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Modeling a Sustainable Multi-objective Supplier Selection and Order Allocation Problem under Disruption of Supplier

Farnaz Javadi Gargari[1], Shahla Ahmadi[2]

1- MSc in Industrial Engineering of Alzahra University,Tehran, Iran
2- MSc in Industrial Engineering of Alzahra University,Tehran, Iran

*F.Javadigargari@gmail.com

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Abstract

The strong competition in today's global markets and huge customer attention to factors such as price, quality, time delivery and product variety has caused the investors to focus on supply chain management. In this regard, selecting the choosing and determining the quota of each one is one of the most important and crucial decisions that not only is responsible for supplying the parts, but also accountable for maintaining the organization in the competitive environment. This paper is devoted to determine the optimal order of each product in a multi-objective and multi-period problem. The considered multiple objective functions include minimizing total purchase and order costs, transportation costs, percentage of returned and delayed products, also maximizing the total reliability of selected suppliers according to the necessary of supplying for each product. Due to the existence of unsustainable situation in the real world, in this paper the sustainable approach is introduced to create robust result.

Keywords: Disruption of supplier, sustainable approach, Reliability, Multi-objective modeling, Quota allocation, Supplier selection

1. Introduction and literature review

The supply chain is a complex logistics system in which raw materials are converted to the final product and provided to the end user [1]. The term supply chain refers to partnering with foreign organizations for optimal performance in all activities. Supply chain management includes the design, maintenance, and implementation of supply chain processes to meet the needs of the end user. Supply Chain Management (SCM) includes suppliers, manufacturers, distribution centers and retailers; which is a combination of art and science to improve access to raw materials, products or services and their transference to the customer. Ghiani, Laporte and Musmanno argue that the supply chain is a complex logistics system in which raw materials are first converted to the final product and then delivered to end users [7]. Supplier selection is an important part of the chain management process and will play a strategic role in determining the organizational prosperity because it contributes

to achieve high quality products and customer satisfaction. The supplier selection is a multi-criteria decision-making problem that measures qualitative and quantitative performance. So the importance of supplier selection problem and determining their quota is doubled.
The conducted studied so far in the field of supplier selection can be categorized as follows:

- Mathematical programming models with single-objective cost function
- Mathematical programming models with bi-objective cost function (minimizing the cost and maximizing a utility function)
- Mathematical programming models with tri-objective cost function (minimizing the cost, delivery delays, and returned items)
- Fuzzy models with respect to ambiguity and inaccuracy of the parameters (e.g. demand and capacity)
- Models with different types of discounts by supplier
- Models with uncertainty in demand, capacity and …
- Modeling by taking into account of disruptions and risks in the supply chain

In single-objective models, Che and Wang (2008) [15] presented a research that arranges the list of various products for the first time and uses the connection between different products for supplier, common and non-common parts selection and given the limited production capacity of suppliers, the best combination of suppliers of common and non-common parts is selected and then genetic algorithm is proposed to provide acceptable results for choosing the supplier and allocating the quota of each one. The objective function of the proposed model consists of three parts of the cost (purchase, transportation and assembly), time (purchase and assembly) and quality and the model constraints are associated with purchase budget, transport budget, standard quality level, time of purchase and Supplier's Production Capacity. Wu, Zhang, D. Wu and Olson (2010) [6] proposed a two-step integration model that in this multi-objective decision-making process the Analytical Network Process (ANP) and Mixed Integer Programming (MIP) methods are used. Also in the rest of this paper it is expressed how the combination of these two methods can serve as a useful tool in dealing with the qualitative and quantitative assumptions of the supplier selection especially in packaging strategy problems. Mendoza and Ventura (2012) [2] proposed a two-step approach for supplier selection and order allocation. In the first step the analytic hierarchy process (AHP) is used to eliminate a significant number of suppliers and in the second stage a mixed non-linear programming model is provided to obtain optimal orders. In the bi-objective models, Jafari Songhori, Tavana, Azadeh and Khakbaz (2011) [12], proposed the bi-objective mixed integer programming to minimize costs and maximize the overall efficiency. Maden, Eglese and Black (2016) [15] suggest that, in order to increase the competitive ability, organizations must provide products with quality and less cost by standardization and improving the internal processes. They proposed a model with two goals of minimizing cost and maximizing efficiency.
In multi-objective models Yue, Xia and Tran (2010) [9], believe that the order-based manufacturers are faced with complexity in the resource selection process. The authors have addressed this issue to select resource supply partners for key sectors to obtain information about their resource supply partners and quota allocation a heuristic algorithm has been used in this model to improve both the level of service and the cost and delivery time. Rezaei and Davoodi (2011) [8], proposed two nonlinear multi-objective mixed integer programming models for multi period problems with different number of products and suppliers. Each model has three functions of cost, quality, and level of service and they are subject to a set of constraints. Model costs include purchase, order, maintenance and shipping costs. The difference between the first and second models is in allowing shortage. They are used an innovative genetic algorithm for solving models.

In the case of models with uncertainty in input data, Yang, Wee, Pai and Tseng (2011) [13], proposed a multi-product supplier selection model with random demand and taking into account the level of service and budget limitations. As problem objectives, they used the genetic algorithm to obtain optimal value for returning capital and expected profits. Zhang and Zhang (2011) [10] proposed a single-product and single- objective model for supplier selection and an order quantity model under random order.
In the case of goal programming models, Charnes and Cooper (1981) [1], introduced Goal programming (GP) as one of the most used and well known decision making techniques. In the reviewed models, mostly classical structure is used and the general structure of goal programming models, including crisp and fuzzy ones, remained unchanged. However, in the real world situations, decision making problems may arise with different structures which cannot be handled using standard decision making approaches. For example when in a multi objective decision making problem, the decision maker presents multi aspiration levels as goals for each objective, the classical models of decision making including goal programming cannot be applied directly. To deal with this type of problems, it is essential to develop new decision making models. To do this, Chang (2007) [5], proposed a multi-choice goal programming (MCGP) approach to deal with such problems. He revised his approach to make easier understanding and implementation of linear programming packages for solving such problems (2008) [4]. Liao (2009) [15], also presented the formulation of multi-segmented goal programming which can be applied to solve multiple decision making problems which have multi-segmented aspiration levels. In the case about existence of disruption of supply chain management, Scheibe and Blachhurst (2017)[11] examined a case-study approach to qualitative theory to help understand the disruption in the supply chain. It was also shown that the risk correlations, combinational effects, cyclical relationships, competitors' risk, goals and incompatible motives should be considered in order to effectively deal with the disruption. Mackenz (2017) [3]presented a model by which a supply chain manager can examine and control various combinations of disruption management strategies. Pellegrino and Taura (2018) [14], adopting the supply chain perspective, addressed the supply chain financing challenge and analyzed it by the effectiveness of supply chain risk management (SCRM) in reducing the risk

2. Research Method

Given the importance of supplier selection and its role on the supply chain, the problem of supplier selection and its quota in product order is discussed. Also considering that there is no answer to optimize all objectives in the multi-objective decision-making problems, the adaptive optimal answers are considered in multi-objective decision-making problems. Different solutions are considered to solve the decision-making problems over the past three decades; meanwhile the robust programming is a suitable way to solve such problems.
In this paper, the objective functions of the model include minimizing purchase and order costs, transportation costs, returned products, delays and maximizing total reliability of selected suppliers according to the necessity of supply for each product. Also in this paper, the transportation cost is considered as uncertain and probability distribution function and in continue, introducing the type of interval data for creating sustainable condition. Here some of the symbols and formulation of the model are discussed and the results are analyzed using the numerical solution of CPLEX software. Finally, proposals for future research in this area are presented.

✓ **Definition of parameters**

i: Supply index
j: product index

t: time period index
q_{ij}: Return percentage of product j by the buyer sent by supplier i
t_{ij}: percentage of orders delayed by product j sent by supplier i
P_{itj}: Unit price of the product j provided by supplier i
D_{jt}: Demanding product j at time period t
S_{jt}: Measure of the necessity of supplying the product j in period t
C_{ijt}: supplier i capacity in period t
P_{itj}: Unit price of the product j provided by supplier i
T_j: Maximum acceptable percentage for delays in ordering product j
Q_i: maximum acceptable percentage to return the product j
a_{ij}: Transaction cost (unrecognizable) of product j delivered by supplier i at period t
O_{ijt}: ordering cost of product j delivered by supplier i at period t
R_j: likelihood of disruption in supplier i

✓ **Definition of Variables**

X_{ijt}: The amount of demand for product j that is satisfied during the period t through supplier i as the main supplier
Y_{ijt}: binary variable (if the product j is supplied by the supplier i in period t, it is 1 otherwise it will be zero)
ar_{ijt} : binary non negative slack variable to control robust transportation cost
ay_{ijt} : binary non negative slack variable to control robust transportation cost
ap_1 : binary non negative slack variable to control robust transportation cost

$$\text{Min } Z_1 : \sum_i \sum_j \sum_t a_{ijt} y_{ijt} + ap_1 \, \Gamma_1 + \sum_i \sum_j \sum_t ar_{ijt} \quad (1)$$
$$\text{Min } Z_2 : \sum_j \sum_i \sum_t p_{ijt} (1 - R_i) X_{ijt} + O_{ijt} \, y_{ijt} \quad (2)$$
$$\text{Min } Z_3 : \sum_j \sum_i \sum_t q_{ij} (1 - R_i) X_{ijt} \quad (3)$$
$$\text{Min } Z_4 : \sum_j \sum_i \sum_t t_{ij} (1 - R_i) X_{ijt} \quad (4)$$
$$\text{Max } Z_5 : \sum_j \sum_i \sum_t S_{jt} (1 - R_i) X_{ijt} \quad (5)$$

Equation (1) minimizes the cost of the transaction in the type of sustainable robust. Equation (2) minimizes the cost of purchase and order. Equation (3) minimizes the returned products from the buyer to the supplier. Equation (4) minimizes the delay in delivery of products. Equation (5) maximizing the total reliability of selected suppliers according to the necessity of supply for each product.

s.t.

$$\sum_i Y_{ijt} (1 - R_i) X_{ijt} \geq D_{jt} \qquad \forall\, j,t \quad (6)$$
$$\sum_i \sum_t q_{it} \, (1 - R_i) \, X_{ijt} \leq Q_j \sum_t D_{jt} \qquad \forall\, j \quad (7)$$
$$\sum_i \sum_t t_{it} \, (1 - R_i) \, X_{ijt} \leq T_j \sum_t D_{jt} \qquad \forall\, j \quad (8)$$
$$ap_1 + ar_{ijt} \geq a_{ijt} \; ay_{ijt} \qquad \square \; i, j, t \quad (9)$$
$$-ay_{ijt} \leq y_{ijt} \leq ay_{ijt} \qquad \square \; i, j, t \quad (10)$$
$$(1 - R_i) \, X_{ijt} \leq Y_{ijt} C_{ijt} \qquad \forall\, i, j, t \quad (11)$$
$$X_{ijt} \geq 0 \qquad \forall\, i, j, t \quad (12)$$
$$Y_{ijt} = \begin{cases} 0 \\ 1 \end{cases} \qquad \forall\, i, j, t \quad (13)$$
$$ap_1 \geq 0 \quad (14)$$

$ar_{ijt} \geq 0$ □ i, j, t (15)

$ay_{ijt} \geq 0$ □ i, j, t (16)

Constraint (6) is to supply the total demand for product j at time period t. Constraint (7) makes the total returned product for the total suppliers to be less than the allowed return limits for each product. Constraint (8) is to prevent the amount of delayed product of the suppliers than the allowed range of delay for each product. Constraint (9) is to control robust sustainable for transportation cost. Constraint (10) is related to range of slack variable. Constraint (10) indicates the capacity limit. Constraint (11) checks the possibility of the existence of the order. Constraints (12) and (16) are related to the range of variables.

Indeed, in this paper a novel modeling is introduced with emphasis of demand disruption and unsustainable transportation cost that all of them are controlled by new type of variables. As well as, this model is able to solve with all kind of multi-objective method.

3. Numerical example and data analysis

This section, one numerical problem is solved with the model under CPLEX software, that the parameters are considered with introduced data in the table 1.

Table 1 - Parameters

q_{ij} = round(uniform(0.2, 0.7)) ;
T_{ij} = round(uniform(0.2, 0.7)) ;
P_{itj}: = round(uniform500,1000));
D_{jt} = round(uniform(200,800)) ;
S_{jt} = round(uniform(1,9)) ;
C_{ijt} = round(uniform(20,25));
T_j = round(uniform(0.5,0.8));
Q_j = round(uniform(0.5,0.8));
O_{ijt} = round(uniform(100,150));
a_{ij} = round(uniform(10,80));
R_j= round(uniform(0.1,0.6)); q_{ij} = round(uniform(0.2, 0.7)) ;
T_{ij} = round(uniform(0.2, 0.7)) ;
P_{itj}: = round(uniform500,1000));
D_{jt} = round(uniform(200,800)) ;

After the solving model with this parameters, the results are obtained such as the table 2, 3 and 4.

Table 2- Results of variable Xijt

X_{ijt}	t=1		t=2	
j=1	i=1	150	i=1	0
	i=2	0	i=2	238
j=2	i=1	0	i=1	567
	i=2	127	i=2	0

Table 3- Results of variable Yijt

Y_{ijt}	t=1		t=2	
j=1	i=1	1	i=1	0
	i=2	0	i=2	1
j=2	i=1	0	i=1	1
	i=2	1	i=2	0

Table 4- Results of variable ayijt

ay_{ijt}	t=1		t=2	
j=1	i=1	1	i=1	0
	i=2	1	i=2	1
j=2	i=1	0	i=1	1
	i=2	1	i=2	1

According to the results of example, it is clear that the novel model is a feasible solution to solve real problem in the world. As well as, the control of reliability in this model is in the great level.

4. Conclusions and Further Research Ideas

The supplier selection and quota allocation problem under disruption of supplier has been introduced. Given that, in multi-objective decision-making problems, some unsustainable conditions are normal in the real word; therefore, it is obvious that the reliable and robust modeling is very important for all type of supply chain management. In this paper, the novel model is presented with considering demand disruption and sustainable condition for transportation cost. Also, the considered multiple objective functions include minimizing total purchase and order costs, transportation costs, percentage of returned and delayed products, also maximizing the total reliability of selected suppliers according to the necessary of supplying for each product.

For future research, the capacity of each supplier can also be determined by qualitative terms such as very high, high, and medium... It is also possible to acquire a win-win situation with quantifying other benefits of the supply chain and considering these benefits in the objective function and use the multi-criteria decision-making methods to select suppliers.

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