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Planning the Production of the Electrical Distribution Converter (400KV/11) Using Time Series Methods and Goal Programming in the Fuzzy Environment

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Abstract

This Paper aims to plan the production of the electrical distribution converter (400 KV/11) for one month at Diyala Public Company and with more than one goal for the decision maker in a fuzzy environment. The fuzzy demand was forecasting using the fuzzy time series model. The fuzzy lead time for raw materials involved in the production of the electrical distribution converter (400 KV/11) was addressed using the fuzzy inference matrix through the application of the matrix in Matlab, and since the decision maker has more than one goal , so a mathematical model of goal programming was create, which aims to achieve two goals, the first is to reduce the total production costs of the electrical distribution converter (400 KV/11) and the second is to maximize the amount produced from them, where the fuzzy data of the mathematical model were processed using the ranking function. Through the results obtained to solve the mathematical model using Lingo program we find that the mathematical model has achieved both objectives, i.e. reduce the total production costs of the main product to less than (4464254500) Iraqi dinars and maximize the amount produced from the main product for more than (17000) parts per month.

Paper type: Research paper.

Key words: Production Planning (PP), Fuzzy Forecasting Methods (FFM), Fuzzy Lead Time, Fuzzy Inference System (FIS), Goal Programming (GP), Ranking Function (RF)

1-Introduction:

Production planning includes a range of productive activities and events that make things more useful and more valuable, i.e. the process of converting raw materials into goods and services ready for use for the purpose of exploitation or other uses, the production process is a certain combination of machines, workers, working methods, resources, tools and environmental factors that all convert inputs into outputs of goods or services, as the fuzzing of the volume of demand leads to randomness in the volume of quantities produced and stocked. This mainly affects production and we therefore use fuzzy forecasting methods to solve this problem, and fuzzy waiting time is a key to production management because of its importance in industrial organizations. This is because of the sudden difficulties and challenges facing the organization, which affects the timing of the receipt and delivery of materials on time.

Many studies addressed this topic where (Kareem,2013) he main target of this paper used a goal programming approach in production planning. In order to design an efficient production planning system, the mathematical model include multi conflicting objective , every objective function has (positive and negative) deviational variables and explain methods that can be used to solve the model and using (Prioritized or Ranked goals or weighted goals) method to classify priority of goals. The practical application was in electric production company (factory), after determining the main goals(4 goals) of the production plan and data (times, profits) the model formulation and solving by (WINQSP) S.W ,the results explain the cooperation among multiple objective function.

(Ahmed,2015) examined the problem of low level of exploitation of energy available for resources and failure to achieve planned production quantities, as well as repeated interruptions in the production process of the electric motors production plant for the air cooler in the general company of Electrical Industries, which was caused by the fuzzing of the process of determining the quantities of demand for the product and the uncertainty that occurs in waiting times for parts of the product, not to mention the fluctuation cost of the treasury as a result of the continuous changes in the Iraqi market. The most important finding of the study is that the theory of fuzzing numbers is an important tool to get rid of uncertainties, address the waiting time, and also regarding the treasury was treated from fuzzing and production was predicted.

(Ansseif, 2019) dealt with the use of the method of programming goals, which is one of the most important techniques used in the research process to make the decision by modeling the reality in the form of a mathematical model is a reflection of the institution sample research in terms of resources and energies in order to achieve multiple goals at the same time. These objectives are called in the mathematical model of positive and negative deviation variables, which we seek through the objective function to reduce the total deviations of those variables to the extent that achieves the balance of the target constraints and priorities set by the administration in the implementation. So, a multi-objective mathematical model was constructed and aims to achieve the liquidator's objectives of increasing production capacities and improving the quality of products as well as reducing the emissions of toxic gases due to combustion operations inside the refinery.

(Khalaf and Ali,2021) proposed building a comprehensive multi-objective production plan for Al-Rafidain plant spanning 12 months based on two methods – the auto regression integrated moving averages (ARIMA) model to forecast the market demand for the products and the method of goal programming (GP) – to find compatible solutions among the goal to be achieved. The ready-made program MATLAB was used to find the future values of the time series and also to solve the multi-objective mathematical model. For the most important results achieved, the mathematical model was able to achieve the first goal by 97%, which was the maximization of profits. The second goal was achieved successfully because of the decrease that occurred in the costs. Finally, the third goal was achieved by 98%.

2-Methods and Procedure:

2-1Fuzzy Inference System(FIS):

After Zadeh's theory in 1965, scientist Ibrahim Mamdani presented the theory of the fuzzy set theory (1975), the most common and complex type, one of the first control systems built by fuzzy set theory. Mamdani's theory is based on converting certain inputs into outputs using fuzzy logic based on fuzzy rules (If-Then rules). The system refers to the calculations used to evaluate fuzzy language descriptions using concepts such as membership functions, fuzzy logic operators and if-then rules. Since rule-based logic is based on the representation of qualitative knowledge, there is a need to identify it and the logic of blur allows us to relation the quantitative approach to qualitative representation.

The fuzzy inference system for a field consists of the following sections (Bai,2006) as follows:-

1-Fuzzifier: - The inputs of this stage are real values that fall within a certain range of (0-1) because the(FIs) suffers from a lack of understanding of linguistic variables لـit deals with only the numbers that fall between (0-1) so the inputs must be converted into numbers understood by the system using the membership functions and the outputs of this stage are called fuzzy input, which is the degree of affiliation of the input values that fall between(1-0).

2-Fuzzy Rules: - The main part of the fuzzy inference system model is the rules, and if-then fuzzy rules are used based on the knowledge of experts in each field.

3-Interface Engine: - is the process of entering fuzzy (i.e. degrees of membership obtained from the previous stage) and the output is fuzzy by taking into account the fuzzy rule and evaluating the part of the results based on the type of system used, which is a field system.

4-Defuzzifier: - The input of this phase is the output of the previous phase, which is the fuzzy output, which is the result of the compilation of rule decisions into a single resolution, i.e. the fuzzy output is transformed into real value outputs.

2-2 Membership Function

Fuzzy groups are unique in their specific membership, classifying the element within the group as continuous or discontinuous, and membership functions can be formulated using graphs of different shapes (Sivanandam ,2007).

2-3 Types of Membership Functions: - Types of membership functions that were used (Ekel,2020)

1- Trapezoidal membership Function: This function contains four parameters (a_1, a_2, a_3,a_4) and can be represented by the following equation (1) (Ekel,2020):-

$$\mu_A = \begin{cases} \frac{x - a_1}{a_2 - a_1} & a_1 \le x < a_2 \\ 1 & a_2 \le x < a_3 \\ \frac{a_4 - x}{a_4 - a_3} & a_3 \le x \le a_4 \\ 0 & otherwise \end{cases} \quad (1)$$

2-4 Methods of Defuzzification that were used:

1- Ranking function for triangular fuzzy numbers. We assume that $(\widetilde{A})$ of defuzzification: (a, b,c) represents a triangular fuzzy number the ranking function for this fuzzy number is as in equation (2): (puri,2009)

$$\mathcal{R}(\widetilde{A}) = \frac{1}{4} \quad (a + 2\, b + c) \qquad (2)$$

2-Ranking Function for trapezoidal fuzzy numbers; we assume that A=(a.b.c. d) represents a trapezoidal fuzzy number: (kahraman ,yavz,2010)

$$\mathcal{R}(\widetilde{A}) = \frac{1}{4}(a + b + c + d) \qquad (3)$$

2-5 Fuzzy Demand:

Uncertainties are evident in the demand for materials, and uncertainty about randomness, fuzzy or lack of knowledge can be evident. As the orders released by the enterprise for the purchase of raw materials or other known needs are determined from the beginning of each planning process, and from demand forecasts made by in turn, it relies on factors such as past historical sales or competitors' equipment and others, which is reflected in making demand fuzzy in nature (Liu H., 2007)

2-6 Fuzzy Time Series Model: The steps of this method are summarized as follows: (Liu H.,2007,63-80; Liu H., 2009,Poulsen,2009)

Step 1: We calculate the average of data by sorting values in the historical data set of product demand where we arrange the data upwards and then calculate the difference between the successive values in the data set broken by equation (4).

$$\text{AD}\ (\text{xi}.\dots.\text{xn}) = \frac{1}{n-1} \sum_{i=1}^{n-1} \left| \text{xp}(i) - \text{xp}(i+1) \right| \qquad (4)$$

AD: Average distance

n: Number of views

xp (i): Present demand

xp (i+1): Post demand

Step 2: The standard deviation of the average data released from the first step is calculated according to the following equation (5):

$$\sigma_{AD} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_{i\_}\ AD)^2} \qquad (5)$$

As:

σ_{AD}: Standard Deviation

n: Number of views

x_i: View i

Step 3: Using both average and standard deviation, the extreme values of the progressively distributed data set are determined where extreme values are eliminated so that the values supported by the dislocated data meet the following requirement as described in equation (6)

$$AD - \sigma \leq x \leq AD + \sigma \quad (6)$$

After eliminating extreme values, we calculate the AD'' average of revised values obtained from the first step.

Step 4: We identify the overall group so that we determine the lowest value of the data set and subtract the adjusted average from it, as well as determine the highest value of the data set and combine it with the average adjusted through equation (7)

$$U = \{LB = D_{min} - AD'', UB = D_{max} + AD''\} \quad (7)$$

U: Comprehensive Group

LB: The lower limit of the overall group

UB : The upper limit of the overall group

D_{min} :Lowest value from data set

D_{max}: Highest value from data set

AD '': Average Adjusted Distance

Step 5: After the extraction of the highest and minimum values of the overall group is completed, we extract the number of subgroups from the overall group through equations (8) and *(9)*

$$N = \frac{N - AD}{2AD} \quad (8)$$

$$R = UB - LB \quad (9)$$

N: Number of Subgroups

R: Overall range of the overall groups

Step 6: Fuzzy groups are found by subtracting the average rate, which is of the lowest value in the historical data set, and the output represents the beginning of the time series, i.e. spreading on the left side, and then we add the average to the minimum value and this represents the spread on the right side and we complete this to reach the upper limit of the overall group and then we add the adjusted average to the upper limit and the output represents the end of the fuzzy time chain, and then we give a symbol to each fuzzy group.

Step 7: The classification is now made by the membership of the fuzzy groups to membership functions of the application through the use of the Trapezoidal membership function as described in equation (1).

Step 8: The fuzzy is removed, i.e. the four digits are converted into crisp according to equation (3) the equation of the Trapezoidal membership function.

Step 9: After the application has been subjected to packaging and processing, the request is now estimated according to the equation (10), i.e. the procedure of predicting demand through the general trend line equation.

$$Y = a + b\,x \quad (10)$$

2-7 Fuzzy lead Time:

One of the basics of production management is lead time management because of its importance in industrial production planning organizations, where when the organization faces difficult challenges due to sudden changes in the environment that significantly affect the organization's decisions and lead time, making the lead time fuzzy in nature, it will affect the timing of receipt and delivery of materials on time (Bera.et.al, 2012).

2-8 Goal Programming

The viewpoints of the various authors differ concerning GP in that Winston sees it as "a technique used to reach the best decision in case of the existence of multiple goals that are wished to achieve"(Winston et al., 1997), while (Taha,2011) sees it as "the best method to solve multi-goal problems through turning the main goals into one goal to attain the best solution." Also, (Ghosh and Mujumdar,2010) see it as "a technique used in multiple-goal activities to find an intermediate solution among these goals." There are also many applications in which the GP enters, including: production planning, transportation problems, distribution of energy sources, manpower planning, financial planning, project management and scheduling, allocation models, hospital management, media planning, selecting production mixture, and determination of the machine maintenance level (Alidrisi, 2010; Dan and Desmond, 2013).

2-9 Methods of Solving Goal Programming: - To solve goal programming problems, there are two main methods: (Taha, 2007)

Priority Method: - The best solution to this difficulty is to use the priority method. Any priority determination instead of weight where the idea of this method depends on giving priority to the goal to a degree commensurate with the management's view of the importance of that goal, the goals of the lowest importance take into account after the goals of the highest degree and express priorities with the symbol ($P_{i,s}$) for each variable disparity and thus be P_1 priority given to the most important goals P_2 and then the next P_3 (Taha, 2007). The general model of programming goals for the method of priorities in the following mathematical form: (Sen and NandI, 2012)

$$Minimize\ Z = \sum_{i=1}^{m} P_j(d_i^-,\ d_i^+)$$

$$\left.\begin{aligned} & s.t\ : \\ & \sum_{j=1}^{n} C_j X_j - di^+ + di^- = g_i \\ & \sum_{j=1}^{n} a_{ij}\ X_j = bi \\ & d_i^+, d_i^-, X_j \geq 0 \end{aligned}\right\} \quad (11)$$

If: i = 1.2.3.....m

j = 1.2.3.....n

As:

X_i: Resolution variables.

C_j: variable X_i coefficient in goal constraint.

A_{ij}: Variable X_i coefficient in i.

n: Number of restrictions.

m: Number of variables.

di+: Positive deviation variable (above completion) of goal i.

di- : Negative deviation variable (under completion) of goal i.

g_i: Goal value of goal i.

b_i: Goal value constraint of model i.

3. A Real Practical Example

Industrial organizations face many difficulties, problems and many uncertainties and complete uncertainties, especially those related to forecasting and future expectations in various activities and processes, and the process of determining the quantities produced, stocked and predicting demand is one of these problems that is directly affected by environmental changes, making fuzzy logic an important tool to address such uncertainties and uncertainties, and on this basis the process of predicting the fuzzy demand on the electrical distribution converter product (400K/11V) has been studied. Fuzzy demand forecasting provides a broader decision base than the traditional demand forecasting process, which relies on a single time series, as opposed to the fuzzy forecasting process, where it provides several time series based on the original historical series.

Managing waiting times in the fuzzy environment is one of the basics of production management, because it is of great importance to the production planning process in industrial organizations, as organizations face difficult challenges due to the fuzzy environmental indicators being fast or sudden at times and which significantly affect the company's decisions, as these challenges reflect the waiting time, which in turn will affect the dates of receipt and delivery of materials on time for the customer.

Since the decision maker has more than one goal to achieve, the method of programming the objectives was used to deal with the practical reality to solve the problems of production planning in the event of more than one goal of the decision maker; therefore, a monthly production plan was built through optimal planning of the quantities produced, required and stocked to ensure the optimal exploitation of the internal available energies of the company, where a multi-goal mathematical model was formulated and built for one month to be used to issue a production plan within a certain period of time. Taking advantage of the available capacities and maintaining a certain level of treasury, this model has been applied in Diyala General Electric Industries.

3-1 Predicting the Fuzzy Demand by Applying the Fuzzy Time Series Model:

The theory of fuzzy preparation was chosen to address demand forecasting because there are many different methods that can be used in fuzzy prediction such as statistical methods and expert opinions, which led to the selection of fuzzy time series models as a statistical method and their application to the historical data of the product studied for (108) months as described in table (1).

Table (1) Historical demand for an electrical distribution converter product (400KV/11)

year/ month	2012	2013	2014	2015	2016	2017	2018	2019	2020
January	88	162	70	260	45	70	80	240	350
February	105	35	179	58	280	148	437	620	362
March	300	139	425	512	186	305	62	322	373
April	238	350	348	329	25	156	264	442	385
May	420	460	50	195	519	207	523	530	390
June	613	150	272	69	355	348	253	462	397
July	505	40	25	167	412	520	709	360	400
August	802	319	6	600	710	407	458	526	406
September	410	503	10	334	606	850	617	370	415
October	380	714	311	450	362	610	368	718	428
November	267	190	98	246	173	228	134	258	433
December	129	298	121	198	277	190	215	293	442

3-2 Fuzzy Lead Time for the Raw Materials of the Main Product:

The lead time in working life is inherently fuzzy, vague and not without inaccuracies in estimation, as many products are affected by environmental fluctuations that also make the lead time unstable and surrounded by high uncertainty, which makes sense to consider it a fuzzy period.

To get rid of these uncertain environmental changes (fuzzy), we have used a fuzzy inference model that relies on fuzzy waiting time data that are divided into (short, medium, long, very long) and these data are taken from the procurement and production departments, where demand is divided into four levels (small, medium, large, very large) and then we calculate the rate of change by demand after dividing it into (low, moderate, high, very high) on a historical basis according to the fuzzy inference system.

We estimate the lead time according to the experts' opinion of the raw materials that enter the product industry according to the division of demand into levels and calculate the rate of change in demand on a historical basis according to the fuzzy inference system described in the theoretical aspect where the data was taken from the procurement department and the production department of the company Diyala Public as in Table(2) .

Table (2) shows the lead time for the first five raw materials entering the main product industry according to the fuzzy inference

Sequence	Material Name	Short triple fuzzy lead time (day)	medium triple fuzzy Lead time (day)	long triple fuzzy lead time (day)	Very long triple fuzzy lead time (day)
1	Silicon steel	(180,192,201)	(198,210,225)	(222,232.5,246)	(240,255,270)
2	Cold rolled steel	(30,50,70)	(60,80,100)	(90,110,130)	(120,140,160)
3	Hot rolled steel	(30,50,70)	(60,80,100)	(90,110,130)	(120,140,160)
4	Angle 50*50*6	(90,98,104)	(102,110,120)	(118,125,134)	(130,140,150)
5	Angle 65*65*8	(90,98,104)	(102,110,120)	(118,125,134)	(130,140,150)

3-3 Lead Time Matrix: A relationship between demand volume and indicator rate of demand; the matrix relied on data from the Procurement and Production Section. Demand levels have been estimated according to membership functions, i.e. when demand is between (0-300) units, the volume of demand is small; when the demand is between (250-550) units, the volume of demand is moderate; when demand is between (500-800), the volume of demand is large; and when the demand is between (750-1000), the volume of demand is very large as well as these levels have been linked to the rate of change in demand, which was calculated from the historical data of demand for the product by dividing the value of the current demand on its value in the previous period and the results appeared limited between the two values (0-20) and was classified as (low, medium, high, very high), and these rules were clarified by the following matrix, table (3*).*

Table (3) shows the matrix of the relationship between the volume of demand and the indicator rate of demand

		Size demand			
		Small	Medium	Large	Very large
The rate of change by demand	Low	Short	Short	Medium	Medium
	Moderate	Short	Medium	Medium	Long
	High	Medium	Medium	Long	Long
	Very high	Medium	Long	Long	Very long

3-4 Production Planning in the Fuzzy Environment Using Goal Programming:

The goal programming method was used in production planning and the company's distribution laboratory was classified to produce electrical distribution transformers (11/400KV) according to the quality of the machines used to produce some parts within the company where the plant (23) has a machine for the production of the transformer completely and the number of machines for the manufacture of parts is (18) machines for the production of parts for the production of parts converter. The electrician is (34) part and the company works for (22) days per month with two morning and evening work meals for (23) hours per day, i.e. the length of the morning meal (7) hours and the length of the evening meal (16) hours, and it is necessary to know the cost of producing each part and the quantities of production of each part and the minimum amounts required of each part as described in Table (4), for example, we take the first five parts.

Table (4) 11/400 KV electrical distribution converter parts with fuzzy production quantities on each part, fuzzy demand for each part and fuzzy cost per part

Sequence Part	Part name	demand for each part	cost per part (dinars/month)	fuzzy production quantities on each part
1	Upper discharge valve	(400,433,466)	(5300,5350,5400)	(450,500,550)
2	packaging plate	(400,433,466)	(4000,5000,6000)	(450,500,550)
3	first high pressure insulators	(400,433,466)	(9400,9500,9600)	(450,500,550)
4	second high pressure insulators	(400,433,466)	(9400,9500,9600)	(450,500,550)
5	third high pressure insulators	(400,433,466)	(9400,9500,9600)	(450,500,550)

Table (5) shows the first five parts of the parts produced within the company and the fuzzy manufacturing duration of each part

Sequence	Part name	Manufacturing timeper minute
1	packaging plate	(25,30,30)
2	Pressure discharge device	(4,5,6)
3	first iron heart	(4,5,6)
4	second iron heart	(4,5,6)
5	third iron heart	(4,5,6)

Operational capacities available for each machine should also be known, i.e. the minimum alone, as shown in Table 6, for example, we take the first five machines.

Table (6) Types of machines, upper limit and minimum fuzzy operating power available per machine

Sequence	Machine type	The upper limit operating energy available (minute/month)	The lower limit operating energy available (minute/month)
1	GAS GATTING	(15700,15800,15900)	(6400,6450,6600)
2	IRAN WIENR	(30680,31680,32680)	(6550,7550,8550)
3	SHERING 1	(18380,18480,18580)	(7400,7500,7600)
4	Goerg	(18380,18480,18580)	(3900.,4000,4100)
5	ANNELING FURNCE	(16400,16500,16600)	(4100,4200,4300)

3-5 The General Mathematical Model of Production Planning Using the Method of Goal Programming: -

Can be mathematically expressed the general goal programming model for production planning where the target programming is a good alternative to dealing with the practical reality to solve the problems of production planning and to achieve a set of goals and for the purpose of building the mathematical model must define some terms as follows:-

3-5-1 Definition of model symbols and features: **- Table (7) shows the symbols and terminology of the mathematical model.**

Table (7) symbols and terms of the mathematical model

Code	Definition of symbols
i	Number of total parts produced i=1,2,...,34
X_i	The amount produced per unit of part i
C_i	The cost of producing the college includes (administrative and marketing raw materials, worker's salaries, industrial expenses and treasury cost) one unit of part i
D_i	The expected demand amount of part i
H_i	The volume of *Inventory* from part i
N	The lower limit of energy available for machines
M	The upper limit of energy available to machines
UD_i	The maximum amount required from part i
d_i^+	Positive deviation value
d_i^-	Negative deviation value

3-5-2 The goal function of the mathematical model:

After applying an equation (12), we get the main goal function:

$$Min(Z) = Z_1(d_1^+) + Z_2(d_2^-)$$

Objective constraints:

Goal 1: Reducing the total production costs of the main product less than (4464244500,4464254500,4464265400) (dinars/month).

After eliminating the fuzzy of data using the equation (2) of the triangular ranking function

$\sum_{i=1}^{34} C_i X_i + d_1^- - d_1^+ \leq$ (4464245400,4464254500,4464264500)

$$R = \frac{1}{4}(4464245400 + 2 * 4464254500 + 4464264500)$$

$$= 4464254500(\text{dinars/month})$$

Goal 2: Maximize the amount produced from the main product of more than (16900,17000,17100) part per month.

$$\sum_{i=1}^{34} X_i + d_2^- - d_2^+ \geq (16900, 17000, 17100)$$

After eliminating the fuzzy of data using the equation (2) of the triangular ranking function

$$R = \frac{1}{4}(16900 + 2 * 17000 + 17100) = 17000 \text{ part per month}$$

Formulate system constraints

Energy constraints demand volume constraints for the required quantities of main product parts, inventory quantity restrictions and budgetary restrictions between the required quantity, the quantity stored and the quantity produced for the parts of the main product.

The first constraint: Available energy restrictions are divided into the lower and the upper limit of energy available for machines that produce the parts inside the factory.

The lower limit of energy available to machines

$$X_i \geq N \qquad (12)$$

The upper limit of energy available to machines

$$X_i \leq M \qquad (13)$$

The second constraint: The demand size constraints, which is the amount required by the company from any part of the main product, as well as represents the minimum monthly demand rate from the company of the main product parts that the company must meet.

$$D_i \geq UD_i \qquad (14)$$

The third constraint*:* The volume of inventory constraints, which is the amount stored from any part of the main product and equals (0.05,0.06,0.07) of the required quantity.

$$H_i = (0.05, 0.06, 0.07)Di \qquad (15)$$

The fourth constraint: The balance between the quantity produced, required and stocked of the main product parts is balanced and represents the quantity produced from any part of the product equal to the required quantity of that part plus the quantity stored from that part.

$$Xi = D_i + H_i \qquad (16)$$

The fifth constraint: The non-negative constraints.

$$C_i, X_i, D_i, H_i \geq 0 \quad i = 1, \dots, 34 \qquad (17)$$

$$N, M, LD_i \geq 0$$

<u>3-6 Build the mathematical model for planning the production of the KV 11/400 electrical distribution converter using goal programming</u>: - After eliminating the fuzzy of data using the equation (2) of the triangular ranking function, the mathematical model is now being built, which consists of:

Objective constraints: It consists of:

The first goal: It is the constraint of reducing the total production costs of the main product for less or equal (4464254500) (dinars/month).

$$\begin{aligned} 5350 X_1 + \; & 5000X_2 + 9500X_3 + 9500X_4 + 9500X_5 + 5000X_6 + 5000X_7 \\ & + 5000X_8 + 5000X_9 + 31000X_{10} + 15000X_{11} + 18446X_{12} \\ & + 25000X_{13} + 1000X_{14} + 7500X_{15} + 498250X_{16} + 498250X_{17} \\ & + 498250X_{18} + 498250X_{19} + 953755X_{20} + 1950X_{21} + 1950X_{22} \\ & + 1950X_{23} + 1950X_{24} + 260600X_{25} + 260600X_{26} + 260600X_{27} \\ & + 571134X_{28} + 571134X_{29} + 5300X_{30} + 3500X_{31} + 30000X_{32} \\ & + 15000X_{33} + 10000X_{34} + d_1^- - d_1^+ = 4464254500 \end{aligned}$$

The second goal: It is the constraint of maximizing the amount produced for the main product of more than 500 converters per month, i.e. (17000) part per month.

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14} + X_{15} + X_{16} + X_{17} + X_{18} + X_{19} + X_{20} + X_{21} + X_{22} + X_{23} + X_{24} + X_{25} + X_{26} + X_{27} + X_{28} + X_{29} + X_{30} + X_{31} + X_{32} + X_{33} + X_{34} + d_2^- - d_2^+ = 17000$$

<u>System constraints: Consists of:</u>

1.Lower and upper energy constraints available for machines that produce parts within the plant and for the purpose of building this restriction; the manufacturing times of the parts of Table (6) are taken by applying equations (13) and (14) and the value of both N and M is compensated to become the following restrictions- :

Lower and upper energy constraints available for Gas GATTING to produce the packaging plate segment.

$$6450 \leq 30x_1 \leq 15800$$

Lower and upper energy constraints available for machine IRAN WIENR to produce packaging plate and air drying device.

$$7550 \leq 30x_1 + 5x_2 \leq 31680$$

Lower and upper energy constraints available for the machine (SHERING 1) to produce air drying device, tank base and tank cover.

$$7500 \leq 5x_2 + 15x_{12} + 15x_{13} \leq 18480$$

Lower and upper energy constraints available for machine (GOERG) for the production of the first, second, third and fourth iron heart.

$$4000 \leq 5x_3 + 5x_4 + 5x_5 + 5x_6 \leq 18480$$

Lower and upper energy constraints available for the MACHINE ANNELING FURNCE for the production of the first, second, third and fourth iron heart.

$$4200 \leq 5x_3 + 5x_4 + 5x_5 + 5x_6 \leq 16500$$

Lower and upper energy constraints available for ACTIVE PART ASSMPLY for the production of the first, second, third and fourth iron heart.

$$4000 \leq 5x_3 + 5x_4 + 5x_5 + 5x_6 \leq 17500$$

Lower and upper energy constraints available for CORE FORMING to produce the first, second, third and fourth iron heart.

$$4100 \leq 5x_3 + 5x_4 + 5x_5 + 5x_6 \leq 18500$$

Lower and upper energy constraints available for FOLDING for radioactive production

$$3000 \leq 15x_7 \leq 19900$$

Lower and upper energy constraints available for L.V. for the production of first, second and third electrical files.

$$8100 \leq 13x_8 + 13x_9 + 13x_{10} \leq 21120$$

Lower and upper energy constraints available for machine (H.V) for the production of first, second and third electrical files.

$$8000 \leq 13x_8 + 13x_9 + 13x_{10} \leq 21120$$

Lower and upper energy constraints available for PLANT NO PLANTE for the production of first, second and third electrical files.

$$7500 \leq 13x_8 + 13x_9 + 13x_{10} \leq 21120$$

Lower and upper energy constraints available for machine COIL DRYING FURNCE first, second and third electrical files.

$$7600 \leq 13x_8 + 13x_9 + 13x_{10} \leq 21120$$

Lower and upper energy constraints available for FLANGE to produce tank cover.

$$4000 \leq 20x_{11} \leq 16840$$

Lower and upper energy constraints available for RIB WILLDING for tank production.

$$4100 \leq 20x_{11} \leq 17840$$

Lower and upper energy constraints available for PANWCH to produce the reservoir.

$$3000 \leq 15x_{13} \leq 19900$$

Lower and upper energy constraints available for the machine final drying oven to produce tank and tank cover.

$$7500 \leq 20X_{11} + 15x_{13} \leq 18480$$

Lower and upper energy constraints available for the machine washing and cleaning the tank to produce the tank and tank cover.

$$7500 \leq 20X_{11} + 15x_{13} \leq 19800$$

Lower and upper energy constraints available for the machine tank base meat to produce the base of the tank.

$$3000 \leq 15x_{12} \leq 19800$$

2. Demand size constraints: the demand size for each part of the equation (15) is compensated as follows $D_i \geq 433$ where i=1,…,34: -

$D_1 \geq 433$	$D_{13} \geq 433$	$D_{25} \geq 433$
$D_2 \geq 433$	$D_{14} \geq 433$	$D_{26} \geq 433$
$D_3 \geq 433$	$D_{15} \geq 433$	$D_{27} \geq 433$
$D_4 \geq 433$	$D_{16} \geq 433$	$D_{28} \geq 433$
$D_5 \geq 433$	$D_{17} \geq 433$	$D_{29} \geq 433$
$D_6 \geq 433$	$D_{18} \geq 433$	$D_{30} \geq 433$
$D_7 \geq 433$	$D_{19} \geq 433$	$D_{31} \geq 433$
$D_8 \geq 433$	$D_{20} \geq 433$	$D_{32} \geq 433$
$D_9 \geq 433$	$D_{21} \geq 433$	$D_{33} \geq 433$
$D_{10} \geq 433$	$D_{22} \geq 433$	$D_{34} \geq 433$
$D_{11} \geq 433$	$D_{23} \geq 433$	
$D_{12} \geq 433$	$D_{24} \geq 433$	

3. Inventory constraints: The size of demand in the equation (16) is compensated to produce the quantities stored by applying equation (16) as follows $H_i \leq 0.06D_i$ where i=1,…,34:-

$H_1 \leq 0.06D_1$	$H_{13} \leq 0.06D_{13}$	$H_{25} \leq 0.06D_{25}$
$H_2 \leq 0.06D_2$	$H_{14} \leq 0.06D_{14}$	$H_{26} \leq 0.06D_{26}$
$H_3 \leq 0.06D_3$	$H_{15} \leq 0.06D_{15}$	$H_{27} \leq 0.06D_{27}$
$H_4 \leq 0.06D_4$	$H_{16} \leq 0.06D_{16}$	$H_{28} \leq 0.06D_{28}$
$H_5 \leq 0.06D_5$	$H_{17} \leq 0.06D_{17}$	$H_{29} \leq 0.06D_{29}$
$H_6 \leq 0.06D_6$	$H_{18} \leq 0.06D_{18}$	$H_{30} \leq 0.06D_{30}$
$H_7 \leq 0.06D_7$	$H_{19} \leq 0.06D_{19}$	$H_{31} \leq 0.06D_{31}$
$H_8 \leq 0.06D_8$	$H_{20} \leq 0.06D_{20}$	$H_{32} \leq 0.06D_{32}$
$H_9 \leq 0.06D_9$	$H_{21} \leq 0.06D_{21}$	$H_{33} \leq 0.06D_{33}$
$H_{10} \leq 0.06D_{10}$	$H_{22} \leq 0.06D_{12}$	$H_{34} \leq 0.06D_{34}$
$H_{11} \leq 0.06D_{11}$	$H_{23} \leq 0.06D_{23}$	
$H_{12} \leq 0.06D_{12}$	$H_{24} \leq 0.06D_{24}$	

4. Balance constraints between the quantity produced, demanded and stocked for the main product parts: they are by applying equation (17) as follows$X_i = D_i + H_i$where i=1,…,34:-

$$X_1 = D_1 + H_1 \qquad X_{13} = D_{13} + H_{13} \qquad X_{25} = D_{25} + H_{25}$$
$$X_2 = D_2 + H_2 \qquad X_{14} = D_{14} + H_{14} \qquad X_{26} = D_{26} + H_{26}$$
$$X_3 = D_3 + H_3 \qquad X_{15} = D_{15} + H_{15} \qquad X_{27} = D_{27} + H_{27}$$
$$X_4 = D_4 + H_4 \qquad X_{16} = D_{16} + H_{16} \qquad X_{28} = D_{28} + H_{28}$$
$$X_5 = D_5 + H_5 \qquad X_{17} = D_{17} + H_{17} \qquad X_{29} = D_{29} + H_{29}$$
$$X_6 = D_6 + H_6 \qquad X_{18} = D_{18} + H_{18} \qquad X_{30} = D_{30} + H_{30}$$
$$X_7 = D_7 + H_7 \qquad X_{19} = D_{19} + H_{19} \qquad X_{31} = D_{31} + H_{31}$$
$$X_8 = D_8 + H_8 \qquad X_{20} = D_{20} + H_{20} \qquad X_{32} = D_{32} + H_{32}$$
$$X_9 = D_9 + H_9 \qquad X_{21} = D_{21} + H_{21} \qquad X_{33} = D_{33} + H_{33}$$
$$X_{10} = D_{10} + H_{10} \qquad X_{22} = D_{22} + H_{22} \qquad X_{34} = D_{34} + H_{34}$$
$$X_{11} = D_{11} + H_{11} \qquad X_{23} = D_{23} + H_{23}$$
$$X_{12} = D_{12} + H_{12} \qquad X_{24} = D_{24} + H_{24}$$

5. Non-negative constraints: Consists of:

1.5 Non-negative constraints for the demanded quantity variables from the main parts of the product.

$$D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9, D_{10}, D_{11}, D_{12}, D_{13}, D_{14}, D_{15}, D_{16}, D_{17}, D_{18}, D_{19}, D_{20}, D_{21}, D_{22}, D_{23}, D_{24}, D_{25}, D_{26}, D_{27}, D_{28}, D_{29}, D_{30}, D_{31}, D_{32}, D_{33}, D_{34} \geq 0$$

Non-negative restrictions for quantity variables stored from the main product 5.2penalty.

$$H_1, H_2, H_3, H_4, H_5, H_6, H_7, H_8, H_9, H_{10}, H_{11}, H_{12}, H_{13}, H_{14}, H_{15}, H_{16}, H_{17}, H_{18}, H_{19}, H_{20}, H_{21}, H_{22}, H_{23}, H_{24}, H_{25}, H_{26}, H_{27}, H_{28}, H_{29}, H_{30}, H_{31}, H_{32}, H_{33}, H_{34} \geq 0$$

Non-negative restrictions for quantity variables produced from the main product 5.3 penalty.

$$X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, X_{16}, X_{17}, X_{18}, X_{19}, X_{20}, X_{21}, X_{22}, X_{23}, X_{24}, X_{25}, X_{26}, X_{27}, X_{28}, X_{29}, X_{30}, X_{31}, X_{32}, X_{33}, X_{34} \geq 0$$

4-Solution and Discussion of Results:

The First: - the fuzzy time series model based on the historical demand data of the product collected was applied so that we can discuss the results. Matlab program was used to solve the fuzzy time series model and Table (1), presenting the historical demand of the product taken from sales records in the company's marketing department. The results of the order estimate emerged as follow:

1- **The value of alpha is (1.593).**
2- **The value of the beta coefficient is (238.509).**

The amount of demand for the first month of the year (2021) is (408) converted, the amount of demand for the fourth month of the year (2021) is (413) converted, while the amount of demand of the eighth month of the same year is (419) converted.

The Second: - For example, we take the second part (Cold rolled steel) of Table (2) so that we will process the waiting time for this part according to the fuzzy inference system and its data as shown in Table (8):

Table (8) The fuzzy waiting time measured in days for the second part (Cold rolled steel)

Part name	short triple fuzzy waiting time	Medium triple fuzzy waiting time	long triple fuzzy waiting time	Very long triple fuzzy waiting Time
(Cold rolled steel)	(30,50,70)	(60,80,100)	(90,110,130)	(120,140,160)

Figure (1) shows the functions of the indicator membership to the demand, which is a triangular function, since the vertical axis represents the function of membership between zero and one and the horizontal axis the value of its levels distributed between (30) and (160) in other words the waiting time is limited between (30) days and (160) days.

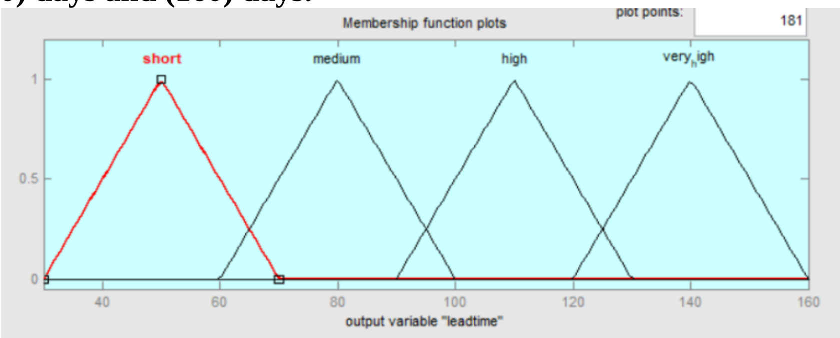

Figure (1) shows the function of membership of the waiting time

Once figure (2) shows the membership function of demand levels, it is trapezoidal membership function, as the vertical axis represents the function of demand levels between zero and one and the horizontal axis represents the four levels of demand, which are limited to (0) units and (1000)) Unity, and explain function of demand indicator, which is a triangular function, where the vertical axis represents the function membership between zero and one and the horizontal axis the value of its levels distributed between (0) and (20), and now we will clarify the rules of fuzzy inference.

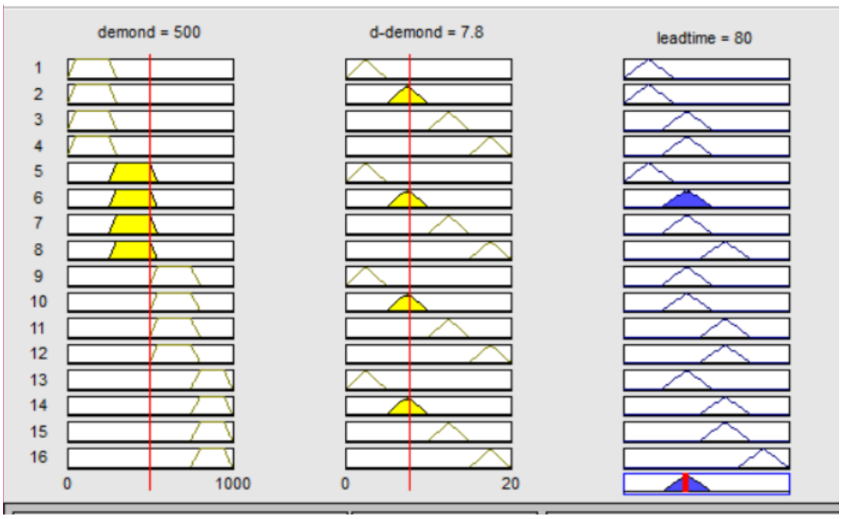

Figure (2) shows the fuzzy treatment of the waiting time

1- The first column (demand) represents the distribution column of the demand membership function on the rules (16) and we note when the request is at the average level that the membership functions will be located between the four rules which are (8,7,6,5).

2- The second column (demand indicator) is the distribution of the membership functions of the demand index to (16) base, meaning that when the indicator is high its value will be limited between the following rules (14,10,6,2).

3- The third column (assembly process) is the processing output column after the process, the assembly that results from a compilation between the order rules and the index rules by demand, meaning when the demand (500) unit will be the output of the indicator by demand is (7.8) and on this basis the waiting period will be (80) days.

After processing the fuzzy waiting time according to the fuzzy inference system for all the main materials involved in the electrical distribution converter industry, the results described in Table 9 were obtained.

Table 9 shows the results of the fuzzy waiting time process for the first five materials in the electrical converter industry

Sequence	name materials	waiting time(day)
1	Silicon steel	211
2	Cold rolled steel	80
3	Hot rolled steel	80
4	Angle 50*50*6	111
5	Angle 65*65*8	111

The third: Lingo-Ver 17.0, which is highly accurate in solving quantitative analysis problems after the construction of the mathematical model consisting of a goals function, goals constraints and system constraints, was obtained the results of variables and the results of limitations of the mathematical model described in Table (10) and (11) as follows:

Table (10) show the results of the variables of the mathematical model

Variables	Variables values	Variables	Variables values	variables	Variables values
d_1^+	0	d_2^+	0	H_3	0
d_2^-	0	D_1	433	H_4	0
X_1	433	D_2	433	H_5	0
X_2	433	D_3	433	H_6	0
X_3	433	D_4	433	H_7	0
X_4	433	D_5	433	H_8	0
X_5	433	D_6	433	H_9	0
X_6	433	D_7	433	H_{10}	0

X_7	433	D_8	433	H_{11}	0
X_8	433	D_9	433	H_{12}	0
X_9	433	D_{10}	433	H_{13}	0
X_{10}	433	D_{11}	433	H_{14}	0
X_{11}	433	D_{12}	433	H_{15}	0
X_{12}	433	D_{13}	433	H_{16}	0
X_{13}	433	D_{14}	433	H_{17}	0
X_{14}	433	D_{15}	433	H_{18}	0
X_{15}	433	D_{16}	433	H_{19}	0
X_{16}	433	D_{17}	433	H_{20}	0
X_{17}	433	D_{18}	433	H_{21}	0
X_{18}	433	D_{19}	433	H_{22}	0
X_{19}	433	D_{20}	433	H_{23}	0
X_{20}	433	D_{21}	433	H_{24}	0
X_{21}	433	D_{22}	433	H_{25}	0
X_{22}	433	D_{23}	433	H_{26}	0
X_{23}	433	D_{24}	433	H_{27}	0
X_{24}	433	D_{25}	433	H_{28}	0
X_{25}	433	D_{26}	433	H_{29}	0
X_{26}	433	D_{27}	433	H_{30}	0
X_{27}	433	D_{28}	433	H_{31}	0
X_{28}	433	D_{29}	433	H_{32}	0
X_{29}	433	D_{30}	433	H_{33}	0
X_{30}	433	D_{31}	433	H_{34}	0
X_{31}	433	D_{32}	433		
X_{32}	433	D_{33}	433		
X_{33}	433	D_{34}	433		
X_{34}	433	H_1	0		
d_1^-	0	H_2	0		

Table (11) shows the results of the limitations of the mathematical model

Sequence constant	left side of the constant	signal	Right side of the constant
1	6540	≥	6450
2	2810	≤	15800
3	7605	≥	7550
4	16525	≤	31680
5	7655	≥	7500
6	3325	≤	18480
7	12500	≥	4000
8	1980	≤	18480
9	12300	≥	4200
10	15000	≤	16500
11	12500	≥	4000
12	1000	≤	17500
13	12400	≥	4100
14	2000	≤	18500
15	16900	≥	3000
16	18000	≤	19900
17	13020	≥	8100
18	21100	≤	21120
19	13120	≥	8000
20	21100	≤	21120
21	13620	≥	7500
22	21100	≤	21120
23	13520	≥	7600
24	21100	≤	21120
25	4660	≥	4000
26	8180	≤	16840
27	4560	≥	4100
28	9180	≤	17840
29	3495	≥	3000
30	13405	≤	19900

13	7655	≥	7500
32	3325	≤	18480
33	7655	≥	7500
34	4645	≤	19800
35	3495	≥	3000
36	13305	≤	19800
56	1568	≥	433
57	894	≥	433
64	326	≥	433

The results of the solution show that:

1-The first goal (the goal of reducing the cost of production) has been achieved (d1+=0), i.e. the cost of production is either lower or equal to (4464254500 dinars).

2-The second goal (the goal of maximizing production quantities) has been achieved (d2-=0), i.e. production quantities are either larger or equal (17000 parts per month).

While achieving the two objectives according to their importance by the company: -

1- The quantities produced from the main product parts were produced as follows: (433) (part/month) as shown in Table (10).

2- The company covered the monthly order of the main product parts for all parts (433 pieces per month) during that period.

3- The amount stored from the parts of the product was equal to (0), i.e. there was no stock of parts because of the equal production and demand amounts for those parts as shown in Table (10).

4- The lower limit of energy available for machines are fully exploited as in constraint (1) so that the time required to complete the production process requires (6540) working minutes per month instead of (6450) working minutes per month, as well as other constraints.

5- The upper limit of energy available for machines have not been fully exploited, as in constraint (2) if the time required to complete the production process requires (2810) minutes per month of work instead of (15800) working minutes per month, as well as the rest of the minimum constraints as indicated in table (11).

6- Constraints in Table (11) of (37-71) represent demand restrictions where constraints (37-55) and constraints (58-63) were equal to (0) i.e. demand amounts equal to production quantities of (433) part. For the following three months, the constraint (56) was quantity (1568) a portion that was larger than the specified and constraint (57), which was quantity (894) the portion of the demand was larger than the specified and the constraint (64) was quantity (326) the portion of the demand was larger than the specified.

7- The rest of the constraints (106-139) represent budget constraints that were zero, i.e. budget constraints.

5-Conclusion:

The proposed study to plan the production of the electrical distribution converter (400KV/11) using time series methods and goal programming in the fuzzy environment is of great importance due to its high ability to keep up with the latest environment and respond quickly to market demands. Fuzzy logic helped to study the potential effects of the fuzzy environment at the level of demand and its processing and predictability of future demand. The lead time is a basic of the production planning system because the processing of fuzzy waiting time has a significant impact on the process of receiving and delivering materials on time for customers.

The use of goal programming method provided more room for the decision-maker to think about several goals that can be achieved in a compatible manner and not content with a single goal. Through the application of the mathematical model of fuzzy production planning using goal programming, it was found that the goal of reducing production was achieved, i.e. the cost of production was reduced to less than the limit set by the management of the company as well as the goal of maximizing the amount of production also achieved by reaching the upper limit set by the management of the company and this helped to determine the amount of production required within one month.

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تخطيط إنتاج محولة التوزيع الكهربائي (400KV/11) باستعمال اساليب السلاسل الزمنية وبرمجة الأهداف في البيئة الضبابية

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مستخلص البحث:

يهدف البحث الى تخطيط انتاج محولة التوزيع الكهربائي (400 KV/11) لمدة شهر واحد في شركة ديالى العامة وبوجود اكثر من هدف لمتخذ القرار في بيئة ضبابية ، حيث تم التنبؤ بالطلب الضبابي باستعمال انموذج السلاسل الزمنية الضبابية، أيضا تم معالجة مدة الانتظار الضبابية للمواد الأولية التي تدخل في عملية انتاج المحولة التوزيع الكهربائي(400 KV/11) باستخدام مصفوفة الاستدلال الضبابي من خلال تطبيق المصفوفة ببرنامج Matlab، وبما ان لمتخذ القرار اكثر من هدف فقد تم بناء انموذج رياضي لبرمجة الأهداف والذي يهدف الى تحقيق هدفين هما تقليل تكاليف الإنتاج الكلية لمحولة التوزيع الكهربائي(400 KV/11) وتعظيم الكمية المنتجة منها حيث تم معالجة البيانات الضبابية للنموذج الرياضي باستعمال دالة الرتب ، ومن خلال النتائج المستحصلة لحل النموذج الرياضي باستعمال البرنامج Lingo نجد ان النموذج الرياضي قد حقق كلا الهدفين وهما تقليل تكاليف الإنتاج الكلية للمنتج الرئيسي لأقل من(4,464,254,500) دينار عراقي و تعظيم الكمية المنتجة من المنتج الرئيسي لأكثر من (17000) جزء بالشهر.

المصطلحات الرئيسة للبحث: تخطيط الإنتاج، طريقة التنبؤ الضبابية، نظام الاستدلال الضبابي، برمجة الأهداف، دالة الرتب.

*البحث مستل من رسالة ماجستير