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Inventory Management Under Uncertainty Condition with Fuzzy Logic: A Literature Review

Tia Amelia[1], Rosnani Ginting[2], and Aulia Ishak[3]

[1,2,3] Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Jl. Dr.T. Mansur No.9, Padang Bulan, Medan, Sumatera Utara, 20155, Indonesia

Abstract. Fuzzy set theory, or fuzzy logic, has been in use in inventory systems since the 1980s, with vaguely defined, ill-defined, or imprecise values, or decisions based on individual subjective beliefs. Provides a framework for describing the parameters that can be passed. There are many uncertainties in inventory management that can arise due to many things, such as: Order Changes, Random Supplier Capabilities, or Unexpected Events. Fuzzy logic as a method of inventory control that provides a framework by considering parameters that are vague or poorly defined, or whose values are imprecise and determined based on individual subjective beliefs make it available. The purpose of this white paper is to review previous studies using fuzzy logic in inventory management to see the uncertainty variables used. The method used is a thematic analysis of articles on the application of fuzzy logic in various industries. The results of the review show that variables like fuzzy logic make it easy to obtain results from uncertainty variables that can be applied to industrial activities to enable manufacturing activities to be carried out effectively and efficiently increase.

Keyword: Inventory control, Fuzzy Logic, Fuzzy Inference System.

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1. Introduction

Inventory refers to the collection of raw materials, work-in-progress items, and finished goods that are considered as valuable assets within a business. These items are either ready for sale or in the process of being sold. Inventory plays a crucial role in the operations of a business, as it represents the tangible resources that can be utilized to meet customer demand and generate revenue. Effective inventory management involves tracking, monitoring, and controlling the flow of inventory to ensure optimal levels, minimize costs, and meet customer needs in a timely manner [1]. Inventory management is a key component of the success of any organization and its function is to find sufficient inventory levels to meet demand without creating excess inventory. Critical to meeting customer demands and controlling costs. However, uncertainty can affect delivery and production processes [2].

*Corresponding author at: [Universitas Sumatera Utara, Jl. Dr. T. Mansur No.9, Medan, 20155, Indonesia]
E-mail address: [tia.ameel@gmail.com]

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The basic purpose of inventory analysis, whether manufactured, distributed, retailed, or serviced, is to determine when and for how long goods should be ordered. In distribution, stock is classified as in transit. That is, it is moved to systems and warehouses where inventory in the retailer's warehouse or distribution center contains inventory for immediate sale to customers [3].

Inventory levels are difficult to manage due to many factors involved and uncertain events such as unpredictable supply and demand. Appropriate policies and control systems are required for each product type [4]. Some of the uncertainties in inventory systems cannot be fully explained by the concept of probability theory, leading to the emergence of fuzzy set theory, which has been used in inventory systems since the 1980s [5].

In scenarios like these, the inventory management model based on fuzziness can provide assistance. Fuzzy set theory presents an approach to effectively address and measure imprecision and uncertainty. Fuzzy logic is extensively employed in resolving risk-related issues, artificial intelligence tasks like developing expert systems, and in conjunction with artificial neural networks. The foundation of fuzzy logic lies in the concept of fuzzy sets introduced by Zadeh in 1965. The utilization of fuzziness has gained significant recognition as a method for modeling imprecise data in applications concerning production control [1].

The purpose of this paper is to review previous research on inventory control using fuzzy logic, identify variables used in fuzzy logic for inventory control systems, develop fuzzy logic applications, and discuss the impact on inventory control systems is to check

2. Inventory

The inventory consists of several types such as [6]:

- Raw material inventory is an unmanufactured and unprocessed raw material inventory because it is supplied directly from the supplier.
- Inventory of finished goods. Finished goods ready for shipment or awaiting sale.

Inventory management plays a crucial role in controlling the levels of inventory by determining optimal order quantities and timings. Its primary objective is to ensure efficient maintenance of inventories for various purposes such as production, sales, distribution, and business services, with the aim of maximizing profitability. By effectively managing inventory, businesses can avoid stockouts, minimize carrying costs, optimize production and sales processes, and meet customer demands in a timely manner. Ultimately, successful inventory management contributes to improved operational efficiency, increased customer satisfaction, and enhanced financial performance [4].

3. Fuzzy Logic

Fuzzy logic is a computational technique that allows for the analysis of processes using a range of logic responses beyond traditional binary (0 or 1) values, particularly in computer systems. One advantageous characteristic of fuzzy logic is its ability to convert speech or user experience into numerical values and provide outcomes based on imprecise or uncertain data. By utilizing IF-THEN rules, fuzzy logic effectively manages and produces various types of results [7].

4. Fuzzy inference system

A fuzzy inference system is utilized to establish connections between input and output variables within a system, as illustrated in the provided figure. There are three main methods for fuzzy inference systems: the Mamdani method, the Kanno method, and the Tsukamoto method [8]. The key difference between the Mamdani and Sugeno methods lies in how they represent fuzzy rules. The Mamdani method uses fuzzy sets as rule results, while the Sugeno method employs linear functions. In Tsukamoto's method, each fuzzy rule sequence utilizes a monotonic membership function [9].

In a fuzzy inference system, crisp inputs are transformed into fuzzy inputs through a fuzzification interface. After fuzzification, a rule base is constructed. The combination of the rule base and the database is known as the knowledge base. Defuzzification is then applied to convert fuzzy values back into actual output values. Fuzzy inference systems have been implemented in various applications, including management and manufacturing contexts [10]–[14].

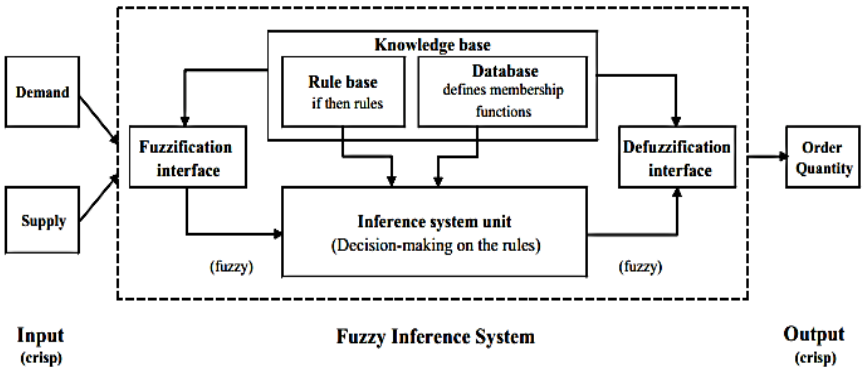

Figure 1 Scheme of Inference Fuzzy Inventory System

5. Research Methodology

This research aims to enhance our understanding of macroergonomics and explore its potential applications in various fields. A comprehensive search was conducted across several databases, including Google Scholar, ScienceDirect, Taylor & Francis, Emerald, JMIR, and Wiley Online Library. Specific keywords, such as "macroergonomics" and "analysis and design of macroergonomics," were used to retrieve relevant articles. The search criteria focused on scholarly journals evaluated by Scimago and Sinta, ensuring the inclusion of high-quality publications discussing the practical implementation of macroergonomics. By conducting this

extensive search, the study aims to gather a comprehensive collection of research and contribute to the advancement of macroergonomics in practice.

6. Results and Discussion

Hsun Hsieh [15] proposed is a fuzzy inventory model that addresses demand and lead time uncertainties. By incorporating fuzzy logic, the model optimizes inventory levels, reorder points, and order quantities. This approach enables businesses to adapt to market dynamics and improve efficiency. The results of the study show that the constructed model can provide the best value for computer mouses industry order numbers. Aengchuan and Phruksaphanrat use fuzzy logic to determine optimal order quantities and order points in the wood-based furniture industry. This study uses variables in the form of number of requests, supply of raw materials, and optimal number of orders. Analysis shows that an inventory system using fuzzy logic provides over 76% inventory cost savings compared to the stochastic EOQ model [4].

Khanlarpour et. al., used genetic algorithms and fuzzy logic to design intelligent warehouses, and analyzed 5 factors such as weather conditions, competitor conditions, consumer income, religious conditions, holidays, and tourism influences. We determined the number of orders in the warehouse and the reorder point based on two variables and customer satisfaction. The results of his research show the optimal order times and the optimal number of orders [16].

Utakumar & Karuppasamy used demand variables, storage costs, order costs, and order quantities to model lot size fuzzy inventory according to order costs in the healthcare industry. Research has shown that the constructed model has a higher total cost than the standard model, but this model can also be used in real situations [17].

Abdul Aleem et al. implemented fuzzy and adaptive neuro-fuzzy inference systems in his work to find the optimal number of orders in the raw material mill problem. As a result, the adaptive neuro-fuzzy and fuzzy inference system gave good results with error values below his 0.0005 [18].

Jamegh et al. created a fuzzy logic for determining safety stocks in the dairy processing industry based on the four variables: demand, raw material availability, end-of-stock and safety stock. The results show that the level of safety stock before and after applying the model has a positive effect, reducing safety stock by about 20% [19].

Jamegh et. al. used fuzzy logic with variable sentiment, such as raw material availability, demand, supply, and inventory security, to identify safety stocks in the beverage industry. increase. There is a research result that fuzzy logic does not cause shortages of 0.1% or more, and it can be seen that fuzzy logic is a necessary technology to solve the shortage problem [20].

Wibawa et al. implemented Tsukamoto fuzzy as a system recommendation in determining good order numbers in the KBS cooperative using demand, supply and order variables. As a result, it

was found that Tsukamoto Fuzzy can recommend the number of orders to the KBS cooperative [21].

Ramadan & Utama implemented Tsukamoto Fuzzy as a decision-making system for determining purchasing quantities in pharmaceutical companies using lead-time, inventory, and purchasing variables. As a result, we found that Tsukamoto Fuzzy can predict the number of purchases that a company needs, so it can make the company's activities more efficient [22].

Ali et al [23] suggested method employs Fuzzy Inference Systems (FIS) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS) to address uncertainties linked to demand, lead times, and inventory levels within a continuous inventory management system. The objective is to ascertain the most suitable order quantities and reorder points. By conducting simulations, the outcomes reveal the benefits and effectiveness of the FIS and ANFIS models when compared to the probabilistic Economic Order Quantity (EOQ) model, demonstrating their advantages and efficiencies. The expected benefits include improved customer loyalty, a potential 7% reduction in total inventory costs, and the absence of any identified shortcomings. By leveraging FIS and ANFIS, the inventory management system can effectively address uncertainties, optimize decision-making, and enhance overall performance.

Table 1 Summary of Research

References	Parameter			
	Demand	**Suplly**	**Leadtime**	**Others**
1. Hsun Hsieh [15]	√		√	
2. Aengchuan and Phruksaphanrat [4]	√	√		√
3. Khanlarpour et al [16]	√			√
4. Uthayakumar & Karuppasamy [17]	√			√
5. Jamegh et al. [19], [20]	√	√		√
6. Wibawa et al [21]	√	√		√
7. Ramadhan & Utama [22]			√	√

Based on the above studies, it can be concluded that the variables used in each study are different and the most commonly used uncertainty variable is consumer demand. This shows how fuzzy logic can be very useful for inventory management in companies with uncertain demand.

7. Conclusion

Efficient inventory management has gained significant importance in recent years as it involves various activities that are susceptible to uncertainties, which in turn affect inventory management outcomes. The findings of the literature review presented in this paper indicate that fuzzy set theory is an appropriate approach to tackle the uncertainties inherent in this field. Its application represents a significant advancement in inventory management practices. The primary objective of each review conducted is to identify the uncertain variables utilized in fuzzy set theory while formulating inventory models. By incorporating fuzzy set theory, businesses can enhance their ability to handle and adapt to the uncertainties present in inventory management, leading to more effective decision-making and improved overall performance.

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