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Implementation of Fuzzy Sugeno in Mobile-Based Inventory Management

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Abstract

Purpose: This study aims to develop a mobile web-based inventory management system for Toko Percetakan Diraza by integrating the Fuzzy Sugeno method to improve stock prediction accuracy and reduce errors caused by manual record-keeping, which previously led to stock shortages, overstock, and inefficient monitoring.

Research Methodology: The research used inventory and sales data from January to June 2025, consisting of 229 product records across six categories. The system applied the first-order Fuzzy Sugeno method with two input variables: inventory level and sales data. Development followed the Waterfall model using PHP, MySQL, and Bootstrap. Validation was conducted through manual calculation comparison and black-box testing.

Results: The system calculation results are consistent with the manual Fuzzy Sugeno computations. For the sample product "Ordinary Map B" (inventory: 36 units; sales: 31 units), the system generated a stock demand prediction of 23 units, which corresponds to the manual calculation results. The implementation of the system enhances stock monitoring efficiency and minimizes the risk of manual recording errors.

Conclusions: The Fuzzy Sugeno method can be effectively implemented in a mobile web-based system to provide accurate and adaptive stock predictions for small businesses.

Limitations: The study only used two main inputs inventory levels and sales data without considering additional factors such as lead time or seasonal demand variations.

Contributions: This study contributes to the field of inventory management and decision-support systems by demonstrating that Fuzzy Sugeno can effectively support small businesses, especially printing stores, in predicting stock needs and improving operational efficiency.

Keywords: *Fuzzy Sugeno, Inventory Management, Stock Prediction, Waterfall Method*

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1. Introduction

Inventory management is an important aspect of ensuring smooth business operations. Properly managed inventory can increase productivity and service quality, while errors in stock management may cause financial losses due to shortages or overstock conditions (Cecilia & Zai, 2026; Oktadiansah & Fitria, 2025). In practice, many Small and Medium-Sized Enterprises (SMEs), including printing shops, still rely on manual record-keeping systems. This method is prone to recording errors, difficult to monitor in real time, and lacks the capability to predict future stock requirements. As a result, businesses often experience stock imbalances that reduce service quality and increase operational costs due to inefficient procurement planning (Egbunike & Oranefo, 2023).

With the rapid development of digital technology, web-based and mobile systems have become effective solutions to improve operational efficiency. Mobile web systems allow business owners to access inventory data anytime and anywhere in real time (Ayoedya, Widiartha, & Puja, 2024; Indratno, Fardani, & Kuntoro, 2024). However, most existing inventory systems primarily focus on recording transactions without integrating predictive analytical methods. Consequently, decision-making related to stock replenishment is still largely based on estimation rather than data-driven analysis. This gap highlights the need for an intelligent inventory management system capable of handling uncertainty and generating accurate stock predictions.

One method widely used in prediction systems is fuzzy logic. Fuzzy logic handles data ambiguity by assigning membership degrees between 0 and 1, enabling flexible and adaptive decision-making (Anton & Gusrianty, 2023; Nisa & Ali, 2025; Putra, Rismawan, & Bahri, 2021; Rifai & Fitriyadi, 2023). The first-order Fuzzy Sugeno model produces numerical outputs directly, making it suitable for stock prediction cases. Previous studies have demonstrated the effectiveness of this method in various sectors such as food, pharmaceuticals, and retail industries (Hajar, Badawi, Setiawan, Siregar, & Windarto, 2020; Nata & Yudiastra, 2022; Soleimani, Dehyadegari, & Gerami, 2021). Nevertheless, limited research has specifically applied the Fuzzy Sugeno method in a mobile web-based inventory management system for small-scale printing businesses, particularly using real operational sales and inventory data.

Based on these problems and research gaps, this study aims to develop and implement a mobile web-based inventory management system integrated with the Fuzzy Sugeno method at a printing shop. The system not only records incoming and outgoing goods transactions but also generates stock predictions based on inventory and sales data (Manurung, Asih, & Elhanafi, 2020; Pahlevi, Birowo, & Rezeki, 2021). By integrating predictive features into a mobile platform, this research seeks to reduce the risk of stock shortages and overstock, improve operational efficiency, and support data-driven decision-making in small businesses within the context of digital transformation and Industry 4.0.

2. Literature Review

2.1 Related Research

Previous studies have extensively explored the application of fuzzy logic in inventory management systems and demonstrated its contribution to improving operational efficiency (Amelia, Ginting, & Ishak, 2023; Atika & Sukmono, 2024; Garai, Chakraborty, & Roy, 2019). Research by Baihaqi and Sriani (2023) shows that the Sugeno method is effective in handling stock uncertainty, achieving an accuracy level of 88.887%. Similarly, Anton and Gusrianty (2023) explains that the implementation of Fuzzy Sugeno in decision support systems enhances accessibility and supports business owners in making more structured stock control decisions. Furthermore, Rifai and Fitriyadi (2023) report that the Sugeno method is capable of generating highly accurate production decisions, with a truth rate of 99.98%.

Other studies confirm that fuzzy logic is suitable for prediction and inventory control across various sectors, including food, pharmaceuticals, and retail (Hajar et al., 2020; Nata & Yudiastra, 2022; Shekarian, Kazemi, Abdul-Rashid, & Olugu, 2017). The method's ability to handle uncertainty makes it particularly relevant for environments with fluctuating demand patterns (Putra et al., 2021; Rifai & Fitriyadi, 2023). Despite these findings, most previous research focuses on manufacturing, pharmacy, or general retail contexts. Limited studies specifically integrate the first-order Fuzzy Sugeno method into a mobile web-based inventory management system tailored to small-scale printing businesses, which typically experience volatile and dynamic sales data. This gap highlights the need for a more adaptive and accessible inventory prediction system for micro and small enterprises.

2.2 Related Research

2.2.1 Logika Fuzzy Logic

Fuzzy Logic is a computational approach designed to handle uncertainty and ambiguity in decision-making processes (Martínez-Vivar et al., 2025). Unlike classical logic, which operates on binary values (true or false), fuzzy logic assigns degrees of membership ranging from 0 to 1, allowing a value to partially belong to multiple sets simultaneously (Anton & Gusrianty, 2023). This flexibility enables more realistic modeling of complex real-world problems. In inventory management, uncertainty often arises from fluctuating demand and inconsistent stock movement. Fuzzy logic allows numerical (crisp) data to be converted into linguistic variables through membership functions, enabling systems to process data in a way that resembles human reasoning (Baihaqi & Sriani, 2023). Membership Functions:

$$\mu[x] = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} \; ; & a < x \leq b \\ 1 & x \geq b \end{cases} \tag{1}$$

2.2.2 Fuzzy Sugeno

Model The fuzzy Sugeno Model, The Fuzzy Sugeno model, also known as the Takagi-Sugeno-Kang (TSK) model, was introduced to provide a systematic framework for constructing fuzzy rules based on input and output data (Baihaqi & Sriani, 2023). The general form of a Sugeno rule is: Model Fuzzy Sugeno Orde-Nol:

$$IF\ (x_1\ is\ A_1)\ AND\ (x_2\ is\ A_2)\ THEN\ z_i \tag{2}$$

In the first-order Sugeno model, the consequent is expressed as a linear function:

$$IF\ (x_1\ is\ A_1)\ \ldots\ldots\ (x_2\ is\ A_2)\ THEN\ z\ = p_1 * x_1 + \ldots\ldots + p_n * x_n + q \tag{3}$$

The main advantage of the Sugeno method lies in its ability to produce crisp numerical outputs directly, making it suitable for prediction and control systems (Putra et al., 2021; Rifai & Fitriyadi, 2023). The implementation of the Sugeno method generally involves several stages:

1. Determination of Fuzzy Variables
   The initial stage in implementing fuzzy logic is to determine the input and output variables that represent the system conditions and the expected results. In this study, the input variables consist of inventory, which indicates the amount of stock available, and sales, which describe the level of product demand. The output variable is demanding prediction, namely the quantity of goods that need to be prepared or ordered as a basis for procurement decision-making. Each variable is represented in the form of linguistic sets to facilitate interpretation and handle data uncertainty.
2. Fuzzy Set of Input Variables
   The inventory input variable is divided into the linguistic sets low and high, while the sales variable consists of low and high. This classification aims to categorize stock and demand conditions more flexibly. The system output, in the form of demand prediction, is generated based on the predefined fuzzy rules. Membership Functions

The membership function is used to map numerical input values into degrees of membership within a range of 0 to 1. This process converts crisp data into linguistic values through the fuzzification stage, enabling the system to handle data uncertainty and complexity in a way that more closely resembles human decision-making. This process converts crisp data into linguistic value through the fuzzification stage, so that the system is able to handle the uncertainty and complexity of the data more closely to the way humans make decisions (Baihaqi & Sriani, 2023). To convert numerical input values (such as inventory and sales) into degrees of membership, the membership function formula is used as follows:

1. Linear Function Down

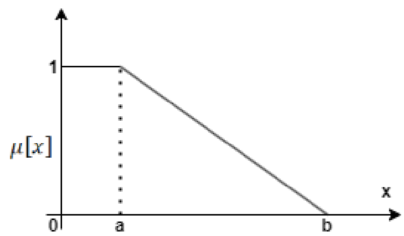

Figure 1. Linear function down

$$\mu[x] = \begin{cases} 1 & x \leq a \\ \frac{b-x}{b-a} ; & a \leq x \leq b \\ 0 & x \geq b \end{cases} \quad (4)$$

2. Linear Ascending Function

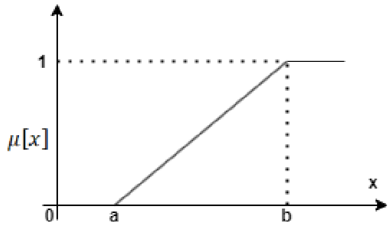

Figure 2. Linear ascending function

$$\mu[x] = \begin{cases} 0 & x \leq a \\ \frac{x-a}{b-a} ; & a \leq x \leq b \\ 1 & x \geq b \end{cases} \quad (5)$$

3. Implication Function
   The Implication Function is an important stage in a fuzzy logic control system, where predefined fuzzy rules are used to generate decisions or outputs. At this stage, the linguistic variables resulting from the membership function process are used as inputs to execute these rules. Each rule contains specific conditions and contributes to the resulting output, allowing the system to make decisions based on a combination of complex fuzzy information. This process consists of three main parts: calculating the degree of truth (α-predicate), determining the output using the linear function (z) of each rule, and applying the fuzzy rules. Zero-Order Sugeno Fuzzy Model Rules:

$$IF\ (x_1\ is\ A_1)\ AND\ (x_2\ is\ A_2)\ THEN\ z_i \quad (6)$$

   If there are two inputs (sales and inventory), the ③-predicate is calculated using *the and* (minimum) operator:

$$\alpha_i = min(\mu A(x_1), \mu B(x_2)) \quad (7)$$

   Description:
   - $(\mu A(x_1), \mu B(x_2)$ adalah derajat keanggotaan dari input terhadap himpunan fuzzy.
   - ③$_i$\$apredicates$ indicate the strength (degree of truth) of the Third rule.

   Each rule produces an output value (consequent) in the form of a linear function (z) according to the formula above.

4. Defuzzification
   Defuzzification is the final stage in a fuzzy logic control system, where outputs that were previously expressed as fuzzy linguistic variables are converted into concrete numerical values or actions that can be directly applied (Anton & Gusrianty, 2023): In the Sugeno defuzzification method, the following calculations are performed:

$$Z^* = \frac{\sum_i^n apredikat_i * z_i}{\sum_i^n apredikat_i} \quad (8)$$

2.3 Supporting Technologies

Web-based systems require reliable server-side programming and database management. PHP is widely used in web development due to its flexibility and server-side processing capability (Noviana, 2022). MySQL functions as an open-source Relational Database Management System (RDBMS) that supports multi-user access and efficient data management (Agarwal, 2025). In addition, Bootstrap provides a responsive front-end framework that supports flexible and user-friendly interface design across various devices (Ayoedya et al., 2024).

3. Research Methodology

3.1 Research Design

This study employs a quantitative applied research design combined with system development and computational modelling. The research aims to design, implement, and evaluate a mobile web-based inventory management system integrated with the first-order Fuzzy Sugeno method to improve stock demand prediction accuracy. The research was conducted at Toko Percetakan Diraza, located in Pesawaran District, Lampung, Indonesia. The object of the study is the store's inventory management process, particularly procurement decision-making based on stock and sales data.

3.2 Data Collection Method

Data collection was carried out using several methods to ensure that the information obtained is accurate, relevant, and scientifically accountable. These methods were selected to support the research analysis and to provide a clear and realistic picture of the actual conditions in the field. The methods used are as follows:

1. Interview
   Interviews were conducted using a semi-structured approach to obtain in-depth information regarding the inventory management process. The interview was carried out with Mr. Suharyanto, the owner and operational manager of Toko Percetakan Diraza, who is directly responsible for procurement decisions and stock control. The discussion focused on the flow of incoming and outgoing goods, the procedures used in manual stock recording, the frequency of stock shortages and overstock conditions, and the decision-making process for determining procurement quantities. The results of the interview revealed that stock estimation was primarily based on experience and intuition without the support of structured analytical methods, leading to inconsistent inventory levels and inefficiencies in procurement planning.
2. Observation
   Direct observation was conducted at Toko Percetakan Diraza in Pesawaran District, Lampung, to examine actual operational activities. The researcher observed daily transaction recording, stock updating procedures, goods storage practices, and the time required to determine procurement decisions. This observation aimed to validate information obtained from interviews and to understand the real workflow of inventory management. The findings confirmed that stock monitoring was performed manually and lacked predictive analysis, which increased the risk of recording errors and inaccurate stock estimation.
3. Literature Studies
   Documentation was carried out by collecting historical inventory and sales data from January to June 2025. The dataset consisted of 229 active product records categorized into six product groups. Each record contained information on stock levels and sales transactions during the observation period. The inventory values ranged from 13 to 99 units, while sales values ranged from 7 to 101 units. The data were selected based on several criteria, including products with consistent sales activity, complete transaction records, and active involvement in daily operations. This ensured that the data used in the modeling process accurately represented actual business conditions and supported reliable prediction analysis.

3.3 Research Flow

The research was conducted through several systematic stages to ensure that the development and implementation of the model were structured and measurable. The stages of the research are described as follows:

a. Problem Identification
   At this stage, the researcher analyzed the existing inventory management system at Toko Percetakan Diraza to identify operational weaknesses. The analysis focused on manual stock recording practices, procurement decision-making mechanisms, inconsistencies in stock levels, occurrences of overstock and stock shortages, and the absence of predictive analytical tools. The findings from

interviews and observations were used to clearly define the core problem, namely the lack of a structured prediction system capable of supporting data-driven procurement decisions.

b. Data Collection
   Data collection was conducted using interviews, direct observation, and documentation. Interviews with Mr. Suharyanto provided qualitative insights into stock management practices and decision-making patterns. Observations were performed to validate operational workflows, including transaction recording and stock monitoring processes. Documentation involved
c. Determination of Fuzzy Variables
   The next stage involved defining the fuzzy system variables in accordance with the first-order Fuzzy Sugeno framework (Yulmaini, 2019). Two input variables were determined, namely inventory and sales, while the output variable was stock demand prediction. The selection of these variables was based on their direct influence on procurement decisions and stock availability. Integration and System Testing after the system has been implemented, testing is carried out using the Blackbox Testing method to ensure that each function runs according to user needs (Samdono, Sari, & Aditiawan, 2024). In addition, an interface test is also carried out to assess the appearance and responsiveness of the system.
d. Design of Universe of Discourse and Membership Functions
   The universe of discourse for each variable was established based on the minimum and maximum values found in the dataset. Linear ascending and descending membership functions were constructed to transform crisp input values into degrees of membership. This fuzzification process enables the system to handle uncertainty and represent operational conditions linguistically (Baihaqi & Sriani, 2023).
e. Rule-Based Construction
   Fuzzy inference rules were formulated to represent realistic procurement logic derived from operational practices. Four rules were designed based on combinations of inventory and sales conditions. The rule structure followed the first-order Fuzzy Sugeno model, where the consequent is expressed as a linear mathematical function (Warmansyah & Hilpiah, 2019). Each rule was designed to minimize the risk of overstock and stock shortages.
f. Implementation of the Fuzzy Sugeno Inference Process
   The inference process consisted of three main steps: fuzzification, calculation of firing strength using the minimum (AND) operator, and defuzzification. The firing strength (α-predicate) of each rule was computed to determine the degree of influence of each rule. The final output was obtained using the weighted average defuzzification formula to produce a crisp numerical prediction (Baihaqi & Sriani, 2023; Budiarto & Alfiyan, 2025).
g. System Implementation and Integration Stage
   The fuzzy algorithm was integrated into a mobile web-based inventory management system. The system was designed to record transactions, monitor stock levels in real time, and automatically generate stock demand predictions based on current inventory and sales data.
h. System Testing and Validation Stage
   The validation process was conducted by comparing the system-generated prediction results with manual Fuzzy Sugeno calculations. This stage aimed to evaluate the conformity, accuracy, and consistency of the implemented algorithm (Laila, Azima, & Zen, 2022). Any discrepancies were analyzed to ensure computational correctness.
i. System Testing and Validation Stage
   The validation process was conducted by comparing the system-generated prediction results with manual Fuzzy Sugeno calculations. This stage aimed to evaluate the conformity, accuracy, and consistency of the implemented algorithm (Laila et al., 2022). Any discrepancies were analyzed to ensure computational correctness.
j. Result Analysis and Evaluation Stage
   The final stage involved analyzing the effectiveness of the developed system in improving stock prediction accuracy, reducing manual estimation errors, and enhancing operational efficiency. The

evaluation also assessed the practical applicability of the system in supporting data-driven decision-making within small-scale businesses.

3.4 Metode Fuzzy Sugeno

In this study, the first-order Fuzzy Sugeno method is applied as an approach to predict stock demand prediction (Budiarto & Alfiyan, 2025; Laila et al., 2022). This method was selected because of its ability to handle uncertain and fluctuating data by transforming numerical input values into linguistic variables and generating outputs in the form of linear mathematical functions that can be calculated directly (Baihaqi & Sriani, 2023; Warmansyah & Hilpiah, 2019).

The Fuzzy Sugeno model is considered suitable for inventory prediction cases due to its flexibility in processing dynamic input variables, such as stock levels and sales volumes. The stages required for implementing the Fuzzy Sugeno method in this study are described as follows (Yulmaini, 2019):

1. Determination of Fuzzy Variables (Input and Output)
   The first step is to determine the variables to be used in the fuzzy system. In the context of stock demand prediction, two input variables are defined, namely inventory and sales, and one output variable, which is the stock demand prediction fuzzy set of input variables. Sales and inventory variables are each divided into two linguistic conditions, namely inventory: few and many, and sales: low and high. This grouping facilitates the decision-making process in fuzzy Systems.
2. Variable Membership Function Input
   The membership function is used to transform numerical (crisp) values into fuzzy values expressed as degrees of membership (Suseno, Purwanto, & Nurmalitasari, 2023). In this study, linear ascending and linear descending membership functions are applied. The universe of discourse for each input variable is defined as follows:

Table 1. Variable input

Variable Input	**Universe Speaker**	**Fuzzy Set**
Inventory	13 - 99	13-99 Bit, Lot
Sales	7 - 101	7-101 Low, High

Table 1 show these values are then used in the initial stage to determine the membership function of each variable within the predefined fuzzy sets. Inventory Membership Function.
Universe Speaker inventory: 13 – 99

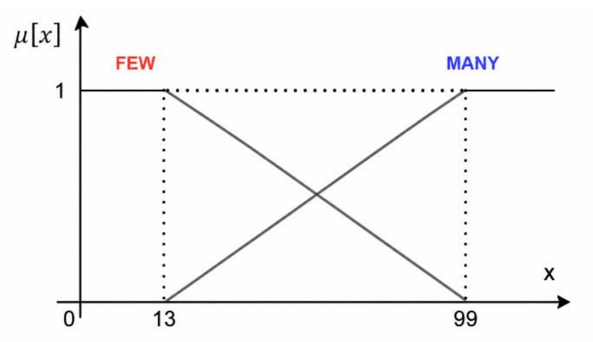

Figure 3. Variable membership function inventory

- Bit (Linear down):

$$\mu[x] = \begin{cases} 1 & x \leq 13 \\ \frac{99-x}{99-13} & ;\ 13 \leq x \leq 99 \\ 0 & x \geq 99 \end{cases} \tag{9}$$

- Lots (Linear Ascending):

$$\mu[x] = \begin{cases} 0 & x \leq 13 \\ \frac{x-13}{99-13} & ;\ 13 \leq x \leq 99 \\ 1 & x \geq 99 \end{cases} \tag{10}$$

a. Sales Membership Function
   Universe Speaker Sales: 7 – 101

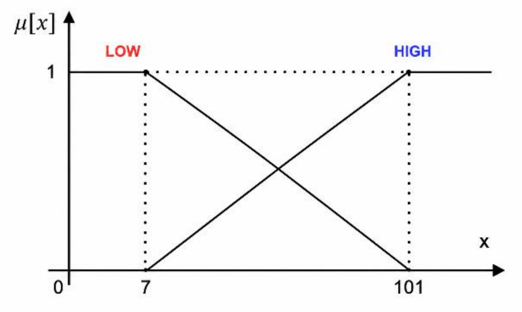

Figure 4. Function variable membership sales

- Low (Linear Down):

$$\mu[x] = \begin{cases} 1 & x \leq 7 \\ \frac{101-x}{101-7} \; ; & 7 \leq x \leq 101 \\ 0 & x \geq 101 \end{cases} \tag{11}$$

- Height (Linear Rise):

$$\mu[x] = \begin{cases} 0 & x \leq 7 \\ \frac{x-7}{101-7} \; ; & 7 \leq x \leq 101 \\ 1 & x \geq 101 \end{cases} \tag{12}$$

3. Rule

The rule formulation is conducted by considering the realistic relationship between the input variables (inventory and sales) and the output variable (stock demand prediction). The rules are designed based on combinations of operational conditions that frequently occur in practice, enabling the system to generate appropriate procurement recommendations. The objective is to allow the system to adjust stock demand predictions flexibly according to actual business conditions. The following provides a logical explanation of the four fuzzy rules implemented in this system:

R_1: IF inventory is high AND sales are low THEN demand prediction = inventory – sales
This rule is applied when the available stock is abundant while sales are relatively low. Under this condition, additional procurement in large quantities is unnecessary. The predicted value is calculated based on the difference between the current inventory and sales volume, representing the remaining stock surplus. This approach helps prevent overstock conditions and reduces unnecessary inventory holding costs.

R_2: IF inventory is low AND sales are low THEN demand prediction = sales
This rule is applied when both inventory and sales levels are low. Although demand is not high, the limited stock availability requires procurement at least equal to the sales volume to maintain product availability. This approach ensures that stock remains sufficient to meet ongoing demand and prevents potential stock shortages.

R_3: IF inventory is high AND sales are high THEN demand prediction = sales
This rule is applied when both inventory and sales levels are high. Although stock availability is currently sufficient, high sales indicate strong demand. Therefore, procurement is adjusted according to the sales volume to maintain stock stability and prevent sudden stock depletion.

R_4: IF inventory is low AND sales are high THEN demand prediction = 1.25 × (inventory − sales)
This rule addresses the most critical condition, where stock availability is limited while demand is high. In this situation, the system anticipates potential shortages by adding a 25% safety buffer to the calculated difference between inventory and sales. This buffer ensures that procurement exceeds the minimum requirement, thereby reducing the risk of stockouts that could disrupt business operations.

4. Results and Discussions

4.1 Manual Calculation

To validate the implementation of the Fuzzy Sugeno method, a manual calculation was performed using one sample product, namely *Ordinary Map B*. The inventory and sales data for June were 36 units and 31 units, respectively. The objective was to predict stock demand for July. The products analyzed in this study include six main categories: document folders (including Ordinary Map B), stationery, paper products, books, office supplies, and adhesives. These products were selected because they represent the most actively traded items in daily store operations.

The universe of discourse for each input variable is defined as follows:

- Universe Speaker Inventory: 13 – 99
- Universe Speaker Sales: 7 – 101

The settlement steps with sugeno method are as follows:

1. Determining Fuzzy Variables (Input and Output)
   There are three fuzzy variables consisting of two input variables, namely inventory and sales, and one output variable, namely the predicted goods requirements
2. Fuzzy Sets of the Input Variables
   The inventory input variable consists of two fuzzy sets, namely little and much, while the sales input variable consists of two fuzzy sets, namely low and high
   a. Inventory Membership Function
      We will find the membership value. If the inventory is 36, then the fuzzy membership value in each set is:
      Universe Speaker Inventory: 13 – 99

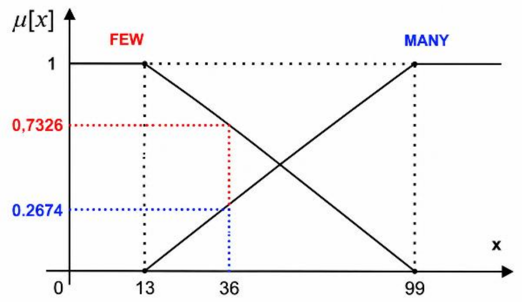

Figure 5. Function Inventory Membership

- Bit (Linear down):

$$\mu[x] = \begin{cases} 1 & x \le 13 \\ \dfrac{99-x}{99-13} & ; \; 13 \le x \le 99 \\ 0 & x \ge 99 \end{cases}$$

$$\mu Sedikit(x) = \frac{99-x}{99-13} = \frac{99-36}{86} = \frac{63}{86} = 0{,}7326 \quad (13)$$

- Lots (Linear Ascending):

$$\mu[x] = \begin{cases} 0 & x \le 13 \\ \dfrac{x-13}{99-13} & ; \; 13 \le x \le 99 \\ 1 & x \ge 99 \end{cases}$$

$$\mu Banyak(x) = \frac{x-13}{99-13} = \frac{36-13}{86} = \frac{23}{86} = 0{,}2674 \quad (14)$$

b. Sales Membership Function
   We will find the membership value, if the sale is 31 then the fuzzy membership value in each set is:
   Universe Speaker Sales: 7 – 101

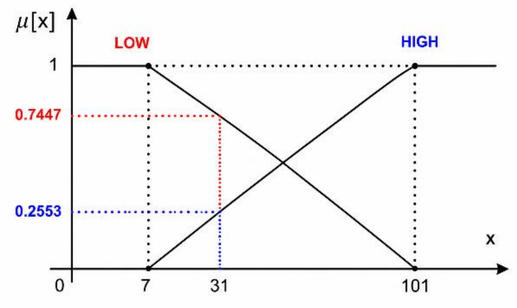

Figure 6. Function Sales Membership

- Low (Linear Down):

$$\mu[x] = \begin{cases} 1 & x \leq 7 \\ \dfrac{101 - x}{101 - 7} ; & 7 \leq x \leq 101 \\ 0 & x \geq 101 \end{cases}$$

$$\mu Rendah(x) = \frac{101-x}{101-7} = \frac{101-31}{94} = \frac{70}{94} = 0{,}7447 \quad (15)$$

- Height (Linear Rise):

$$\mu[x] = \begin{cases} 0 & x \leq 7 \\ \dfrac{x - 7}{101 - 7} ; & 7 \leq x \leq 101 \\ 1 & x \geq 101 \end{cases}$$

$$\mu Tinggi(x) = \frac{x-7}{101-7} = \frac{31-7}{94} = \frac{24}{94} = 0{,}2553 \quad (16)$$

3. Implication Function
   After that, the process involves finding the α-predicate value and z-value for each rule. This rule uses the first-order Sugeno fuzzy model, where the output of each rule takes the form of a linear equation dependent on two input variables. There are four fuzzy rules used in this system:
   R1: IF inventory is high AND sales are low, then demand prediction = inventory-sales
   - $a - predikat_1 = \mu_{Banyak}(x) \cap \mu_{Rendah}(x)$
     $= \min\,[\mu_{Banyak}(36) \cap \mu_{Rendah}(31)]$
     $= \min[0.2674; 0.7447] = 0.2674$ (17)
   - $z_1 = 36 - 31 = 5$

   R2: IF inventory is few AND sales are low THEN predicted demand = sales
   - $a - predikat_2 = \mu_{Sedikit}(x) \cap \mu_{Rendah}(x)$
     $= \min\,[\mu_{Sedikit}(36) \cap \mu_{Rendah}(31)]$
     $= \min[= 0.7326;\ 0.7447] = 0.7326$ (18)
   - $Z2 = 31_2 = 31$

   R3: IF inventory is plentiful AND sales are high THEN predicted demand = sales
   - $a - predikat_3 = \mu_{Banyak}(x) \cap \mu_{Tinggi}(x)$
     $= \min\,[\mu_{Banyak}(36) \cap \mu_{Tinggi}(31)]$
     $= \min[0.2674; 0.2553] = 0.2553$ (19)
   - $Z3 = 31_3 = 31$

   R4: IF inventory is few AND sales are high THEN predicted demand = 1.25 × inventory - sales
   - $a - predikat_4 = \mu_{Sedikit}(x) \cap \mu_{Tinggi}(x)$
     $= \min\,[\mu_{Sedikit}(36) \cap \mu_{Tinggi}(31)]$
     $= \min[0.7326; 0.2553] = 0.2553$ (20)
   - $z_4 = 1{,}25 \times 36 - 31 = 45 - 31 = 14$

4. Defuzzification
   Substitution into the formula:

$$z = \frac{(a_1 \times z_1) + (a_2 \times z_2) + (a_3 \times z_3) + (a_4 \times z_4)}{a_1 + a_2 + a_3 + a_4}$$

$$z = \frac{(0.2674 \times 5) + (0.7326 \times 31) + (0.2553 \times 31) + (0.2553 \times 14)}{0.2674 + 0.7326 + 0.2553 + 0.2553}$$

$$z = \frac{1{,}337 + 22{,}7106 + 7{,}9143 + 3{,}5742}{1{,}5106} = \frac{35{,}5361}{1{,}6512} = 23{,}5237 \qquad (21)$$

Based on the calculation of defuzzification, the predicted value of ordinary Map B for July is 23 pcs. The results of this study are in the form of a mobile web-based inventory management system that can assist the printing shop in recording stock and predicting goods requirements using the Sugeno Fuzzy Logic method. The prediction results are displayed automatically in the system to support decision-making for ordering goods.

Product Name	Inventory	Sales	Demand Forecast
Standard Map B	36	31	23.5237
Standard Map H	84	101	84.0814
Standard Map K	82	75	54.7914

Figure 7. Display stock prediction results in the system

Figure 7 display shows that the system operates according to the Sugeno fuzzy calculation flow, from the input of numerical data to generating predictive outputs in the form of concrete numbers. With this feature, the admin can determine the estimated stock requirements, allowing procurement to be carried out efficiently and without excess. As a continuation of the implementation process, the following are the results of the system in the form of the user interface:

4.2 System Implementation (Mobile Web-Based Application)

The Fuzzy Sugeno method was implemented in a mobile web-based inventory management system developed using PHP as the server-side programming language and MySQL as the database management system, providing robust data handling and processing capabilities (Firzana, Nurrachman, Fatihah, & Putra, 2024; Wijaya & Putri, 2025). The system's interface was designed with Bootstrap, ensuring a responsive and user-friendly layout across various devices. For development and testing purposes, XAMPP was used as the local server environment, facilitating smooth integration of the web components. Being mobile web-based, the system can be accessed through smartphones, tablets, or desktop browsers without the need for installation, and its responsive design guarantees optimal usability across different screen sizes.

4.3 Integration of Sugeno Calculation in the Application

Once the admin inputs the inventory and sales data, the system automatically performs fuzzification, converting crisp numerical values into fuzzy sets based on predefined membership functions. This process translates precise data into linguistic terms, such as "high," "medium," or "low," which are suitable for the fuzzy rule evaluation. By handling fuzzification internally, the system ensures that the subsequent rule processing accurately reflects the degree to which each input belongs to its respective fuzzy categories, laying the foundation for reliable predictions.

Following this, the firing strength (α-predicate) for each rule is calculated, the z-value of each rule is generated, and the defuzzification formula is executed programmatically. The final prediction result is then displayed automatically in the prediction table. This automated approach ensures the predictions remain consistent with manual calculations while eliminating potential human errors.

4.4 *Testing*

Testing was conducted to ensure that the system operates in accordance with user needs. The method used is Blackbox Testing, which focuses on evaluating the system's functionality without considering the underlying program code. The testing examines whether each feature behaves as expected based on specified requirements. Below are the results of testing several main features of the system:

4.4.1 System Interface Testing

Interface testing was conducted to ensure that each page of the system can be accessed and displayed properly. The evaluation was carried out manually by the admin, who assessed aspects such as visual layout, button functionality, text readability, and layout responsiveness. The following are the results of the interface testing for each page, as shown in Table 2.

Table 2. System interface testing

No	Features	Aspects Tested	Results
1	Login page login	Form appears, input can be typed, and active buttons	Function
2	Dashboard	Data summary: Data appears, sidebar functions	Function
3	Data page	Table items appear neat and button functions	Function
4	Page type	of Table items that appear can add/edit/delete data	Function
5	Page unit	The table shown and the Action Button are working	Working
6	Incoming goods page	Table transaction table showing, pagination running	Working
7	Outgoing goods page	A table showing and a button running	Working
8	Stock report page	The table showing, filter, and Print button working	Working
9	Incoming goods report page	Table and export/print are working correctly	Working
10	Goods report page exit	The Table and Export buttons are active	Function
11	Management page user	The table appears, the edit button & delete button work	Function
12	Stock prediction (fuzzy)	The prediction table appears, and the value is displayed	Function

4.4.2 System Interface Testing

System feature testing is done to ensure that every available function can operate smoothly and in accordance with the design that has been made. The following are the results of testing the system's main features, as shown in Table 3.

Table 3. Testing system features

No	Features	Input	Output Expected	Results
1	Login	Username and password are valid	Managed to get into the dashboard	Successful
2	Add Data Items to	The Form data item is filled out	of Data items stored and appear in the table of	Success
3	Edit & Delete Items	Change or remove data items from the table	Changes stored / data erased	Success
4	The Goods Enter	The name of the goods and the amount of incoming	Stock goods increased according to the input	A Successful

5	Items Out	The name of the goods and the amount of the out(sale)of	Stock items are reduced in accordance with input	A Successful
6	Prediction of Stock	sales Data, inventory(stock)	The predictive value of the stock is shown	Successful
7	Print a Report	Click the print button	a PDF File printed according to the data	Success
8	Export Data	Click the export button	Excel File successfully downloaded	The Successful
9	Add User	Name, username, password, and the level of	The user data is stored and appears in the table of the	Successful
10	Edit & Delete User	Change or remove the user from the table	Changes stored / user deleted	Successfully

Based on the tests that have been carried out, all main features of the system are functioning properly and in accordance with user needs. No errors or malfunctions were found during the testing process.

4.5 Preservation
The maintenance phase is carried out after the system is implemented to ensure its stability and reliability. Activities during this phase include bug fixes (corrective) to resolve errors, adjustments to new requirements (adaptive) to accommodate evolving needs, enhancements to features and interfaces (perfective) to improve usability, as well as preventive measures such as data backup and system security protection. Through this maintenance process, the system is expected to operate sustainably and continue supporting the daily operations of the print shop effectively.

4.6 Discussions
The results demonstrate that the Sugeno Fuzzy method was successfully implemented for inventory prediction in a mobile web-based system. The consistency between the manual calculation and the system-generated prediction confirms that the fuzzification, rule evaluation, and defuzzification processes were correctly implemented. Furthermore, the successful Blackbox Testing results indicate that all major system functions, including inventory management, stock prediction, reporting, and data processing, operated as expected. These findings suggest that the developed system can support inventory control while reducing manual calculation errors and improving operational efficiency. Despite these positive results, the prediction model is limited to two input variables, namely inventory and sales. In real-world inventory management, additional factors such as seasonal demand, promotional activities, and supplier lead time may also influence stock requirements. Therefore, future studies should consider incorporating these variables or comparing the Sugeno Fuzzy method with other forecasting techniques to further improve prediction accuracy and system performance.

5. Conclusions
5.1 Conclusion
Based on the results of the research and development process, it can be concluded that the mobile web-based inventory management information system has been successfully developed to support printing businesses in managing inventory, recording incoming and outgoing goods transactions, and generating organized and structured reports. The system is also equipped with a stock requirement prediction feature based on the Fuzzy Sugeno method, which utilizes sales data and current inventory levels as the primary input variables to estimate future stock requirements, thereby enabling more accurate and efficient procurement planning. Furthermore, the results of Black Box Testing and user interface testing demonstrate that all system functionalities operate as intended and meet user requirements. The interface has also been designed to be user-friendly, responsive, and accessible across a wide range of devices, ensuring an effective and convenient user experience.

5.2 Research Limitations
This study has several limitations. First, the prediction model only considers two input variables, namely inventory level and sales data, while other factors that may influence stock demand, such as

seasonal demand, supplier lead time, promotional activities, and customer purchasing trends, were not included. Second, the system was developed and evaluated using inventory data from a single printing store, which may limit the generalizability of the findings to other business sectors or larger-scale inventory environments. Finally, system validation focused on consistency between manual and system calculations as well as functional testing through Blackbox Testing, without comparing prediction performance against other forecasting methods.

5.3 Suggestions and Directions for Future Research

Future studies are encouraged to enhance the prediction model by incorporating additional variables that influence inventory demand, such as supplier lead time, seasonal patterns, promotional activities, and customer purchasing behavior. Furthermore, comparative studies involving other forecasting methods, including Mamdani, Tsukamoto, or machine learning approaches, are recommended to evaluate prediction performance under different business conditions. Future system development may also include features such as automatic low-stock notifications, automated data backup, and real-time inventory monitoring to further improve operational efficiency and support decision-making.

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Author Contributions

MTF contributed to the conceptualization, methodology, software development, data collection, formal analysis, system implementation, validation, visualization, and writing of the original draft. YY contributed to the supervision, methodology review, validation, manuscript review and editing, and final approval of the manuscript. FF contributed to the supervision, validation, manuscript review and editing, and final approval of the manuscript. RK contributed to the supervision, validation, manuscript review and editing, and final approval of the manuscript. All authors have read and agreed to the published version of the manuscript.

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