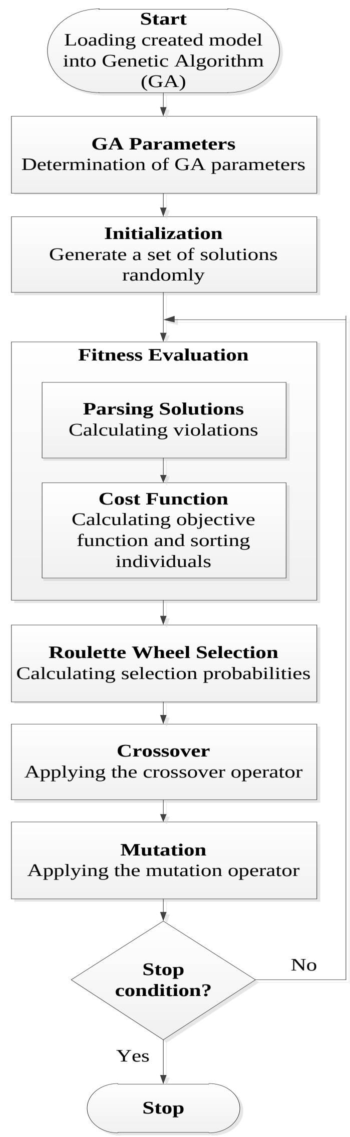

Figure 1 - GA flowchart

Since, we assumed that better suppliers should have smaller weight as their background factor in the problem definition, it is required that one unit be subtracted by it so that the regarded factor could be derived. 8 more FANP repetitions are performed and the results are presented in tables below.

Table 5 - Plant i's credit from the warehouse j's point of view

0.19	0.21	0.33	0.28
0.4	0.2	0.1	0.3
0.15	0.25	0.5	0.1
0.6	0.05	0.2	0.15

Table 6 - Warehouse j's credit from the retailer k's point of view

0.3	0.15	0.15	0.3	0.1
0.25	0.1	0.05	0.4	0.2
0.15	0.15	0.15	0.2	0.35
0.1	0.3	0.35	0.2	0.05

Table 7 - product transportation cost from plant i to warehouse j

14	15	17	21
17	21	19	17
14	27	29	11
20	20	16	23

Table 8 - Product transportation cost from warehouse j to retailer k

11	20	26	10	11
28	10	17	18	18
26	21	19	26	13
23	13	24	18	28

Table 11 - Resulted solutions from solution process

GAMS		GA	
Z1	1	Z1	1
Z3	1	Z3	1
X11	656	X11	331
X14	311	X14	325
		X31	230
		X34	81
Y11	222	Y11	222
Y13	67	Y14	164
Y14	192	Y15	175
Y15	175	Y42	121
Y42	121	Y43	256
Y43	190	Y44	29
$P'1$	68.39	$P'1$	76.23
$P'4$	80.18	$P'4$	66.12
Solved time	1001 Seconds	Solved time	152 Seconds
GA Solution gap:		**2%**	

Table 9 - Plants' information

Product's initial price in each plant			
50	92	64	90
Product's presented quality in each plant			
19	12	11	12
Minimum production of the product in each plant			
324	221	311	264
Maximum production of the product in each plant			
978	1216	753	1148
Cost of placing an order on plant i			
1435	1471	1186	1244

Table 10 - Retailers' information

Demanded quality of each retailer				
18	11	19	16	19
Demand of each retailer				
222	121	257	192	175

According to the above tables, the proposed solution methodology chooses the first and the third plants. In addition, purchase allocation process in the whole network resulted in the answers shown above (zero answers were not considered here).

In order to illuminate the efficiency and quality as well as rapidity of our proposed methodology, we compare our results to the exact solution. The model is solved by GAMS optimization software using BARON solver which is executed on a Pentium 4 with Intel Core 2

Duo 2.00 GHz CPU processor using 2 GB of RAM. The results and the comparison can be noticed in the table 11.

Conclusion

In this study, a multi-supplier multi-buyer supply chain was developed and both supplier selection problem and supply chain configuration were considered. Presented model in this study is developed in comparison with old ones, to maintain higher practicality and functionality, and also to present more real-life results by considering more extensive scope of factors in supply network like dynamic price, quality, transportation cost, and background of contribution. In this model, some constraints are considered for the minimum allowable order given to producer, maximum production capacity of suppliers, and maximum number of required plants; and this issue not only capacitates the problem to find the best supplier, but also will present the optimum amount of purchase from each supplier. Also, the approach used for solving the suggested mathematical model in this study, is an integrated approach which is combination of real and binary Genetic algorithm. In this approach, rather big and complex problems can be solved in timely manner. The comparison of the results to exact solution proved the quality of the solutions as well as the technique rapidity.

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