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A New Newsvendor Policy Model for Supply Chains by Considering Disruption Risk and Special Order in Fuzzy Mode

Ashkan Mohsenzadeh Ledari [a]

[a] *Department of Industrial Engineering, University of Science and Technology of Mazandaran, Behshahr, Iran,*

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ABSTRACT

In this paper we proposed newsvendor problem with two suppliers that first supplier channel is in priority and first supplier is replaced by second supplier. Both of supplier prone to disruption risk and we use second supplier when in first supplier disruption risk occurred. If in both supplier disruption risked occurred, we use first supplier and for difference between order and amount which response we use special order from production. Budget that is allocated for buying a product from a production, amount of product that a production of first channel can deliver to the retailer/wholesaler and percentage that is payable in case of disruption in first channel that are fuzzy numbers. For solving this model, we use Maple 16 software and did sensitivity analysis on probability of disruption risk in each channel.

1. Introduction and Literature review

In today's world, organization and manufacturing company s usually utilized several suppliers to provide for primary materials required for production, such that they consider a trustworthy supplier, which is working with them for years, as the main supplier and treat other suppliers as alternatives. And they usually utilize alternative suppliers when the primary supplier no longer has the conditions as before and/or its product quality be low and/or if it is unable to respond consumer needs. One of the most important situations in which the primary supplier may not be utilized is when the primary supplier would like not to respond consumer needs due to disruption risk. In this

[a] Corresponding author email address: ashkanmo87@gmail.com (Ashkan Mohsenzadeh Ledari).
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case, the alternative supply channel should be used to satisfy the needs. disruption -risk occurrence and the first suppliers reluctance to provide consumer requirements are probabilistic.

Yu et al. [12] proposed a newsvendor model with fuzzy price-dependent demand, and discusses the conditions to determine the optimal pricing and inventory decisions jointly so that the expected profit could be maximized. Xu and Hu [11] developed the newsvendor model for description of the uncertain demand, with random fuzzy demand that maximizes the profit. By the credibility measure of fuzzy event, the expected profit model is presented. Wang et al. [9] peresented the newsvendor does not know the price-dependent probability distribution of demand, but is able to estimate lower and upper limits of the market size and consumer willingness-to-pay. H. Tabrizi and Razmi [5] presented a supply chain network design problem because supply chains play an inevitable role in prompt handling of varying customers' needs. Administration of a successful supply chain depends on how efficiently the network design is accomplished. Shao and Ji, [13] considered the multi-product newsvendor problem with fuzzy demands under budget constraint. Ryu and Yücesan [7] consider a fuzzy approach to the newsvendor problem. They used several fuzzy parameters in the model for the demand, the wholesale price, and the market sales price. Hu et al. [6] considered a two-echelon supply chain system with one retailer and one manufacturer for perishable products that Facing to imperfect quality and fuzzy random market demand.
Chen and Ho [1] proposed an analysis method for the single-period (newsvendor) inventory problem with fuzzy demands and incremental quantity discounts.

Dutta et al. [4] presented a single-perid inventory problem in an imprecise an uncertain mixed enviroment. Chen and Ho, [2] analyzed the optimal inventory policy for the single-order newsvendor problem with fuzzy demand and quantity discounts.

Chen and Chen [3] developed a model for the multiple-item budget-constraint newsvendor problem considering a reservation policy to meet marketing needs.

Xanthopoulos et al. [10] presented a model in which there is a two-channel single-product chain, and each of the supply channels was prone to disruption independently.

Silber Mayr and Minner, [8] presented a multi-level inventory control model that was divided to two parts of ON and OFF during each period. ON shows that the supplier is available, and OFF shows that the supplier is unavailable. Deligiannis and et al [14] proposed a model of a firm sourcing non-storable substitute products from an expensive reliable supplier and an inexpensive unreliable supplier to meet a deterministic time-varying demand over a finite horizon. The unreliable supplier has a random capacity with an unknown parameter. Karmaker and et al [16] identified the SCR factors and analyzing their interactions using an integrated approach, including Pareto analysis, fuzzy theory, total interpretive structural modeling (TISM), and a Matriced' Impacts Cruises Multiplication Applique a un Classement (MICMAC) analysis. Mohsenzadeh Ledari and et al [15] investigated a newsvendor model without lead time, which have difference between distributer and wholesale/retailer. At the end of day, the residual products of newsvendor sold to a secondary market at a unit salvage value. Also, the number of orders that cannot be met, should be paid the penalty for each unit. In addition, in each one of channels, the percent of these\ orders cannot be met by the distributer.

The structure of the paper is as follows. Problem assumptions are discussed in the ‘Problem description’ section 2. In the ‘Model Definition’ section 3, the mathematical model is described and is tested in a real case in the ‘Numerical analysis Conclusion section 4. Concluding remarks are in the ‘Conclusions’ section 5.

2. Problem description

In this paper, a newsdealer model with two supply channels is represented where the newsvendor tends to meet his required merchandise from the first supply channel due to its high quality, and provides his merchandise from the second supply channel when the first supplier is not available. In this model, each supply channel consists of 5 parts including raw material supplier, producer, distributer, wholesaler/retailer, and market demand, and the newsvendor provides his required goods in each of the channels from the distributer.

The reason of first supply channels unavailability is the probability of the disruption risk occurrence, and each of the supply channels is susceptible to the disruption risk due to political factors.

So, the newsvendor acts in the manner that he first orders his goods to the first supply channel, and he would order the second supply channel if the disruption risk occurred in the first channel and the order was not met. The second channel would provide for the order if there was no disruption risk in the second supply channel, but if there existed disruption risk in the second channel and thus it could not satisfy the whole order, then the newsvendor would purchase as many goods as possible from the first supplier and the rest is satisfied in the form of special order from the producer with higher price than distributer.

The amount of order which could be satisfied from the first supply channel if disruption risk occurred, is fuzzy and it would not definitively be khown how many of that is met from it. Furthermore, the first channels production capacity, as well as the amount of budget considered for the special order, are fuzzy meaning that we donot have deterministic information about them.

At the end of the day,the newsvendor sells the remaining goods by auction and he should pay penalties for the amount of demand that he was unable to meet.

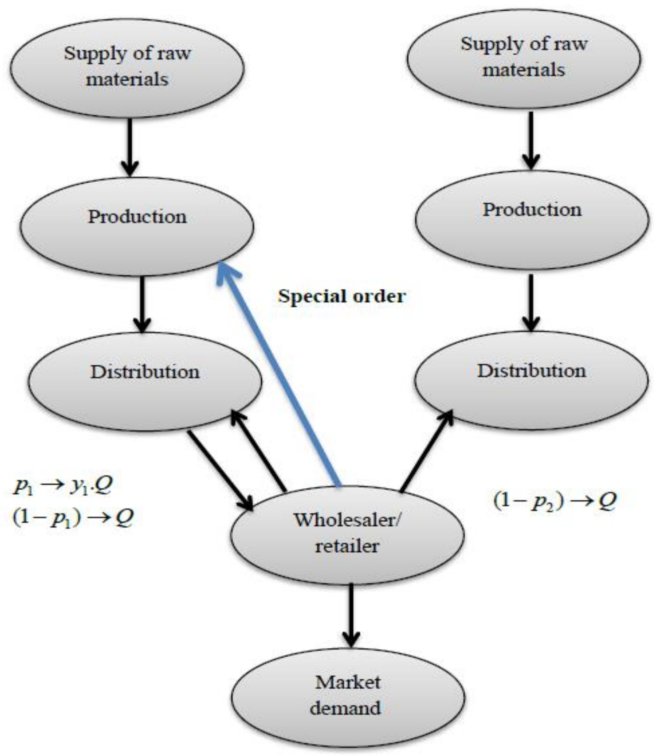

Figure.1. The two-echelon supply chain network with disruption risk

Model asumptions:

✓ using the first channel has priority,

✓ The second supply channel is the alternative for the first one,

✓ The second supply channel would be utilized if disruption risk occurred in the first supply channel,

✓ If both channels faced by the disruption, then the first channel along with the special order would be used,

✓ goods amount is Q at the beginning of the day,

✓ percentage amount of the order provision if disruption occurs, as well as the right hand side of the budget constraint for special order and production capacity of the first supply channel, are fuzzy.

3. Model Definition

x : Stochastic variable of demand that is continuous and has positive numbers, with density function $f(x)$ and cumulative distribution function $F(x)$,

p_1: probability of disruption between two levels of distributer and retailer/wholesaler in first channel,

p_2: probability of disruption between two levels of distributer and retailer/wholesaler in second channel,

s : Sale price of the product from the retailer/wholesaler to the customer ($s \geq c_1, c_2$),

c_1: Sale price of the product from the distributer in first channel,

c_2: Sale price of the product from the distributer in second channel,

$c_1^{'}$: Sale price of the product from the production in first channel ($c_1^{'} \geq c_1$),

n_1: Maximum capacity of the distributer in first channel,

n_2: Maximum capacity of the distributer in second channel,

$n_1^{'}$: Maximum capacity of the production in first channel in each special order that is fuzzy numbers. $\tilde{n}_1^{'} = (n_1^{'}, n_2^{'}, n_3^{'})$,

y_1: Demand percentage that is payable in case of disruption in first channel that is fuzzy numbers. $\tilde{y}_1 = (y_1, y_2, y_3)$,

r : salvage value for the remaining units at the end of the day,

k : Penalty for each unmet demand that $k \geq r$,

b : maximize budget considered for purchasing the product from distributer in both channels,

$b^{'}$: maximize budget considered for purchasing the product from production in special order that is fuzzy numbers $\tilde{b}^{'} = (b_1, b_2, b_3)$,

α : Minimum amount of service level,

Variable decision:

Q : Optimal amount of ordering in channel,

Objective is maximization of the profit that equals to revenue of direct sales and salvege value minuse the cost of buying and Fines shortage,

The model can be formulated as:

If there is not any disruption in any first channel:

$$G_1 : (1-p_1)(\int_0^Q (s.x - c_1 Q + r.(Q-x))f(x)dx + \int_Q^\infty ((s.Q - c_1.Q) - k.(x-Q))f(x)dx) \qquad (1)$$

If disruption occurs only in the first channel and any in secon channel:

$$G_2 : (p_1.(1-p_2))(\int_0^Q (s.x - c_2.Q + r.(Q-x))f(x)dx + \int_Q^\infty ((s.Q - c_2.Q) - k.(x-Q))f(x)dx) \qquad (2)$$

If we have disruption in both channels:

$$G_3 : (p_1.p_2)(\int_0^Q (s.x - (c_1.\tilde{y}_1.Q + c^{'}_1.(Q - \tilde{y}_1.Q)) + r.(Q-x))f(x)dx + \int_Q^\infty ((s.Q - (c_1.\tilde{y}_1.Q + c^{'}_1.(Q - \tilde{y}_1.Q)) - k.(x-Q))f(x)dx) \qquad (3)$$

And the total profit is equal to:

$$MaxG : G_1 + G_2 + G_3 \qquad (4)$$

Subject to:

1-The fifth constraint represents the minimum service level that should be more than a minimal in order to meet the customer satisfaction as:

$$\int_{0}^{Q_1+Q_2} f(x)dx \geq \alpha \qquad (5)$$

2-The limitation is related to the maximum budget that is allocated for buying a product from a distributor.

$$(1-p_1).c_1.Q + p_1.(1-p_2).c_2.Q \leq b \qquad (6)$$

3-The limitation is related to the maximum budget that is allocated for buying a product from a production.

$$(p_1.p_2).(c_1.\tilde{y}_1.Q + c'_1.(Q-\tilde{y}_1.Q)) \leq \tilde{b}' \qquad (7)$$

4-The limitation is related to the maximum amount of product that a distributer of first channel can deliver to the retailer/wholesaler.

$$(1-p_1).Q \leq n_1 \qquad (8)$$

5-The limitation is related to the maximum amount of product that a distributer of second channel can deliver to the retailer/wholesaler.

$$p_1.(1-p_2).Q \leq n_2 \qquad (9)$$

6-The limitation is related to the maximum amount of product that a production of first channel can deliver to the retailer/wholesaler.

$$p_1.p_2(Q-\tilde{y}_1.Q) \leq \tilde{n}'_1 \qquad (10)$$

7- The order amount have positive value.

$$Q \geq 0 \qquad (11)$$

After de fuzzification we have:

$$Max:(1-p_1)(\int_0^Q (s.x-c_1Q+r.(Q-x))f(x)dx+\int_Q^\infty ((s.Q-c_1.Q)-$$
$$k.(x-Q))f(x)dx)+(p_1.(1-p_2))(\int_0^Q (s.x-c_2.Q+r.(Q-x))f(x)dx$$
$$+\int_Q^\infty ((s.Q-c_2.Q)-k.(x-Q))f(x)dx)+(p_1.p_2)$$
$$(\int_0^Q (s.x-(c_1.y_1.Q+c'_1.(Q-(\frac{y_1+4y_2+y_3}{6}).Q))$$
$$+r.(Q-x))f(x)dx+\int_Q^\infty ((s.Q-(c_1.(\frac{y_1+4y_2+y_3}{6}).Q+$$
$$c'_1.(Q-(\frac{y_1+4y_2+y_3}{6}).Q))-k.(x-Q))f(x)dx) \tag{12}$$

Subject to:

$$\int_0^Q f(x)dx \geq \alpha) \tag{13}$$

$$(1-p_1).c_1.Q+p_1.(1-p_2).c_2.Q \leq b \tag{14}$$

$$(p_1.p_2).(((\frac{y_1+4y_2+y_3}{6}))(c_1.Q-c'_1.Q)+c'_1.Q) \leq \frac{b_1+4b_2+b_3}{6} \tag{15}$$

$$(1-p_1).Q \leq n_1 \tag{16}$$

$$p_1.(1-p_2).Q \leq n_2 \tag{17}$$

$$p_1.p_2.Q-p_1.p_2.(\frac{y_1+4y_2+y_3}{6}).Q) \leq \frac{n'_1+4n'_2+n'_3}{6} \tag{18}$$

$$Q \geq 0 \tag{19}$$

4. Numerical analysis

For solving such a model we need some optimization software as Math CAD, Maple etc. We use software of maple 16 for achieving the optimum amount of objective function.

The number of demands is imposed on wholesaler/retailer from customers has a uniform distribution in the range of (0-1000) that its dense function is $\frac{1}{1000}$, with the means of 500 and variance of 8333.33. Data related to numerical solving of model has been produced in random manner.

Table 1. Data for solving model

n_1	n_2	p_1	p_2	s	c_1	c_2	$c_1^{'}$	α	b	r	k
700	700	0.8	0.1	50	12	11	25	0.2	3000	10	15

$$\tilde{y}_1 = (y_1, y_2, y_3) = (0.5, 0.8, 0.9)$$

$$\tilde{n}_1^{'} = (n_1^{'}, n_2^{'}, n_3^{'}) = (300, 400, 600)$$

$$\tilde{b}^{'} = (b_1, b_2, b_3) = (1400, 1800, 2200)$$

After solving decision variables and objective function value are equal to:

$$Q = 290.697$$
$$G = 5743.4784$$

For sensetivity analysis we change value of p_1 and p_2 and show that,that parameters What influence have on amount of order and benefit.

Data for sensitivity analysis:

Table 2. Data for sensitivity analysis

n_1	n_2	p_1	p_2	s	c_1	c_2	$c_1^{'}$	α	b	Q	G
700	700	0.8	0.1	50	12	11	25	0.2	3000	29.0697	5743.478
700	700	0.7	0.1	50	12	11	25	0.2	3000	284.900	5504.765
700	700	0.6	0.1	50	12	11	25	0.2	3000	279.329	5273.7617
700	700	0.5	0.1	50	12	11	25	0.2	3000	273.972	5050.115
700	700	0.4	0.1	50	12	11	25	0.2	3000	268.817	4833.495

Table 3. Data for sensitivity analysis

n_1	n_2	p_1	p_2	s	c_1	c_2	c_1'	α	b	Q	G
700	700	0.8	0.1	50	12	11	25	0.2	3000	290.6976	5743.478
700	700	0.8	0.2	50	12	11	25	0.2	3000	317.796	6666.728
700	700	0.8	0.3	50	12	11	25	0.2	3000	350.467	7732.467
700	700	0.8	0.4	50	12	11	25	0.2	3000	374.168	8440.644
700	700	0.8	0.5	50	12	11	25	0.2	3000	299.334	5771.939

By using of Kuhn-Tucker method, it can be shown that the optimum amount of ordering has necessary condition of optimization and also by using of gradient in the second degree, it is shown that the model of problem is concave programming so it has sufficient condition for optimization and consequently the considered points are global optimum. At first the objective function should to multiply negative.

$$-G = -0.0262333333Q^2 - 0.04948Q.(1000-Q) + 7500 - 0.0039973333Q.(1000-Q)$$

$$\frac{\partial^2(-G)}{\partial Q} = 0.05448800001$$

Subject to:

$$0.2 \le 0.001.Q$$
$$0.01866667.Q \le \frac{1250}{3}$$
$$1.2026666.Q \le 1800$$
$$10.32.Q \le 3000$$
$$0.2.Q \le 700$$
$$0.72.Q \le 700$$

All constrain are linear.

So $(-G)$ is covex programming and G is concave programming and point obtained is the global optimum.

5. Conclusion

In this paper, a newsvendor model has been solved to maximized the profit.this model has a primary supplier-which is trustworthy and its products are of high quality-and an alternative supplier which would be used if disruption risk occurred in the first channe.moreover, both channels are susceptible to disruption risk, and if both channels suffer from the disruption risk, then only the first supply channel along with the special order will be utilized. The amount of the order provision in the first channel, as well as special order budget and the producers capacity for special order in the first channel, are fuzzy.

It could be concluded that existence of the alternative supply channel would lead to decreased effect of the disruption risk in the chain.

After solving the model, we found that increased probability of the disruption risk incidence in each of the supply channels leads to increased order quantity because increased order quantity would reduce the losses from un-met orders and from the penalties, as well as it would increase the profit.

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