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A Goal-Programming Model for Determining Economic Order Lot Sizing Regarding the Benefits of the Whole Supply Chain

Ahmad Tavakoli[1], Mohammad hossein Vadiei[2] and Amir Shams Kolookhi[3*]
[1]Management Department, Ferdowsi University of Mashhad, IRAN
[2]Accounting Department, Ferdowsi University of Mashhad, IRAN
[3]Department of Accounting, Torbat-e-Jam Branch, Islamic Azad University, Torbat-e-Jam, IRAN

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Abstract

Inpast, organizations used to make decisions independently; but, at the moment, ignoring the connections between those decisions and their related subgroups can yield serious and negative repercussions. So, the organizations tend to the integrated design and control for the whole segments to produce better services and goods. Nowadays, effective interaction with pieces suppliers and products distributers from the view of the managers is the key to survive in the competitive markets. In this respect, the present paper provides an ideal planning model for the effective integration of suppliers and customers regarding their common and favorite criteria to provide the benefits of both sides in Electrosteel Company. In this model, 3 measures of quality, time, and cost are considered and the benefits of both suppliers and customers are taken into account simultaneously. In this model, the order amount to the suppliers is determined. Also, two individual models considering the benefits at a chain level is provided and used with different weights of the model and benefit model. Also, two single entity models((1) and (2)) regarding the benefits of one chain level were provided and compared in different weights with multiple entity model of the benefits. Using fiscal year information of2010, Electrosteel Company and its suppliers were examined. The results showed that by exerting goal programming for creating win-win relations in supply chain with the aim of minimizing total costs, delayed order delivery, and increasing received goods better results are provided compared with single-entity models.

Keywords: Supplier selection, buyer, multi-purpose modeling, supply chain.

Introduction

Since a producer uses different suppliers to fulfill some goals like cost minimization, on-time delivery and quality maximization, relative supply of all these goals is not possible by trial and error; it may impose many costs on the system. Instead, a multi-purpose programming which follows a simultaneous access to a favorable level of various goals enables manufacturing companies to achieve their goals exactly and scientifically. The issue of supplier selection is regarded in the field of seller-buyer coordination in which both of the supplier and buyer are regarded at the same time. As mentioned before, the importance of coordination among organizations plays a significant role in improving service quality; thus, recent research attempts have focused on the development and improvement of effective inter organizational relations. Creating win-win relations between two organizations with different legal entities has many complexities. Its complexity in supply chain is more. However, few studies have probed modeling and strategy offering for creating win-win relations among organizations. On this basis, a model for minimizing total costs and delayed delivery of the goods as well as coordinating buyer and supplier will be examined in this paper to provide the benefits of both sides as well as maximizing the quality of received goods.

Research theories: Supply chain management: In 1960s, examining the internal relations between storekeeping, transportation, and integration, the experts could decrease their inventory which resulted in the studies called "*distribution management*". On the evolution path, adding the discussions of construction, provision, and orders to the distribution management created a logistic concept "*supply chain*", resulting from the connection among different operational circles. In that circle, suppliers are at the start point and the customers are at the final point.

This change is a dynamic process including simultaneous activities, continuous evaluations of two involved sides, technologies, and organizational structures. It provides the customers with more alternatives with the aim of value creation for the customers. All these factors help profitability and competitiveness[1].

Effective factors in supplier selection: To select a proper supplier among the nominees, various factors can be regarded as mentioned below: i. *Qualitative abilities of the suppliers.* Quality is mainly regarded in the discussions of suppliers' management. During suppliers' evaluations, their abilities for goods and service provision should be based on the acceptable service/goods quality for the buyer. A prerequisite for such goal is an exact definition of qualitative features required by the buyer. ii. *The ability of accessing and adoption with new technologies.* Suppliers should have the capability of accessing new technologies and adoption with them. If suppliers are not able to recognize future needs of customers, they won't prepare themselves to meet them; as a result, the possibility of their failure in the market increases. Providence and meeting future needs are the important features of a good supplier. *iii. Financial abilities.* Financial abilities and weaknesses of the suppliers can directly impact the provision of customers' needs. The factors like credit rate, capital structure, and capital return can be used as financial evaluation indices of the suppliers. Besides, financial abilities of the suppliers should be regarded as a main factor in selecting them. iv. *Managerial abilities.* Evaluation of organization, structure, and management can be regarded in the process of selecting suppliers. Goals, strategies, policies, organizational structure, managers' qualification, educational and information system, and suppliers 'processes can be evaluated in this regard. Performance evaluation in different supply units like, marketing, production, and sale can be useful in this regard[2].

Dividing the issues of supplier selection: To differentiate supplierissues, various indices have been offered in different works by the authors such as Aissoui and Hasouari[3] and Deboer et al.[4]. Providing a summary of these works, 6 indices are defined as follows: i. Number and types of the goals /selection criteria, ii. Time periods (one-period or multi-periods which significantly impacts the existing management policies), iii. The number of various pieces/raw materials for outsourcing/provision, iv. Discount strategies, delayed payment, v. Deterministic or probabilistic variables and parameters, vi. Single source/multi source selection system (selecting one or more suppliers)

Criteria determination in supplier selection: When the debates on selection and decision-making rise, the basic question isthe basis on which decision-making should be mounted. The answer to this question depends on the goals that decision-makers aim to fulfill. In other words, in a good decision-making, first the goals should be defined, the measures should be determined and then, the decisions should be made. In business affairs cost measures play the most significant roles. Sensitivity of some organizations to these criteria is in a way that in some cases even non-financial criteria are changed into cost criteria. A huge research body in this field also reveals the importance of this issue in decision-makings.

Nowadays, one single measure is rarely used in decision-makings; thus, selection of an alternative, especially in the case of suppliers is based on examining many factors. For this reason, various researches have focused on the measures for selecting suppliers, introducing some patterns for it.

Weber et al[5] represented some measures, definitions and applications in their work. Ha and Krishman[6] evaluated and categorized 30 measures in supplier selection. A SCOR model has been offered by SCC, turning into a standard framework for all industries. This model enables the companies to connect the chain elements together, evaluate their performance purposefully, and prepare management development programs in supply chain. In the frame of 4 groups includingdelivery reliability, flexibility and responsiveness, costs, assets, this model introduces 12 performance measures. For more information, the study of Wung and Huang[7] can be referred. BOCR (benefits, opportunities, costs, risks) pattern is another model in which 14 measures have categorized a control with 4 branches of costs, benefits, opportunities, and risks for comparisons and decision-makings. In the studies of Xia Wu[8], Amid[9], Farahani and Elahipanah[10], Faez et al.[11], 3 key factors of cost, quality, and time have been regarded in decision-makings. The importance of them is so significant that they have been focusedin standard frames like PMBOK (project management body of knowledge). In each of these 3 factors, various measures are defined and the way of their definition and formulation has different effects on the organizational activities like inventory management, production plan / control, financial requirements, and service/goods quality. Cost measure is regarded in the following forms: i. Cost:i.e. the sum of supply cost, production, and distribution should be the minimum. ii. Price: i.e. the price of materials/service should be the minimum. iii. Profit: i.e. the profit from final products should be the maximum.

In the quality field some measures are defined for supplier selection in the following forms: i. Minimizing product damage received from the supplier[8,12,13]. ii. Minimizing purchase returns from the customers to the suppliers[9,11]. iii. Defining the minimum expected quality in purchase or shopping which enters as a restriction in the problem[14]. iv. In the time field, the measures are dynamic. They are mostly regarded in relation with order delivery time and methods. 3 general conditions in supplier selection can be as follows: i. Maximizing on-time goods/services delivery[8], ii. Minimizing delayed goods/services delivery, iii. Minimizing the sum (of early comers + late comers). This state is regarded in JIT systems[10].

In this study, these 3 above-mentioned factors are regarded in decision-makings. i. Cost goal is defined in the form of minimizing total costs of the system in the frame of two groups of buyer and supplier costs. ii. Quality is defined as Maximizing safe received goods from the suppliers. iii. Time is defined as minimizing delayed order delivery.

Single-period and multi-period models: As said before, time is of great importance in supplier selection. So far, in various represented approaches, single-period models have been more considered for short-term planning issues. Selecting suppliers with low order costs and ordering them in small boxes with huge amounts can significantly reduce the costs. Purchase in large extent can lead to the discount receipt. But, on the other hand, it naturally increases their maintenance costs. For this reason, in multi-period problems reaching a proper point for benefiting from the advantages and disadvantages of a choice is of great importance. In multi-period problems and selecting suppliers, using economic order value in inventory management is prevalent. Exact classification of the researches on the suppliers from the view of single-period or multi-period problems was done in the study of Aissaoui et al.[3]. The problem in this paper is of multi-period type.

The role of products number in selection issue: Regarding production strategy and delivery to the final customers,a buyer needs to provide one or some pieces for the final customer from the suppliers. The more diversified the pieces, the bigger the issue will be. This paper models different pieces' provision from some suppliers.

Discount strategy / delayed payment: Discount strategy has been regarded in recent years by some researchers and organizations[15]. The issues of discount strategy and delayed payment are regarded when inventory and time management are concerned. In most cases in which discount issue is posed, a balance between the discount resulting from much purchase and storage cost increase is aimed. However, discount issue is not regarded in the domain of this article.

Deterministic and probabilistic variables and parameters: A key discussion leading to the discrimination between research topics in supplier selection is the nature of the variables and parameters. Although in some cases volatility and the changes can be ignored, technology advances and software revolution increase scientists' tendency to create real conditions and explain more indefinite states[9].

Single-source/ Multi-source selection system: Another factor in supplier selection is choosing one or some alternatives from potential suppliers. Experimental studies show that in most studies multi-source selection is more acceptable. Simplifying the rules and cost differences among developed and developing countries creates a wide range for searching suppliers at international level. Although this cost economization can be at the expense of a longer delivery time with less certainty, the managers' fear from dependence on one supplier leads them toward multi-source supply. Such purchases divide the risk among different organizations and yield some advantages for its user[16]. In other words, when the final goal is one-by-one interaction; single-source selection system is needed. But when one-to-some or some-to-some interaction is regarded, multi-source selection system works better. The latter is the focus of this study. According to given explanations, supplier's selection issues are regarded from two aspects: coordination domain and issue definition ways (table-1).

Based on Model 1, supplier selection issues can be codified in the following order: (Supply source number, factors determination, discount strategy, pieces number, time period, goals number, coordination domain).On this basis, the codes of under-discussion issues will be:(Op(ME), MO, MP, MI, WOD, Det, MS)

Table-1
Classifying supplier selection issues

Abbreviations	Indices	Domain
- St (Strategic) - Op (Operational) IM (Inventory management) SE (Single entity) ME (Multiple entity)	-Strategic -Operational -Inventory Management Single Entity Multiple Entity	Categorization indices in coordination domain
 SO(Single objective) MO(Multiple objective) SP (Single Period) MP (Multiple Period) SI (Single Item) MI (Multiple Item) WOD(Without Discount) WD (With Discount) Det (Deterministic) Prb (Probabilistic) SS (Single Sourcing) MS (Multiple Sourcing)	-The number of selection criteria Single objective Multiple Objective -Time period Single Period Multiple Period -The number of pieces Single Item Multiple Item– -Discount strategy Without Discount With Discount -Factor determination Deterministic Probabilistic -Source number for final supply Single Sourcing Multiple Sourcing	Categorization indices in contentdomain

Table-2
Used references of the study in the frame of defined coding

Reference Code	Reference
(Op(ME), SO, MP, SI, WOD, Det, MS)	1
(Op(SE), MO, SP, SI, WD, Prb, MS)	9
(Op(ME), SO, MP, SI, WD, Det, MS)	17
(Op(SE), SO, MP, SI, WOD, Det, MS)	14

Goal programming: A multi- objective decision-making method is goal programming, developed by Ignizio and Lee. In goal programming, the decision-maker identifies a program for each goal, enabling the formulation of contradictory goals in the form of linear equation titled goalfunction; real restrictions like purchase budget, capacity and etc are the restrictions of pieces supply. Solving this model, the extent of received pieces from each supplier can be determined in a way that it can provide the maximum optimization, covering the proper extent for each goal.

Methodology

This study aims to develop and solve an arithmetic model of goal programming for selecting suppliers in Electrosteel Company whose main activity is producing freezers, coolers, and refrigerators.

Research questions: i. Does the total cost of buyer and supplier in the model of multiple entity benefits differs with that of single entity benefits? ii. Does the extent of delayed goods in the model of multiple entity benefits differ with that of single entity benefits? iii. Does the quality of received safe goods in the model of multiple entity benefits differ with that of single entity benefits?

The present study examines Electro steel Company and its main pieces' suppliers including 100 suppliers using its information of fiscal year in 2009.

Developing and solving arithmetic model of goal programming: Used parameters and variables in the model of this study include:
Parameters;
D: annual demands for the final products
N: suppliers' number
n l_i : delayed delivery percent of the supplier *i* to the buyer (i=1,2,…,n)
α_i : Safe delivery percent from supplier *i* to the buyer (*i*=1,2,…,n)
C_i : purchase price from supplier *i*(*i*=1,2,…,n)
A_i : order cost to supplier*i*(*i*=1,2,…,n)
r: annual cost rate of inventory storage
z_i : production/supply variable cost of every primary piece by supplier *i*(*i*=1,2,…,n)
S_i : preparation cost of supplier *i* (*i*=1,2,…,n)
G_i : annual capacity of supplier *i*(*i*=1,2,…,n) E: imposed cost of every unit of delayed goods to the suppliers (overwork cost, inventory increase, and etc)
F: imposed cost of every unit of delayed goods to the buyers
K: imposed cost to the suppliers to compensate for repair cost of every unit of defective delivered pieces to the buyer
Variables;
T: order period (in year)
Q: the sum of orders to suppliers in each period. Since the order is periodical with fixed annual demands, Q value will be constant; thus, Q=DT.

$$\sum_{i=1}^{n} Q_i = Q$$

Q_i : fulfilled demand by *supplieri* in each period. Naturally this value will be constant in all periods and the equation

holds true.

x_i :demand extent annually provided by supplier*i*.
Based on the mentioned points, the following equation will be regarded:

$$0 \le x_i \le D \quad ، \quad \sum_{i=1}^{n} x_i = D$$

$$x_i = \frac{1}{T} Q_i \qquad \forall i = 1,2,..,n$$

($\frac{1}{T}$ value shows the number of the periods in a year).

Y_i : binary number which is 1 in the case of selectingsupplier *i*and otherwise, 0.

The coefficients of relative importance of these 3 criteria with weights, introduced by Hwang and Yoon are shown by the following equation:

$$(w_1, w_2, w_3): \quad \sum w_i = 1, \quad w_i > 0$$

The final model of the problem will be as follows:

$$Max \;\; Z_1 = \sum_{i=1}^{m} \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} \alpha_{ij} x_{ij}$$

$$Min \;\; Z_2 = \sum_{i=1}^{m} \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} l_{ij} x_{ij}$$

$$Min \;\; Z_3 = \sum_{i=1}^{m} \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} (C_{ij} + z_{ij} + E_{ij} l_{ij} + K_{ij}(1-\alpha_{ij})) x_{ij} + \sum_{i=1}^{m} F_i \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} l_{ij} x_{ij} + \frac{D}{Q} \sum_{i=1}^{m} \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} (A_{ij} + S_{ij}) Y_{ij} + \frac{rQ}{2D^2} \sum_{i=1}^{m} \sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} C_{ij} x_{ij}^2$$

s.t.

$$\sum_{j=n_{i-1}+1,\dots,n_i}^{n_i} x_{ij} = D \qquad \forall i = 1,2,..,m$$

$$0 \le x_{ij} \le G_{ij} \qquad \forall i = 1,2,..,m \qquad \forall j = n_{i-1}+1,..,n_i$$

$$x_{ij} \le DY_{ij} \qquad \forall i = 1,2,..,m \qquad \forall j = n_{i-1}+1,..,n_i$$

$$x_{ij} \ge \varepsilon Y_{ij} \qquad \forall i = 1,2,..,m \qquad \forall j = n_{i-1}+1,..,n_i$$

$$Y_{ij} = \{0,1\} \qquad \forall i = 1,2,..,m \qquad \forall j = n_{i-1}+1,..,n_i$$

Innovative method for solving the problem: To solve the problem, the explained method of Hong and Haya[18] was used. Regarding y_i = 1 for every*i*=1,…, n, an optimum answer results for the problem (in the case of the lack of a reasonable answer, the problem will be unreasonable and the algorithm ends). At this point, allocated value to the supplier with the least (non-zero) order extent (x_j) equals zero. If the new point becomes unreasonable, omitted x_j returns to the problem and the allocated value to the next supplier with the least order equals zero. These operations continue until reaching a reasonable point or examining all x_i s in the present point.

We go to step 4 if there is any reasonable point. Then, the algorithm ends and the optimum answer willequal the minimum value in goal function in step 4.

We solve the problem for reasonable point and register goal function and order lot to suppliers and go to step 2.

Reasonability of a point or lack of it is determined based on the fulfillment capability of the demand (D) based on suppliers 'capacity.

Figure-1 shows the steps of accessing an optimum answer in the mentioned algorithm.

Results and Discussion

Received values for the combined goal function defined in 3 models have been reflected in figure-2.

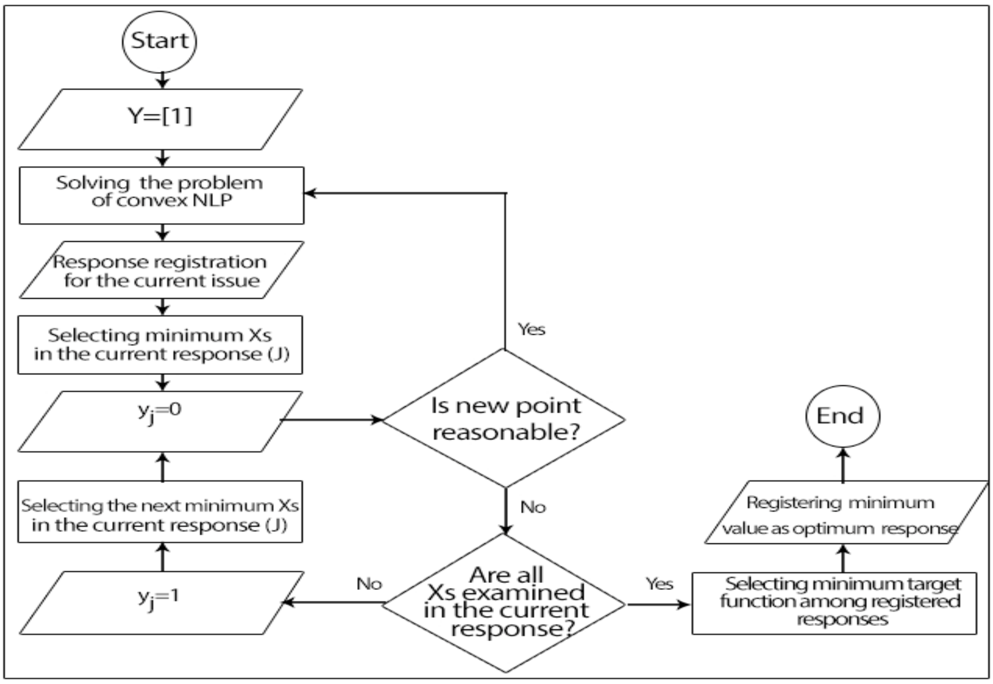

Figure-1
Steps of accessing an optimum answer in algorithm

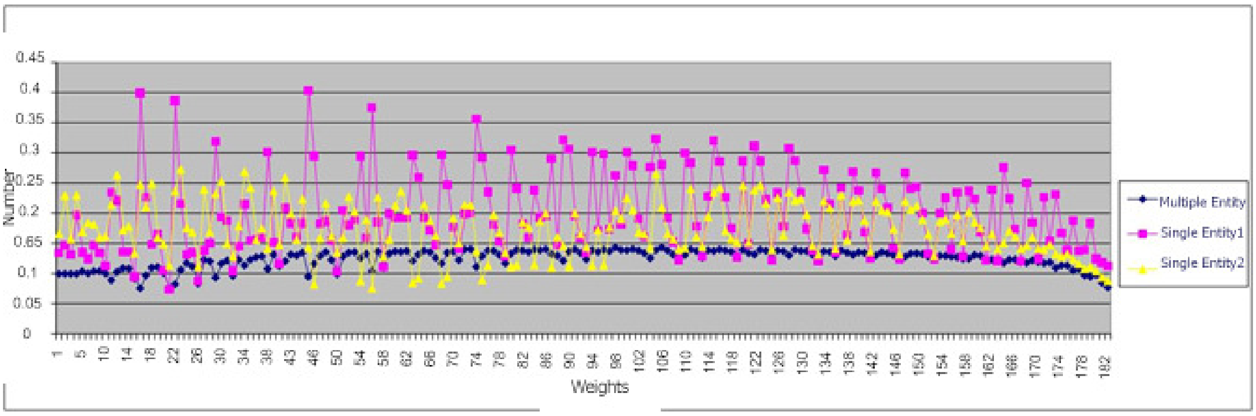

Figure-2
Comparative Figure of the combined function in 3 different states

As seen in figure-2, the value for the combined function of 3 goals has less volatility in the multi-entity model and is in lower rank compared with both single-entity models. In figure-3, target values are examined and separately compared in 3 different states. In these figures, the significance coefficient of the goal has an ascendant trend.

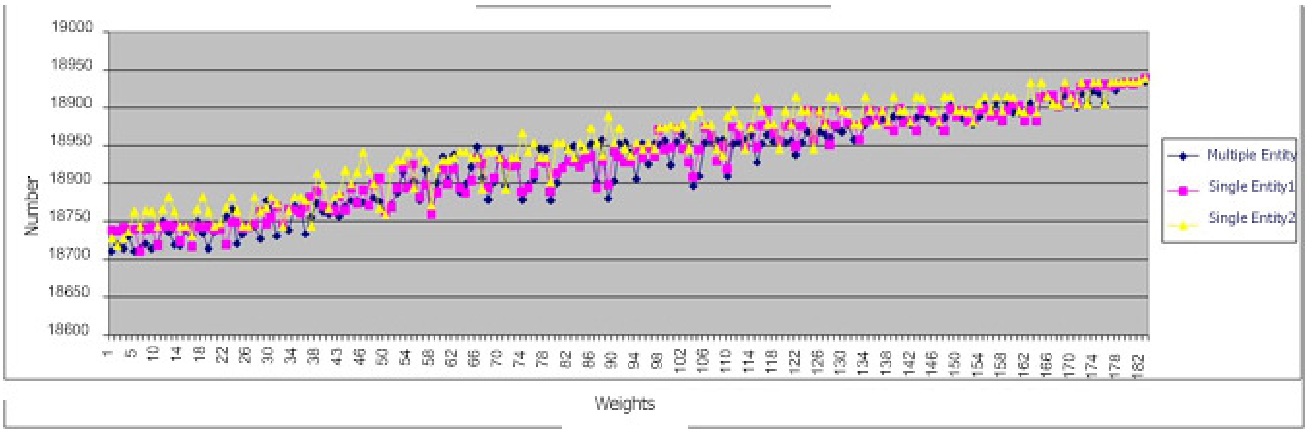

Figure-3
Comparative Figure of the combined function in 3 different states

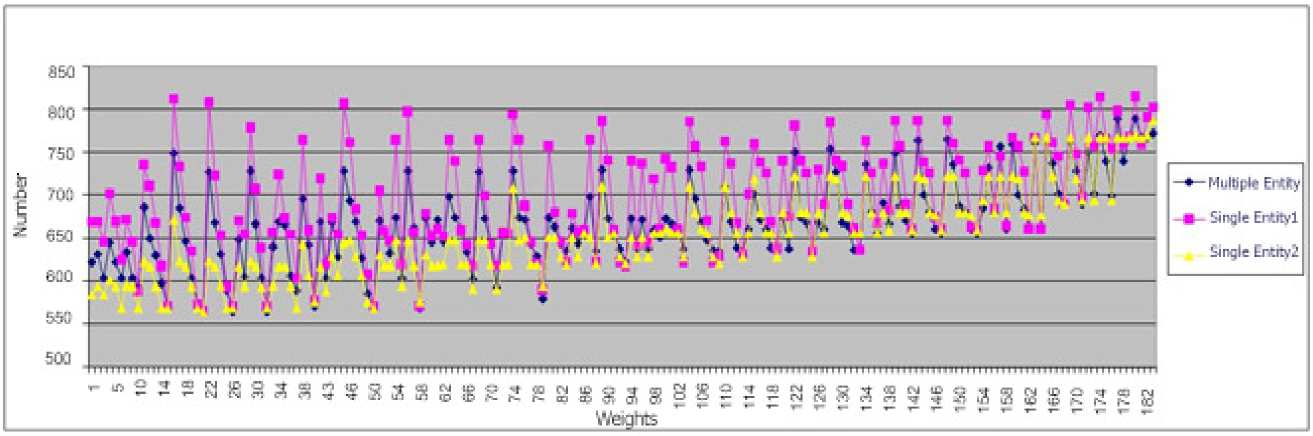

Figure-4
Comparative Figure of on-time delivery function in 3 defined model

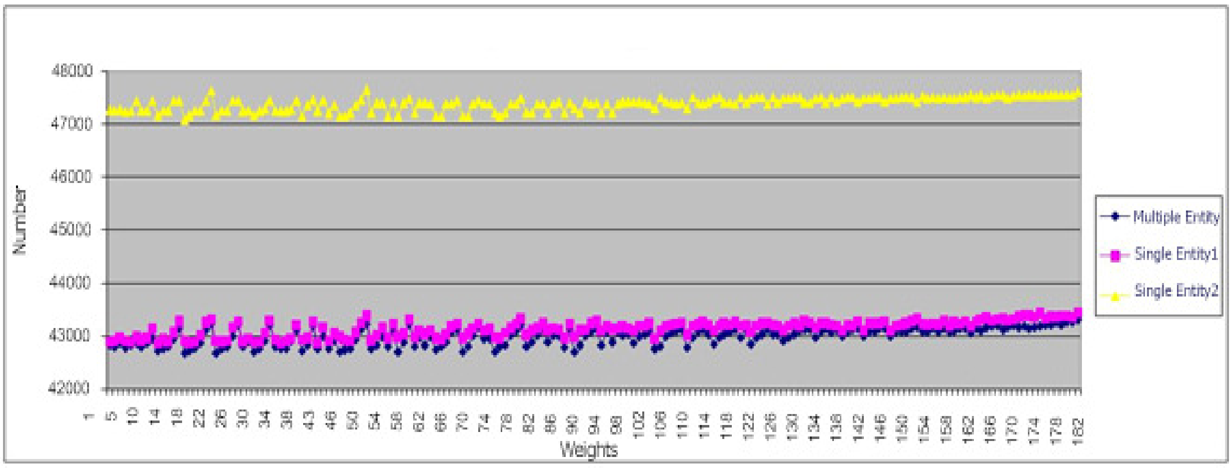

Figure-5
Comparative Figure of total chain costs in 3 defined model

Comparing the values for 3 goals in the models of multiple-entity, single-entity (1), and single-entity (2). As seen in figure-3, there was no significant difference among target values of quality. Quality goal values in each model improve for different weight coefficients with an ascendant trend and low volatility.

In the goal of on-time delivery, the descendent trend of the delays' numberis signified by increasing the coefficient of the function. From the other hand, there is no significant difference among 3 states, especially in high-weight coefficients. But, the values of this goal in single entity model (2) have more volatility compared with lower weight coefficients (figure-4).

In the figure of cost function (figure- 5), the principal of improving goal function is observable with increasing its significance coefficient. Big difference of cost values of single-entity model (2) with single-entity model (1) and multiple-entity model is shown in figure-5. In all cases, cost value in multiple-entity model is smaller than single-entity model (1) and (2).

The sum of these figures confirms the results for improving the levels of goal fulfillment in the offered model for a coordinatedplan between two levels of the chain.

Conclusion

This paper offers a model to coordinate buyers and suppliers efficiently based on common and favorable measuresin the organizations of both sides, in a way that the benefits of both sides are provided simultaneously. In this respect, the corresponding concepts of supply chain were examined with scrutiny. Then, a model, its parameters, and measures were introduced and a solution was offered. Then the results were interpreted.Benefits were observed to be higher for multiple entity model compared with both single entity models. Also, in coordinated state the goals of buyer and supplier were better provided.

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