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# Using Fuzzy Supply Chain Management in Food Industry

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***Abstract* – There are a number of distinct elements of uncertainty and complex interrelationships among various entities in a supply chain system; as a result, most of the time, it is very difficult to govern a supply chain appropriately. Furthermore, a supply chain becomes even more complicated when a new product is being released, thus customers' demand will be more unpredictable due to lack of historical data. To cope with it and similar problems, in this paper, fuzzy set theory applied to capacity allocated to each product has been utilized to handle supply chain uncertainties. Moreover, three levels of supply chain including manufacturers, distributers, and retailors have been considered. Maple software has been used to run the model and obtain feasible solutions. The proposed approach helps decision makers to reduce costs in a supply chain and improve inventory management strategies in food industry.**

***Keywords* – Customers' Demand, Fuzzy Set Theory, Capacity Allocated to Each Product, Fuzzy Supply Chain Model, Inventory Management Strategies.**

## I. Introduction

Business enterprises have been considering supply chains to enhance customer service levels and decreasing inventory costs, due to the heightening competition in todays' global market in the last few decades. A supply chain (SC) is an integrated process where various types of business entities including suppliers, manufacturers, distributors, and retailors work together in order to manufacture products from raw materials and deliver these products to customers [1].

Handling an appropriate supply chain is challenging due to various factors of uncertainty and complex interrelations at different levels that exist in the supply chain [2]. Furthermore, deducting product life cycle and increased consumer's expectations have also made the supply chain even harder to handle, specifically for innovative products. Although newest products may result in gaining more profit margins for a company, demand will be more unpredictable, since no historical data is available [3]. Different papers have been published for developing supply chain inventory strategies to model supply chain uncertainty such as demand by probability distribution which is usually predicted from historical data [4-16]. However, the stochastic models may not be a practical solution for addressing the problem of uncertainty [17], specifically when statistical data is unreliable or unavailable [18]. Bellman and Zadeh [19] used fuzzy approach to consider the idea of fuzzy method and decision making theory. Lai and Hwang [20] could propose the model and situation in which all the parameters would be fuzzy. Fuzzy set theory [21] may support an alternative approach to cope with the supply chain uncertainty. A few articles conducted researches about using fuzzy set theory in managing supply chain inventory strategies [22-30]. Petrovic et al. [25, 26] developed a model consisting of uncertain demand and supplier's reliability with fuzzy set theory. Giannoccaro et al. [27] developed a supply chain inventory policy utilizing the periodical review policy based on the concept of fuzzy echelon stocks in order to minimize inventory holding cost on the serial supply chain. Moreover, Carlsson and Fuller [31] proposed a fuzzy logic approach to decrease the bullwhip effect [22] due to demand distortion. Chanas et al. [32] used parametric programming method for solving the transportation model including fuzzy demands and supplies according to criterions Bellman and Zadeh [19] suggested.

There are several sources of uncertainty such as supplier performance, manufacturing process, and customer demand [5]. However, no published paper has considered capacity allocated to each product in a distributor or retailors which may be uncertain specifically when demand is highly fluctuated or is related to the new product that there is no available historical data. In other words, it is obvious that demand can change throughout a year due to different reasons including releasing a new product or seasonality; as a result, due to constrain of fixed total capacity of a distributor or a retailor, need of allocating different capacity to each product is a prominent factor to reduce the costs in a supply chain or reducing lost sales. Neglecting this factor may result in increasing different types of cost including holding cost, spoilage cost, fixed cost, and price. It is worth mentioning that capacity for each product cannot be fixed and it changes throughout a year because demand is not constant so it may be uncertain in many distributors and retailers. To cope with this uncertainty, in this paper, a supply chain model has been developed for 3 levels of manufacturer, distributor, and retailor by considering fuzzy logic approach applied to capacity allocated to each product in distributors and retailers. Furthermore, proposed fuzzy supply chain model aims to reduce holding cost, spoilage cost, and fixed cost. Consequently, assigning manufacturers to each distributor and each distributer to each retailer is considered as long as optimal demand that should be satisfied in each distributor and each retailor has been generated.

## II. Fuzzy Supply Chain Model

The scope of this paper is to propose a supply chain model that includes fuzzy set theory applied to capacity of each product in a distributor and a retailer in order to address the problem of uncertainty of capacity allocated to each product. It is obvious that demand could be highly fluctuated in many cases; as a result, considering a practical scenario for satisfying demand effectively as long as the costs are minimized are crucial points that many industries have been always considered. To cope with fluctuated demand, the capacity allocated to each product in fuzzy environment has been considered in this article. In other words, using fuzzy approach leads to better estimation of each product needed to be stored in distributors or retailors to prevent lost sales and spoilage in food industry efficiently. The proposed traditional model is useful to permit decision makers to understand and analysis their risk attitudes to evaluate supply chain performances and elect an appropriate supply chain inventory strategy in distributor and retailer which may reduce the supply chain costs including holding cost, spoilage cost, fixed cost, and price.

### 2.1. *Modeling the Supply Chain*

The proposed fuzzy supply chain model consists of 3 levels of manufacturer, distributer, and retailer related to a food industry that performs the functions of shipping products from manufacturers to distributers and distributers to retailers. Different indexes and parameters have been considered in this model that is illustrated in this paper. We assumed that there are different costs including holding cost, spoilage cost, fixed cost, and price. Moreover, products can be supplied from different manufacturers. We also assumed that demand is not constant and in order to prevent lost sales and reduce inventory and transportation cost we need to specify appropriate capacity for each product in each distributer and retailer. Since demand is highly fluctuated, the appropriate capacity allocated to each product cannot be the same so we used capacity for each product in fuzzy environment.

#### 2.1.1. *Index Sets*

L = Index for manufacturer, for all l=1,2,...,t
J= Index for distributer, for all j= 1, 2,…, u
N= Index for retailer, for all K=1,2,…, s
P= Index for product, for all p=1,2,…,w

#### *2.1.2. Parameters*

$K_{pjl}$= Purchase price of product P which is transferred from manufacturer L to distributer J.
$N_{pj}$= Cost of spoilage for each product P in distributer J.
$N_{pn}$= Cost of spoilage for each product P in retailer N.
$H_{pn}$= Holding cost for each product P in retailer N.
$\Delta_{pj}$= Capacity allocated to product P in distributer J.
$\Delta_{pn}$= Capacity allocated to product P in retailer N.
$D_{pj}$=Demand of product P in distributer J.
$D_{pn}$=Demand of product P in retailer N.
$C_j$=Fixed cost of distributer J.

#### 2.1.3. *Decision Variables*

$S_{lj}$=If manufacturer L ships a product to distributer J (0-1).
$F_{jn}$=If distributer J ships a product to retailer N (0-1).
$W_j$= If distributer J is established (0-1).
$Z_{plj}$= Number of product P transferred from manufacturer L to distributer J.
$X_{pjn}$= Number of product P transferred from distributer J to retailer N.

#### 2.1.4. *Proposed Model*

The objective of the proposed model is to develop a supply chain model in which capacity allocated to each product has been considered in fuzzy environment. This model is useful to minimize total cost including holding cost, spoilage cost, fixed cost, and price in a supply chain.

Fuzzy set theory is employed to present the fluctuated capacity for each product in 3 levels. Accordingly, the objective function of the proposed model is as follow:

$$MIN\ Z\ = V$$

$$\sum_j C_J W_J + \sum_p \sum_l \sum_j Z_{plj}(K_{plj}) \quad (1)$$

$$+\sum_j \sum_p N_{pj}\left(\sum_l Z_{plj} - \sum_n X_{pjn}\right) \quad (2)$$

$$+\sum_j \sum_p H_{pj}\left(\sum_l Z_{plj} - D_{pj}\right) \quad (3)$$

$$+\sum_p \sum_n H_{pn}\left(\sum_n X_{pjn} - D_{pn}\right) \quad (4)$$

The constrains are as follows:

$$W_j \ge S_{lj} \quad (5)$$

$$W_j \ge F_{jn} \quad (6)$$

$$\tilde{\Delta}_{pn}\, W_j \ge \sum_p X_{pjn} \quad ,\forall\, j, n \quad (7)$$

$$\tilde{\Delta}_{pj}\, W_j \ge \sum_p Z_{plj} \quad ,\forall l, j \quad (8)$$

$$X_{pjn} \le \tilde{\Delta}_{pn}.F_{jn} \quad (9)$$

$$Z_{plj} \le \tilde{\Delta}_{pj}.S_{lj} \quad (10)$$

$$\sum_n X_{pjn} \le \sum_l Z_{plj} \quad ,\forall p, j \quad (11)$$

$$\sum_j \sum_p X_{pjn} \ge \sum_p D_{pn} \quad (12)$$

$$\sum_i \sum_p Z_{plj} \ge \sum_p D_{pj} \quad (13)$$

$$F_{jn}, S_{lj}, W_j \in \{0,1\} \quad (14)$$

$$X_{pjn}, Z_{plj} \ge 0 \quad (15)$$

## III. Solution Procedure

In order to compute the lower limit of the objective function and the upper limit of the objective function, equation 16 and 19 has been considered [33].

$$MinZ = \sum_j C_j X_j \quad (16)$$

$st.$

$$\sum_j a_{ij}.X_j \leq \tilde{\Delta_i} \qquad i = 1,...,m \quad (17)$$

$$X_j \geq 0 \qquad \forall\, j \quad (18)$$

$$Min\beta \quad (19)$$

$s.t$

$$\beta(Z_u - Z_l) - CX \leq -Z_l \quad (20)$$

$$\beta p_i + \sum_j a_{ij} X_j \leq b_i + p_i \qquad \forall i \quad (21)$$

$$\beta \geq 0 \quad , \quad x_j \geq 0 \qquad \forall j \quad (22)$$

As a result, the upper limit of the objective function (Zu) will be:

Min $Z_u$=V

s.t (5), (6), (11), (12), (13), (14), (15)

$$Z_{plj} \leq (\Delta_{pj} + R_{pj}) S_{lj} \quad (14)$$

$$X_{pjn} \leq (\Delta_{pn} + R_{pn}) F_{jn} \quad (15)$$

$$\sum_p \sum_l Z_{plj} \leq \sum_p \Delta_{pj} \quad (16)$$

$$\sum_p \sum_n X_{pjn} \leq \sum_p \Delta_{pn} \quad (17)$$

And the lower limit of the objective function ($Z_l$) will be:

Min $Z_l$=V

s.t (5), (6), (11), (12), (13), (14), (15)

$$Z_{plj} \leq \Delta_{pj} S_{lj} \quad (18)$$

$$X_{pjn} \leq \Delta_{pn} F_{jn} \quad (19)$$

$$\sum_l \sum_p Z_{plj} \leq \sum_p \Delta_{pj} \quad (20)$$

$$\sum_n \sum_p X_{pjn} \leq \sum_p \Delta_{pn} \quad (21)$$

Consequently, by inserting main objective function into Min $Z_u$ and Min $Z_l$, the model will be transformed into mixed integer programming from fuzzy mixed integer programming and can be solved in Maple software.

## IV. Numerical Example And Result

As a case study, we considered 3 different products, 3 manufacturers, 3 distributers and 3 retailors. We ran the model on Maple software and could obtain feasible solutions by including decision variables below:

$S_{lj}$=If manufacturer L ships a product to distributer J (0-1).
$F_{jn}$=If distributer J ships a product to retailer N (0-1).
$W_j$= If distributer J is established (0-1).
$Z_{plj}$= Number of product P transferred from manufacturer L to distributer J.
$X_{pjn}$= Number of product P transferred from distributer J to retailer N.

P=3, i=3, j=3, n=3, w1=w2=w3=1

S11=S12=S21=S22=S31=S32=F22=F31=1, X213=20500, X221=3000, X222=20000, X231=4500, X313=20500, X321=30000, X322=20000, X331=4500, Z111=41000, Z112=20000, Z113=9000, $Z_U$=22382700

S11=S12=S21=S22=S31=S32=1, X213=16800, X221=5000, X222=9000, X232= 1333, X313= 11200, X321=5000, X322=9000, X332=667, Z111=28000, Z112=10000, Z113=2000, $Z_L$=14243000

X213=18650, X221=4000, X222=14500, X232=667, X313=15850, X321=4000, X322=14500, X332=334, Z111=34500, Z112=15000, Z=18312850, **β**=0.610

## V. Conclusion

Supply chain models have various applications in industries specially in decreasing cost in a system. Since demand would be fluctuated due to different reasons such as seasonality and releasing a new product, an appropriate policy to adopt in order to reduce the total cost as long as the lost sales is low plays a prominent role in each supply chain system. One important parameter which can help the system to gain the mentioned goal would be capacity allocated to each product. However, due to fluctuated demand, an appropriate capacity for each product is hard to predict; as a result, we used fuzzy approach to solve the problem of ambiguity of capacity allocated to each product. The objective function was considered as minimizing the total cost including holding cost, spoilage cost, fixed cost, and price. The model is run by Maple software and meaningful outcomes have proved that applying fuzzy logic is feasible and more practical in comparison with the convenient methods. The results represent optimal number of each product to be shipped from each manufacturer to each distributor, and the optimal number of each product to be shipped from each distributor to each retailor. The results also showed upper limit of Z and lower limit of Z in order to be compared with optimal Z.

## References

[1] D. Simchi-Levi, P. Kaminsky, E. Simchi-Levi, “Designing and managing the supply chain: concepts, strategies, and case studies”, McGraw-Hill, New York, 2000.
[2] M. Momeni Tabar, N. Akar, D. Zaghi, H. R. Feili, M. Ghaderi, “Fuzzy mathematical modeling of distribution network through location allocation model in a three-level supply chain design”, Journal of Mathematics and Computer Science, Vol. 9 (3), pp. 165 – 174, 2013.
[3] M.L. Fisher, “What is the right supply chain for your product”, Harvard Bus., Rev., Vol. 75, pp. 105–116, 1997.
[4] S.M. Sajjadi, A.S. Yazdankhah, F. Ferdowsi, “A new gumption approach for economic dispatch problem with losses effect based on valve-point active power”, Electric Power Systems Research, Vol. 92, November 2012, pp. 81-86, ISSN 0378-7796.
[5] H.L. Lee, C. Billington, “Material management in decentralized supply chain”, J. Oper. Res., Vol. 41 (5), pp. 835–847, 1993.
[6] F. Ferdowsi, A. S. Yazdankhah, H. Rohani, “A combinative method to control output power fluctuations of large grid-

International Journal of Engineering Innovation & Research
Volume 5, Issue 3, ISSN: 2277 – 5668

connected photovoltaic systems", Environment and Electrical Engineering (EEEIC), 2014 14th International Conference on, Krakow, 2014, pp. 260-264.
[7] arXiv:1604.06691 [cs.SY].
[8] F. Ferdowsi, C.S. Edrington, T. El-mezyani, "Real-time stability assessment utilizing non-linear time series analysis", North American Power Symposium (NAPS), Charlotte, NC, 2015, pp. 1-6.
[9] H.L. Lee, C. Billington, "The evolution of supply-chain-management models and practice at Hewlett-Packard", J. Interfaces, Vol. 25 (5), pp. 42–63, 1995.
[10] D.J. Thomas, P.M. Griffin, "Coordinated supply chain management", Eur. J. Oper. Res., Vol. 94 (1), pp. 1–15, 1996.
[11] F. Ferdowsi, C. S. Edrington, T. El-mezyani, "Small signal stability assessment in power electronic-based components", 2015 FREEDM Systems Center Annual Industry Review and Conference, Raleigh, NC, Jan 2015.
[12] C.J. Vidal, M. Goetschalckx, "Strategic production-distribution models: a critical review with emphasis on global supply chain models", Eur. J. Oper. Res., Vol. 98 (1), pp. 1–18, 1997.
[13] B.M. Beamon, "Supply chain design and analysis: models and methods", Int. J. Prod. Econom., Vol. 55, pp. 281–294, 1998.
[14] S.C. Graves, S.P. Willems, "Optimizing strategic safety stock placement in supply chains", J. Manuf. Service Oper. Manage., Vol. 2 (1), pp. 68–83, 2000.
[15] F. Cheng, M. Ettl, G. Lin, D.D. Yao, "Inventory-service optimization in configure-to-order systems", J. Manuf. Service Oper. Manage., Vol. 4 (2), pp. 114–132, 2002.
[16] M. Goetschalckx, C.J. Vidal, K. Dogan, "Modeling and design of global logistics systems: a review of integrated strategic and tactical models and design algorithms", Eur. J. Oper. Res., Vol. 143 (1), pp. 1–18, 2002.
[17] H. R. Feili, S. Nasiri, and N. Akar, "Integrating risk management and value engineering in the development of Renewable energy project", 6th International Symposium on Advances in Science and Technology, Malaysia, 2012.
[18] H. R. Feili, N. Akar, H. Lotfizadeh, M. Bairampour, S. Nasiri, "Risk analysis of geothermal power plants using failure modes and effects analysis (FMEA) technique", Energy Conversion and Management, Vol. 72, pp. 69-76, 2013.
[19] R. Bellman, L.A. Zadeh, "Decision making in a fuzzy environment", J. Management Sci. Vol. 17 (B), pp. 141-164, 1970.
[20] Y.J. Lai, C.L. Hwang, "Fuzzy mathematical programming methods and application", Springer, Berlin, 1992.
[21] L.A. Zadeh, "Fuzzy sets as a basis for a theory of possibility", J. Fuzzy Sets and Systems, Vol. 1 (1), pp. 3–28, 1978.
[22] H.L. Lee, V. Padmanabhan, S. Whang, "Information distortion in a supply chain: the bullwhip effect", J. Manage. Sci., Vol. 43, pp. 546–558, 1997.
[23] Z. Michalewicz, "Genetic Algorithms+ Data Structures=Evolution Programs", Springer, Berlin, 1992.
[24] D. Petrovic, "Simulation of supply chain behaviour and performance in an uncertain environment", Int. J. Prod. Econ., Vol. 71 (1–3), pp. 429–438, 2001.
[25] D. Petrovic, R. Roy, R. Petrovic, "Modelling and simulation of a supply chain in an uncertain environment", Eur. J. Oper. Res., Vol. 109 (1), pp. 200–309, 1998.
[26] D. Petrovic, R. Roy, R. Petrovic, "Supply chain modeling using fuzzy sets", Int. J. Prod. Econom., Vol. 59 (1–3), pp. 443–453, 1999.
[27] I. Giannoccaro, P. Pontrandolfo, B. Scozzi, "A fuzzy echelon approach for inventory management in supply chains", Eur. J. Oper. Res., Vol. 149 (1), pp. 185–196, 2003.
[28] M. Rakhshan, N. Vafamand, M. Shasadeghi, M. Dabbaghjamanesh, A. Moeini, "Design of networked polynomial control systems with random delays: sum of squares approach". International Journal of Automation and Control, Vol. 10 (1), pp. 73-86, 2016.
[29] M. Dabbaghjamanesh, A. Moeini, M. Ashkaboosi, P. Khazaei, K. Mirzapalangi, "High performance control of grid connected cascaded H-Bridge active rectifier based on type II-fuzzy logic controller with low frequency modulation technique", International Journal of Electrical and Computer Engineering (IJECE), Vol 6(2), 2015.
[30] P. Khazaei, S.M. Modares, M. Dabbaghjamanesh, M. Almousa, A. Moeini, "A high efficiency DC/DC boost converter for photovoltaic applications", International Journal of Soft Computing and Engineering (IJSCE), Vol. 6 (2), 2016.
[31] C. Carlsson, R. Fuller, "Reducing the bullwhip effect by means of intelligent, soft computing methods", in: Proc. thirty-fourth Hawaii Int. Conf. on System Sciences (HICSS-34), Island of Maui, Hawaii, USA, January 3–6, 2001.
[32] S. Chanas, D. Kuchta, "Fuzzy integer transporting problem", J. Fuzzy Sets and Systems, Vol. 98, pp. 291- 298, 1998.
[33] H.J. Zimmermann, "Fuzzy set theory and its applications", Kluwer Academic Publishers, Boston, 1991.

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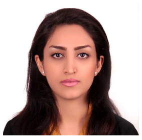

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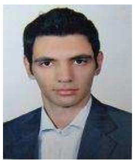

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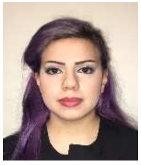

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