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Designing a robust supply chain management based on distributers' efficiency measurement

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C H R O N I C L E

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A B S T R A C T

An appropriate supply chain design helps survival in competitive markets. Achieving maximum efficiency may also help decision makers have a better selection for the supply chain network. The purpose of this paper is to design an efficient supply chain model in terms of the distribution channels under uncertain conditions. The proposed study produces multi products using different materials by considering four layers of multiple suppliers, producers, storages and customers. There are two objectives of maximizing efficiency of distributers and minimizing total cost of supply chain management. The proposed model locates producers as well as suppliers and determines the amount of orders from different suppliers. In order to measure the relative efficiency, the study uses the method developed by Klimberg and Ratick (2008) [Klimberg, R. K., & Ratick, S. J. (2008). Modeling data envelopment analysis (DEA) efficient location/allocation decisions. *Computers & Operations Research*, 35(2), 457-474.]. In addition, to handle the uncertainty, the study uses the robust optimization technique developed by Molvey and Ruszczyński (1995) [Mulvey, J. M., & Ruszczyński, A. (1995). A new scenario decomposition method for large-scale stochastic optimization. *Operations research*, 43(3), 477-490.]. The preliminary results indicate that the proposed model is capable of providing efficient solutions under various uncertain conditions.

1. Introduction

During the last two decades, there have been tremendous efforts in development of supply chain management systems (Ganeshan & Harrison, 1995; Minner, 2003; Meixell & Gargeya, 2005; Sarkis et al., 2011; Shen, 2007; Bala, 2014). Altiparmak et al. (2006) developed a new technique based on genetic algorithms to detect the set of Pareto-optimal solutions for multi-objective supply chain network. In addition, to handle multi-objective and help decision maker analyze a larger numbers of alternative solutions, they developed two different weight approaches. They also provided the implementation of the proposed method for a real-world case study in Turkey. Baghalian et al. (2013) provided a stochastic mathematical modeling for designing a network of multi-product supply chains comprising different capacitated production facilities, distribution centers and retailers in markets under uncertainty. The model handled demand-side and supply-side uncertainties, simultaneously.

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They also considered a discrete set as potential locations of distribution centers and retailing outlets and studied the impact of strategic facility location decisions on the operational inventory and shipment decisions of the supply chain. They applied a path-based formulation, which helps investigate supply-side uncertainties, which are possible disruptions in manufacturers, distribution centers and their connecting links.

Gan et al. (2014) investigated the transformation mechanism for formulating a multiproduct two-layer problem as a network flow model. Castillo-Villar et al. (2014) investigated capacitated model for supply chain network design (SCND), which determines manufacturing, distribution, and quality costs. Costa et al. (2011) considered the two-level network design problem with intermediate facilities by designing a minimum cost network respecting some needs, usually described in terms of the network topology or in terms of a desired flow of commodities between source and destination vertices. They considered a hybrid decomposition method, which heuristically determined tentative solutions for the vertex facilities number and location and applied these solutions to limit the computational time of a branch-and-cut algorithm.

Georgiadis et al. (2011) proposed an optimal design of supply chain networks under uncertain transient demand variations. Jayaraman and Pirkul (2001) offered a model for planning and coordination of production and distribution facilities for multiple commodities. Melo et al. (2006) provided a dynamic multi-commodity capacitated facility location by presenting a mathematical modeling framework for strategic supply chain planning. Pierce and Giles (1997) provided a preconditioned multi-grid technique for compressible flow calculations on stretched meshes. Pishvaee and Torabi (2010) presented a possibilistic programming technique for closed-loop SCND under uncertainty.

Pishvaee et al. (2011) offered a robust optimization technique to closed-loop supply chain network design under uncertainty. Pishvaee et al. (2012), in other work, presented a robust possibilistic programming for socially responsible SCND. Seuring (2013) presented a comprehensive review of modeling techniques for sustainable supply chain management. Syam and Côté (2010) presented a location–allocation model for service providers with application to not-for-profit health care organizations. Tang and Nurmaya Musa (2011) determined risk issues and research advancements in supply chain risk management. Finally, Xu and Nozick (2009) presented a modeling for supplier selection and the implementation of option contracts for global supply chain design.

2. The proposed study

Supply chain management involves three levels of strategic decisions (long-term decisions), tactical level (medium-term decisions) and operational level (decision day) (Ganeshan & Harrison, 1995). Designing a supply chain network is one of the most important strategic decisions to be taken in the initial stages of supply chain management. Supply chain design plays essential role on the supply chain network and it has an important impact on the efficiency, flexibility, and cost competitiveness of an enterprise's abilities (Shen, 2007). The primary objective of this paper is to integrate supply chain management with the idea of data envelopment analysis to integrate an efficient supply chain. The proposed model tries to determine the optimum locations of factors and inventories to increase the efficiency of the total system and minimizes total costs. The following summarizes the parameters used in the proposed study.

Parameters

I	Set of customers
J	Set of distribution centers
K	Set of factories
L	Set of products

R	Set of raw materials
V	Set of suppliers
N	Set of output indices
h	Set of input indices
S	Set of scenarios
c'_{js}	Fixed annual setup cost of opening a storage facility *j* in scenario *s*
c''_{ks}	Fixed annual setup cost of opening a factory *k* in scenario *s*
v'_{jls}	Holding cost of one unit of product *l* in facility *j*
v_{lks}	Production cost of one unit of product *l* in facility *j* in scenario *s*
t_{vkrs}	Unit cost of transportation and the purchase of raw material *r* from supplier *v* to plant *k* in scenario *s*
t'_{ijkls}	Unit cost of product *l* shipped from factory *k* to warehouse *j* and from warehouse *j* to customer *i* in scenario *s*
a_{ils}	Demand for product *i* for customer *l* in scenario *s*
w_{js}	Throughput of distributer (warehouse) *j* in scenario *s*
D_{ks}	Capacity of factory *k* in scenario *s*
S_{vrs}	Capacity of supplier *v* to provide raw material *r* in scenario *s*
u'_{rl}	Rate of raw material *r* in product *l* in scenario *s*
u_l	Utilization rate of one unit production *l* from the capacity of the factory in scenario *s*
u''_l	Rate of consumption of product *l* from supplier's throughput in scenario *s*
W	Maximum number of allowable warehouses for establishment in scenario *s*
P	Maximum number of allowable factories for establishment in scenario *s*
O_{njs}	The amount of n^{th} output for inventory *j* in scenario *s*
I_{hjs}	The amount of h^{th} output for inventory *j* in scenario *s*
Λ	The standard deviation of the objective function coefficient of distributor
λ'	The standard deviation of the objective function coefficient of total costs
Ω	The sum of penalty coefficients of distributers
ω'	The sum of penalty coefficients of total cost
p_s	The likelihood of each scenario

Decision variables

z_j	A binary variable, which is one if a warehouse is established on location *j* and zero, otherwise
p_k	A binary variable, which is one if a factory is established on location j and zero, otherwise
y_{ij}	A binary variable, which is one if warehouse *j* supplies customer *i* and zero, otherwise
q_{vkr}	The amount of raw material *r* shipped from warehouse *v* to factory *k*
q'_{ijkl}	The amount of product *l* shipped from factory *k* to customer *i* using warehouse *j*
$x_{lk} = \sum_i \sum_j q'_{ijkl}$	The amount of product *l* produced in factory *k*
$1 - d_j$	Total harmonic output of warehouse *j*
f_{jh}	Weighted coefficient of input h for warehouse *j*
g_{jn}	Weighted coefficient of output n for warehouse *j*
δ^a_{js}	Penalty variable throughput constraints vendor (store) *j* in scenario *s*
δ^b_{vrs}	Penalty variable of supplier capacity constraints *v* to supply raw material *r* in scenario *s*
δ^c_{ks}	Penalty variable of capacity of plant *k* in distributers *j*

δ_{ijls}^{d}	Penalty variable of constraint of customer *i* from distributer *j* for product *l* in scenario *s*
θ_s	An auxiliary variable for linearization process of the first objective function
θ'_s	An auxiliary variable for linearization process of the second objective function

The preliminary model of this paper is written based on a combination of the works by Jayaraman and Pirkul (2001) and Altiparmak et al. (2009). The model considers the supply chain consists of four layers, supplier, manufacturer, warehouse (wholesale) and the client. The primary objective of this paper is to locate the factories and warehouses and it determines the amount of order from each supplier. The production plan in this model is limited to single stage, it is also a forward operation and no product is recycled. Adabi and Omrani (2015) considered this model where all parameters are available and all the precise value of all parameters are available. The proposed study of this paper extends the problem statement where there are different scenarios. The capacities of all factors are limited and finally there is a fixed setup cost and a variable cost associated with production of each unit. The mathematical model is as follows,

$$\min z_1 = \sum_j c'_j z_j + \sum_i \sum_j \sum_l v'_{jl} a_{il} y_{ij} + \sum_k c''_k p_k + \sum_i \sum_j \sum_l \sum_k v_{lk}\, q'_{ijkl} + \sum_v \sum_k \sum_r t_{vkr} q_{vkr} + \sum_i \sum_l \sum_k \sum_j t'_{ijkl} q'_{ijkl} \tag{1}$$

subject to

$$\sum_j y_{ij} = 1 \qquad \forall i \tag{2}$$

$$\sum_i \sum_l u''_l a_{il} y_{ij} \leq w_j z_j \qquad \forall j \tag{3}$$

$$\sum_j z_j \leq W \tag{4}$$

$$\sum_k q_{vkr} \leq S_{vr} \qquad \forall v, r \tag{5}$$

$$\sum_i \sum_j \sum_l u'_{rl} q'_{ijkl} \leq \sum_v q_{vkr} \qquad \forall k, r \tag{6}$$

$$\sum_i \sum_j \sum_l u''_l q'_{ijkl} \leq D_k p_k \qquad \forall k \tag{7}$$

$$\sum_k q'_{ijkl} = a_{il} y_{ij} \qquad \forall i, j, l \tag{8}$$

$$\sum_{k} p_k \leq P \tag{9}$$

$$z_j = \{0,1\} \qquad \forall j \tag{10}$$

$$p_k = \{0,1\} \qquad \forall k \tag{11}$$

$$y_{ij} = \{0,1\} \qquad \forall i, j \tag{12}$$

$$q_{vkr} \geq 0 \qquad \forall v, k, r \tag{13}$$

$$q'_{ijkl} \geq 0 \qquad \forall i, j, k, l \tag{14}$$

Eq. (2) is associated with the allocation of warehouse to customer. Eq. (3) determines the capacity of warehouse. Eq. (4) determines the capacity of producer of raw material. Eq. (5) shows the capacity of production of raw materials. According to Eq. (6), the amount of raw materials sent to each factory must be greater than its needs. Eq. (7) demonstrates the capacity of each producer. Eq. (8) explains that the amount of products shipped from different factories to warehouses must meet customers' demands. Eq. (9) determines the maximum number of producers and the other constraints determine the type of variables.

Measuring the efficiency of similar units plays an important role for productivity improvement and there are literally various techniques to measure the efficiency of similar units such as data envelopment analysis (DEA) (Charnes et al., 1978). Porembski et al. (2005), for example, applied an application of DEA for various branches of a German bank. Klimberg and Ratick (2008) developed and investigated location modeling formulations, which utilize characteristics of the DEA efficiency measure to detect optimal and efficient facility location/allocation patterns. The proposed study of this paper applies the same idea and the mathematical model named SDEA is as follows,

$$\max z = \sum_{r} (1 - d_r) \tag{15}$$

$$\sum_{i=1}^{I} v_{ri} I_{ir} = 1 \qquad \forall r \tag{16}$$

$$\sum_{j=1}^{J} u_{rj} O_{jr} + d_r = 1 \qquad \forall r \tag{17}$$

$$\sum_{j=1}^{J} u_{rj} O_{jk} - \sum_{i=1}^{I} v_{ri} I_{ik} \leq 0 \qquad \forall r, \forall k, k \neq r \tag{18}$$

$$v_{ri}, u_{rj} \geq \varepsilon \quad \forall j, i, r \tag{19}$$

$$d_r \geq 0 \qquad \forall r \tag{20}$$

where O_{jr} and V_{rj} are the j^{th} output and input of unit r, and v_{ri} and u_{rj} are the weight variables of the output and input parameters. Now, we present a mathematical model, which uses the idea of SDEA with the preliminary model earlier stated.

$$\max z_1 = \sum_{j=1}^{J}(1-d_j) \quad (21)$$

$$\min z_2 = \sum_j c'_j z_j + \sum_i\sum_j\sum_l v'_{jl}a_{il}y_{ij} + \sum_k c''_k p_k + \sum_i\sum_j\sum_l\sum_k v_{lk}\, q'_{ijkl} + \sum_v\sum_k\sum_r t_{vkr}q_{vkr} + \sum_i\sum_l\sum_k\sum_j t'_{ijkl}q'_{ijkl} \quad (22)$$

subject to

$$\sum_h f_{jh}I_{hj} = z_j \qquad \forall j \quad (23)$$

$$\sum_n g_{jn}O_{nj} + d_j = z_j \qquad \forall j \quad (24)$$

$$\sum_n g_{jn}O_{nt} - \sum_h f_{jh}I_{ht} \le 0 \qquad \forall j{:}\, \forall t{:}\, (j \ne t) \quad (25)$$

$$g_{jn} \ge \varepsilon z_j \qquad \forall j, n \quad (26)$$

$$f_{jh} \ge \varepsilon z_j \qquad \forall j, h \quad (27)$$

$$d_j \ge 0\ \forall j \quad (28)$$

$$g_{jn} \ge 0 \qquad \forall j, n \quad (29)$$

$$f_{jh} \ge 0 \qquad \forall j, h \quad (30)$$

Constraints 2-14

In this model, there two objective functions, where the first one maximizes the efficiency and the second one minimize the cost of supply chain management.

3. Scenario based robust optimization

In this section, we briefly describe the robust optimization method based on different scenarios developed by Mulvey and Ruszczyński (1995) and Mulvey et al. (1995). Consider the following mathematical problem,

$$\min z = c^T x + d^T y \quad (31)$$

Subject to

$$Ax = b \quad (32)$$

$$Bx + Cy = e \quad (33)$$

$$x, y \ge 0 \quad (34)$$

Let x be design variables and y_s be the control variables for each scenario, s, respectively with $\Omega = \{1,2,,3, \dots, S\}$. For each scenario, we consider a probability $\mathrm{p_s}$ with $\sum_{s=1}^{S} \mathrm{p_s} = 1$. Therefore, we have

$$\min \quad \sigma(x, y_1, y_2, \dots, y_s) + \rho\omega(\delta_1, \delta_2, \dots, \delta_s) \tag{35}$$

subject to

$$Ax = b \tag{36}$$

$$B_s x + C_s y_s = e_s \quad \forall\, s \in \Omega \tag{37}$$

$$x \geq 0, \quad y_s \geq 0 \quad \forall\, s \in \Omega \tag{38}$$

We define $\xi = c^T x + d^T y$ and $\sigma(0) = \sum_{s\in\Omega} p_s \xi_s$. We use a parameter λ to find the trade-off between two parts of objective functions in robust optimization as follows,

$$\sigma(x, y_1, y_2, \dots, y_s) = \sum_{s\in S} p_s \xi_s + \lambda \sum_{s\in S} p_s \left(\xi_s - \sum_{s'\in S} p_{s'} \xi_{s'} \right)^2 . \tag{39}$$

As the value of λ increases, the model becomes less sensitive to changes of parameters. However, the model is nonlinear and we need to use the method developed by Yu and Li (2000) to change the model into linear form as follows,

$$\sigma(x, y_1, y_2, \dots, y_s) = \sum_{s\in S} p_s \xi_s + \lambda \sum_{s\in S} p_s \left| \xi_s - \sum_{s'\in S} p_{s'} \xi_{s'} \right| \tag{40}$$

Yu and Li (2000) further developed by the model as follows,

$$\min z = \sum_{s\in S} p_s \xi_s + \lambda \sum_{s\in S} p_s [(\xi_s - \sum_{s'\in S} p_{s'} \xi_{s'}) + 2\theta_s]. \tag{41}$$

subject to

$$\xi_s - \sum_{s'\in S} p_{s'} \xi_{s'} + \theta_s \geq 0 \tag{42}$$

$$\theta_s \geq 0 \tag{43}$$

We apply the proposed robust optimization stated by Eq. (41) to Eq. (43) to the supply chain problem and the model becomes as follows,

$$\min z_1 = Ez_1 + \lambda \sum_{s} p_s \left[\sum_{j} (d_{js} - 1) - Ez_1 + 2\theta_s \right] + \omega(\sum_{j} \sum_{\mathrm{s}} \delta_{js}^{a} + \sum_{\mathrm{v}} \sum_{\mathrm{r}} \sum_{\mathrm{s}} \delta_{vrs}^{b} + \sum_{k} \sum_{\mathrm{s}} \delta_{ks}^{c} + \sum_{\mathrm{i}} \sum_{\mathrm{j}} \sum_{\mathrm{l}} \sum_{\mathrm{s}} \delta_{ijls}^{d}) \tag{44}$$

$$\min z_2 = Ez_2 + \lambda' \sum_s p_s \Bigg[\Bigg(\sum_j c'_{js} z_j + \sum_i \sum_j \sum_l v'_{jls} a_{ils} y_{ij} + \sum_k c''_{ks} p_k + \sum_i \sum_j \sum_l \sum_k v_{lks}\, q'_{ijkl} + \sum_v \sum_k \sum_r t_{vkrs} q_{vkr} + \sum_i \sum_l \sum_k \sum_j t'_{ijkls} q'_{ijkl} \Bigg) - Ez_3 + 2\theta'_S \Bigg] + \omega' \Big(\sum_j \sum_s \delta^a_{js} + \sum_v \sum_r \sum_s \delta^b_{vrs} + \sum_k \sum_s \delta^c_{ks} + \sum_i \sum_j \sum_l \sum_s \delta^d_{ijls} \Big) \tag{45}$$

$$Ez_1 = \sum_s p_s \sum_j \left(d_{js} - 1 \right) \tag{46}$$

$$Ez_2 = \sum_s p_s \Bigg(\sum_j c'_{js} z_j + \sum_i \sum_j \sum_l v'_{jls} a_{ils} y_{ij} + \sum_k c''_{ks} p_k + \sum_i \sum_j \sum_l \sum_k v_{lks}\, q'_{ijkl} + \sum_v \sum_k \sum_r t_{vkrs} q_{vkr} + \sum_i \sum_l \sum_k \sum_j t'_{ijkls} q'_{ijkl} \Bigg) \tag{47}$$

subject to

$$\Bigg(\sum_j c'_{js} z_j + \sum_i \sum_j \sum_l v'_{jls} a_{ils} y_{ij} + \sum_k c''_{ks} p_k + \sum_i \sum_j \sum_l \sum_k v_{lks}\, q'_{ijkl} + \sum_v \sum_k \sum_r t_{vkrs} q_{vkr} + \sum_i \sum_l \sum_k \sum_j t'_{ijkls} q'_{ijkl} \Bigg) - Ez_2 + \theta'_s \geq 0 \qquad \forall s \tag{48}$$

$$\sum_j \left(d_{js} - 1 \right) - Ez_1 + \theta_s \geq 0 \qquad \forall s \tag{49}$$

$$\sum_i \sum_l u''_l a_{ils} y_{ij} - \delta^a_{js} \leq w_{js} z_j \qquad \forall j, s \tag{50}$$

$$\sum_k q_{vkr} - \delta^b_{vrs} \leq S_{vrs} \qquad \forall v, r, s \tag{51}$$

$$\sum_i \sum_j \sum_l u_l q'_{ijkl} - \delta^c_{ks} \leq D_{ks}\, p_k \qquad \forall k, s \tag{52}$$

$$\sum_k q'_{ijkl} + \delta^d_{ijls} = a_{ils} y_{ij} \qquad \forall i, j, l, s \tag{53}$$

$$\sum_h f_{jhs} I_{jhs} = z_j \qquad \forall j, s \tag{54}$$

$$\sum_n g_{jns} O_{jns} + d_{js} = z_j \qquad \forall j, s \tag{55}$$

$$\sum_n g_{jns} O_{tns} - \sum_h f_{jhs} I_{ths} \leq 0 \qquad \forall s, \forall j{:}\, \forall t{:}\, (j \neq t) \tag{56}$$

$g_{jns} \geq \varepsilon z_j$ $\forall j, n, s$ (57)

$f_{jhs} \geq \varepsilon z_j$ $\forall j, h, s$ (58)

$d_{js} \geq 0$ $\forall j, s$ (59)

$f_{jhs} \geq 0$ $\forall j, h, s$ (60)

$g_{jns} \geq 0$ $\forall j, n, s$ (61)

$\theta_s \geq 0$ $\forall s$ (62)

$\theta'_s \geq 0$ $\forall s$ (63)

$\delta^a_{js} \geq 0$ $\forall j, s$ (64)

$\delta^b_{vrs} \geq 0$ $\forall v, r, s$ (65)

$\delta^c_{ks} \geq 0$ $\forall k, s$ (66)

$\delta^d_{ijls} \geq 0$ $\forall i, j, l, s$ (67)

Next, we present details of the proposed study by implementing the method on a sample data as follows,

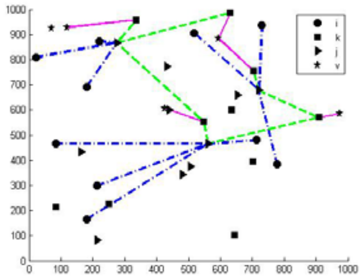
I	10	a_{il1}	U[10,100]
J	10	a_{il2}	U[1,110]
K	10	a_{il3}	U[20,110]
L	2	w_{js}	$U[0.17\sum_i\sum_l u''_l a_{ils}, 0.5\sum_i\sum_l u''_l a_{ils}]$
R	2	D_{ks}	$U[0.17\sum_i\sum_l u_l a_{ils}, 0.5\sum_i\sum_l u_l a_{ils}]$
V	5	S_{vrs}	$U[0.17\sum_i\sum_l u'_{rl} a_{ils}, 0.5\sum_i\sum_l u'_{rl} a_{ils}]$
n	3	u'_{rl}	$\begin{bmatrix} 4 & 5 \\ 5 & 2 \end{bmatrix}$
h	4	u_l	[3,5]
s	3	u''_l	[3,5]
c'_{j1}	U[10000,30000]	O_{jn1}	U[40,100]
c'_{j2}	U[8000,32000]	O_{jn2}	U[30,110]
c'_{j3}	U[12000,32000]	O_{jn3}	U[50,110]
c''_{k1}	U[10000,30000]	I_{jh1}	U[50,100]
c''_{k2}	U[8000,32000]	I_{jh2}	U[40,110]
c''_{k3}	U[12000,32000]	I_{jh3}	U[60,110]
v'_{jl1}	U[1,10]	t_{vkr1}	1*Euclidian norm
v'_{jl2}	U[1,11]	t_{vkr2}	1.1*Euclidian norm
v'_{jl3}	U[2,11]	t_{vkr3}	1.2*Euclidian norm
v_{lk1}	U[1,10]	t'_{ijkl1}	1*Euclidian norm
v_{lk2}	U[1,11]	t'_{ijkl2}	1.1*Euclidian norm
v_{lk3}	U[2,11]	t'_{ijkl3}	1.2*Euclidian norm
P	5	W	5

Table 1 shows the results of our findings. In addition, Fig. 1 shows the results of facilities under certain and uncertain conditions. In this figure, only the results for efficiency objective function have been depicted when α is equal to 0.1, 0.5 and 0.9. The stars indicate the position of the primary suppliers, the square indicates the position of producers, triangles indicate the location of warehouses (Distributors) and the circles indicate the location of customers. The pink line color shows the flow from supplier to producer, the dot green color demonstrates the flow from producer to distributer and finally, the blue color shows the flow from distributers to customers.

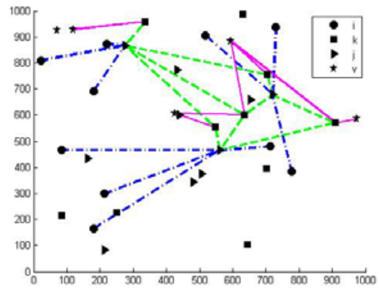
Table 1
The summary of the robust optimization under different scenarios

Efficiency coefficient		Deterministic		Scenario based		
		Efficiency	Cost	Efficiency	Cost	Penalty
α	1-α	Zmax	Zmin	Zmax	Zmin	Zmin
0	1	7.625	2721617	7.625	1863875.42	1125
0.1	0.9	9.560	2721617	9.560	1863875.42	1125
0.2	0.8	9.741	2742525	9.741	1883827.45	1125
0.3	0.7	9.741	2742525	9.741	1883827.45	1125
0.4	0.6	9.741	2742525	9.741	1883827.45	1125
0.5	0.5	9.841	2829757	9.741	1883827.45	1125
0.6	0.4	9.841	2829757	9.841	1937207.88	1125
0.7	0.3	9.894	2924968	9.841	1937207.88	1125
0.8	0.2	9.955	3151608	9.841	1937207.88	1125
0.9	0.1	9.955	3151608	9.955	2174452.04	1125
1	0	9.955	9582397	9.955	8395172.73	1125

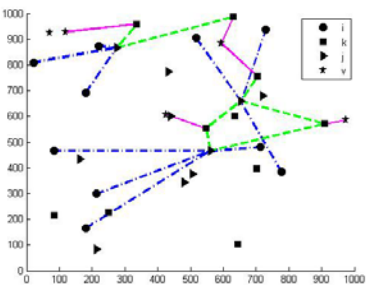
Since there are two objective functions, we consider two objectives by applying a linear combination of two objective functions using a parameter α. We also scale the first objective function by multiplying it by 10^6 to scale it into appropriate range. Fig.1 shows the results obtained in terms of the geographical locations of the facility under uncertain and indeterminate circumstances.



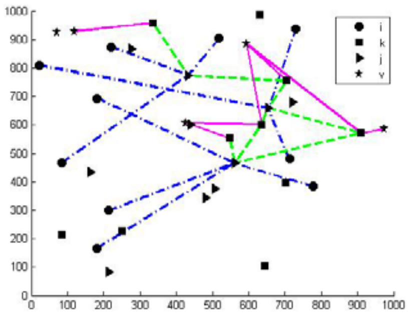
Optimal solution of uncertain model with α = 0.1



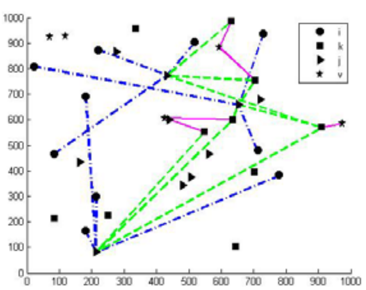
Optimal solution of determinist model with α = 0.1

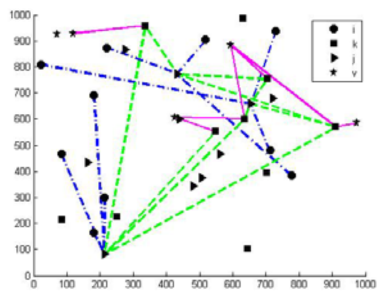


Optimal solution of uncertain model with α = 0.5



Optimal solution of deterministic model with α = 0.5





Optimal solution of uncertain model with α = 0.9 Optimal solution of deterministic model with α = 0.9

Fig. 1. The position of different locations under uncertain and deterministic model

3. Conclusion

The paper has presented a robust efficient supply chain model in terms of the distribution channels under uncertain conditions. The proposed study produces multi products using different materials by considering four layers of multiple suppliers, producers, storages and customers. There were two objectives of maximizing efficiency of distributers and minimizing total cost of supply chain management. The proposed study has implemented robust optimization technique developed by Molvey and Ruszczyński (1995) to consider various scenarios. The preliminary results have indicated that the proposed model was capable of providing efficient solutions under various uncertain conditions.

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