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IMPLEMENTATION OF FUZZY MODEL TAHANI IN DECISION SUPPORT SYSTEM FOR OPTIMAL PRODUCTION SCHEDULING

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Abstract: In the manufacturing industry, production scheduling become an important aspect that affects operational efficiency and customer satisfaction. The main challenge in scheduling is optimizing the use of resources to meet demand by minimizing production costs and time. Suboptimal scheduling can lead to problems such as delays in stocking, stock buildup, and increased operational costs. Thus, a method can to handle the complexity and uncertainty in the production process is needed. The Fuzzy Tahani Model is an approach in decision support systems. this can be used to help companies achieve more efficient and adaptive production scheduling, to consider various variables such as demand, production capacity, and inventory levels. This research aims to develop and implement the model in the context of production scheduling, with the hope of improving operational performance and customer satisfaction. At this time, the proposed Fuzzy Model Tahani technology is in TKT 4, which is the validation stage of technology components in a laboratory environment. The system creates an optimal production schedule based on fuzzy rules and defuzzification results, making it a useful tool for production decisions.

Keywords: fuzzy model tahini; decision support system; production optimization; production scheduling.

Abstrak: Dalam industri manufaktur, penjadwalan produksi adalah aspek penting yang mempengaruhi efisiensi operasional dan kepuasan pelanggan. Tantangan utama dalam penjadwalan adalah mengoptimalkan penggunaan sumber daya untuk memenuhi permintaan dengan meminimalkan biaya dan waktu produksi. Penjadwalan yang tidak optimal dapat menyebabkan masalah seperti keterlambatan pengiriman, penumpukan stok, dan peningkatan biaya operasional. Oleh karena itu, diperlukan suatu metode yang mampu menangani kompleksitas dan ketidakpastian dalam proses produksi. Fuzzy Model Tahani adalah salah satu pendekatan yang dapat digunakan dalam sistem pendukung keputusan untuk membantu perusahaan mencapai penjadwalan produksi yang lebih efisien dan adaptif, dengan mempertimbangkan berbagai variabel seperti permintaan, kapasitas produksi, dan tingkat persediaan. Penelitian ini bertujuan untuk mengembangkan dan mengimplementasikan model tersebut dalam konteks penjadwalan produksi, dengan harapan dapat meningkatkan performa operasional dan kepuasan pelanggan. Pada saat ini, teknologi Fuzzy Model Tahani yang diusulkan berada pada TKT 4, yaitu tahap validasi komponen teknologi dalam lingkungan laboratorium. Sistem ini menciptakan jadwal produksi yang optimal berdasarkan aturan fuzzy dan hasil defuzzifikasi, menjadikannya alat yang berguna untuk pengambilan keputusan produksi.

Kata kunci: fuzzy model tahani; optimasi produksi; penjadwalan produksi; sistem pendukung keputusan;

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INTRODUCTION

In the manufacturing industry, production scheduling is a critical factor in achieving operational efficiency and ensuring customer satisfaction. Poor scheduling can result in numerous issues, including delivery delays, excessive inventory buildup, and rising operational costs [1], [2]. As global competition intensifies, manufacturing companies must respond swiftly and efficiently to market demand.

The research using the Fuzzy Model Tahani method for production scheduling yielded clear conclusions [3]. Optimal production scheduling can be achieved by focusing on three key input variables: demand, production capacity, and inventory level [4], [5]. This method allows the system to create production schedules that effectively respond to changes in demand and production capacity [6], [7].

A study in the International Journal of Production Research (2023) found that about 60% of manufacturing companies in Southeast Asia face inefficient production scheduling. Furniture maker Mr. Ediyal struggles with time management for tasks like frames, doors, and windows, which is further complicated by fluctuating consumer demand for different models and sizes. This highlights the need for adaptive solutions, such as the Fuzzy Model Tahani, to address these challenges effectively.

This research focuses on developing a decision support system using the Fuzzy Tahani Model to optimize production scheduling in manufacturing companies. The goal is to increase operational efficiency and reduce production costs by addressing uncertainties in the scheduling process.

METHOD

The explanation of the method includes an explanation of variables, Fuzzy Inference systems, Fuzzy tahani model, and data and process analysis.

The Tahani Model utilizes fuzzy membership functions categorized into input, process, and output variables. Input variables include demand, production capacity, and inventory levelsThe output variable is the production schedule.

Input variables (independent variables) in the form Demands, Production Capacity, Fuzzy Membership Functions. Demands measures the number of products requested by customers in a given period. Fuzzy Categories: Low, Medium, High. This defines the maximum production capacity of the facility within that period. The capacity is categorized as follows: Low, Medium, High. Inventory Levels indicates the quantity of product stock available in the warehouse before production begins. Fuzzy Categories: Low, Medium, High.

The output variable is the Production Schedule, which determines the exact number of units to be produced in a specified timeframe. It uses fuzzy categories: Low, Medium, and High. The output is calculated with a defuzzification method, like the centroid method, to ensure accuracy.

Lotfi A. Zadeh introduced fuzzy sets as an extension of classical set theory. In a classical set, the membership of an element is indicated by either 0 or 1 [8]. A value of 1 signifies that the element is a member of the s et, while a value of 0 indicates that the element is not a member of the set[9]. In a fuzzy set, the membership of an element is clearly expressed by a value between 0 and 1,

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known as the membership function (μA(x)). This function unequivocally defines the degree to which element x belongs to fuzzy set A. This capability effectively represents uncertainty and ambiguity in data and information. [10], [11].

The function of fuzzy logic can be calculated using the formula:

$$\mu A(x): X \rightarrow [0,1] \quad (1)$$

Describe:
X : represent the set of universes
μA(x): Denote the degree of membership of element x in fuzzy set A.

Membership functions are fundamental to fuzzy sets, and their shapes can be effectively customized to suit the specific requirements of various applications. Some of the most commonly utilized membership functions are Triangular Membership Function (formula (2)), Gaussian Membership Function (formula(3)).

$$\mu A_x = \begin{cases} 0 & , x \leq a \\ \frac{x-a}{b-a} & , a < x \leq b \\ \frac{c-x}{c-b} & , a < x \leq c \\ 0 & x > c \end{cases} \quad (2)$$

Describe:
a, b, c: the parameters that determine the shape of the triangle.

$$\mu A_x = exp\left(-\frac{(x-c)^2}{2\sigma^2}\right) \quad (3)$$

Describe:
c : the center of the Gaussian function
σ : the width of the curve.

The function of formula (3) to used for more subtle and frequent representation in statistical analysis.

In addition to the membership function in the fuzzy inference system there is an asembly function. The concepts of Fuzzy Operations, including Union (∪), Intersection (∩), and Complement (¬), which are defined as Union, Insertion, and complement.

The union operation states the highest degree of membership between the two fuzzy sets A and B for element x. Union operations are defined by formula (4).

$$\mu A \cup B(x) = \max(\mu A(x), \mu B(x)) \quad (4)$$

The intersection operation describes the lowest degree of membership between fuzzy sets A and B for element x. Insertion operations are defined formula (5).

$$\mu A \cap B(x) = \min(\mu A(x), \mu B(x)) \quad (5)$$

The complement operation reveals how much element x belongs to the fuzzy set A. Complement operations are defined by the formula (6).

$$\mu \neg A(x) = 1 - \mu A(x) \quad (6)$$

Fuzzy relations extend the concept of relations in classical set theory. Let X and Y be two sets. A fuzzy relation R between X and Y is represented as a fuzzy set within the Cartesian product X × Y. This fuzzy relation is defined by a membership function that assigns a degree of membership for each element in the Cartesian product.

$$\mu R(x,y): X \times Y \rightarrow [0,1] \quad (8)$$

Fuzzy relations model the connection between two fuzzy sets, particularly in control and decision-making systems.

The Basic Principles of the Fuzzy Tahani Model effectively combine fuzzy logic with relational databases. This model utilizes fuzzy sets to accurately represent ambiguous or uncertain information. It employs a fuzzy pattern

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matching mechanism to draw robust conclusions and to query the fuzzy database confidently [12].

The main components of the Fuzzy Tahani Model include Fuzzy Set, Fuzzy relations, Fuzzy Query, Inference Algorithm. Every attribute in a database must be represented by a fuzzy set. This approach ensures precise categorization and analysis of data. Fuzzy relations replace traditional relational models in databases.

This relationship not only connects two tables or attributes but also considers the degree of fuzzy membership of the involved elements. Users can submit queries that include vague terms. For instance, the query "Search for all products with high quality and low price" will utilize a fuzzy membership function to interpret what is meant by "high quality" and "low price". This algorithm is designed to match the data in the database with the fuzzy conditions specified in the query. It evaluates each entity based on its degree of membership in the relevant fuzzy set.

The stages of the implementation of the Fuzzy Tahani Model are in the form of: Defining Fuzzy Sets for Attributes, Define a fuzzy set for each relevant attribute in the database; Establishing Fuzzy Relations, Establish a clear fuzzy relationship to connect entities within a database. This approach ensures a more nuanced understanding of pricing for each product; Fuzzy Query Process, Create a query that searches the database using fuzzy terminology, This process involves matching membership degrees and utilizing fuzzy operators such as "AND," "OR," and "NOT"; Evaluation and Inference, Query evaluation using a fuzzy inference algorithm results in a list of entities that meet the defined fuzzy criteria, along with their degree of conformity.

From the explanation of the previous method and the data collected, the data is presented in the form of a description of data analysis and process.

Step 1: Definition of Input Variables. The three main input variables include Demand, Production Capacity, and Inventory Level. Each of these variables is associated with three fuzzy sets: high, medium, and low.

Step 2: Fuzzy Set Definition and Membership Function. Each input variable is represented by a fuzzy set, each with its own membership functions: Demand, Low: $\mu\_low(d) = 1$ if $d \leq 50$, 0 if $d \geq 100$, and linear between 50-100. Medium (Medium): $\mu\_medium(d) = 0$ if $d \leq 50$ or $d \geq 150$, linear between 50-100 and 100-150. High: $\mu\_high(d) = 1$ if $d \geq 150$, 0 if $d \leq 100$, and linear between 100-150; Production Capacity, Low: $\mu\_low(c) = 1$ if $c \leq 30$, 0 if $c \geq 70$, and linear between 30-70. Medium: $\mu\_medium(c) = 0$ if $c \leq 30$ or $c \geq 100$, linear between 30-70 and 70-100. High: $\mu\_high(c) = 1$ if $c \geq 100$, 0 if $c \leq 70$, and linear between 70-100; Inventory Level, Low: $\mu\_low(i) = 1$ if $i \leq 20$, 0 if $i \geq 60$, and linear anta-ra 20-60. Medium (Medium): $\mu\_medium(i) = 0$ if $i \leq 20$ or $i \geq 80$, linear between 20-60 and 60-80. High: $\mu\_high(i) = 1$ if $i \geq 80$, 0 if $i \leq 60$, and linear between 60-80;

Step 3: Definition of Output Variables (Production Schedule), The output of the system is the production schedule, which will also be represented by the fuzzy set of Production Schedule (Production Schedule): Low: $\mu\_low(p) = 1$ if $p \leq 30$, 0 if $p \geq 70$, and linear between 30-70; Medium (Medium): $\mu\_medium(p) = 0$ if $p \leq 30$ or $p \geq 100$, linear between 30-70 and 70-100; High:

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μ_high(p) = 1 if p ≥ 100, 0 if p ≤ 70, and linear between 70-100.

Step 4: Developing Fuzzy Rules, Here are some fuzzy rules for production scheduling:

R1: If the demand is high, production capacity is high, and inventory levels are low, then the production schedule should be set to high**;**

R2: If the demand is medium, production capacity is medium, and inventory levels are moderate, then the production schedule should be set to moderate**;**

R3: If the demand is low, production capacity is low, and inventory levels are high, then the production schedule should be set to low.

Step 5: Fuzzy Inference, The data available is as follows: Demand is 120 units, production capacity is 80 units, and the inventory level is 50 units. Calculate the membership degree for each input variable and apply the fuzzy rules with the membership degree:

Demand (for 120 unit): μ_low(120) = 0, This is below the minimum range); μ_medium(120) = (150-120)/(150-100) = 0.6, μ_high(120) = (120-100)/(150-100) = 0.4;

Production level (80 unit) : μ_low(80) = 0 , This is below the minimum range); μ_medium (80) = (100-80)/(100-70) = 0.67; μ_high(80) = (80-70)/(100-70) = 0.33.

Inventori Level (50 unit): μ_low(50) = (60-50)/(60-20) = 0.25, μ_medium(50) = (80-50)/(80-60) = 0.5, μ_high(50) = 0. This is below the maximum range; c and d. Application of Fuzzy Rules and Inference: Rule 1: μ_high(120) * μ_high(80) * μ_low(50) = 0.4 * 0.33 * 0.25 = 0.033 (High Production Schedule); Rule 2: μ_medium(120) * μ_medium(80) * μ_medium(50) = 0.6 * 0.67 * 0.5 = 0.201 (Medium Production Schedule); Rule 3: μ_low(120) * μ_low(80) * μ_high(50) = 0 * 0 * 0 = 0 (Low Production Schedule).

Step 6: Defuzzification,

After obtaining the fuzzy output, the next step is defuzzification, which provides a concrete value for the production schedule. The Centroid method is employed in this process of defuzzification. Assuming the output values for a high production schedule are set at 90 and for a medium production schedule at 60, the resulting production value can be effectively calculated as:

$$p=\frac{0.33*90+0.201*60}{0.033+0.201}=64.23$$

RESULT AND DISCUSSION

The results of defuzzification yield a definitive production schedule value, which is approximately 64 units. This is the optimal production amount for the designated period (weekly/monthly).

In this study, the Fuzzy Model Tahani method is used to solve the problem of production scheduling by considering three main input variables: De-mand, Production Capacity, and In-ventory Level. This process aims to determine an opti-mal production schedule by utilizing the concept of fuzzy sets and fuzzy rules that have been set. The following is a detailed discussion of the steps that have been taken.

In this initial step, we clearly define the input variables: Demand, Production Capacity, and Inventory Level. Each variable is categorized into three distinct levels: Low, Medium, and High. This structured approach effectively captures variations in input data and decisively informs our production schedules to align with the current conditions.

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In the second stage, we create fuzzy sets and membership functions for each input variable. These functions convert numerical input values into degrees of membership in specific fuzzy categories. For example, if demand is recorded at 120 units, it might have a membership degree of 0.6 in the Medium category and 0.4 in the High category. This means the demand is moderately likely to fall into the Medium category, with some chance of being classified as High. We use linear membership functions to enable smooth transitions between categories, allowing for a clearer understanding of how input values relate to fuzzy classifications.

Step Three is Definition of Output Variables (Production Schedule). The output of the system is the Production Schedule, represented as a fuzzy set comprising three categories: Low, Medium, and High. This fuzzy set allows for expressing the output in terms of membership degrees, which can capture variations in production schedule decisions more effectively.

The fourth step is crucial and involves the formation of fuzzy rules. These rules will clearly define the relationship between input variables and output outcomes. For instance, an effective rule states: "If demand is high, production capacity is high, and inventory levels are low, then the production schedule must be high." This rule embodies the decision-making logic based on input conditions and will play a vital role in the fuzzy inference process.

In the fifth step, fuzzy inference, we use the actual input data, which consists of a request for 120 units, a production capacity of 80 units, and a supply level of 50 units, to calculate the degree of membership for each input variable. Next, we apply fuzzy rules to produce fuzzy outputs. For instance, based on the existing rules, we determine that for the given combination of inputs, the membership degree for a High Production Schedule is 0.033, while for a Medium Production Schedule, it is 0.201.

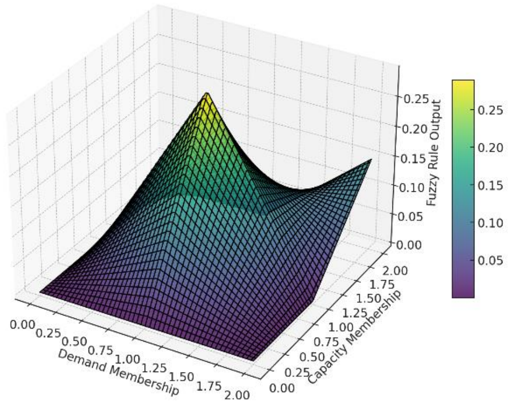

Image 1. Result

After fuzzy inference, the next essential step is defuzzification, which transforms the fuzzy output into a precise value. We utilize the centroid method for this process, yielding a production schedule value of 64 units. This result is a direct outcome of combining the membership degrees of various output categories with the central values of the relevant fuzzy set.

The final step, Interpretation and Implementation, is crucial for achieving optimal results. The defuzzification results decisively indicate that the ideal production amount is 64 units for the specified period. This conclusion stems from a rigorous fuzzy analysis of the relevant input variables, including demand, production capacity, and current inventory levels.

Production managers must leverage these findings to effectively adjust production schedules, significantly reduce operational costs, and ensure product availability aligns precisely with market demands. By employing the

Fuzzy Model Tahani method, the system confidently addresses uncertainty and variations in input data, resulting in superior operational efficiency in production scheduling.

CONCLUSION

This research used the Fuzzy Model Tahani method to improve production scheduling. The study found that effective production scheduling requires three key factors: Demand, Production Capacity, and Inventory Level. By using the Fuzzy Model Tahani method, the system can create production schedules that respond better to changes, like shifts in demand and differences in production capacity. This research applied the Fuzzy Model Tahani to develop a data-driven solution for production scheduling. The defuzzification results indicate that an optimal production schedule is around 64 units, showing that the fuzzy method effectively meets production needs. The Fuzzy Model Tahani method effectively addresses production scheduling by considering various influencing variables. The system generates an optimal production schedule using fuzzy rules and defuzzification results, making it a useful tool for production decision-making. The Fuzzy Model Tahani method effectively tackles production scheduling issues, especially in complex and uncertain situations. It addresses input variations and provides a scalable, practical solution for real-world industrial applications.

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