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EMPLOYMENT OF ADVANCED APPROACH TO CONTROL INVENTORY LEVEL BY MONITORING SAFETY STOCK IN SUPPLY CHAIN UNDER UNCERTAIN ENVIRONMENT

Abstract:

In order to overcome uncertainty situation and inability to meet with customers' demand due to uncertainty, the organizations tend to keep a certain safety stock level. In this paper, the researcher used soft computing to identify optimal safety stock level (SSL), the fuzzy model uses dynamic concept to cope with high complexity environment status and control the inventory. The proposed approach deals with demand stability level, raw material availability level, and on hand inventory level by using fuzzy logic to obtain SSL. In this approach, demand stability, raw material, and on hand inventory are described linguistically and treated by inference rules of fuzzy model to extract best level of safety stock. The numerical dairy industry case study was applied with yogurt 200 gm cup product.

Keywords:

Inventory optimization, soft computing, safety stock optimization, dairy industries, inventory optimization.

JEL Classification: C63

1. Introduction

Safety stock considered an effective tool which is used to protect against the fluctuation in demand and supply, these fluctuations occurred according to uncertainty conditions of organizations [1].

The inventory management considered one of the most important tools in the hands of managers to efficiently control the performance of a supply chain. So, it is very important to develop approaches and models to control inventory which is characterized with enough flexibility and high respond ability to the dynamic real life of the current markets [2]. Therefore, the inventory managers always try to obtain optimal inventory level in order to minimize financial loss. A shortage occurring in the supply of raw material may lead to disruption, and as a result, failure to meet with customer demand. The main objective of inventory control is to make a tradeoff off between the total cost minimization and maximization of the customer demand satisfaction [3].

Keeping of a suitable level of safety stock is an important part of customer service. An insufficient level of safety stock means that firms fail to meet with customer demand [4].

Many organizations and supply chains work under pressure to present high service level to customer while keeping low inventory levels. Simultaneously, the supply chain exposes to different risks types, such as demand uncertainty, supply uncertainty, yields uncertainty, lead times uncertainty, and natural disasters [5].

In order to cope with this uncertainty status of in inventory, safety stocks are held to protect against ambiguity conditions [6].

The models of inventory control in different researches and textbooks assume that the demand distribution and its other parameters is known, while in the applied area this assumption is not available [1].

2. Literature review

The literature review of safety stock (SS) is sizable and there are different researches and papers related. We refer readers to Graves (2000) who develop a general framework which used to model strategic safety stock level in a supply chain based on demand uncertainty. The main assumptions of this framework were guaranteed service time (GST), periodic review base stock inventory, and bounded demand. The application of the proposed model helped the company (Kodak) to reposition inventories in its internal supply chain to reduce inventory level and also increase the service performance where the proposed model presented solutions by identifying SSL in a few strategic places rather than putting SS along the supply chain [7].

A safety stock model in multi-echelon supply chain based on demand and lead time uncertainty was developed by (H. Osman and K. Demirli in 2012) [8]. The supply chain contains multi-source storage which faces disrupted demand and lead time. Two models were proposed, a decentralized model which identifies safety stock for each stock point in order to face lead time demand of it subsequent node and an consolidation model that finds and maintains safety stock in s specific center at each echelon. After the application of the proposed models on the case study, they found that the second model (consolidation model) leads to reduction in the amount of safety stock by 45.2–62% and this led to a reduction in the cost with a ratio of 22.2-44.2% compared to the first model [8].

The use of fuzzy logic in the calculation of SS is considered a rare research. H. R. Rezaei in 2012 developed model which was able to calculate SS. The proposed model presents a general framework that is used to identify safety stock level by using fuzzy logic [9].

N. G. Hua and S. P. Willems proposed a model to optimize safety stock in two echelon supply chain based on guaranteed service approach (GSA). They applied an analytical model to show the impact of holding cost and lead time on safety stock cost. The researchers employed two important concepts to analyze the results, these are cost allocation and lead time allocation, after a series of mathematical experiments and taking different values for these two concepts, the researcher concluded that it is impossible to put the SS at the upstream zone [10].

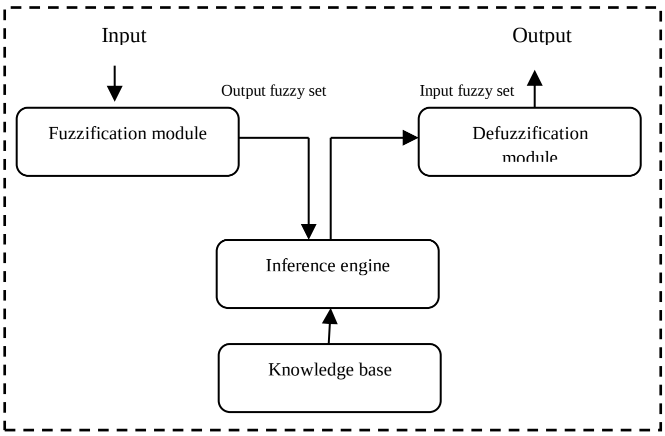
The integration of strategic safety stock and tactical lot sizing model was presented by [11], where these two variables are optimized independently. The integrated model was developed to minimize production and inventory costs based on meeting service-level predefined of customers demand [11].

3. Fuzzy logic

Fuzzy logic is an extension of multi-valued logic whose objective is approximate reasoning rather than exact solution. In conventional crisp logic, it is like binary logic where all variables must take only truth values, which are true or false represented by 1 and 0, respectively, while the variables in fuzzy logic will take a range of values that is ranging in belonging degree between 0 and 1 [12].

As shown in Fig. 1, fuzzy logic system consists of four modules. First, the fuzzification module which is used to transforms crisp inputs to fuzzy sets by using different shapes of membership functions. The second module is a knowledge-base storage which contains the IF-THEN rules. The third module is the inference engine that is used to conclude the required and fired rules, Finally, the defuzzification stage module which obtains the required output by transforming the fuzzy values of fuzzy sets [13].

Fig. 1 Fuzzy logic components [12]



4. Proposed model

The proposed model which is used to identify safety stock in a supply chain consisting of the following steps:

Step (1): Identification of (N) dynamic factor.

Step (2): Identification of period specification (PS) factor.

Step (3): Identification of demand stability level.

Step (4): Identification of raw material availability level.

Step (5): Identification of on hand inventory level.

Step (6): Identification of unique output (safety stock level)

Detailed description of the steps of the proposed model.

Step (1): Identification of (N) dynamic factor.

In this step, it is important to identify (N) dynamic factor which is used to describe the behavior of demand level in a specific month and this lead to more control on demand variation, (N). The dynamic factor is calculated by following the steps below:

Identification of demand level for the product for the first time period (day) D(i,j).

Identification of demand level for the second time period (day) D(I,j+1).

Identification of increasing or decreasing demand rate between these two adjacent sub periods numerically.

Repeat steps (a-c) for all main time horizons (months).

Building a table represents (N) dynamic factor for each month.

Step (2): Identification of period specification (PS) factor.

This step is crucial in the proposed model where it represent the ratio in which the level of safety stock will be identified. The steps below are followed to identify this factor:

Identify maximum, middle, and minimum values for each product sales at each period of time (T)

Classify the year into three main parts which are peak demand, normal demand, and low demand; corresponding to maximum, middle, and minimum of step a, respectively.

Identify ratio of safety stock level as the maximum value of universe of discourse of output variable, as shown in Table 1 below.

Table 1 Period specification values

No	Peak period	Normal period	Weak period
1	30% Dcurrent day	20% Dcurrent day	10% Dcurrent day

Step (3): Identification of demand stability level.

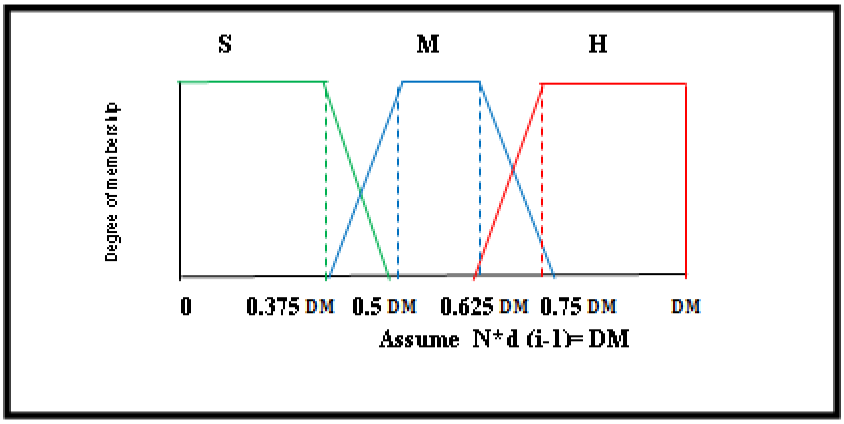
The fuzzy logic used has three input variables which are demand stability level, raw material availability, and on hand inventory level and one output (safety stock level). The demand stability level plays crucial in the proposed model. The uncertainty of demand is embedded in this approach by following the steps below:

a) Building a membership function set for the demand stability level to describe the status of the demand stability level, as shown in Fig. 2.

b) Identify the maximum value of universe discourse of current day (D(i)) by multiplying the (N) dynamic factor which was obtained from step (1) by the demand of the previous day (D(i-1)).

c) Input of value of demand of current month (D(i)).

Figure (2) fuzzy set of demand stability level



Step (4): Identification of raw material availability level.

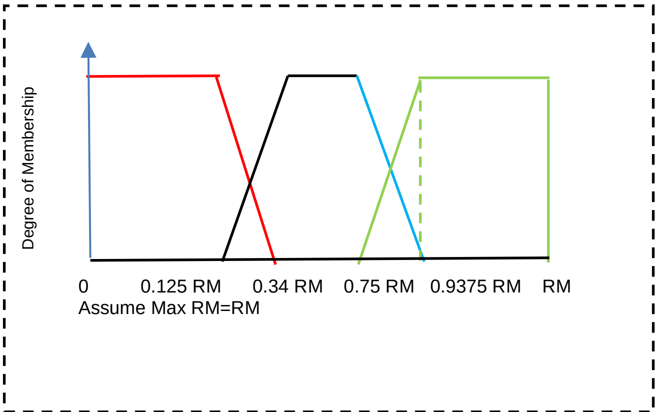
Raw material availability is a second variable of the proposed model. Unavailability of raw material leads to the unfulfillment in meeting customer demand. The steps below explain how this variable was embedded in the model.

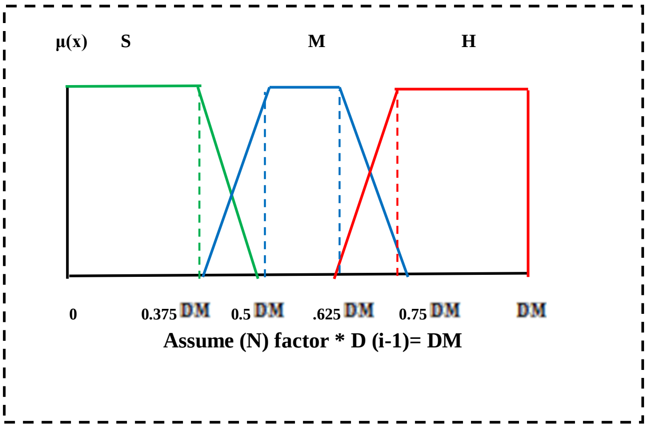
a) Use of membership functions to describe raw material availability level, as shown in Fig. 3.

b) Identifying maximum value and minimum values of raw material availability to represent universe of discourse of this variable.

c) Input daily value of raw material availability current day (D(i)).

Fig. 3 Fuzzy set of availability of raw material.





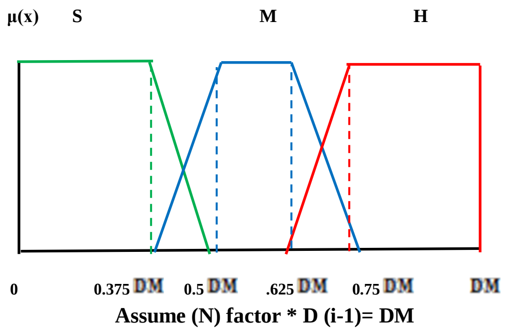
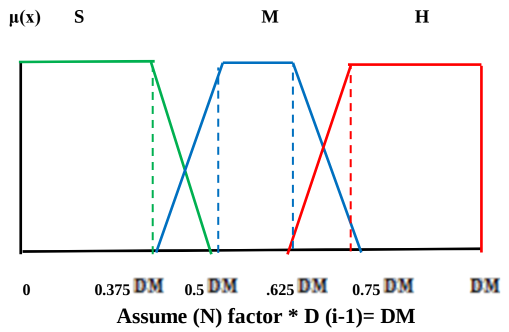


Fig. 2 Fuzzy set of demand stability level



Step (5): Identification of on hand inventory level.

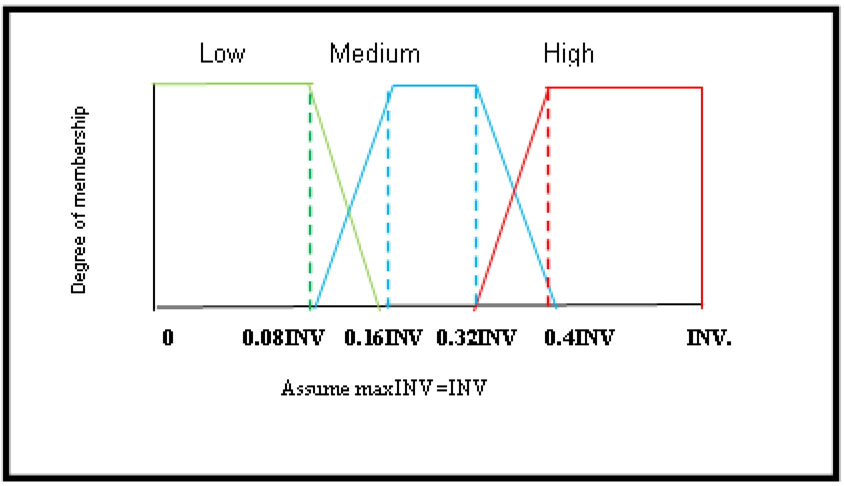
Finally, the level of on hand inventory is an important element and must be taken into consideration in order to identify SSL. Next steps describe how on hand inventory was employed in the proposed model:

a) Building a set of membership functions to describe the status of on hand inventory, as shown in Fig. 4.

b) Identifying the maximum value and minimum values of on hand inventory to represent universe of discourse of the variable.

c) Input of daily value of on hand current day inventory (D(i)) and this value is also changed daily.

Fig. 4 Fuzzy sets of inventory level.



Step (6): Identification of unique output (safety stock level)

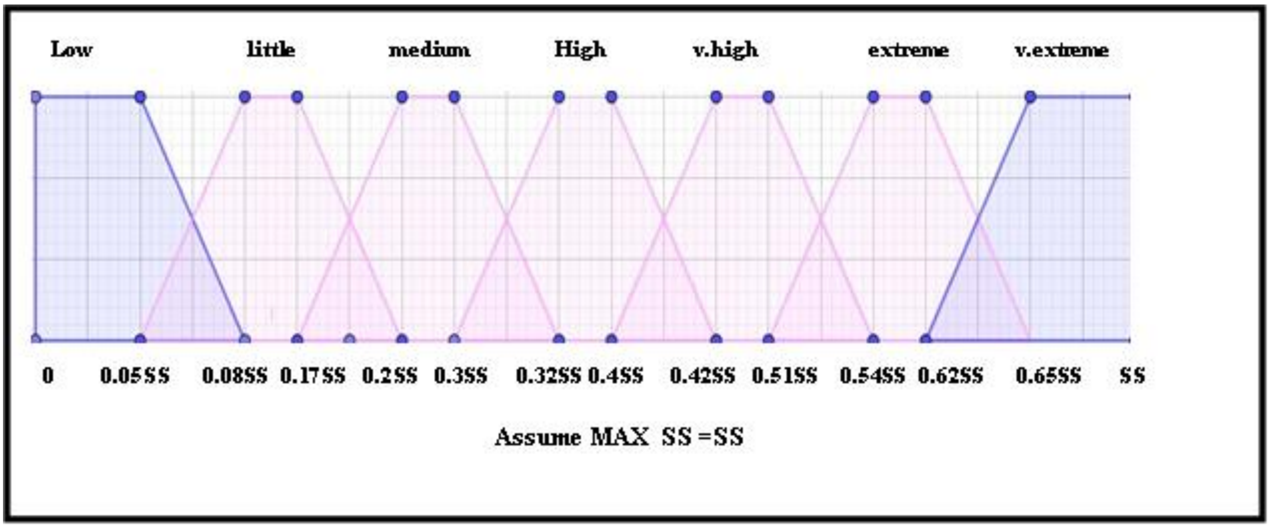
SSL is the only output of this system; where the rules of reasoning are applied to the system after the entering of all the variables. The maximum value of universe of discourse is changed daily which allows high flexibility for the proposed model and dynamic status based on the period specification which is mentioned in step (2). The steps used to obtain SSL are shown as below:

a) Identifying the percentage values of safety stock which represents the maximum value of safety stock (universe of discourse) that is ranging from 10-30% of the current period demand D(i) based on the demand specification period, these values are 10%, 20%, and 30% for the weak, normal, and peak periods, respectively.

b) Building membership functions of variable sets to describe the status of safety stock level, as shown in Fig. 5.

c) Identifying universe of discourse for this variable by multiplying demand of the current day (D(i)) with the percentage value that is mentioned in step (a) above.

Fig. 5 Fuzzy sets of safety stock (output variable)



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5. Case study

In order to examine the validity of the proposed model, dairy product type (yogurt 200 gm) was selected. For the consideration of perishable products, the process of inventory management is a crucial part. Demand uncertainty and short shelf life forces the organization toward adopting an advanced inventory approach which has ability to deal with this complexity. Three input variables i.e. demand stability level, raw material availability, inventory on hand and unique output (safety stock) form the fuzzy logic to solve the problem of perishability and demand in the dairy industry. Table II below shows sample of data related to the specific product (January month)

Table 2 Sample of data of yogurt product

Day	(N) factor		d(i)[demand]	Max raw material	daily raw material	max inventory
1	6	0.1	580	8.11	7.75	500
2	6	0.1	310	8.11	7.75	500
3	6	0.1	628	8.11	7.75	500
4	6	0.1	90	8.11	7.75	500
5	6	0.1	447	8.11	7.75	500
6	6	0.1	185	8.11	7.75	500
7	6	0.1	330	8.11	7.75	500

8	6	0.1	190	8.11	7.75	500
9	6	0.1	545	8.11	7.75	500
10	6	0.1	245	8.11	7.75	500
11	6	0.1	430	8.11	7.75	500
12	6	0.1	50	8.11	7.75	500
13	6	0.1	325	8.11	7.75	500
14	6	0.1	190	8.11	7.75	500
15	6	0.1	445	8.11	7.75	500
16	6	0.1	360	8.11	7.75	500
17	6	0.1	90	8.11	7.75	500
18	6	0.1	355	8.11	7.75	500
19	6	0.1	380	8.11	7.75	500
20	6	0.1	255	8.11	7.75	500
21	6	0.1	545	8.11	7.75	500
22	6	0.1	205	8.11	7.75	500
23	6	0.1	105	8.11	7.75	500

Solution of Case Study

Step (1): (N) factor, which appears in column 2 of Table II,

Which represents maximum increasing rate for demand of two adjacent days. From table II (N) factor is (6), where the demand of day 12 was (50) package and the demand of day 13 was (325) package.

Step (2): Period specification value was identified by knowing the level of sales during the year and in the form of periods to determine the highest level of safety stock, which represents the universe of discourse for the specified variable (safety stock). For column 3 in Table 2, period specification value at January for yogurt is 0.1, which mean that the sales of product in a weak period.

Step (3): Identification of demand stability level.

The universe of discourse of first variable of proposed model (demand stability level) is identified by multiplying the demand of previous period D (i-1) by dynamic (N) factor (obtained from step 1), by applying Equation (1). Table 3 shows the universe of discourse demand stability level and Table IV shows the implementation process of first variable for specific case study. The fuzzy set boundary conditions for (yogurt) were shown. The demand of previous day is 100.

Max. Universe of discourse for second day (DM) = D (i-1) *N …………………………… (1)

Table 3 boundary conditions of variables

Universe of discourse of demand stability level First variables	Linguistic variable	Linguistic symbol	Numerical range
Demand uncertainty condition	Low	L	0-0.5 DM
	Medium	M	0.375-0.75 DM
	High	H	0.625-1 DM

The universe of discourse for the third day for example according to Equation (1) equals to 6*310=1860, where 6 represents the N factor for yogurt at January and 310 represents the demand of the second day. Table 4 shows the results of demand uncertainty universe of discourse.

Table 4 Numerical values of universe of discourse of demand stability level

System variables	Linguistic variable	Linguistic values	Numerical ranges
Demand uncertainty condition	Low	L	(0-0.5)*1860
	Medium	M	(0.375-0.75)*1860
	High	H	(0.625-1)*1860

<u>Step (4):</u> Identification of raw material availability level.

The universe of discourse for the second variable (raw material availability) was identified; the daily level of raw material availability is entered to the model. Table 5 provides the universe of discourse of this variable, while Table 6 shows the value of universe of discourse of the variable for example at January where maximum level of raw material is 8.11 tons.

Table 5 Universe of discourse of raw material availability

Raw material availability	Unavailable	UAV	0-0.34 RM
	Rare available	RAV	0.125-0.9375 RM
	Available	AV	0.75-1 RM

Table 6 Numerical values of universe of discourse of raw material availability

Raw material availability	Unavailable	UAV	(0-0.34)*8.11
	Rare available	RAV	(0.125-0.9375)*8.11
	Available	AV	(0.75-1)*8.11

Step (5): Identification of on hand inventory level.

The universe of discourse for on hand inventory and fuzzy sets are identified in this step. Table 7 and Table 8 are show the universe of discourse of this variable and numerical values respectively, for the example in January where the maximum level of on hand inventory is 500 packages.

Table 7 Universe of discourse of inventory on hand conditions

On hand inventory	Low	L	0-0.16 INV
	Medium	M	0.08-0.4 INV
	High	H	0.32-1 INV

Table 8 Numerical values of universe of discourse on hand inventory

On hand inventory	Low	L	(0-0.16)*500
	Medium	M	(0.08-0.4)*500
	High	H	(0.32-1)*500

Step (6): Identification of unique output (safety stock level).

Safety stock level is determined as unique output. Seven sets are used to identify the safety stock level. The period specification plays an important role in identifying the universe of discourse for the variable. For example, in January, and referring to Table 2, the specification value for yogurt is 0.1, the period is weak; so the maximum universe of discourse of the third day of January is calculated as 0.1*628, where 0.1 represents the period specification value and 628 represents the demand of the third day. Table IX shows the universe of discourse of SS level, while Table 9 presents the numerical values of fuzzy sets in January.

Table 9 Universe of discourse of safety stock level

	Low	L	0.0-0.08 SS
	Little	LI	0.05-0.2 SS

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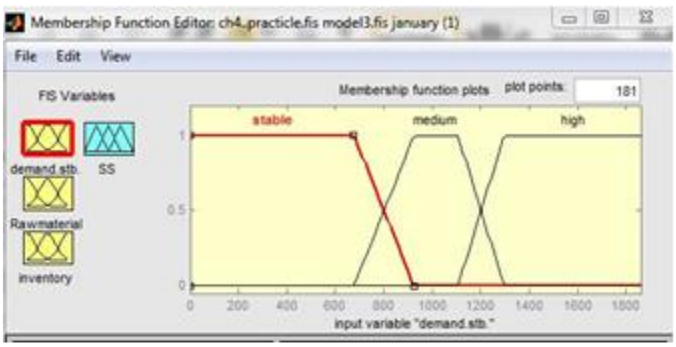
Safety stock level	Medium	M	0.17-0.32 SS
	High	H	0.3-0.42 SS
	Very high	VH	0.4-0.54 SS
	Extreme	E	0.51-0.65 SS
	Very extreme	VE	0.62-1 SS

Table 10 Numerical values of universe of discourse of safety stock level (yogurt) on third day of January

Safety stock level	Low	L	(0.-0.08)*62.8
	Little	LI	(0.05-0.2)*62.8
	Medium	M	(0.17-0.32)*62.8
	High	H	(0.3-0.42)*62.8
	Very high	VH	(0.4-0.54)*62.8
	Extreme	E	(0.51-0.65)*62.8
	Very extreme	VE	(0.62-1)*62.8

By feeding the parameter of January which appears in Table 2, the level of SS for the third day was identified by applying the proposed model as appear in table 10. The demand of the previous period (second day) equals to 310 packages, daily raw material availability is 7.5, period specification level is 0.1, and demand of the current day is 628 packages, then the maximum value of safety stock is 62.8 package. i.e. (MAX.SS= 30% of D(i)), SS= 10%*628=628. Fig. 6 below shows the membership functions of the model variables, while Fig. 7 shows the fired rules of the parameters above.

Fig. 6 Membership functions of model variables



Step (I): **Identifying the crisp input values** of the model in our example, Table 2 shows these values.

Step (II) **Fuzzification**: In this step, the system works to turn the input values (crisp values) into degree of membership function which represents its belonging to fuzzy sets. Fuzzification process will be done by employing fuzzy sets of models variables. As shown in Table 6, Table 8, and Table 10 above.

Step (III) **Logical operator** (AND) used in all rules which means that the minimum values of membership function (μ) in each rule are selected. The antecedent of each rule is represented by a single value (minimum) because of using the logical operator (AND). Just one rule is inferred in this example as shown in Fig. 7, which is R1.

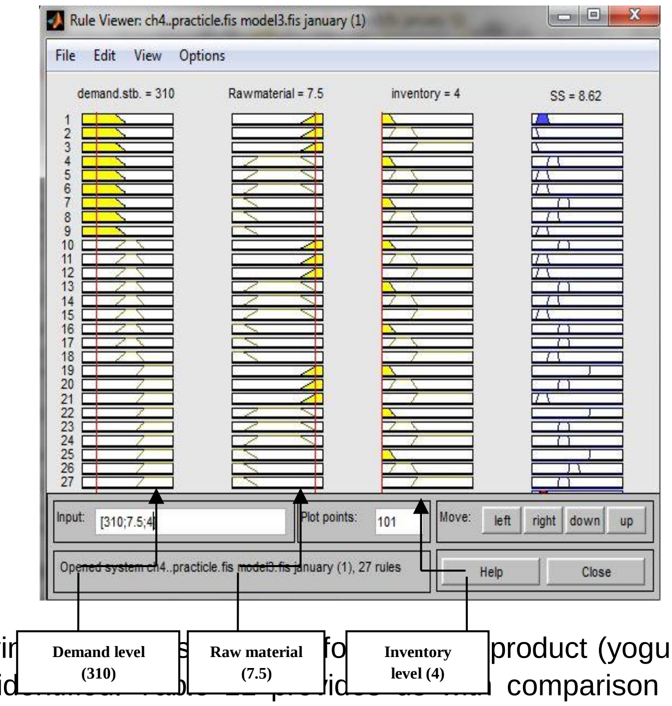
Step (IV): **Implication**: In this step, the applied implication approach is explained. The goal of this step is to identify the output value by aggregation of rules output variables based on minimum value of μ.

Step (V): **Defuzzification**: In this step, the output of each inferred rule which is aggregated depending are calculated based on the center of gravity concept.

According to the rules set for the proposed fuzzy inference system, the output of fired rule (R1) is minimal, which is ranging from (0.05-0.2)* 62.8, and referring to Fig. 5, the calculation of the center of gravity for this shape is done as below and represents the level of safety stock.

$$SS = 3.88 + \left(\frac{12.56 - 3.88}{2}\right) = 8.22 \cong 9$$

Fig. 7 Fired rules of proposed fuzzy logic



By applyi[illegible] fo[illegible] product (yogurt), great reduction in safety stock level is id[illegible] comparison statues of implementation of the model, the values of the original demand, current safety stock level, and new level of safety stock of the proposed model.

Table 11 Comparison of SS level before and after applied model

	Yogurt (January)

Day	Demand	Current	Developed

Finally, the results of applying the proposed model for the product yogurt at 12 months, are shown in Table 12 below.

Table 12 SS reduction ratios for 12 months

No.	Month	SS reduction value
1	January	95.9%
2	February	94%
3	March	91%
4	April	90%
5	May	92%
6	June	92%
7	July	93%
8	August	88%
9	September	88%
10	October	89%
11	November	85%
12	December	85%

Conclusion

This study showed that the use of traditional statistical models in the identification of safety stocks negatively affects the performance of the organizations due to the significant increase in inventory.

As these methods take into account the change in demand without taking into account the circumstances surrounding the work environment such as the state of the season and the amount of change that gets to the demand, so the optimal level of inventory cannot be obtained unless we rely on a platform of modern technologies, which can take into account the high mobility in the data, especially with organizations which consider tactical plans as a core of their policy.

The use of fuzzy logic and the employing of expert expertise lead to obtaining high quality results, as a result of building a scientific system that identifies the optimum safety stock level taking into account all the factors that affect it.

References

A. Persona, D. Battini, R. Manzini, and A. Pareschi, 2007"Optimal safety stock levels of subassemblies and manufacturing components," International Journal of Production Economics, vol. 110, pp. 147-159,.

O. Dey,2017 "A fuzzy random integrated inventory model with imperfect production under optimal vendor investment," Operational Research, pp. 1-15,.

V. Kumar and P. Kumar, 2016"Modeling of an Inventory System with Variable Demands and Lead Times using a Fuzzy Approach," in Optimal Inventory Control and Management Techniques, ed: IGI Global, pp. 133-151.

J. Korpela, A. Lehmusvaara, K. Kylaheiko, and K. Tuominen, 2003 "Adjusting safety stock requirements with an AHP-based risk analysis," in System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on, p. 7 pp.

Y. Boulaksil, 2016 "Safety stock placement in supply chains with demand forecast updates," Operations Research Perspectives, vol. 3, pp. 27-3,.

S. Minner, 1997 "Dynamic programming algorithms for multi-stage safety stock optimization," Operations-Research-Spektrum, vol. 19, pp. 261-271.

S. C. Graves and S. P. Willems, 2000 "Optimizing strategic safety stock placement in supply chains," Manufacturing & Service Operations Management, vol. 2, pp. 68-83.

H. Osman and K. Demirli, 2012 "Integrated safety stock optimization for multiple sourced stockpoints facing variable demand and lead time," International Journal of Production Economics, vol. 135, pp. 299-307.

H. R. Rezaei, 2012 "Developing an Intelligent Inventory Control Model, Applying Fuzzy Logic and Association Rule Mining," Paul Bharath Bhushan Petlu Chaylasy Gnophanxay, p. 41.

N. G. Hua and S. P. Willems, 2016"Analytical insights into two-stage serial line supply chain safety stock," International Journal of Production Economics, vol. 181, pp. 107-112.

K. Kumar and T. Aouam, 2018 "Integrated lot sizing and safety stock placement in a network of production facilities," International Journal of Production Economics, vol. 195, pp. 74-95.

C. Wang, 2015"A study of membership functions on mamdani-type fuzzy inference system for industrial decision-making,".

S. Chettibi and S. Chikhi, 2016 "Dynamic fuzzy logic and reinforcement learning for adaptive energy efficient routing in mobile ad-hoc networks," Applied Soft Computing, vol. 38, pp. 321-328.