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Yaoting Chen (✉ [chenyaoting23@163.com](mailto:chenyaoting23@163.com))

Minnan Normal University

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## Original article

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**Manuscript title**

# **Analysis and Modeling of Supply Chain Management of Fresh Products Based on Genetic Algorithm in E-commerce Environment**

**Yaoting Chen**

*School of Business, Minnan Normal University, Zhangzhou 363000, China;*

*Corresponding author: [chenyaoting23@163.com](mailto:chenyaoting23@163.com)*

**Abstract**

**Background**

Supply chain provides the chance to enhance chain performances by decrease these uncertainties. It is a demand for some level of co-ordination of activities and processes within and between organization in the supply chain to decrease uncertainties and increase more cost for customers. Partner selection is an important issue in the supply chain management of fresh products in E-commerce environment. In this paper, we utilized a multi-objective genetic algorithm for evaluation supply chain of fresh products in E-commerce environment.

**Results**

The proposed multi-objective genetic algorithm is to search the set of Pareto-optimal solutions for these conflicting objectives using by weighted sum approach. The proposed model suitable for fresh products in E-commerce environment to optimize supply chain are derived. The value of objective 1 ( $f_1$ ) performs approximately nonlinearly with the increasing the value of objective 2,3 and 4 ( $f_2, f_3$  and  $f_4$ ). At the value of objective 1 of  $3.2 \times 10^5$ ,  $f_2, f_3$  and

$f_4$  is about  $4.3 \times 10^5$ , 86 and  $5.6 \times 10^4$ . When the value of objective 1 is increased to  $7.6 \times 10^5$ , the minimum  $f_2$ ,  $f_3$  and  $f_4$  is about  $3.0 \times 10^5$ , 38 and  $2.56 \times 10^4$ . It is noted that the value of objective 1 is increased from  $6.4 \times 10^5$  to  $7.6 \times 10^5$ , the variation of  $f_2$ ,  $f_3$  and  $f_4$  is 11.7%, 17.4% and 3.4% respectively. It is pointed out that the variation of  $f_2$  and  $f_3$  with  $f_1$  and  $f_4$  is kept within obvious ranges. This practical result highlights the fact that the effects of the fact that effects of  $f_2$  and  $f_3$  are important factors affecting the performance supply chain network of fresh product in E-commerce environment.

## Conclusions

In this paper, we utilized a multi-objective genetic algorithm for evaluation supply chain of fresh products in E-commerce environment. Four objectives for optimal process are included in the proposed model: (1) maximization of green appraisal score, (2) minimization of transportation time and total time comprised of product time, (3) maximization of average product quality, (4) minimization of transportation cost and total cost comprised of product cost. In order to evaluate optimal process, set of Pareto-optimal solutions is obtained based on the weighted sum method.

**Keywords:** Supply Chain Management, Fresh Product, Genetic Algorithm, E-commerce Environment

## 1. Introduction

A supply chain of fresh products in E-commerce environment is included in some special characteristics such that the plant flowering and growing process is related to climate in farmland; the quantity of fresh products to be harvested is limited by the increasing process which is scarcely controllable; the wastage process of any fresh products begins just after

harvested and is related to the handling process; and all fresh products should be directly expended by customers or used for the purpose of fresh materials in food factories before they become decomposed. It is regretful that the total loss of fresh products is about 20% to 60% of total fresh products in any country [Widodo, K. H, 2006; Vorst, J. G. A. J, 2000]. A lot of loss may be caused by mismatch between harvesting and supply processes in timing and in quantity. Therefore practitioners and academicians pay more attention to supply chain management of fresh products [Chan, F,2015; Jones,T. C., 1985], issues on fresh products in E-commerce environment are not managed sufficiently and keep unsolved because of the above intrinsic characteristics.

Improvement chain ability is limited by the indefinite factors to do with making decision. The indefinite factors are included machine breakdowns, late deliveries, leads to increased inventories, unnecessary slack time, additional capacities or order cancellations [Clark, A. J., 1960; Zhou,L., 2015; Murray,B. C.,2009]. The indefinite factors that plagues complex networks is a practical problem. It is uncertainty to finding remedies to reduce. Supply chain provides the chance to enhance chain performances by decrease these uncertainties. It is a demand for some level of co-ordination of activities and processes within and between organization in the supply chain to decrease uncertainties and increase more cost for customers. The key properties in the process are related to the synchronization, elimination or the availability of information and reduction of time-consuming processes.

A single firm is investigated using by a developed multi-period model, and minimization total cost subject to an emissions constraint for the total time span is the objective [Inkaya,T., 2017; Ghasimi,S. A., 2014]. The proposed model is related with the benefits of having emissions flexibility from period to period. Since practical costs are realized over time, it is opportunity for the firm to change future period emissions targets. The flexibility is shown to decrease costs through the time horizon [Houtum,V., 1996; Tatavarthy,S. R., 2015].

The weak points of most analytical models are the fact that a great deal of constraints should be content before results can be used to practices. Most models only include few variables, for example, cost of running out of stock and inventory, and neglect other cost such as transportation, order processing and handling. These models ignore capacity limitations and non-correlated treat systems in time. It did not include the complex material relationships that occur if upstream installations fail to serve downstream installations [Atabaki,M. S., 2017; Coello,C. A. C., 2001], and this is the essence of supply chain management of fresh product in E-commerce environment. Supply chain management of fresh product in E-commerce environment definitely focuses on the correlated two-way flow of products (services and materials) and information with linking operational and managerial activities to obtain a high degree of flexibility (responsiveness). This paper presents a mathematical model of a multi-objective genetic algorithm for solving green supplier selection and production volumes transportation problems. Supply chains are becoming competitive and the only way to survive is to maximize the channel profit and to evenly share the profit among the members involved in the supply chain. Hence this paper adopted the weighted sum approach to obtain the set of Pareto-optimal solutions offering the decision maker to evaluate some better of alternative solutions.

## **2. Problem Description and Mathematical Methods**

The problem of this paper considered about a company which is producing fresh product in in E-commerce environment at Zhangzhou. The company should make decisions such as green supplier selection and warehouse to be select, and must satisfy total market demand and capacity constraints. The problem is a multi-product, multi-stage supply chain network problem. Figure 1 is the flow path of supply chain network problem.

**Figure 1** Flow path of supply chain network problem

A Multi-objective optimization modeling framework can simultaneously resolve two different objectives with customer satisfaction maximization and cost minimization. It can be put into use for the purpose of choose suppliers of the supply chain. The multi-objective optimization problems include a lot of optimal solutions which are Parato-optimal solutions [Abdulah, A. A., 2020]. It can be expressed as in the following.

When a minimization problem and two vectors  $\vec{u} = (u_1, u_2 \dots u_m)$  and  $\vec{v} = (v_1, v_2 \dots v_m)$  are considered. If  $\vec{u}$  is assumed as dominate  $\vec{v}$ , and if

$$\forall i \in \{1, \dots, m\}, u_i \leq v_i \wedge \exists i \in \{1, \dots, m\}: u_i < v_i \quad (1)$$

Where  $m$  is the dimension of the objective space.

All decision vectors are not guided by another decision vector of a given installation, which are call Pareto-optimal installation or non-dominated installation. There are many solution methods for resolving multi-objective problems such as goal-programming, goal attainment, direction-based method, weighting method, distance-based method and so on [Nakamba, C.C., 2017, Mani, V., 2018]. In this paper, genetic algorithm was used to acquire Pareto-optimal solutions for multi-objective problems. A multi-objective mixed-integer non-linear model is proposed that included four objectives and nine parameters in the model. Four objectives are maximization of green appraisal scores, minimization of the total time, minimization of the total cost and maximization of average product quality respectively. There are some assumptions used in the model in the following. It assumes that required amount of all demand sides is available. Minimum boot-strap producing capacity and maximum producing capacity exist in accessory ordering. The suppliers should accept order fore on condition that ordering amount is between minimum boot-strap producing capacity and maximum producing capacity. Transportation amount is not related to transportation cost.

Unbalanced property between demand amount from customers in each phase of supply chain and accessory amount provided by suppliers is caused by producing losses. The proposed model included transportation loss rate and product yield rate for the losses. The objectives and used parameters of proposed model can be expressed as in the following. Optimum mathematical programming model of defective supply chain network.

$$Minf_1 = \sum_{x=1}^{X-1} \sum_{y=1}^Y \left\{ \sum_{n=1}^N \left| PC_{x,y}^n \left\| \frac{L_{z=1}^{Q(x,y)}}{r} \right\| \right\} + \sum_{z=1}^Z \sum_{n=1}^N (TC_{(x,y)(x+1,z)} Q_{(x,y)(x+1,z)}^n) \right\} \quad (2)$$

$$Minf_2 = \sum_{x=1}^{X-1} \sum_{y=1}^Y \left\{ \sum_{n=1}^N \left| PT_{x,y}^n \left\| \frac{L_{z=1}^{Q(x,y)}}{r} \right\| \right\} + BT_{x,y} \sum_{z=1}^Z \sum_{n=1}^N (Q_{(x,y)(x+1,z)}^n) \right\} \quad (3)$$

$$Minf_3 = \sum_{x=1}^X \sum_{y=1}^Y \left\{ \sum_{n=1}^N AQ_{x,y} \right\} FSN_{x,y} \quad (4)$$

$$Minf_4 = \sum_{x=1}^X \sum_{y=1}^Y \sum_{a=1}^{24} w_a G_{x,y}^a FSN_{x,y} \quad (5)$$

Equations (2)-(5) gives the objectives of the proposed model. In order to the simulated result is understood easily, the last two objectives of four objectives is transformed into minimization. While (2) defines the total cost of the green supply chain, (3) defines the total time of the green supply chain, (4) and (5) give the objectives about product average product quality and appraisal scores, respectively.

Where  $x$  can be defined as supply chain stage ( $x=1,2,3,\dots,X$ ).  $y$  can be defined as partner  $y$  of stage  $x$  ( $x=1,2,3,\dots,X$ ;  $y=1,2,3,\dots,Y$ ).  $z$  can be defined as partner  $z$  of stage  $x$  ( $x=1,2,3,\dots,X$ ;  $z=1,2,3,\dots,Z$ ).  $n$  can be defined as the product number of supply chain system ( $n=1,2,3,\dots,N$ ).

Where  $FSN_{xy}$  can be defined as if supply chain partner  $y$  of stage  $x$  has operation,  $FSN_{xy}$  is 1. Other,  $FSN_{xy}$  is 0. This variable determines whether of partner  $y$  of stage  $x$  will be selected or not.  $Q_{(x,y)(x+1,z)}^n$  can be defined as the quantity transported from of partner  $y$  of stage  $x$  to partner  $z$  of stage  $x+1$  among the  $n$ -th product.

Where  $K_{(x,y)(x+1,z)}$  can be defined as transportation loss rate from of partner  $y$  of stage  $x$  to partner  $z$  of stage  $x+1$ .  $L_{x,y}$  can be defined as minimum operational production capacity of partner  $y$  of stage  $x$ .  $U_{x,y}$  can be defined as maximum operational production capacity of partner  $y$  of stage  $x$ .  $\| R \|$  can be defined as integral value of value  $R$ .  $J_{x,y}$  can be defined as

product yield rate of partner  $y$  of stage  $x$ .  $PC_{x,y}^n$  can be defined as partner  $y$  of stage  $x$  among the  $n$ -th product unit manufacturing cost.  $TC_{(x,y)(x+1,z)}$  can be defined as unit transportation cost of partner  $y$  of stage  $x$  to partner  $z$  of stage  $x+1$ .  $BT_{x,y}$  can be defined as batch transportation time of partner  $y$  of stage  $x$ .  $D_{x,k}^n$  can be defined as market demand of the  $n$ -th product on the partner  $k$  of stage  $x$ .  $AQ_{x,y}$  can be defined as partner  $y$  of stage  $x$  among the  $n$ -th product average product quality.  $S_{x,y}$  can be defined as green appraisal scores of partner  $y$  of stage  $x$ .

Where  $G_{x,y}^1$  can be defined as customer's purchase or not of partner  $y$  of stage  $x$ . If customers are going on with purchase,  $G_{x,y}^1$  is 1. And  $G_{x,y}^1$  is 0 with other situation.  $G_{x,y}^2$  can be defined as green customer's market share of partner  $y$  of stage  $x$ . If the value is above 80%,  $G_{x,y}^2$  is 1; if the value is between 60% to 80%,  $G_{x,y}^2$  is 2; if the value is between 40% to 60%,  $G_{x,y}^2$  is 3; if the value is between 20% to 40%,  $G_{x,y}^2$  is 4, if the value is less than 20%,  $G_{x,y}^2$  is 5.  $G_{x,y}^3$  can be defined as passing ISO14000 verification of partner  $y$  of stage  $x$ . If it is passing,  $G_{x,y}^3$  is 1; if it is more than 50%,  $G_{x,y}^3$  is 2; if it is less than 50%,  $G_{x,y}^3$  is 3; if it is not passing yet,  $G_{x,y}^3$  is 4.  $G_{x,y}^4$  can be defined as having environmental protection policies of partner  $y$  of stage  $x$ . If it has done,  $G_{x,y}^4$  is 1; if it is more than 50%,  $G_{x,y}^4$  is 2; if it is less than 50%,  $G_{x,y}^4$  is 3; if it is none,  $G_{x,y}^4$  is 4.  $G_{x,y}^5$  can be defined as having environmental protection plans of partner  $y$  of stage  $x$ . If it has done,  $G_{x,y}^5$  is 1; if it is more than 50%,  $G_{x,y}^5$  is 2; if it is less than 50%,  $G_{x,y}^5$  is 3; if it is none,  $G_{x,y}^5$  is 4.  $G_{x,y}^6$  can be defined as having recycling product design of partner  $y$  of stage  $x$ . If it has done,  $G_{x,y}^6$  is 1; if it is more than 50%,  $G_{x,y}^6$  is 2; if it is less than 50%,  $G_{x,y}^6$  is 3; if it is none,  $G_{x,y}^6$  is 4.  $G_{x,y}^7$  can be defined as having renewable product design of partner  $y$  of stage  $x$ . If it has done,  $G_{x,y}^7$  is 1; if it is more than 50%,  $G_{x,y}^7$  is 2; if it is less than 50%,  $G_{x,y}^7$  is 3; if it is none,  $G_{x,y}^7$  is 4.  $G_{x,y}^8$  can be defined as product recycling percentage of partner  $y$  of stage  $x$ . If it is more than 80%,  $G_{x,y}^8$  is 1; if it is between 70% to 80%,  $G_{x,y}^8$  is 2; if it is between 60% to 70%,  $G_{x,y}^8$  is 3; if it is between 50% to 60%,  $G_{x,y}^8$  is 4; if it is less than

50%,  $G^8_{x,y}$  is 5.  $G^9_{x,y}$  can be defined as having reverse logistics system of partner  $y$  of stage  $x$ . If it has done,  $G^9_{x,y}$  is 1; if it is more than 50%,  $G^9_{x,y}$  is 2; if it is less than 50%,  $G^9_{x,y}$  is 3; if it is none,  $G^7_{x,y}$  is 4.  $G^{10}_{x,y}$  can be defined as solid wastes of partner  $y$  of stage  $x$ .  $G^{11}_{x,y}$  can be defined as energy consumption of partner  $y$  of stage  $x$ .  $G^{12}_{x,y}$  can be defined as air pollution of partner  $y$  of stage  $x$ .  $G^{13}_{x,y}$  can be defined as waste water of partner  $y$  of stage  $x$ .  $G^{14}_{x,y}$  can be defined as led content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{15}_{x,y}$  can be defined as mercury content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{16}_{x,y}$  can be defined as hexavalent chromium content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{17}_{x,y}$  can be defined as polybrominated biphenyl content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{18}_{x,y}$  can be defined as polybrominated biphenyl ether content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{19}_{x,y}$  can be defined as cadmium content of electrical and electronic equipments of partner  $y$  of stage  $x$ .  $G^{20}_{x,y}$  can be defined as solid wastes treatment costs of partner  $y$  of stage  $x$ .  $G^{21}_{x,y}$  can be defined as chemical wastes treatment costs of partner  $y$  of stage  $x$ .  $G^{22}_{x,y}$  can be defined as air pollution treatment costs of partner  $y$  of stage  $x$ .  $G^{23}_{x,y}$  can be defined as water pollution treatment costs of partner  $y$  of stage  $x$ .  $G^{24}_{x,y}$  can be defined as energy consumption costs of partner  $y$  of stage  $x$ .

$$L_{x,y}FSN_{x,y} \leq \sum_{z=1}^Z \sum_{n=1}^N Q^n_{(x,y)(x+1,z)} \leq U_{x,y}FSN_{x,y} \quad \text{for } x=1; y=1,2,\dots,Y \quad (6)$$

$$L_{x,z}FSN_{i,z} \leq \sum_{y=1}^Y \sum_{n=1}^N Q^n_{(x,y)(x+1,z)} \leq U_{s_{x,z}}FSN_{x,z} \quad \text{for } x=2,3; j=1,2,\dots,J \quad (7)$$

Where equations (6) and (7) indicate the restriction of partner's production capacity.

$$\sum_{y=1}^Y J_{x+1,z} (1 - K_{(x,y)(x+1,z)}) Q^n_{(x,y)(x+1,z)} \parallel = D^n_{x+1,z} \quad \text{for } x=x-1; z=1,2,\dots,Z; n=1,2,\dots,N \quad (8)$$

$$\sum_{y=1}^Y J_{x,z} (1 - K_{(x,y)(x+1,z)}) Q^n_{(x,y)(x+1,z)} \parallel = \sum_{l=1}^{L+4} Q^n_{(x+1,z)(x+2,l)} \quad (9)$$

for  $x=x-2, x-3, \dots, 1; z=1,2,\dots,Z; n=1,2,\dots,N$

Where equations (8) and (9) provide the satisfaction of warehouses and customer requirements for the product.

$$G_{x,y}^8 < 4 \text{ for all } x,y \quad (10)$$

Where equations (10) indicates the product recycling rate of partner y of stage x must be less than 4.

$$G_{x,y}^{14}, G_{x,y}^{15}, G_{x,y}^{16}, G_{x,y}^{17}, G_{x,y}^{18} \leq 1000 \text{ for all } x,y \quad (11)$$

Where equation (11) shows the stage  $i$ 's supplier  $j$ 's electrical and mercury, cadmium and hexavalent chromium, polybrominated biphenyl, electronic equipments's led, polybrominated diphenyl ether contents shall be less than 1000 ppm.

$$G_{x,y}^{12} \leq 100 \text{ for all } x,y \quad (12)$$

Where equation (12) indicates stage  $i$ 's supplier  $j$ 's electrical and electronic equipments' cadmium contents shall be less than 100 ppm.

$$Q_{(x,y)(x+1,z)}^n \geq 0 \text{ and in integer, for all } x,y,z,n \quad (13)$$

Where equation (13) indicates the non-negative limitation on decision parameter  $Q_{(x,y)(x+1,z)}^n$ .

$$FSN_{x,y} \in \{0,1\} \text{ for all } x,y \quad (14)$$

Where equation (14) indicates the integrality limitation on decision parameter  $FSN_{x,y}$ . Since the first and second objectives are non-linear, the proposed model is a mixed-integer non-linear programming model.

### 3. Proposed modeling

The evaluation process for supply chain of fresh products based on genetic algorithm in E-commerce environment is developed. The flow chart of genetic algorithm used to search optimum mathematical planning model is shown in Figure 2.

**Figure. 2.** Flow chart of genetic algorithm used to search optimum mathematical planning model

The selection criteria include two types such as quantity and quality principles. quality principles consist of average passing ISO14000 verification and product quality *et al.* Quantity consist of production cost and yield *et al.*;

Collect relative information of each supply partner consist of production cost, air pollution treatment cost, yield, transportation time *et al.* It can be developed as the database for customer information. The proposed mathematical model can be optimal using by genetic algorithm. The optimal process must repeat eight steps in each generation. A weighted sum of multi-objective with a scalar fitness function is included into the optimal process. Therefore, the weights of the multiple objective functions are not constant but randomly specified for each selection.

Firstly, it generates an initial population which must satisfy all constraints, as shown in equations (6)-(14). And then, the objective function of each chromosome is calculated, for example, equations (2)-(5). Objective functions with different measure units should be normalized using by the weighted sum method. Each objective of equation (15) in the following should be normalized.

$$f'_i = \frac{f_i - f_i^{\min}}{f_i^{\max} - f_i^{\min}}, i=1,2,\dots,n \quad (15)$$

Where  $f_i^{\min}$  and  $f_i^{\max}$  are the minimum and the maximum value of *ith* objective function. It should update a tentative set of Pareto-optimal solutions after first iteration.

The fitness value  $f(x)$  of each string are calculated using by equations (16) and (17) in the following.

$$f(x) = w_1 f_1(x) + w_2 f_2(x) + \dots + w_n f_n(x) \quad (16)$$

$$w_i = \frac{rnd_i}{\sum_{j=1}^n rnd_j} \quad (17)$$

Where  $f(x)$  is a combined fitness function,  $x$  is a chromosome,  $w_i$  is a constant weight for  $f_i(x)$ ,  $f_i(x)$  is the  $i$ th objective function, and  $n$  is the number of the objective function.  $rnd_i$  and  $rnd_j$  are non-negative random integers.

A pair of chromosomes from the population can be selected based on the following selection probability. The selection probability can be obtained using by equations (18) and (19).

$$P(x) = \frac{f(x) - f_{min}(\psi)}{\sum_{x \in \psi} \{f(x) - f_{min}(\psi)\}} \quad (18)$$

$$f_{min}(\psi) = \min\{f(x) \mid x \in \psi\} \quad (19)$$

An offspring with the crossover probability is generated based on the crossover operation. The best value of each objective is considered as an elitist solution for multi-objective optimization problem. The proposed model can preserve these solutions to the next generation. Therefore,  $n$  chromosomes from current population can be removed using by the elitist strategy. It can add the same number of strings from a tentative set of Pareto-optimal solutions. Until the iteration times is reached, or repeated evaluation, selection, crossover, mutation and elitist strategy. The set of Pareto-optimal solutions can be obtained using by the multi-objective optimization algorithm. It can select the best solutions.

#### 4. Simulation results and discussion

The proposed model of this paper is to analysis and model of supply chain of fresh products partner and production volumes transportation in E-commerce environment. The problem is analyzed using by a multi-objective optimization algorithm. It can obtain the set of Pareto-optimal solutions offering to the best decision to select according to the proposed model. The concept of the system is shown in a {4,4,4,4} supply chain network. There is unit transportation cost, maximum capacity, different yield and minimum for each supplier. And each route may be transportation routes. The supply chain network includes four products. Table 1 shows demand volumes of each product of each customer.

**Table 1** Demand volumes of each product of each customer

The fresh products supply chain network problem with three and four objectives in E-commerce environment is to be evaluated, thus the original problem is divided into four problems. The original problem is different from the four problems. All constraints of the original problem with different objectives are the same. The four problems are shown in the following.

Problem 1 can be considered as  $\min f_1$ ,  $\min f_2$  and  $\min f_3$ . Problem 2 can be considered as  $\min f_1$ ,  $\min f_3$  and  $\min f_4$ . Problem 3 can be considered as  $\min f_2$ ,  $\min f_3$  and  $\min f_4$ . Problem 4 can be considered as  $\min f_1$ ,  $\min f_2$ ,  $\min f_3$ , and  $\min f_4$ .

**Table 2** Simulated results of the four problems

The generation size, population size, crossover probability and mutation probability of the parameters in genetic algorithm for the four problems is 200, 400, 0.6 and 0.04 respectively. Simulated results of the above four problems are shown in Table 2. All parameters had been determined after preliminary simulations. We utilized the average number of Pareto-optimal solutions to evaluate performances of proposed modeling. The average number of Pareto-optimal solutions for the four problems is 7.5, 9.2, 7.9 and 5.3 respectively.

The calculated results for problem 1 with the value of objective 1, 2 and 3 ( $f_1, f_2$  and  $f_3$ ) are shown in Figure 3. The value of objective 1 ( $f_1$ ) performs approximately linearly with the decreasing the value of objective 2 ( $f_2$ ) and decreasing the value of objective 3 ( $f_3$ ). At the value of objective 1 of  $3.2 \times 10^5$ ,  $f_2$  and  $f_3$  is about  $4.3 \times 10^5$  and 86. When the value of objective 1 is increased to  $7.6 \times 10^5$ , the minimum  $f_2$  is about  $3.0 \times 10^5$  and the minimum  $f_3$  is about 38.

**Figure 3** Calculated results for problem 1 with the value of objective 1, 2 and 3 ( $f_1, f_2$  and  $f_3$ )

The calculated results for problem 2 with the value of objective 1, 3 and 4 ( $f_1, f_3$  and  $f_4$ ) are shown in Figure 4. The value of objective 1 ( $f_1$ ) performs approximately linearly with the decreasing the value of objective 3 ( $f_3$ ) and decreasing the value of objective 4 ( $f_4$ ). At the value of objective 1 of  $3.2 \times 10^5$ ,  $f_3$  and  $f_4$  is about 86 and  $5.6 \times 10^4$ . When the value of objective 1 is increased to  $7.6 \times 10^5$ , the minimum  $f_3$  is about 38 and the minimum  $f_4$  is about  $2.6 \times 10^4$ . It is noted that the value of objective 1 is increased from  $6.4 \times 10^5$  to  $7.6 \times 10^5$ , the variation of  $f_3$  and  $f_4$  is 17.3% and 3.3% respectively.

**Figure 4** Calculated results for problem 2 with the value of objective 1, 3 and 4 ( $f_1, f_3$  and  $f_4$ )

The calculated results for problem 3 with the value of objective 2, 3 and 4 ( $f_2, f_3$  and  $f_4$ ) are shown in Figure 5. The value of objective 2 ( $f_2$ ) performs approximately linearly with the increasing the value of objective 3 ( $f_3$ ) and increasing the value of objective 4 ( $f_4$ ). At the value of objective 2 of  $4.3 \times 10^5$ ,  $f_3$  and  $f_4$  is about 86 and  $5.6 \times 10^4$ . When the value of objective 2 is decreased to  $3.0 \times 10^5$ , the minimum  $f_3$  is about 38 and the minimum  $f_4$  is about  $2.6 \times 10^4$ . It is noted that the value of objective 2 is decreased from  $3.5 \times 10^5$  to  $3.0 \times 10^5$ , the variation of  $f_3$  and  $f_4$  is 26.9% and 5.1% respectively.

**Figure 5** Calculated results for problem 3 with the value of objective 2, 3 and 4 ( $f_2, f_3$  and  $f_4$ )

The calculated results for problem 4 with the value of objective 1, 2, 3 and 4 ( $f_1, f_2, f_3$  and  $f_4$ ) are shown in Figure 6. The value of objective 1 ( $f_1$ ) performs approximately nonlinearly with the increasing the value of objective 2,3 and 4 ( $f_2, f_3$  and  $f_4$ ). At the value of objective 1 of  $3.2*10^5$ ,  $f_2$ ,  $f_3$  and  $f_4$  is about  $4.3*10^5$ , 86 and  $5.6*10^4$ . When the value of objective 1 is increased to  $7.6*10^5$ , the minimum  $f_2$ ,  $f_3$  and  $f_4$  is about  $3.0*10^5$ , 38 and  $2.56*10^4$ . It is noted that the value of objective 1 is increased from  $6.4*10^5$  to  $7.6*10^5$ , the variation of  $f_2$ ,  $f_3$  and  $f_4$  is 11.7%, 17.4% and 3.4% respectively. It is pointed out that the variation of  $f_2$  and  $f_3$  with  $f_1$  and  $f_4$  is kept within obvious ranges. This practical result highlights the fact that the effects of the fact that effects of  $f_2$  and  $f_3$  are important factors affecting the performance supply chain network of fresh product in E-commerce environment.

**Figure 6** Calculated results for problem 4 with the value of objective 1, 2, 3 and 4 ( $f_1, f_2, f_3$  and  $f_4$ )

## 5. Conclusion

In this paper, we utilized a multi-objective genetic algorithm for evaluation supply chain of fresh products in E-commerce environment. Four objectives for optimal process are included in the proposed model: (1) maximization of green appraisal score, (2) minimization of transportation time and total time comprised of product time, (3) maximization of average product quality, (4) minimization of transportation cost and total cost comprised of product cost. In order to evaluate optimal process, set of Pareto-optimal solutions for the decision maker is obtained based on the weighted sum method. The value of four objective with each problem is calculated using by genetic algorithm. In the future work, a modified weight sum method can be investigated for optimal process with uncertainty of costs and demands.

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- **Ethical Approval and Consent to participate**

Not applicable

- **Consent for publication**

Written informed consent for publication was obtained from all participants.

- **Availability of supporting data**

The data sets supporting the results of this article are included within the article and its additional files.

- **Competing interests**

The author declare that he has no competing financial interests

- **Funding**

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- **Authors' contributions**

Chen yaoting contributed significantly to data analyses and manuscript preparation.

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## Tables

	<b>Type-A</b>	<b>Type-B</b>	<b>Type-C</b>	<b>Type-D</b>
Customers-4.1	30	45	55	65
Customers-4.2	35	60	45	65

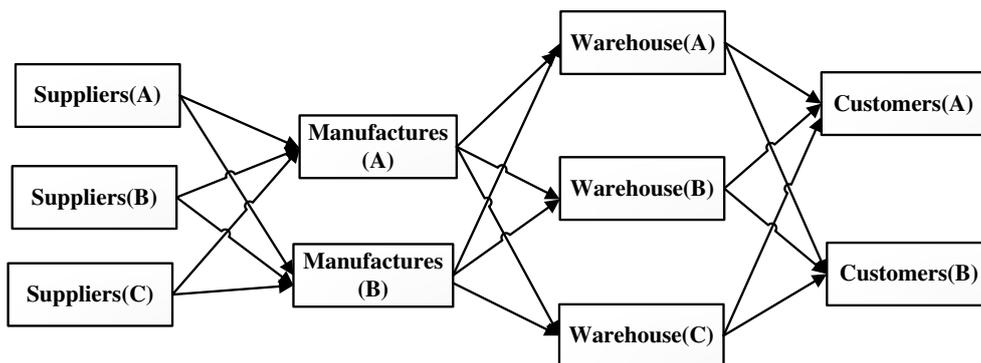
Customers-4.3	40	55	70	50
Customers-4.4	45	70	75	60

**Table 1** Demand volumes of each product of each customer

	Average number of Pareto-optimal solutions	Generation size	Population size	Crossover probability	Mutation probability
Problem 1	7.5	200	400	0.6	0.04
Problem 2	9.2	200	400	0.6	0.04
Problem 3	7.9	200	400	0.6	0.04
Problem 4	5.3	200	400	0.6	0.04

**Table 2** Simulated results of the four problems

**Figures**



**Figure 1** Flow path of supply chain network problem

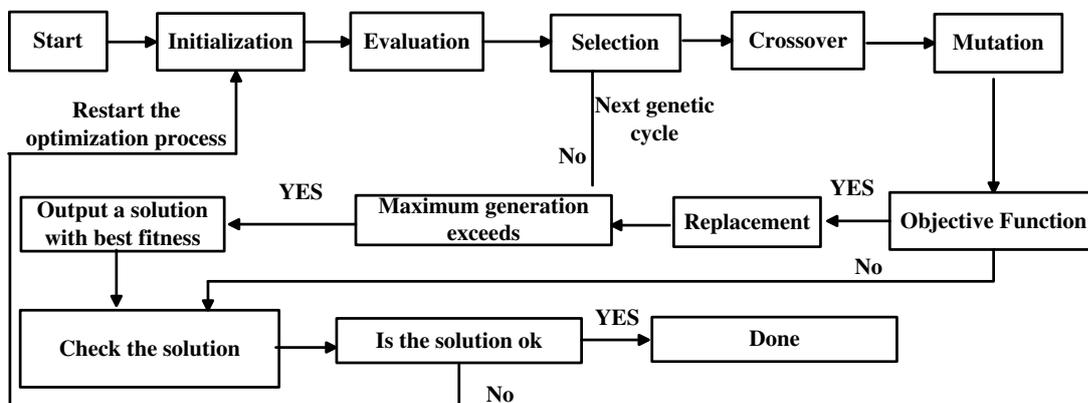
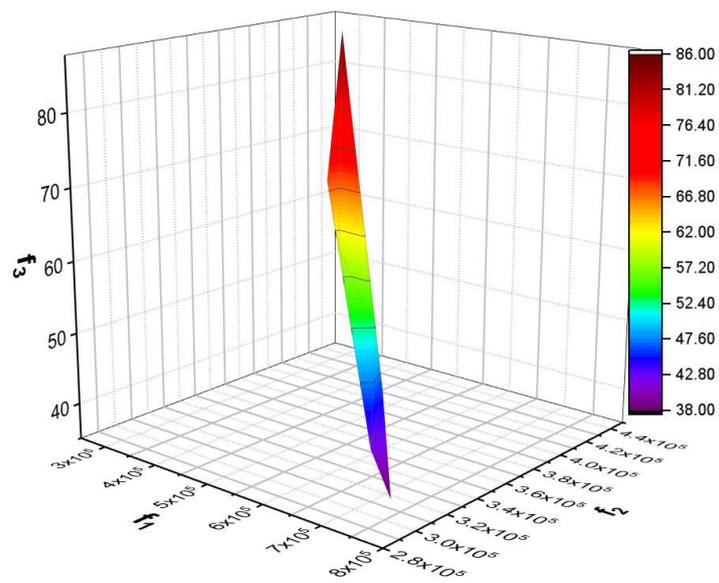
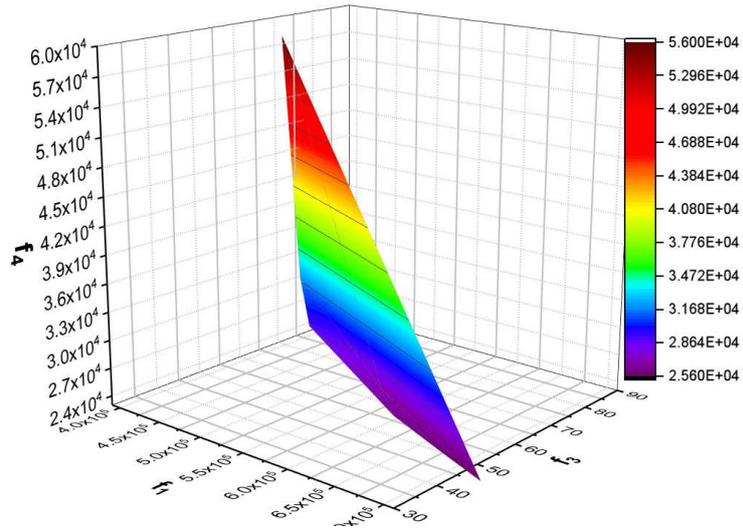


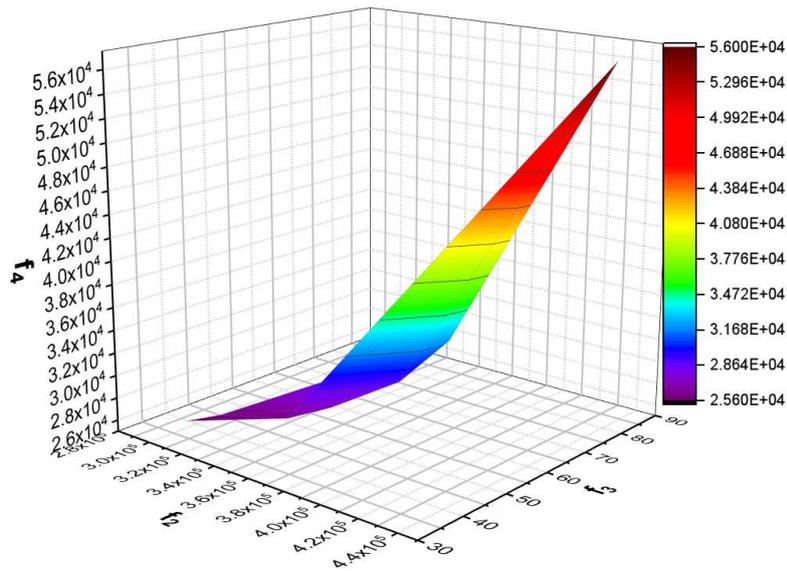
Figure. 2. Flow chart of genetic algorithm used to search optimum mathematical planning model



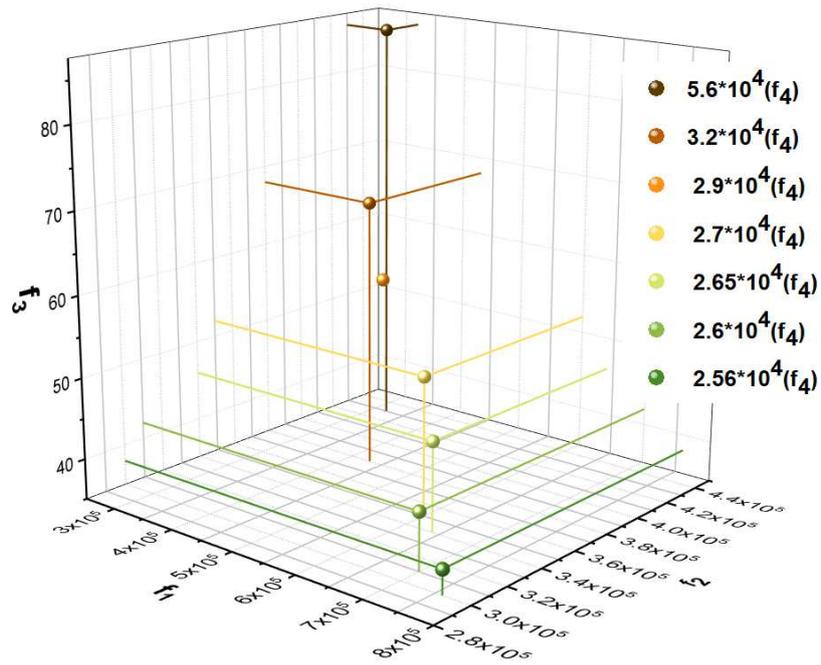
**Figure 3** Calculated results for problem 1 with the value of objective 1, 2 and 3 ( $f_1, f_2$  and  $f_3$ )



**Figure 4** Calculated results for problem 2 with the value of objective 1, 3 and 4 ( $f_1, f_3$  and  $f_4$ )



**Figure 5** Calculated results for problem 3 with the value of objective 2, 3 and 4 ( $f_2, f_3$  and  $f_4$ )



**Figure 6** Calculated results for problem 4 with the value of objective 1, 2, 3 and 4 ( $f_1, f_2, f_3$  and  $f_4$ )

# Figures

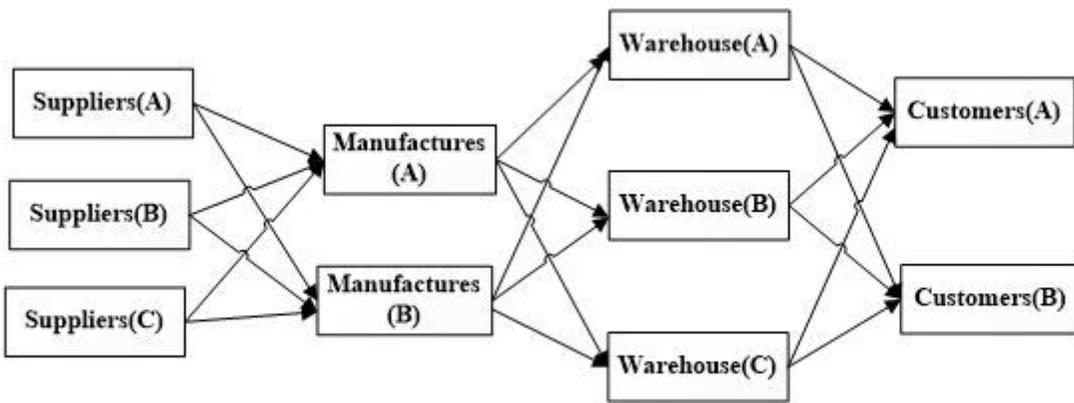


Figure 1

Flow path of supply chain network problem

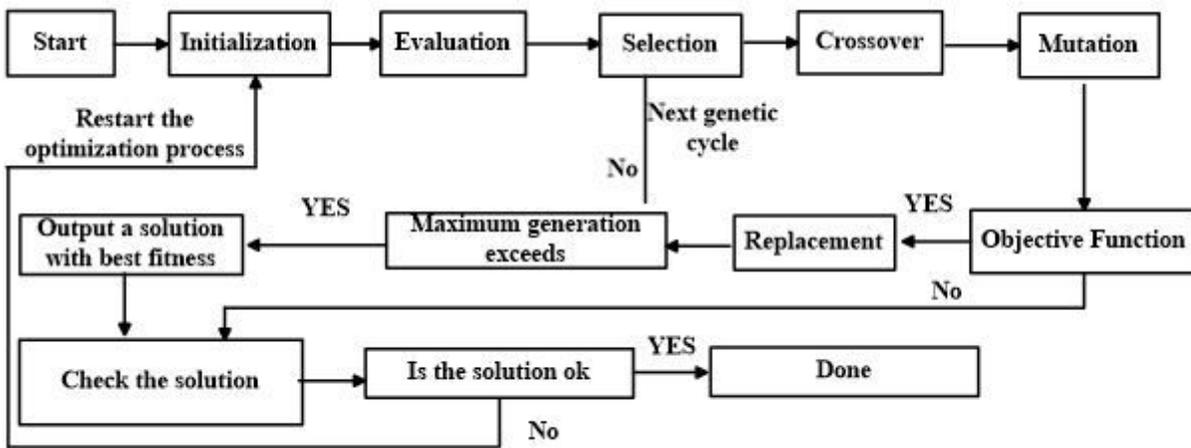


Figure 2

Flow chart of genetic algorithm used to search optimum mathematical planning model

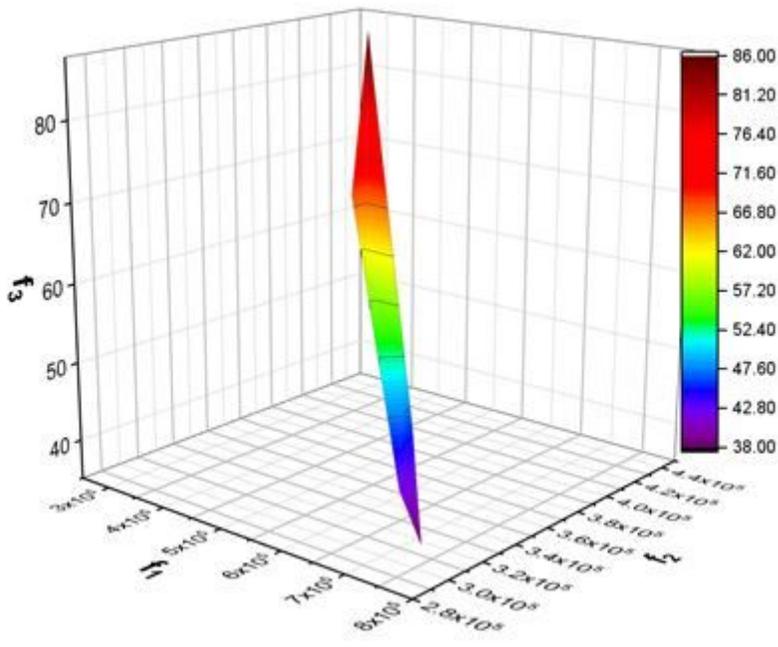


Figure 3

Calculated results for problem 1 with the value of objective 1, 2 and 3 ( $f_1, f_2$  and  $f_3$ )

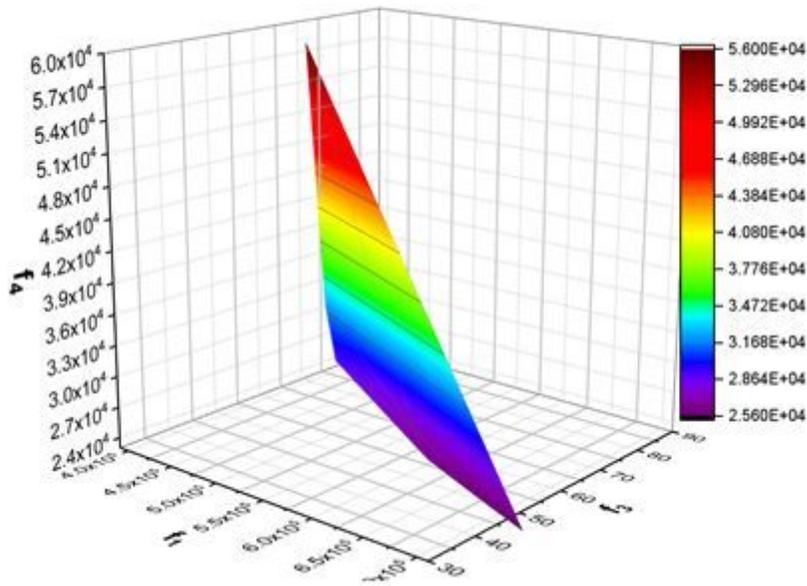


Figure 4

Calculated results for problem 2 with the value of objective 1, 3 and 4 ( $f_1, f_3$  and  $f_4$ )

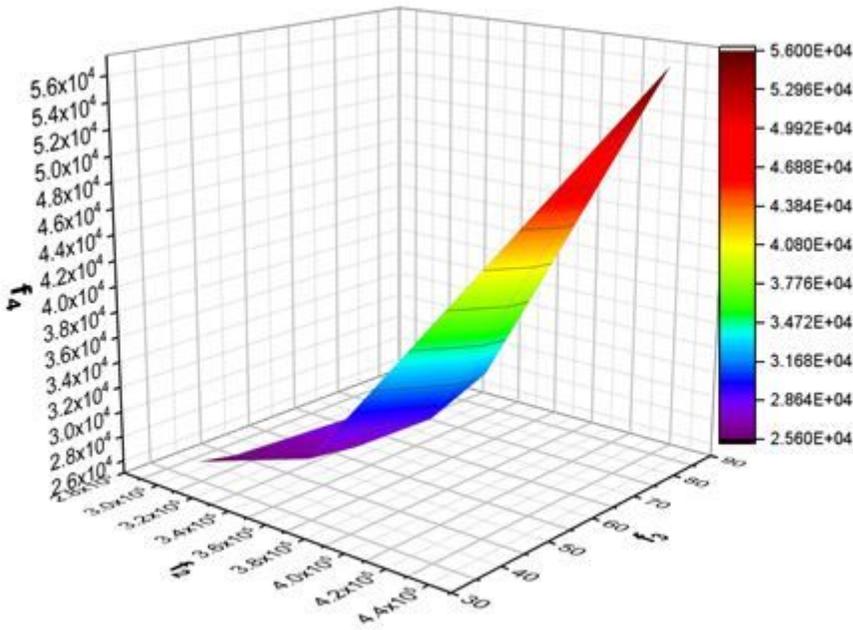


Figure 5

Calculated results for problem 3 with the value of objective 2, 3 and 4 ( $f_2, f_3$  and  $f_4$ )

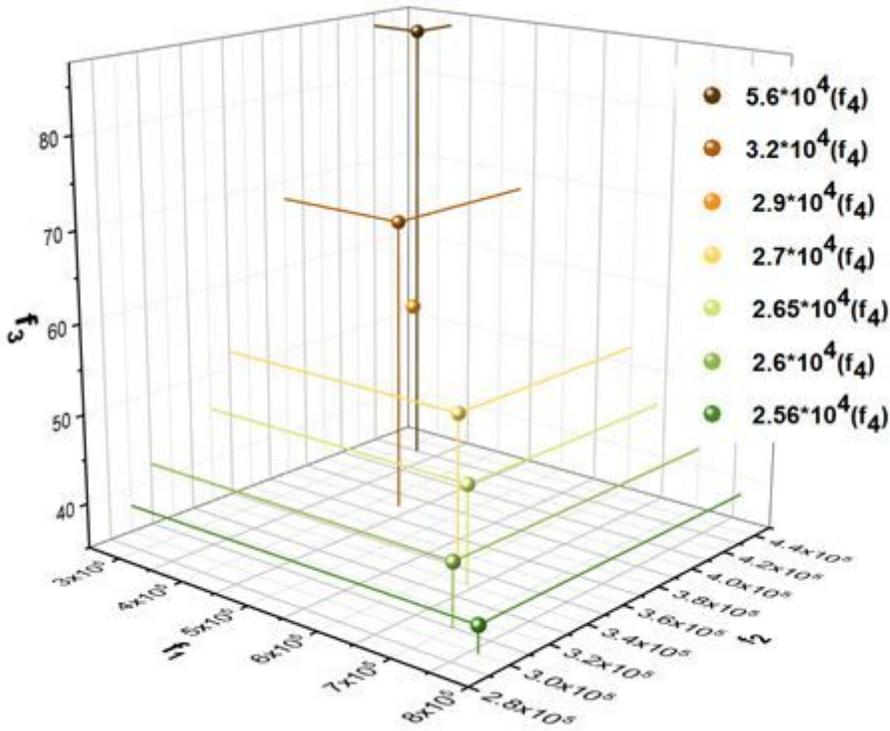


Figure 6

Calculated results for problem 4 with the value of objective 1, 2, 3 and 4 ( $f_1, f_2, f_3$  and  $f_4$ )