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# THE PREDICTION SYSTEM OF A PREGNANT WOMEN AT RISK OF ANEMIA USING A FUZZY LOGIC

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**ABSTRACT**
Prenatal development determines whether a child is normal or abnormal. The health of the mother and her nutritional intake during pre- and pregnancy will influence the birth of a healthy baby. The nutritional problems during pregnancy during antenatal check-ups are vital because nutrition is one of the factors that affect the incidence of chronic energy deficiency (CHD) in pregnant women. This research aims to prepare a prediction system for pregnant women at risk of anemia by applying fuzzy logic. This research will use steps that include problem identification, preparation of input variables , application of fuzzy logic and system testing. This research is expected to produce output variables in the form of predictions of pregnant women at risk of anemia or not at risk. The results of this study can provide valid initial information about the anemia-related conditions of a pregnant woman to avoid unwanted things during childbirth and postpartum. The rule base contains input variables (hemoglobin, blood pressure, conjunctiva examination) and output variables in the form of anemia prediction and its level in a pregnant women.

Keywords: anemia; fis; pregnant women

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## INTRODUCTION

A Prenatal development determines the condition of the pregnant mother to encounter the period of childbirth. The genetics of the parents will determine the normality and abnormality of the child's physique and disposition. The health of the mother and her nutritional intake during the pre- and pregnancy phases are factors that influence the birth of a healthy baby. This is certainly supported by other factors such as good psychology during pregnancy or attention from prospective parents in pregnancy care (Mirnawati., 2022). Knowledge about nutrition during pregnancy during pregnancy check-ups is vital because nutrition is one of the factors that can affect the incidence of chronic energy deficiency (CHD) in pregnant women (Rosita & Rusmimpong, 2022). The incidence of pregnant women experiencing anemia is based on hemoglobin (Hb) examination and signs such as weakness, fatigue, lethargy, pallor, and foggy eyes from a sitting position to standing. Anemia status of a pregnant women is related to age and gestational age (Aprilia, 2020).

The Antenatal care is key in determining whether a pregnant woman is at risk of anemia. However, the results of the examination are manually commented in the pregnancy book and are not used as a warning sign that the pregnant woman is at risk of anemia. This is due to factors such as poorly documented examination results, unscheduled examinations and other non-technical factors. Therefore, it is necessary to develop a risk prediction system for pregnant women at risk of anemia.This research applies the basic principles of using a fuzzy logic in problem solving that contains solutions or solutions in a broader scope than logic that

is only false or true. The research objective is to prepare a prediction system for pregnant women at risk of anemia by applying fuzzy logic. This study uses input variables in the form of antenatal cares results within the scope of the working area of one of the Puskesmas in Aceh Province. The input variables used in this study include hemoglobin levels, blood pressure, and visual examination results in the form of conjunctival examination. This research can produce output variables in the form of prediction results of pregnant women at risk of anemia and their levels.

The results showed that input variables in the form of hemoglobin (Hb), blood pressure and conjunctival examination affect the level of anemia in pregnant women. This research is based on expert knowledge that can be the basis for determining the condition of pregnant women at risk of anemia with a certain severity or in normal conditions. The implementation of expert knowledge will be translated into fuzzy logic through a fuzzy inference system (FIS) which in this study uses Mamdani FIS. The selection of this type of FIS is due to its reliability and ease of proof through MATLAB software which has proven its validity (Rifa'i & Prabowo, 2022).The results of this study are expected to provide valid baseline information about anemia-related conditions of a pregnant woman that can be used as an initial diagnosis and supporting recommendation for a medical action to avoid unexpected things during childbirth and postpartum. It is hoped that this system can become an early warning detection system in order to prevent and take further action to overcome anemia in pregnant women. The concept of modeling in this research can be developed into a basis for developing programming applications for early detection systems for pregnant women at risk of anemia.

This research uses a fuzzy logic approach as a problem solving method as used in several related studies such as the application of fuzzy logic in several applications related to health problems. This research shows that the fuzzy logic approach does not require complete knowledge of the problem model with a high accuracy ratio of the Fuzzy Expert System (FES) and is considered valid by the doctors involved in this research. The robustness and reliability of the developed FES has been proven on patients by doctors with the support of figures and arguments. When obtained laboratory records obtained from patients will be used as input parameters to obtain the output by being fuzzified and the rule base is built with expert doctors (Allahverdi., 2014).The fuzzy expert system (FES) can be used to diagnose diseases in the patient's body by diagnosing symptoms and complaints that occur in patients. There are 3 fuzzy methods, including mamdani, Sugeno and Tsukamoto. The reason the mamdani method is used is because it is expected to produce the right classification regarding the level of danger in the disease. The reason for choosing mamdani fuzzy is because the method of mamdani fuzzy method has a rule base that is more intuitive and easier to understand (Dagar et al., 2015). This study was conducted to detect the risk of anemia in pregnant women related to anemia parameters such as blood pressure, hemoglobin (hb) and conjunctive examination. The result is a category or level of anemia in pregnant women, namely not anemia, mild anemia and severe anemia.

## METHOD

The research stages from the early stages to the system testing stage can be described in this section.

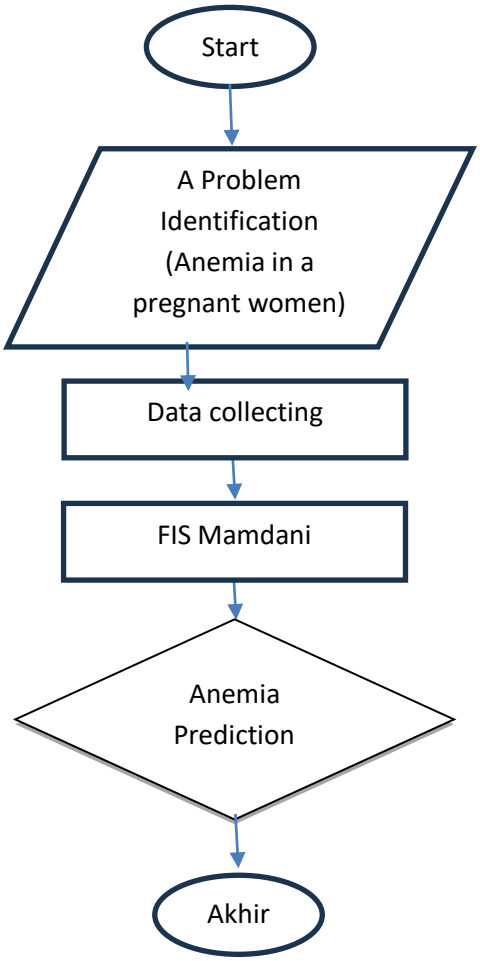


Figure 1. The research steps using FIS Mamdani

This research was initiated with a problem identification step related to the condition of anemia in a pregnant woman. From this condition, the consequences of anemia in pregnant women will be known, which can endanger the fetus and risk the baby when the mother gives birth. In addition, several factors are obtained as the main indicators that result in anemia conditions in pregnant women. In this study, the variables of hemoglobin (Hb), systolic and diastolic blood pressure and conjunctival examination were used. The underlying factor for taking these variables is based on consultation with experts based on facts from scientific journals and knowledge in the field of gynecology. Next is to collect related data that has been defined in the previous stage which is sourced from data in *antenatal care* at one of puskesmas in the Aceh Province. The data will be used for testing the system designed in this research.

The following stage offered in this research for a prediction system for pregnant women at risk of anemia. Mamdani FIS was chosen based on the considerations described in the previous section. This stage applies the same as other fuzzy methods by setting up a fuzzy set that represents the membership of an element in a finite set through the degree of membership between 0 and 1 in a membership function μ(x). a membership function μ(x). A fuzzy set contains linguistic and numerical variables that show the relationship with one another. Next will be arranged universe that contains the value of the fuzzy variable and the domain containing the range of values. The process contained in this step is the fuzzification stage (Thakur et al., 2016) (Malu, 2015)

The subsequent stage is the preparation of an inference system that contains rules / rules related to input variables with consequences in the form of outputs. This stage is a stage that determines the accuracy/validity of the output generated from the designed system. This stage involves experts who are related to the scientific field and have experience in examining pregnant women and diagnosing anemia in pregnant women. Furthermore, the preparation of implications or the process of determining the fuzzy output of each rule using fuzzy operators. Furthermore, composing the output of all rules with the maximum method. The last stage is converting the output value in the fuzzy set into crisp / numbers to determine the output of the system (Aramideh & Jelodar, 2014).

## RESULT

Based on the methodology, the first step is to form variables both input variables and output variables. In this study, the input variables are hemoglobin (Hb), a blood pressure and a conjunctival examination. While the output variable is the prediction of anemia. Based on these input and output variables, the fuzzy set for each variable is as follows.

a. The hemoglobin (Hb) input variable consists of 3 fuzzy sets, low medium, normal;
b. The blood pressure input variable consists of 3 fuzzy sets, namely low, normal, high;
c. The conjunctiva examination input variable consists of 2 fuzzy sets, namely pale and not pale;
d. The anemia prediction output variable consists of 3 fuzzy sets, namely normal, mild anemia and severe anemia.Berikut ini adalah tabel variabel dan universal sets

Table 1.
Fuzzy Variable and Universal Set

| Function | Input Variable | Universal Set |
|---|---|---|
| Input | Hemoglobin | [0-15] |
| Input | Blood pressure | [0-200] |
| Input | Conjunctiva examination | [0 1] |
| Output | Anemia prediction | [0-1] |

If the system is implemented and data is entered in the MATLAB program, the system design is as shown below.

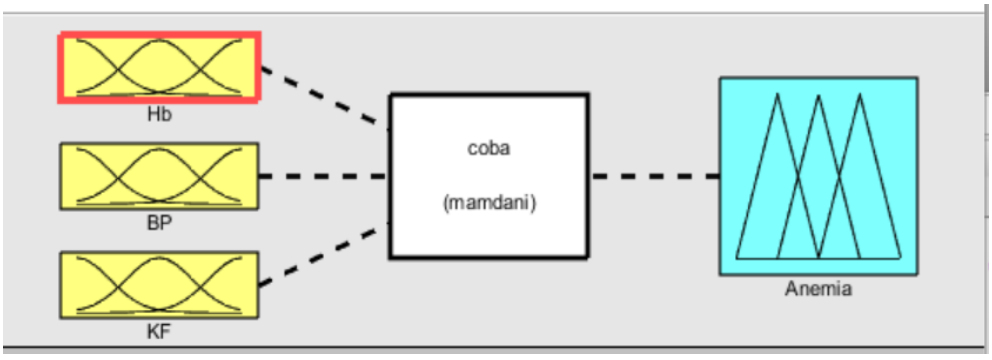


Figure 2. The Design of The Anemia Prediction System

Based on the design, the membership function of the input variable hemoglobin in the below figure.

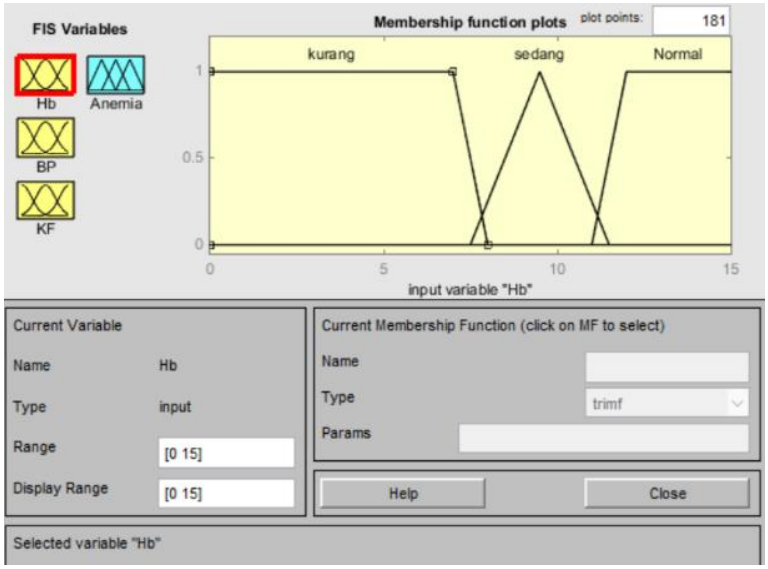


Figure 3. Membership function of the input variable Hemoglobin

Table 2.
The form of the membership function of the input variable Hemoglobin

| No | The membership | The values | Universal Set |
|---|---|---|---|
| 1. | Low | 1 | X<=7.5 |
| | | 8-x/8-7,5 | 7,5<x<8 |
| | | 0 | x>=8 |
| 2. | Midle | 0 | x<=7,5 or x>=11,5 |
| | | x-7,5/9,5-7,5 | 7,5<x<9,5 |
| | | 11,5-x/11,5-9,5 | 9,5<x<11.5 |
| | | 1 | x = 9,5 |
| 3. | Normal | 0 | X<=11 |
| | | x-11/11,5-11 | 11<x<11,5 |
| | | 1 | x>=11,5 |

The results of the membership function design of the input variable blood pressure can be seen in the following figure

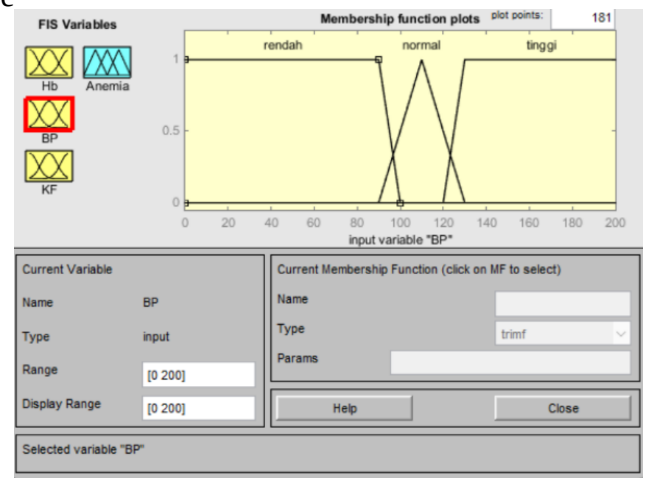


Figure 4. Membership function of the input variable blood pressure

Table 3.
The form of the membership function of the input variable blood pressure

| No | The membership | The values | Universal Set |
|---|---|---|---|
| 1. | Low | 1 | X<=90 |
| | | 100-x/100-90 | 90<x<100 |
| | | 0 | x>=100 |
| 2. | Normal | 0 | x<=90 or x>=130 |
| | | x-90/110-90 | 90<x<110 |
| | | 130-x/130-110 | 110<x<130 |
| | | 1 | x = 110 |
| 3. | High | 0 | x<=120 |
| | | x-120/130-120 | 120<x<130 |
| | | 1 | x>=130 |

The results of the membership function design of the input variable conjunctival examination can be seen in the following figure.

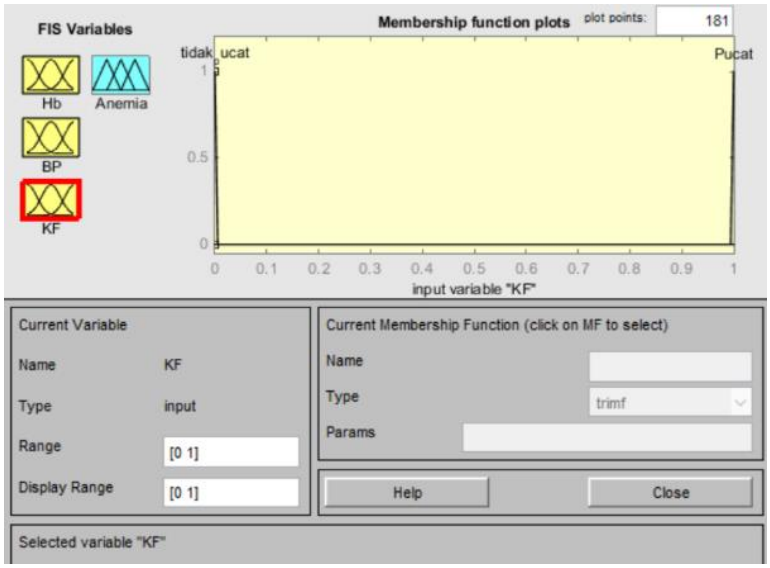


Figure 5. Membership function of the input variable conjunctival examination

Table 4.
The form of the membership function of the input variable conjunctival examination

| The membership | The values | Universal Set |
|---|---|---|
| Pale | 1 | 1 |
| No Pale | 0 | 0 |

The results of the membership function design of the output variable Anemia prediction can be seen in the following figure.

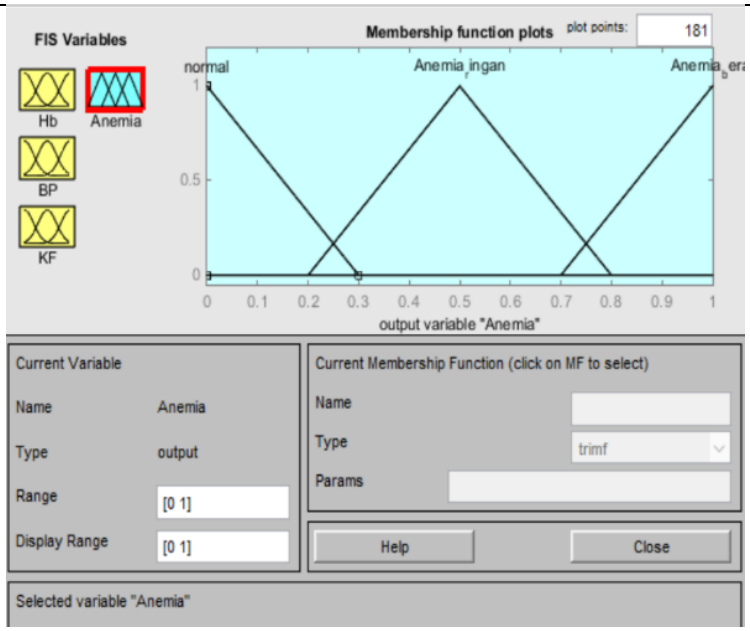


Figure 6. Membership function of the output variable Anemia Prediction

Table 5.
The form of the membership function of the output variable Anemia Prediction

| No | The membership | The values | Universal Set |
|---|---|---|---|
| 1. | Normal | 0,3-x/0,3-0 | 0<=x<=0,3 |
| 2. | Mild Anemia | 0 | x<=0,2 or x>=0,8 |
| | | x-0,2/0,5-0,2 | 0,2<x<0,5 |
| | | 0,8-x/0,8-0,5 | 0,5<x<0,8 |
| | | 1 | x = 0,5 |
| 3. | Severe Anemia | x-0,7/1-0,7 | 0,7<=x<=1 |

**DISCUSSION**

1. IF Hb is low, Blood pressure is normal, conjunctive examination is not pale THEN the result is Mild ANEMIA;
2. IF Hb is low, Blood pressure is low, conjunctive examination is pale THEN Severe ANEMIA result;
3. IF Hb is medium, Blood pressure is high, conjunctive examination is not pale THEN the result is NOT ANEMIA;
4. IF Hb is medium, Blood pressure is normal, conjunctive examination is not pale THEN the result is NOT ANEMIA:
5. IF Hb is medium, Blood pressure is normal, conjunctival examination is pale THEN the result is Mild ANEMIA;
6. IF Hb is medium, Blood pressure is low, conjunctival examination is pale THEN the result is Mild ANEMIA
7. IF Hb is normal, Blood pressure is high, conjunctival examination is not pale THEN the result is NOT ANEMIA;
8. IF Hb Normal, Blood pressure normal, conjunctive examination not pale THEN result NOT ANEMIA
9. IF Hb Normal, Blood pressure low, conjunctive examination pale THEN result Mild Anemia.

A fuzzy rule (rule base) is a rule based on fuzzy logic that is summed up to unify the situation, then combined with all input and output variables for each fuzzy set in a predetermined category within a certain range to produce a fuzzy set domain value. In addition, with the fuzzy inference diagram view, the rule base can be combined using the

rule viewer with each rule in the rule base to process the input variables so that the output variable results are obtained (Boadh et al., 2022). The following data on the results of examinations of pregnant women at the health center will be used as sample data to test the system that has been designed.

Table 6.
The sample data from antenatal care

| NO | Name | BP | Hb | Conjunctival Examination |
|---|---|---|---|---|
| 1 | Ny. E | 110 | 12 | No pale |
| 2 | Ny R | 100 | 12 | No pale |
| 3 | Ny. LF | 100 | 11 | Pale |
| 4 | Ny. MS | 100 | 11 | Pale |
| 5 | Ny. M | 180 | 10 | No pale |
| 6 | Ny. FDB | 110 | 10 | Pale |
| 7 | Ny. SF | 120 | 10 | No pale |
| 8 | Ny. Mo | 110 | 12 | No pale |
| 9 | Ny. HA | 110 | 12 | No pale |
| 10 | Ny. F | 90 | 11 | Pale |
| 11 | Ny. Z | 80 | 5 | Pale |
| 12 | Ny. S | 80 | 7,5 | Pale |

After obtaining a number of rules, the defuzzification of each rule that has been determined can be obtained (Ema Julpia Aenun, 2014). The combined defuzzification results of the 9 rules in this study will show the output value of anemia prediction based on the membership function for the output variable of anemia prediction in a pregnant women. Referring to the sample data from the table, if the data parameters for number 1 are entered into the rules by applying FIS mamdani with the mean of Maximum (MOM) method, the prediction of anemia will be obtained that the pregnant woman does not suffer from anemia. This result is in accordance with rule number 8 in the rule base that has been determined. The predicted value of anemia is 0 or when viewed on the membership function of the output variable shows that it is in the normal area. if the data parameters for number 1 are entered into the rules by applying FIS mamdani with the bisector method, the prediction of anemia will be obtained 0,08 which indicates the pregnant woman does not suffer from anemia. On the other hand, if the data for number 1 is entered into the rules by applying FIS mamdani with the centroid method, the prediction of anemia will be obtained 0,09 which indicates the pregnant woman does not suffer from anemia.

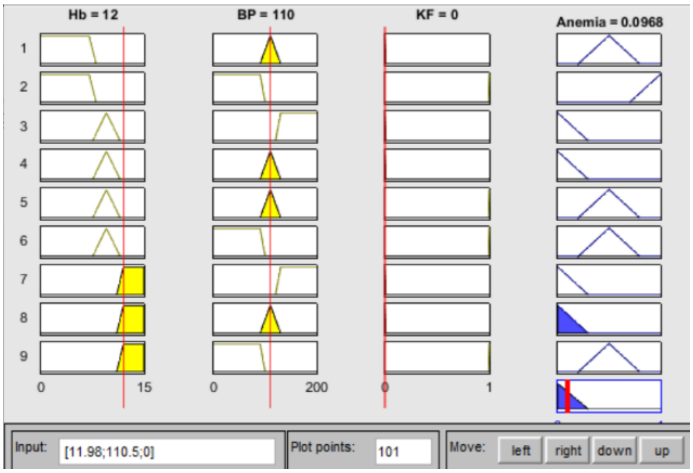


Figure 7. Defuzzification using centroid method of the sample data (No.1)

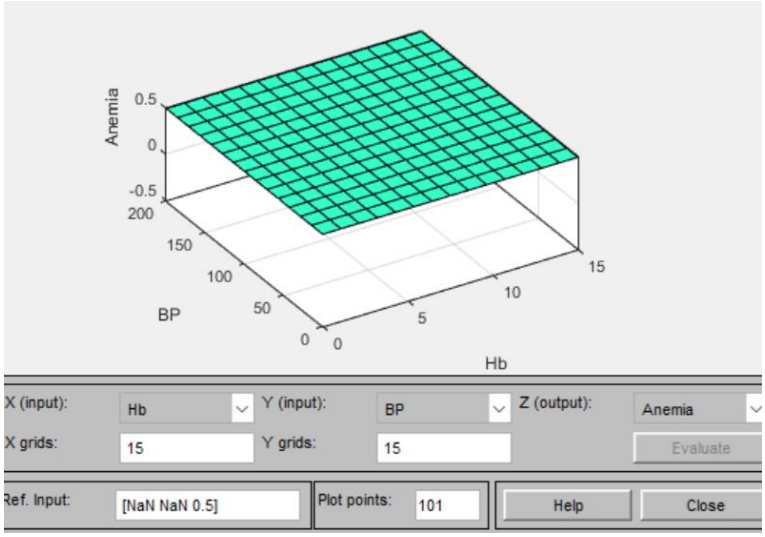


Figure 8. The surface viewer of the sample data (No.1)

If testing sample data number 10 with the centroid method for defuzzification, an anemia prediction value of 0.5 will be obtained. The same result when using the bisector and MOM methods. This shows conformity with rule base number 6 which indicates that the pregnant woman has the potential to suffer from mild anemia. The detailed data for the results that have been tested using the system designed in this study as in the following table

Table 7.
The results of The anemia prediction system

| No | Name | BP | Hb | Conjunctival Examination | MOM | Bisector | Centroid | Anemia Prediction system | Expert |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ny. E | 110 | 12 | No pale | 0 | 0,08 | 0,09 | Normal | Normal |
| 2 | Ny R | 100 | 12 | No pale | 0,08 | 0,11 | 0,11 | Normal | Normal |
| 3 | Ny. LF | 100 | 11 | Pale | 0,5 | 0,5 | 0,5 | Mild Anemia | Mild Anemia |
| 4 | Ny. MS | 100 | 11 | Pale | 0,5 | 0,5 | 0,5 | Mild Anemia | Mild Anemia |
| 5 | Ny. M | 180 | 10 | No pale | 0,04 | 0,09 | 0,10 | Normal | Normal |
| 6 | Ny. FDB | 110 | 10 | Pale | 0,5 | 0,5 | 0,5 | Mild Anemia | Mild Anemia |
| 7 | Ny. SF | 120 | 10 | No pale | 0,06 | 0,11 | 0,11 | Normal | Normal |
| 8 | Ny. Mo | 110 | 12 | No pale | 0 | 0,08 | 0,09 | Normal | Normal |
| 9 | Ny. HA | 110 | 12 | No pale | 0 | 0,08 | 0,09 | Normal | Normal |
| 10 | Ny. F | 90 | 11 | pale | 0,5 | 0,5 | 0,5 | Mild Anemia | Mild Anemia |
| 11 | Ny. Z | 80 | 5 | pale | 0,90 | 0,92 | 1 | Severe Anemia | Severe Anemia |
| 12 | Ny. S | 80 | 7,5 | pale | 0,9 | 0,94 | 0,96 | Severe Anemia | Severe Anemia |

Based on the results of the study, it shows that the application of the system to predict the risk of pregnant women having anemia using FIS mamdani can be tested and in accordance with the rule base and can be compared with the results of doctors from registered patients from experts. These results can be initial data for pregnant women in anticipating unwanted things during pregnancy and undergoing childbirth, especially related to anemia. Even so, pregnancy examinations by doctors or midwives remain the main basis for decision making related to the diagnosis and treatment of pregnant women. This research indicates that the condition of input variables in strict numbers can be converted into fuzzy sets that better represent input

and output variables within a certain range so that the results obtained contain a more detailed scope than only with human logic or feelings (Anggrek & Suhartana, 2023). This can be proven from research if a pregnant woman is in the mild anemia zone based on the results of FIS mamdani, then there is also a possibility that the mother has the potential for severe anemia and normal or not anemia with a smaller coefficient than mild anemia. fuzzy logic is a standard of computing in unlimited conditions, most of the human mind takes information then responds with the right action (Buriboev et al., 2019). Fuzzy inference systems can offer the right simulation to answer health-related issues (Teti et al., 2024). The most important factor in the formation of fuzzy logic model is the formation of a membership functions and a rule base. The rule base itself is based on the knowledge of midwives at the health center in examining pregnant women. In addition, in this research, only three supporting criteria were used, namely hemoglobin, blood pressure and conjunctival examination, where the three criteria are still less complex in providing the complexity and the accuracy in anemia prediction system of a pregnant women. This research model is also presented in a study that uses Mamdani FIS to build membership functions to assign linguistic variations. A set of rule bases will be analyzed to determine the type of Thalassemia in the patient. defuzzification process of the fuzzy system fuzzy system provides an objective process of risk factors, as well as to see the surface view of the risk determination by using simulation (Thakur et al., 2016). There are still many factors that must be taken into account in developing anemia prediction system of a pregnant women (Setyanugraha et al., 2022).

Malnutrition during pregnancy may result in impaired growth fetus which also increase the mortality rate and infant morbidity. Therefore, the need for seriousness in the effort to design a prediction system for anemia in a pregnant women is due to this fact. The research with expert system demonstrated a 94% accuracy rate for analyzing the three maternal complications (preeclampsia, GDM, and maternal sepsis) using a set of risk factors (Gebremariam et al., 2024). Other studies have shown the effectiveness of using FIS mamdani. Research to detect preeclampsia cases using input data in the form of blood pressure measurements, proteinuria and the results of doctors' medical records. This system can be used to diagnose preeclampsia as early as possible in pregnant women as a prevention of further complications that can cause death. The preeclampsia diagnosis system with FIS Mamdani is a new breakthrough in the field of Mathematics and Health because although there have previously been similar systems, this system has never been implemented in the case of preeclampsia (Mada et al., 2023). This research also uses defuzzification methods in the form of bisector, centroid and MOM methods to obtain a variety of results and can be compared with one another so that good reasoning is obtained. Research to detect preeclampsia cases using different defuzzification methods shows the bisector method is very good when compared to other methods (Teti et al., 2024). There are various software can be used for diagnosed with FIS but MATLAB tool considered as best provider for optimum results. MATLAB can be implemented more than 7 parameters for optimum prediction system related with a disease (Thukral & Bal, 2019). The integration of FIS rules that have been compiled using the MATLAB toolbox is very useful for solving precisely because it uses software when compared to manual calculations that are vulnerable to errors (Abdullah et al., 2017). Research related to cholesterol detection using input data in the form of blood pressure and BMI made using MATLAB software can detect cholesterol levels to prevent heart disease and other dangers (Novita et al., 2023).

## CONCLUSION

The results showed that input variables in the form of hemoglobin, blood pressure and conjunctival examination can determine the risk of anemia in pregnant women. This is evidenced from a sample of pregnancy examination data showing variables such as

hemoglobin have a very large influence on the potential of a pregnant woman at risk of anemia both mild and severe anemia (Eduhealt, 2023). Although there are studies also suggest that higher than normal hemoglobin concentrations should be considered as an indicator of possible pregnancy complications (Yip, 2000). the application of the system to predict the risk of pregnant women experiencing anemia using FIS mamdani can be tested and in accordance with the rule base and can be compared with the results from experts. The conclusion based on experimental approach to develop these types of systems and the emergent need where specific expertise not available and the user can predict the disease from existing software's like MATLAB. Modeling of this system can be used as an algorithm in developing applications related to the health of pregnant women in the future. The Mamdani Fuzzy Inference System (FIS) method algorithm implemented through MATLAB software produces an accuracy rate of the Mamdani FIS method test results reaching 95% so that the Mamdani fuzzy method can be used as an option for designing a detection system and MATLAB as a perfect tool (Cahyadi et al., 2023). The system work processes by applying the mamdani fuzzy algorithm can be built using the functions of the Fuzzy Inference System (FIS) contained in the Fuzzy Logic Toolbox (FLT) in MATLAB application software. The prediction results of the expert system compared to using the calculation of the fuzzy mamdani algorithm only have an error rate of 0.1% (Purnawirawan & Afirianto, 2023). Another things is the need for further research related to the same problem using other FIS such as Tsukamoto for comparison of results.

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