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Productivity Estimation of Any Manufacturing Industry Using Fuzzy Logic in MATLAB Software

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Abstract

In every industry/organization, labor productivity plays a major part in overall growth and production. Many times, it is observed that industries do not attain their desired goals due to poor labor productivity. Labor productivity is dependent on many different factors like delay-in-payment, management supervision over workers, proper work planning and scheduling, poor site safety programs, lack of financial motivation system, etc. In this study, we estimated labor productivity in various industries by gathering extensive data, conducting surveys, and interviewing industry professionals. The primary objective of this project is to determine the factors that affect labor productivity. In any industry. The 50 factors for estimating labor productivity are chosen from the industrial projects. The survey was done through wide data collection, a questionnaire survey, and experts' views which were then ranked through the RII scale. The ranking is done through RII and then it is used for deciding top ranking factors that are responsible for labor productivity. After deciding factors for estimating labor productivity, fuzzy logic, and Artificial Neural Network (ANN) are used in the MATLAB environment.

Keywords*:* Labor productivity, fuzzy logic, MATLAB software, productivity analysis, fuzzy inference systems, membership functions, rule-based systems, computational analysis, data evaluation, performance metrics, Industrial engineering, Workforce efficiency, advanced control systems

INTRODUCTION

Labor productivity in manufacturing industries is a critical factor that determines a nation's overall efficiency and economic growth. In the Indian context, this aspect gains immense significance, given the country's vast workforce and its transition towards becoming a global manufacturing hub [1]. Labor productivity measures the output per labor hour and is influenced by various factors such as technological advancements, skill levels, work environment, and managerial practices [2].

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India's manufacturing sector has grown significantly in recent years, thanks in part to initiatives like "Make in India," which promote local production and encourage foreign investment. However, there are still hurdles to overcome in reaching the ideal levels of labor productivity. The Indian manufacturing industry often grapples with issues such as outdated machinery, inadequate training programs, and rigid labor laws that can hinder performance [3].

Enhancing labor productivity in India's manufacturing sector requires a multi-faceted approach that includes investment in modern technology, upskilling the workforce through

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continuous training and education, fostering innovation, and creating a flexible policy framework conducive to business growth. If India focuses on these areas, it can boost its manufacturing abilities while achieving sustainable economic growth and strengthening its position in the global market [4].

LITERATURE REVIEW

India's manufacturing labor productivity has been widely studied, especially concerning how it has been affected by economic reforms and structural changes over the years. Several studies have highlighted the nuanced factors that influence productivity across different sectors of the manufacturing landscape [5].

A significant finding from Das et al. [6] indicates that a flexible labor market has had a notable impact on productivity, employment, and real wages in Indian manufacturing industries, emphasizing the interconnectedness of these variables. At the national level, labor productivity in India continues to grow; however, regional disparity remains a significant concern [7].

Economic reforms of the 1990s were also assessed for their impact on manufacturing productivity, indicating that these policy shifts played a pivotal role in shaping current productivity trends [8]. However, research shows that overall productivity in Indian manufacturing still lags significantly behind that of more developed economies such as the United States, highlighting the urgent need for investments focused on enhancing worker capabilities to drive future growth [9]. Corona-Suárez et al. [10] presented two methods to improve the productivity of any manufacturing facility, while the prior technique is more inclined towards increasing productivity with the help of instruments that are easy and close to anyone's understanding, while the other uses a decision-making tool for evaluation.

Heshmati and Bhandari [11] presented a combined approach of hit and average range criteria used for productivity evaluation. However, the study has the limitation that it provides a range of productivity instead of a precise value and cannot be applied when the industry has increased capability. Kapuria et al. [12] have presented that for the productivity management department of any manufacturing industry, labor productivity analysis should be done quickly while linking the decrease in productivity with appropriate compensating measures [13]. The author's approach combines data acquisition methods and a structured evaluation process. A limitation of this technique is that it has a narrow application area [14, 15].

METHODOLOGY

Fuzzy Logic: Introduction

Fuzzy logic, created by Lotfi Zadeh in 1965, is a type of logic that allows reasoning in terms of approximate values rather than strictly fixed or precise answers. Unlike classical binary logic, in which a statement is either true or false (1 or 0), fuzzy logic allows for a continuum of truth values ranging between 0 and 1. This means that variables can have a degree of truth, which makes fuzzy logic particularly well-suited for handling the concept of partial truth.

One of the primary motivations behind fuzzy logic is to emulate human reasoning, which is often imprecise and based on subjective judgment. For example, terms like "warm" or "high" are inherently imprecise and can vary depending on context. Fuzzy logic systems can process such data using linguistic variables and rules that resemble human decision-making processes.

A fuzzy logic system is made up of four key parts:

1. *Fuzzification:* This involves converting input data into suitable linguistic values based on predefined membership functions.
2. *Knowledge base:* This stores the set of rules and membership functions used to define how the system interprets the input data.

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3. *Inference engine:* This part uses the rules and applies them to the fuzzified inputs to produce the fuzzy outputs.
4. *Defuzzification:* This process converts fuzzy output back into a precise quantity or value.

Fuzzy logic is used in many areas, including control systems, pattern recognition, and decision-making. In control systems, for example, it is used to handle processes that are difficult to model mathematically due to their complexity or variability-such as managing heating systems where inputs like "temperature" and "humidity" may not always have clear thresholds Imagine a person named Rahul learning about fuzzy sets. Unlike classical sets, fuzzy sets allow for a range of membership rather than a strict "in" or "out" rule. In a classical set, the elements either fully meet the criteria to belong or do not. However, with fuzzy sets, the elements can be part of the set to varying degrees. This approach offers a more flexible way of grouping things, capturing cases where membership is not absolute but somewhat "fuzzy" or partial (Figure 1).

A fuzzy set $\tilde{A}$ in the universe of information U can be defined as a set of ordered pairs and can be represented mathematically as

$$\tilde{A} = \{(y, \mu_{\tilde{A}}(y)) \mid y \in U\}$$

Here, $\mu_{\tilde{A}}(y)$ = degree of membership of y in \wide tilde{A}, which assumes values in the range from 0 to 1, that is, $\mu_{\tilde{A}}(y) \in [0,1]$.

Let us now consider two cases of the universe of information and understand how a fuzzy set can be represented.

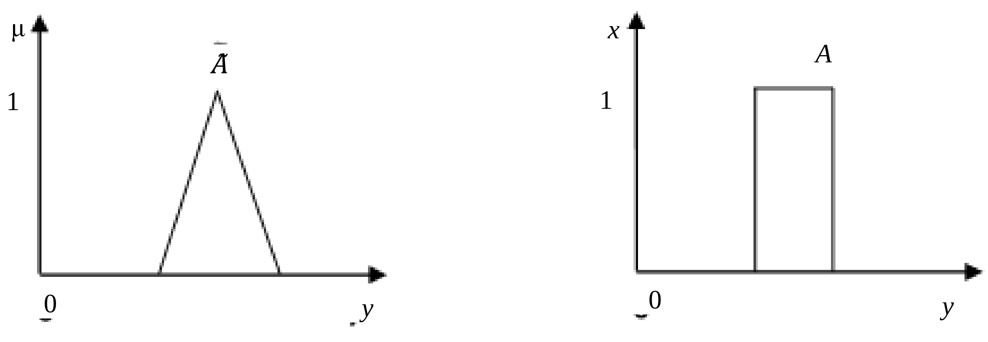
Case 1: When the universe of information U is discrete and finite

$$\tilde{A} = \{\frac{\mu_{\tilde{A}}(y_1)}{y_1} + \frac{\mu_{\tilde{A}}(y_2)}{y_2} + \frac{\mu_{\tilde{A}}(y_3)}{y_3} + \ldots\}$$
$$= \{\sum_{i=1}^{n} \frac{\mu_{\tilde{A}}(y_i)}{y_1}\}$$

Case 2: When the universe of information U is continuous and infinite

$$\tilde{A} = \{\int \frac{\mu_{\tilde{A}}(y)}{y}\},$$

In the above representation, the summation symbol represents the collection of each element.



(a) Membership Function of Fuzzy set $\tilde{A}$

(b) Membership Function of classical set A

Figure 1. Complement in the classic set.

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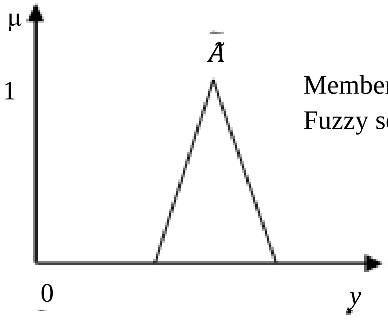

Figure 2. Membership function.

Membership Function

Fuzzy logic is not about being unclear or vague; it is a method of handling uncertainty or imprecision. This uncertainty is represented by a membership function that shows the extent to which something belongs to a certain category (Figure 2). In simpler terms, the membership function indicates how true a statement is using fuzzy logic.

Membership functions were introduced in 1965 by Lofti A. Zadeh in his groundbreaking paper, Fuzzy Set. These functions describe the fuzziness of a fuzzy set, capturing all the information within it and whether the elements are discrete or continuous. Membership functions serve as a way to address real-world problems through experience rather than relying solely on formal knowledge. They are often represented graphically. The rules for defining fuzziness are fuzzy.

FUZZINESS IN NEURAL NETWORKS

As previously mentioned, each neuron in an ANN is connected to every other neuron via a connection link, which is linked to a weight that contains input signal information. Therefore, we can conclude that the weights provide information regarding inputs that are helpful in solving issues.

The following justifies the use of fuzzy logic in neural networks:

- The weights in neural networks are mostly defined using fuzzy reasoning from fuzzy sets.
- Fuzzy values are employed when it is not possible to apply crisp values.
- Training and learning have been shown to improve neural network performance under unforeseen circumstances. Crisp values would not be as applicable at that time as fuzzy values.
- When neural networks employ fuzzy logic.

DATA COLLECTION

Numerous factors influencing worker productivity were identified after a thorough literature search, and expert comments from industry professionals were obtained. Fifty parameters that impact worker productivity were finalized and included in the survey questionnaire. Two sections, A and B, comprised the questionnaire that was created. The respondents' personal information (such as name, age, years of service, organization, and gender) is included in Part A. Part B gathered data on the factors that contribute to labor productivity in the industry. All components are categorized in this section, including worker characteristics, socio-psychological factors, management-side aspects, and physical factors.

RESULTS

After performing RII on the survey data for labor productivity prediction and computations, parameters with higher rankings were chosen. Of all the factors, the top five parameters with the highest RII values were considered for further discussion. Selected parameters and their RII values are listed in Table 1.

The fuzzy system may then provide results using the rule and range of each input and output parameter with a membership function and may easily be understood by the following algorithm. For

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labor productivity estimation, a fuzzy model was developed using the Mamdani method with five input parameters and one output parameter. Membership functions with five inputs and one output are established for each linguistic variable. These are represented by a mix of triangular and trapezoidal fuzzy numbers. According to the RII in labor productivity estimation, the factor that is ranked first is management supervision over workers with RII value of 0.78. The second-ranked factor affecting labor productivity is proper work planning and scheduling with RII value of 0.728. The third factor affecting labor productivity is the poor site safety program, with an RII value of 0.7. The fourth factor affecting labor productivity is the lack of financial motivation system with RII value of 0.692. The fifth-ranked factor affecting labor productivity is delay-in-payment, with an RII value of 0.688 (Figures 3–10).

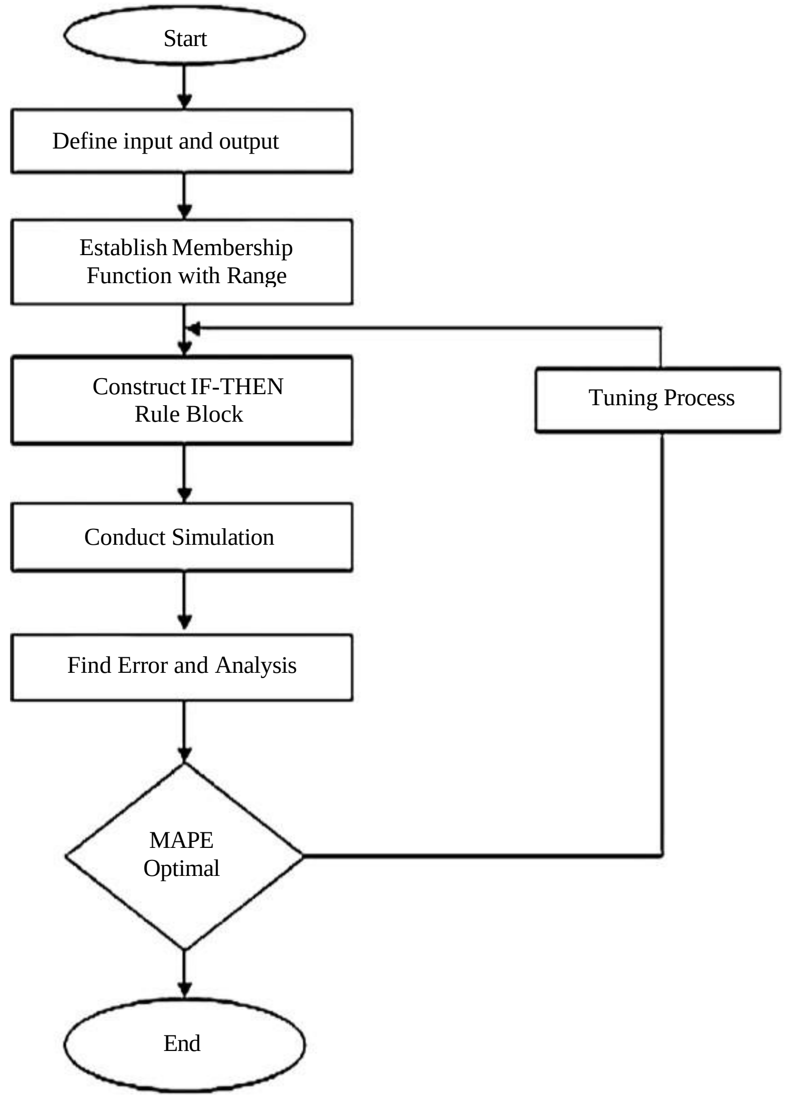

Figure 3. Algorithm for the fuzzy logic model.

Table 1. The top five factors with the highest RII value.

Factors	RII value	Rank
Management supervision over workers	0.78	1
Proper work planning and scheduling	0.728	2
Poor site safety program	0.7	3
Lack of financial motivation system	0.692	4
Delay-in-payment	0.688	5

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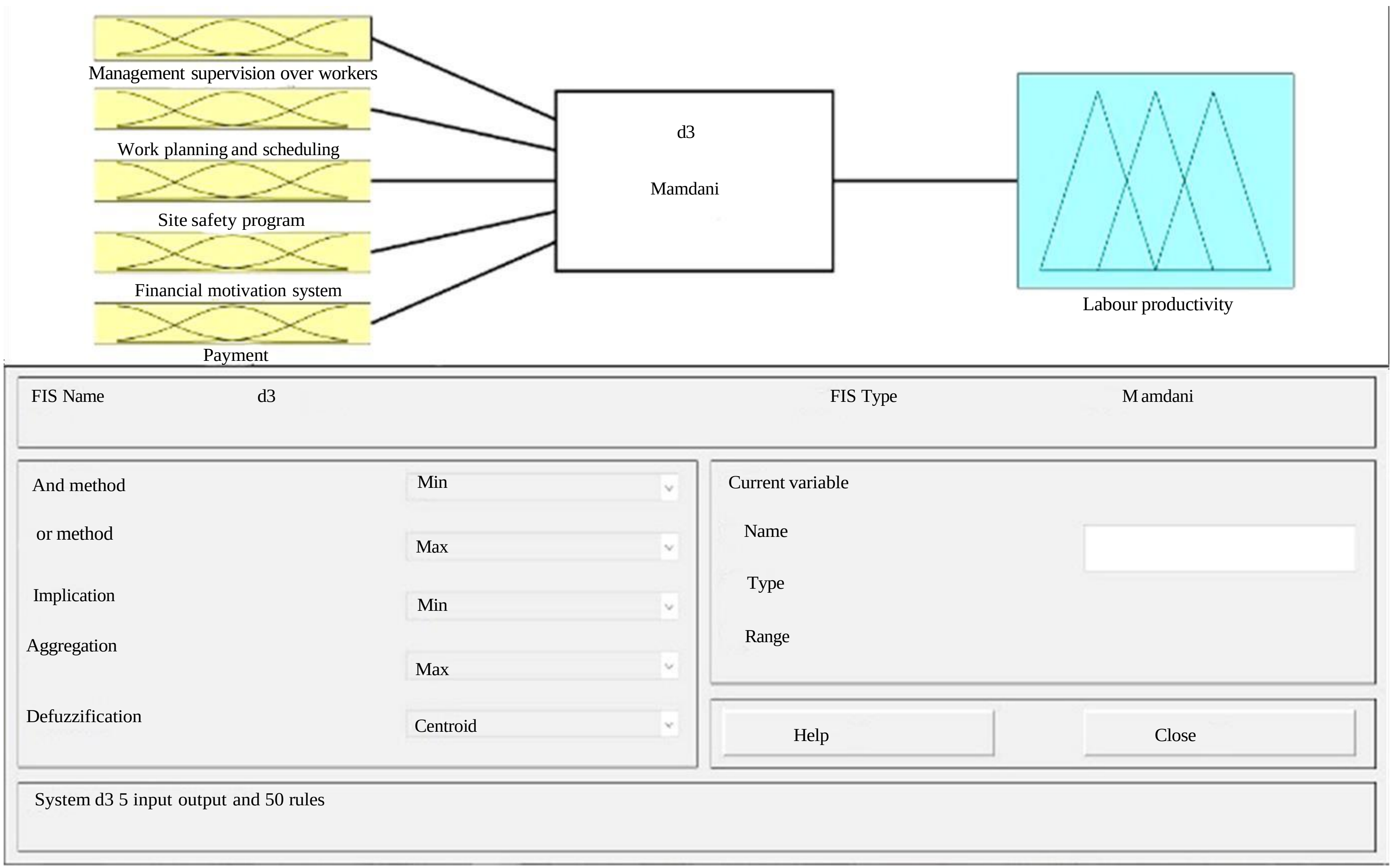

Figure 4. FIS editor.

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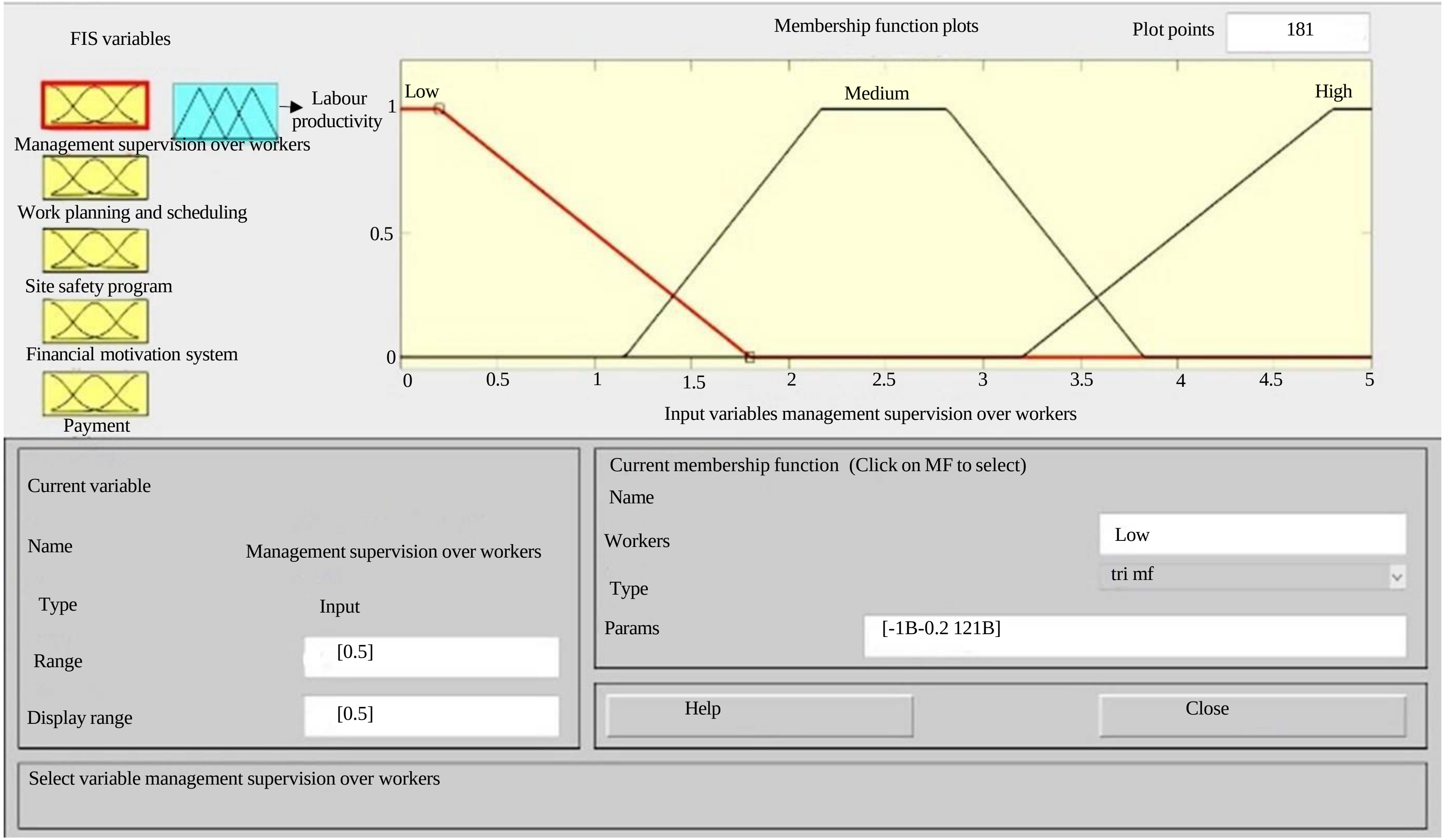

Figure 5. Membership function editor for management supervision over workers.

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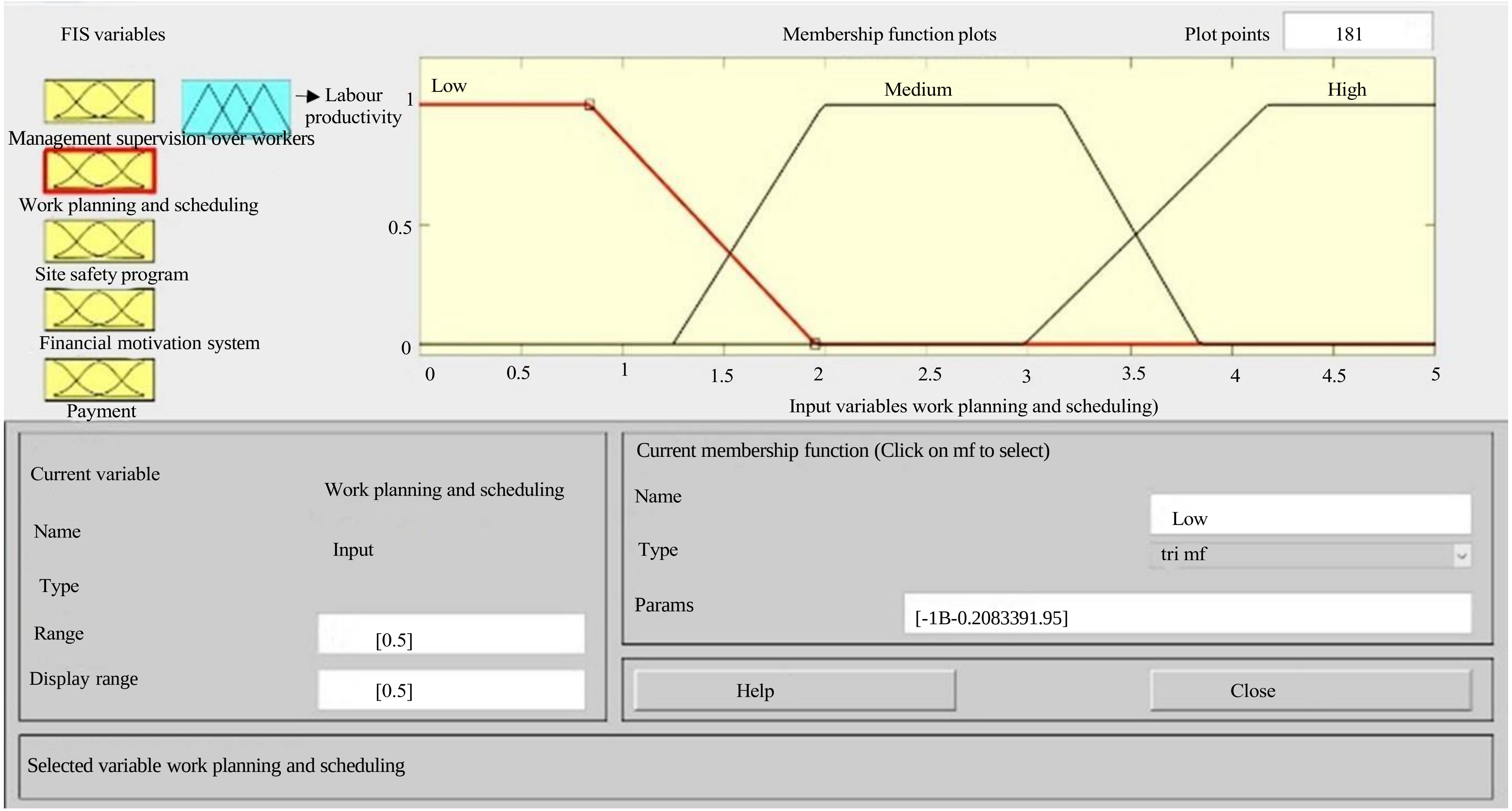

Figure 6. Membership function editor for proper work planning and scheduling.

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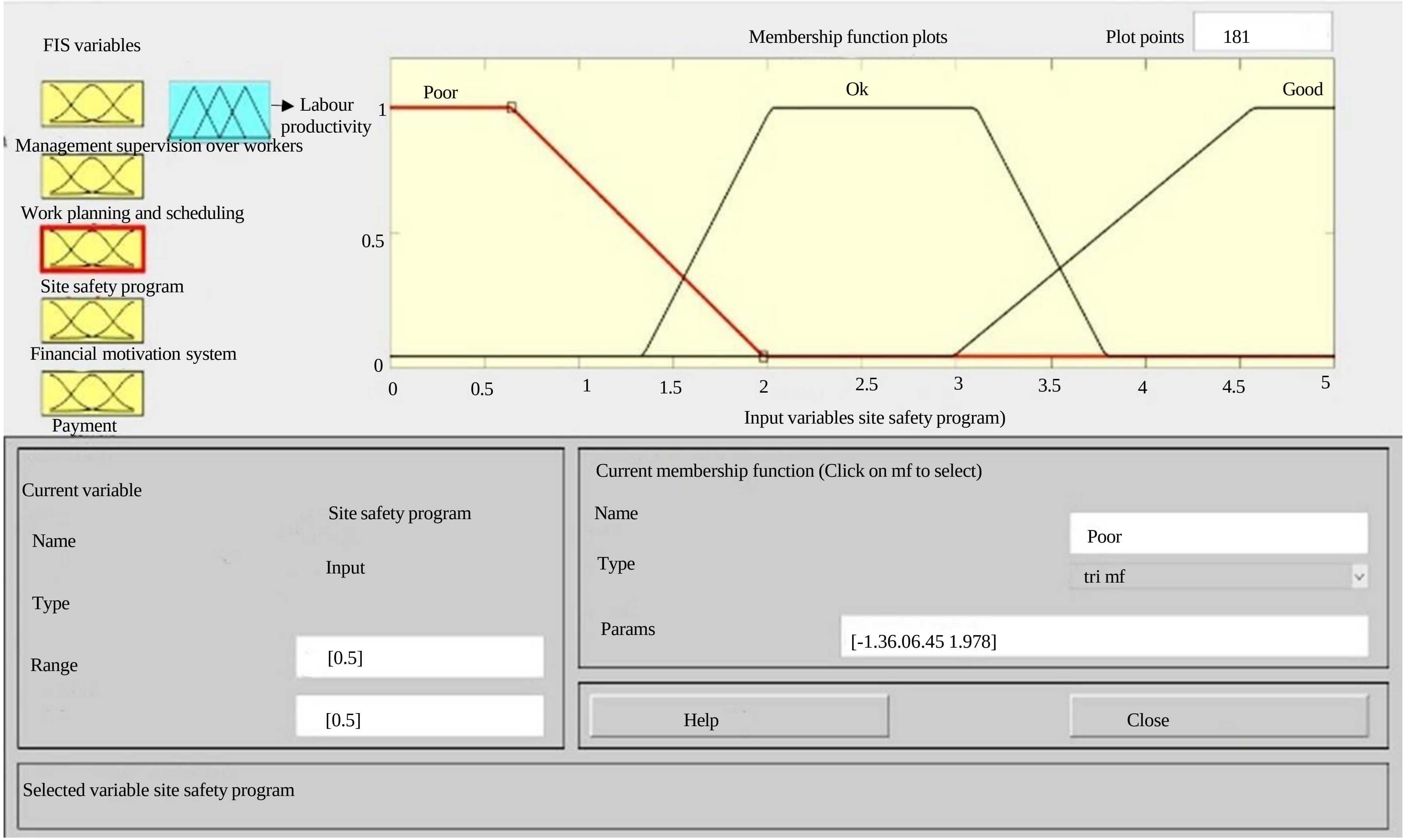

Figure 7. Membership function editor for poor site safety Program.

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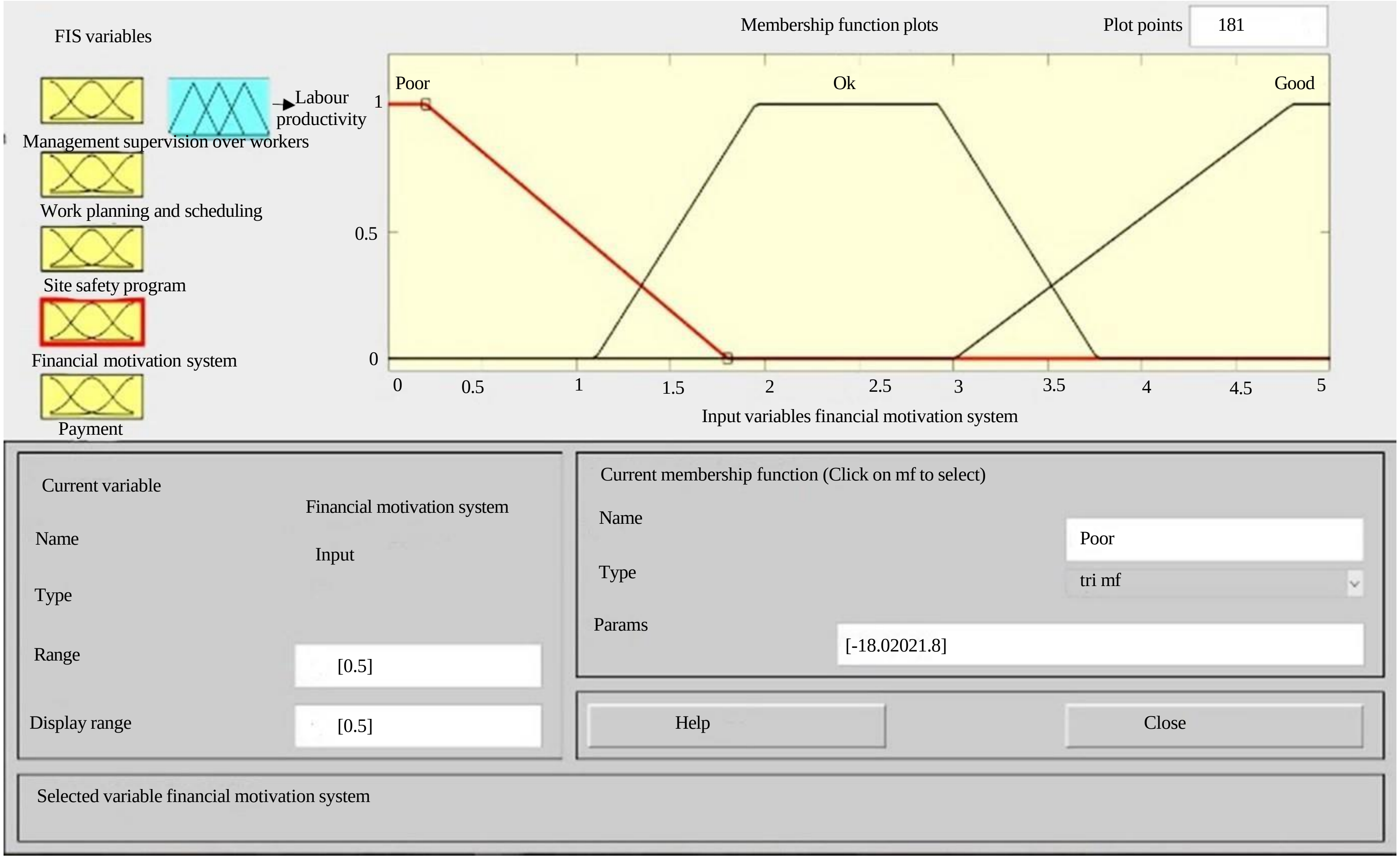

Figure 8. Membership function editor for lack of financial motivation system.

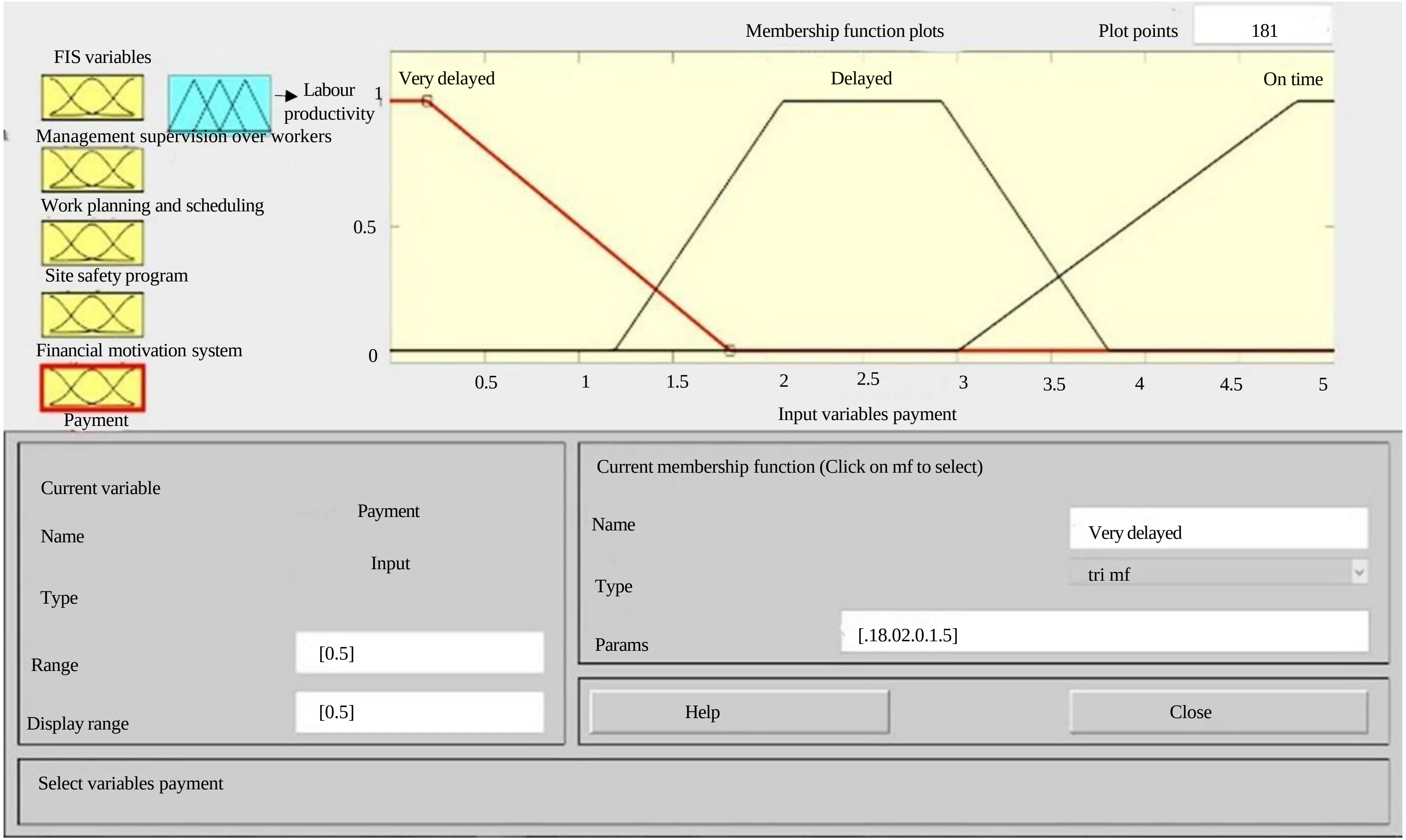

Figure 9. Membership function editor for delay in payment.

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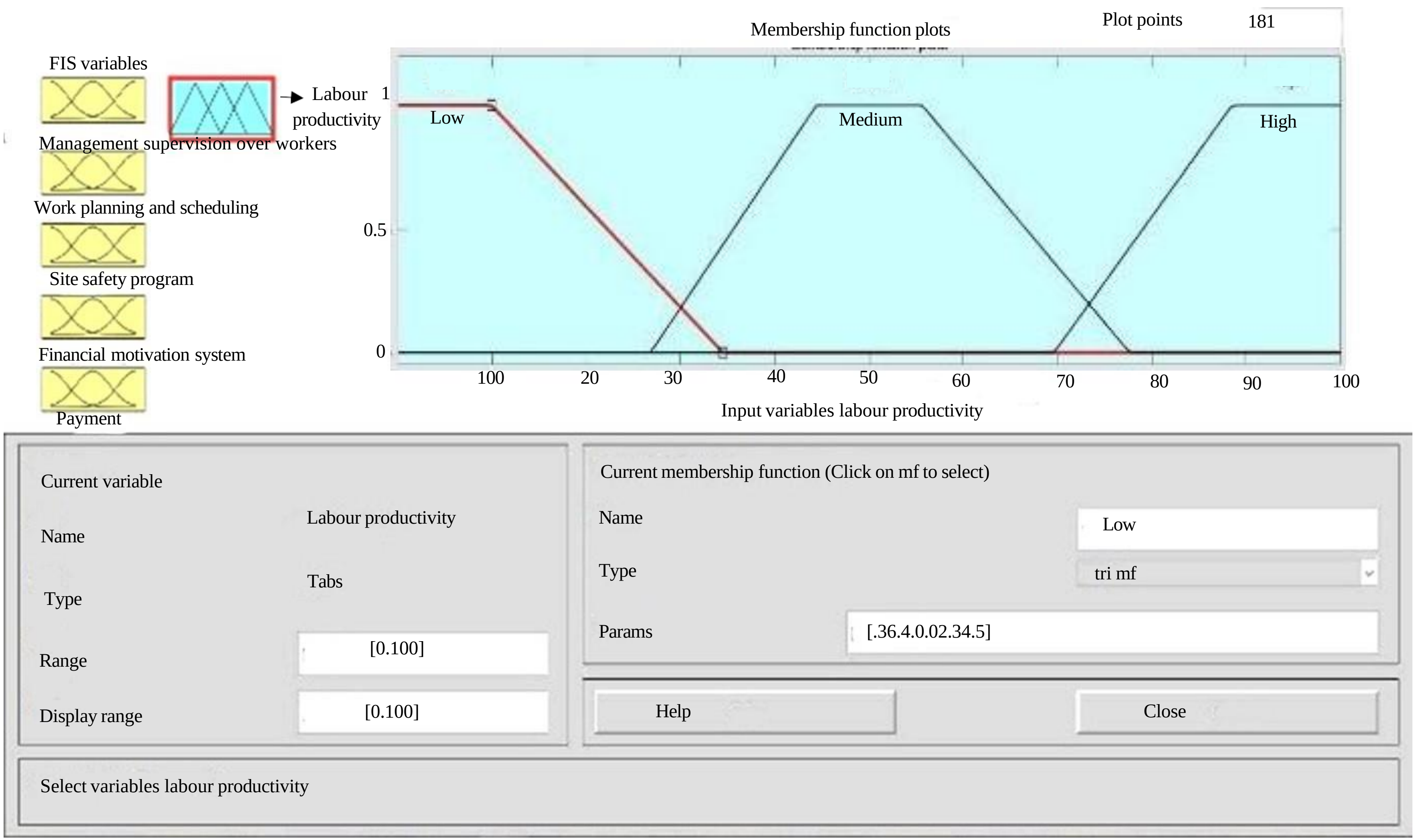

Figure 10. Membership function editor for labor productivity.

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A fuzzy logic model was developed to predict labor productivity. A Mmadman interface engine with triangular membership functions was used for this model. Fuzzy subsets were used in the input subsets, namely, very low (L), medium (M), and high (H).

CONCLUSIONS

This study aims to identify and rank the factors affecting productivity in the manufacturing industry through expert opinion surveys. A model was developed to analyze productivity and provide recommendations for improvement.

A comprehensive literature review was conducted to determine the key factors affecting employee productivity. Fifty criteria were shortlisted. The RII tool successfully ranked all the aspects based on their importance index. Five factors are shortlisted. A model for estimating worker productivity was successfully constructed using the fuzzy logic toolbox. This model was constructed using a fuzzy logic toolbox and questionnaire data.

After analyzing the results, it can be concluded that this study will be very useful in analyzing productivity by simulating the above-mentioned fuzzy model with any manufacturing industry survey data, thereby assisting them in improving productivity by improving the underlying factors that are primarily responsible for low productivity. The present study verifies the ability of fuzzy logic to estimate worker productivity.

A survey was conducted, and the data was organized. The RII was applied to the data, and all factors were ordered accordingly. In this study, we used the top five criteria to determine labor predictivity. After finalizing the factors, fuzzy logic was effectively implemented, resulting in variations in labor productivity dependent on the input factor values. A fuzzy logic toolbox in MATLAB was used to complete this task.

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