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Fuzzy-Based Application Model and Profile Matching for Recommendation Suitability of Type 2 Diabetic

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Abstract*—Diabetes Mellitus (DM) is a metabolic disease characterized by hyperglycemia due to insulin secretion abnormalities and a global health threat. DM has several types, namely type 1, 2, gestational, and other types. Type 2 diabetes patients have the largest number in the world. DM therapy can be done in 2 (two) ways: improving lifestyle and administering drugs. The problems and risks in recommending drugs are essential in the patient's healing process because they are likely to take medicine for life. Approximately 260,000 patients with type 2 diabetes experienced medication errors in 2017. The doctor's mistake in recommending drugs causes a long healing process and costs more. Recommending drugs requires pharmacological knowledge, and not all hospitals have pharmacologists. Several researchers have researched recommendations for antidiabetic drugs, but no studies have yet been found that discuss recommendations for combination antidiabetic drugs for type two to determine dosage and frequency. The number of medications used is 6 to 7, with many parameters 5 to 8. The latest endocrinology guidelines for 2020 state that in recommending antidiabetic drugs, not only 6 to 7 participants, but still need to maintain other aspects. Therefore, this study aims to build an expert system model with a new approach in recommending antidiabetic drugs with more complete parameters and recommend dosage and frequency. The model developed uses the Fuzzy Profile Matching method. Fuzzy is used to calculate the suitability between the patient's condition and the type of antidiabetic drug. Profile Matching is used to calculate the core factor and secondary factor to obtain each drug's total value. The dose was calculated using the FIS Tsukamoto for inputting low dosage, and high dosage calculated the weighted average value. Determination of frequency using the IF-Then function. Model evaluation is done by comparing recommendation data from doctors. The results of the evaluation of the model obtained an accuracy of 90%. This system will reduce medical personnel errors in recommending antidiabetic drugs that can positively impact patients' time, the healing process, and costs. This study provides knowledge that antidiabetes drugs' determination requires many parameters, while other studies used only 4 to 8. This study also provides an overview of the dosages of drugs that drug companies can produce. Usually, the company only makes low and high dosage. This study shows that creating multiple drug dosage is more efficient for patients.

***Keywords*—Model evaluation; diabetic type 2; fuzzy Tsukamoto; profile matching; drugs; dosage; frequency.**

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I. INTRODUCTION

Diabetic Mellitus (DM) Type 2 is a group of metabolic diseases with hyperglycemia characteristics that occurs because of an abnormality receptor insulin that lasts long also affects its secrecy. DM type is classified into 4 (four) groups, namely Type 1 DM, type 2 DM, gestational DM, and other type DM [1][2]. Blood glucose levels are expressed as diabetic, among others, with a rate of HbA1c > 6.5% (mmol/L) [3]. Until today DM is still one of the global health threats. Epidemiological research indicates the tendency to increase the incidence rate and prevalence of type 2 Diabetic Mellitus in various parts of the world[4]. The majority of DM is predicted to grow 3 (three) times in 2030. This increase has been expected by the World Health Organization (WHO) that the year 2030 will reach 21.3 million[1], and Predicted from the International Diabetic Federation (IDF) in 2045 will reach 16.7 million [3].

DM can occur in patients accompanied by other diseases. DM therapy can be done 2 (two) to improve the lifestyle and Drug Administration [2]. Treatment of medications using Oral and Insulin types [5]. Commonly used oral drugs are types of Sulfonylurea, Glinide, Biguanide, Tiazolidin, Alpha

Glucose inhibitors, GLP-1, SGLT-2, DPP-4, while for Insulin there are Lispo, Aspart, Glulysine and Faster Aspart [6]. The goal of therapy in DM is to reduce hyperglycemia symptoms, reduce the onset and development of complications, reduce mortality, and improve life quality [6]. Antidiabetic drugs usually pay attention to age, comorbidities, risk of hypoglycemia, and many other factors [7].

Efforts to manage DM still have obstacles in terms of service and health financing [4]. It should be noted that health workers in carrying out their work require high pharmacological accuracy and knowledge [8]. Around 260,000 patients with diabetes experienced medication errors in 2017 [8]. Ignorance and negligence of action to the patient will have an impact on patient safety. One thing that must be considered is the procedure for administering injectable and oral drugs. Giving injection drugs is more at risk of causing hypoglycemic conditions that are dangerous for patients. In addition to economic wastage, irrational drug use patterns can decrease treatment services quality, increase drug side effects, increase treatment failure, and increase insulin resistance [9]. Cases in various health institutions were found to be incorrectly given unnecessary drug combinations. The selection of an appropriate oral hypoglycemic drug is crucial to the success of diabetic therapy, depending on the severity and condition of the patient. Oral hypoglycemic pharmacotherapy can be done using one drug or a combination of two types of drugs [7].

Sub-therapeutic drug administration results in ineffective drug therapy. Drug administration with excessive dosage results in hypoglycemic effects and the possibility of toxicity [10]. Inappropriate use of Insulin often results in hypoglycemia and can lead to weight gain. Unwanted drug effects can occur in long-term use, such as lipodystrophy or loss of fat tissue at the injection site, and allergic reactions can occur, including edema [11]. Treatment must be started as early as possible to prevent or slow the progression of beta-cell failure in people with impaired glucose tolerance [4].

Several researchers have conducted research that discusses antidiabetic drug recommendations. In the study showed Rung-Ching Chen *et al.* [12], the drug recommendations used the SWRL technique with 6 (six) types of antidiabetic drugs Metformin, DPP4, Sulfonylurea, Glinide, Thiazolidinedione, Alpha-Glucosidase (AGI) with 6 (six) parameters of HbA1c, Hypoglycemia, Renal, Heart, BMI, and liver. This research was developed with the Fuzzy method that can display the results of drug recommendations based on the most appropriate level of choice [13]. Drug recommendations are also carried out using Fuzzy-TOPSIS with 7 (seven) types of drugs and 8 (eight) parameters [14]. In 2018 Fuzzy, combined with MULTIMOORA with input data scoring, recommended antidiabetic drugs using 8 (eight) parameters. Several researchers have researched recommendations for antidiabetic drugs, but no studies have yet been found that discuss recommendations for combination antidiabetic drugs for type two to determine dosage and frequency. The number of medications used is 6 to 7, with many parameters 5 to 8. The latest endocrinology guidelines for 2020 state that in recommending antidiabetic drugs, not only 6 to 7 participants, but still need to maintain other aspects such as glucagon secretion (Cell Alpha Pancreas), insulin secretion (Cell Beta), glucose fat, glomerular filtration, muscle glycogen and contraindications with pregnant or nursing women and infections [15]. Drug recommendations must be adapted to the patient's condition or variables to avoid errors and drug side effects. The number of patient variables has the main and second variables [16]; therefore, the Profile Matching (PM) method is very appropriate because it has a Core Factor and Secondary Factor calculations.

The problem and the risk of recommending drugs are essential in healing patients to maintain health services quality [10]. This research supports this research; this study aims to build an expert system model with a new approach to recommending antidiabetic drugs with more complete parameters and recommend dosage and frequency. The model developed uses the Fuzzy Profile Matching method. Fuzzy is used to calculate the suitability between the patient's condition and the type of antidiabetic drug. Profile Matching is used to calculate the core factor and secondary factor to obtain each drug's total value. Model evaluation is done by comparing recommendation data from doctors. A safe treatment system needs to be developed and maintained to ensure that patients receive good drug services due to the increasingly varied drugs and the increasing number of drugs and types of antidiabetic drugs [17]. This study's results can be used as an alternative to help paramedics. Young doctors recommend the right dosage and frequency of medicines to improve the quality of health services, accelerate the healing process, and reduce medical costs.

II. Materials and Method

The application of the suitability of antidiabetic drugs to the patient's health condition was developed by illustrating the proposed model's architecture. The development of the model consists of 2 (two) main parts, namely the development knowledge base and development environment presented in Fig. 1 model was developed from the drug suitability model [16].

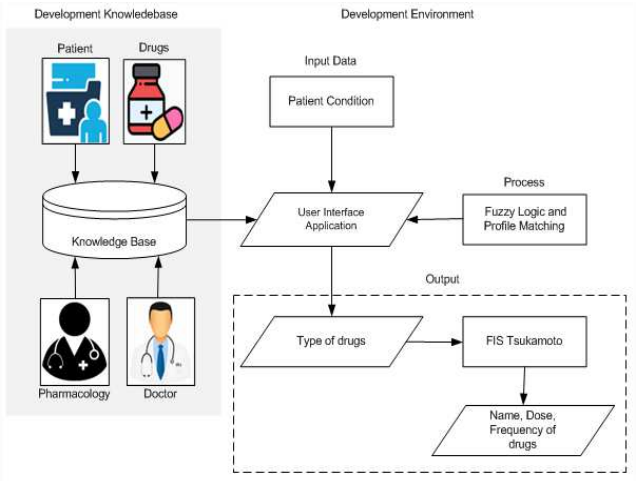


Fig. 1. Model of the suitability of type 2 antidiabetic drugs

A. Development Stages

The first development from the expert consultation stage and the result is presented in Figure. 2. Expert consultation was carried out by specialists in internal medicine, diabetes, and pharmacology to obtain parameters and knowledge base. The next step is the process of matching antidiabetic drugs to the patient's condition using a membership curve. The next

match's result was calculated by the core and secondary factors using the Profile Matching method. In addition to the type of drug, for determining the dose using Tsukamoto FIS. The stages of development can be seen in Fig. 2.

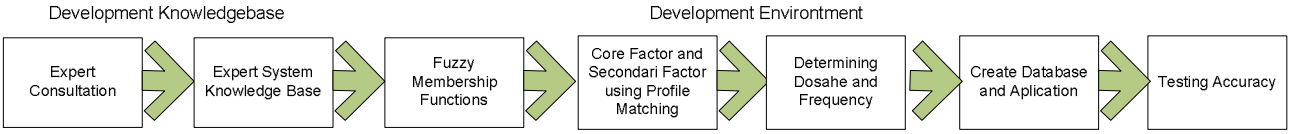


Fig. 2 Stages of model development

B. Expert Consultation

Based on consultations with internists and pharmacologists, as well as a review of several works of literature [5], [18], [19], [4], there are 17 (seventeen) parameters that influence determining the delivery of antidiabetic type 2 drugs. In addition to considering the patient's health parameters, the drug's efficacy and price are presented in Table I.

TABLE I
INPUT PARAMETERS FOR THE DETERMINATION OF ANTIDIABETIC MELLITUS TYPE 2 DRUGS

P1	P2	P3	P4	P5	P6	P7	P8	P9
HbA1c	Age	Body mass index	Renal	Liver	Heart	Blood pressure	Hypoglycemia	Cell of beta
%	year	kg/m^2	mg/dl	µ/L	pg/ml	mm/Hg	%	%

P10	P11	P12	P13	P14	P15	P16	P17
Cell of alpha	Free fatty acid	Muscle glycogen	Filtration glomerulus	Pregnant/lactating	Infection	Efficacy	Cost
%	%	%	ml/minutes	Yes/No	Yes/No	High/Middle	Low/High

Brief description of each patient's health parameters that influences in determining the type 2 antidiabetic drug administration:

- HbA1c (hemoglobin A1c) is a protein containing iron in red blood cells. High or low HbA1c levels will affect drug administration. Intake of HbA1c by pricking a needle in a vein in the arm. Normal levels of Hba1c <6.5% [2]
- Age is taken from the year of birth. Age>60 years old and <60 years old is young. The age of the patient will determine the choice of drug type because not all ages can be given the same drug [1]
- BMI is taken from body weight and height [20]. Kadar normal BMI <25. If someone has a BMI>25, then the drug to be given is different from patients who have a BMI <25kg/m^2[20]
- Renal is the level of kidney health obtained based on laboratory tests with the Enzymatic method performed on patients by calculating creatinine levels [21]. Patients with kidney patients need special attention from doctors [18]
- The liver is SGPT (Serum Glutamic Pyruvic Transaminase) level is an abundant enzyme in the liver. Normal levels of 7-56 micro per liter of serum (µ/L) [22].
- Heart health uses the value of B-type natriuretic peptide (BNP) is a hormone produced by the heart. The BNP hormone (NT-proBNP) is a non-active hormone released from the same molecule that has BNP [23]
- Hypoglycemia is a condition when the body's blood sugar levels are too low. Hypoglycemia normal <50% mmol/L [5]. Provision of antidiabetic drugs pay attention to the effects of hypoglycemia [24]
- Beta cells (β cells) are cells found in pancreatic islets that synthesize and secrete Insulin. Beta cells account for about 50-70% of cells in the islet of the pancreas in the human body [25]
- Pancreatic Alpha Cells are cells that function to produce glucagon hormone. This hormone increases blood sugar levels, breaks down the liver reserves in the liver, and then carries it to the blood. Alfa cells account for around 25% of the island of Langerhans [22]
- Free fatty acid (FFA) is the content of free fatty acids in the body that cause cholesterol that can affect drug administration. Normal levels of 30-50 FFA%[4]
- Muscle glycogen is a type of sugar polysaccharide that is stored in liver cells and body muscle cells. Glycogen data is obtained by converting glucose levels obtained from food [22]
- Glomerular filtration is the average rate of blood filtration that occurs in the glomerulus in ml/min units [26]
- Pregnant/lactating is the condition of the patient's history of being pregnant or breastfeeding. Some anti-diabetic drugs have contraindications with this condition [10]
- Infection is the condition of the patient who has a wound or postoperatively. Patients who are experiencing disorders should not be given drugs Sulfonilurena, Glinide, Biguanide, and SGLT-2 [18]
- Efficacy is the level of effectiveness of the drug [18]
- Cost is the cost of purchasing drugs. Determination of the price of medicines taken from the guidelines for the treatment of type 2 diabetes [5]

C. Expert System Knowledge Base

The parameters used are made in the form of a knowledge base for each parameter's degree of compatibility with the type of antidiabetic drugs. The knowledge base is presented in Table II. Almost all type 2 diabetic drugs should not be given to DMT2 patients with impaired liver or kidney function, liver, high blood pressure, and severe heart problems. Patients with T2DM aged ≥60 years and overweight (BMI) should be aware of the onset of hypoglycemia. There are types of contraindicated drugs in patients with impaired renal function with LFG ≤ 30 mL/[4]. Also, drug administration needs to be considered for pregnant or breastfeeding patients and have infections [10].

TABLE II
KNOWLEDGEBASE FOR THE SUITABILITY OF ANTI-DIABETIC DRUGS [5], [18], [19], [4]

Type	HbA1c	Age	BMI	Renal	Liver	Heart	Blood pressure	Hypoglycemia	Cell Beta Pancreas	Cell Alpha	Free Fatty Acid	Muscle Glycogen	Filtrasi Glomerulus	Pregnant /Lactating	Infection	Efficacy	Cost
Biguanide	>6.5	17-60	25-35	>1.2	<56	<100	>90	>50	>50%	<20%	<50%	<1%	>30	No	No	High	Low
Sulfonilurena	>7.0	<60	<25	<1.2	<56	>100	>140	<50	<50%	<20%	<50%	>1%	<30	No	No	High	Low
Glinide	>7.5	>60	<25	>0.55	<56	>100	<140	<50	<50%	<20%	<50%	>1%	<30	Yes	No	High	High
Thiazolidin	>7.0	18-45	<25	>0.55	<56	<100	<140	>50	>50%	<20%	>50%	<1%	<30	Yes	Yes	High	Low
Alpha Glucose	7.5 - 9	<60	>25	<1.2	<56	>100	<140	>50	>50%	<20%	<50%	>1%	>30	Yes	Yes	High	Low
GLP-1	7-9	>55	>25	>1.2	>56	>100	>140	>50	<50%	>20%	<50%	>1%	>30	Yes	Yes	High	High
SGLT2	>9	>55	>25	>1.2	>56	>100	>140	>50	>50%	<20%	<50%	>1%	>45	Yes	No	Middle	High
DPP-4	7-9	>55	>18.5	>1.2	<56	>100	>140	>50	<50%	>20%	<50%	>1%	<30	Yes	Yes	Middle	High
Insulin	>9	>13	<25	0.55 - 1.2	>56	<100	>140	<50	>50%	<20%	<50%	>1%	<30	Yes	Yes	High	Low

D. Fuzzy Membership Functions

Based on the knowledge base in table II, they then made in the form of curves and fuzzy logic membership functions for each parameter with the suitability of the type of antidiabetic drug. Curves and membership functions of the kind of antidiabetic drug Biguanide are shown in Table III.

TABLE III
CURVES AND MEMBERSHIP FUNCTIONS FOR BIGUANIDE DRUGS

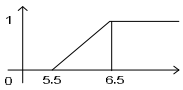
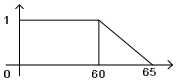
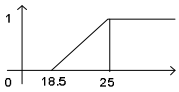
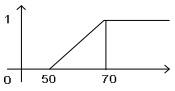
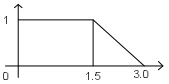
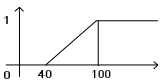
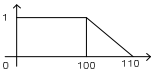
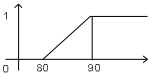
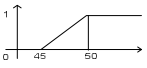
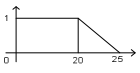
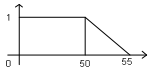
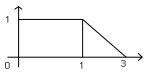
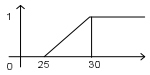
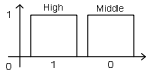
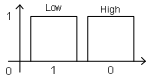
Parameters	Curve	Membership function
HbA1c (%)		$\mu(x) = \begin{cases} 0; & x \le 5.5 \\ \frac{x-5.5}{5.5-6.5}; & 5.5 \le x \le 6.5 \\ 1; & x > 6.5 \end{cases}$
Age (years)		$\mu(x) = \begin{cases} 1; & x \le 60 \\ \frac{65-x}{65-50}; & 60 \le x \le 65 \\ 0; & x > 65 \end{cases}$
Weight (BMI)		$\mu(x) = \begin{cases} 0; & x \le 18.5 \\ \frac{x-18.5}{25-18.5}; & 18.5 \le x \le 25 \\ 1; & x > 25 \end{cases}$
Hypoglycemia		$\mu(x) = \begin{cases} 0; & x \le 50 \\ \frac{x-50}{70-50}; & 50 \le x \le 70 \\ 1; & x > 70 \end{cases}$
Renal		$\mu(x) = \begin{cases} 1; & x \le 1.5 \\ \frac{3.0-x}{3.0-1.5}; & 1.5 \le x \le 3.0 \\ 0; & x > 3.0 \end{cases}$
Liver		$\mu(x) = \begin{cases} 0; & x \le 40 \\ \frac{x-145}{150-145}; & 40 \le x \le 100 \\ 1; & x > 100 \end{cases}$
Heart		$\mu(x) = \begin{cases} 1; & x \le 100 \\ \frac{110-x}{110-100}; & 100 \le x \le 110 \\ 0; & x > 110 \end{cases}$
Blood pressure		$\mu(x) = \begin{cases} 0; & x \le 80 \\ \frac{x-80}{90-80}; & 80 \le x \le 90 \\ 1; & x > 90 \end{cases}$
Cell of beta		$\mu(x) = \begin{cases} 0; & x \le 45 \\ \frac{x-145}{150-145}; & 45 \le x \le 50 \\ 1; & x > 50 \end{cases}$
Cell of alpha		$\mu(x) = \begin{cases} 1; & x \le 20 \\ \frac{25-x}{25-20}; & 20 \le x \le 25 \\ 0; & x > 25 \end{cases}$
Free Fatty Acid		$\mu(x) = \begin{cases} 1; & x \le 50 \\ \frac{55-x}{55-50}; & 50 \le x \le 55 \\ 0; & x > 55 \end{cases}$
Muscle Glycogen		$\mu(x) = \begin{cases} 1; & x \le 1 \\ \frac{3-x}{3-1}; & 1 \le x \le 3 \\ 0; & x > 3 \end{cases}$
Filtration		$\mu(x) = \begin{cases} 0; & x \le 25 \\ \frac{x-25}{30-35}; & 25 \le x \le 30 \\ 1; & x > 30 \end{cases}$
Pregnant /Lactating		$\mu(x) = \begin{cases} 0 & \text{Yes} \\ 1 & \text{No} \end{cases}$
Infection		$\mu(x) = \begin{cases} 0 & \text{Yes} \\ 1 & \text{No} \end{cases}$
Efficacy		$\mu(x) = \begin{cases} 1 & \text{High} \\ 0 & \text{Middle} \end{cases}$
Cost		$\mu(x) = \begin{cases} 1 & \text{Low} \\ 0 & \text{High} \end{cases}$

TABLE IV
CALCULATION VALUE MEMBERSHIP FUNCTIONS

Id	Parameters	Data	Value of membership
1	HbA1c	6.9	1
2	Age	62	0.6
3	BMI	24	0.84
4	Renal	2.3	1
5	Liver	54	1
6	Hearts	98	1
7	Blood pressure	138	1
8	Hypoglycemia	60	1
9	Cell of beta	67	1
10	Cell of alpha	19	1
11	Free fatty acid	45	1
12	Muscle glycogen	2.6	0.2
13	Filtration glomerulus	33	1
14	Pregnant/lactating	No	1
15	Infection	Yes	0
16	Efficacy	High	1
17	Price	Low	1

Membership functions need to be made for the types of antidiabetic drugs Sulfonylurea, Glinid, Thiazolidinedione, Alpha-Glucosidase, GLP-1, SGLT-2, DPP4, and Insulin need to be made. Based on the membership function in Table III,

the value of each parameter is then calculated. Table IV displays the membership values for each parameter with the type of antidiabetic drug Biguanide

E. Core Factor and Secondary Factor

Parameter grouping is divided into 2 (two), namely Core Factor (CF) and Secondary Factor (SF). Core Factor is the leading parameter group where the determination of the type of drug given is very dependent on the parameters in this group, whereas a Secondary Factor is a parameter group that does not have a strong influence on the determination of the type of drug given to patients [27]

TABLE V
CLASSIFYING PARAMETERS CF AND SF

Core Factor (CF)	Secondary Factor (SF)
Age (P2)	HbA1c (P1)
Renal (P4)	BMI (P3)
Liver (P5)	Blood pressure (P7)
Heart (P6)	Cell alpha (P10)
Hypoglycemia (P8)	Free fatty acid (P11)
Cell beta (P9)	Muscle glycogen (P12)
Filtration glomerulus (P13)	Efficacy (P16)
Pregnant/lactating (P14)	Price (P17)
Infection (P15)	

Calculate the value of CF using a formula:

$$CF = \frac{\sum NC}{\sum IC} \quad (1)$$

CF = The average value of the core factor
NC = Total number of core factor values
IC = Number of items CF value

$$SF = \frac{\sum NS}{\sum IS} \quad (2)$$

SF = The average value of the secondary factor
NS = Total number of secondary factor values
IS = Number of secondary factor items

Based on the grouping of core factors and the subsequent factors calculated the average value:
The value of the average core factor parameters

$$\text{CF} = \frac{(0.6+1+1+1+1+1+1+0)}{9} = 0.84$$

The value average secondary factor parameters

$$\text{SF} = \frac{(1+0.84+1+1+1+0.2+1+1)}{8} = 0.88$$

The grouping core factor's value average value multiplied the weight of 75%, and the secondary factor bore with a weight of 25%. The result of the core factor and secondary factor weights are then added to get a matching value:

$$Total = (Weigt\ CF * CF) + (WeightSF * SF) \quad (3)$$

Total = (0.75 * CF) + (0.25 * SF)
= (0.75 * 0.84) + (0.25 * 0.88)
= 0.63 + 0.22
= 0.85

Results calculate of the value 0.85 indicate that the patient "P1" if given the class of antidiabetic medicine Biguanide has suitable (0.85 / 1) x 100% = 85% and for the second medicine 76% that Alpha-glucose, the medications are given can be combined, the show is Table VI.

TABLE VI
DRUG SUITABILITY CALCULATION RESULTS

Id	Type	Value	Level
1	Sulfonylurea	0.56	7
2	Glinide	0.55	8
3	Biguanide	0.85	1
4	Thiazolidinedione	0.71	5
5	Alpha-Glucosidase	0.76	2
6	GLP-1	0.73	3
7	SGLT2	0.52	9
8	DPP-4	0.60	6
9	Insulin	0.72	4

This model can evaluate the suitability of the patient's condition with various types of antidiabetic drugs.

F. Dosage and Frequency Drug

The dose and frequency of drug administration are very influential in the therapeutic effect of the drug. Giving excessive dosage, especially for drugs with a narrow range of therapy, will be very at risk of side effects. Conversely, a too small dose will not guarantee the achievement of less than optimal therapeutic levels [17].

TABLE VII
TYPE, DOSAGE, AND FREQUENCY DRUGS [18][4]

Id	Type	Drugs	Dosage	Frequency (Ones/Day)
1	Sulfonylurea	Glibenclamide	2.5 - 20mg/dl	1-2
		Gliclazide	40 - 320 mg/dl	1-2
2	Glinide	Repaglinide	1-16 mg/dl	2-4
		Nateglinide	180 - 360 mg/dl	2-3
3	Biguanide	Metformin	500 - 3000mg/dl	1-3
		Buformin	50 - 100 mg/dl	1-2
4	Thiazolidinedione	Pioglitazone	15 - 45 mg/dl	1-2
		Rosiglitazone	4 - 8 mg/dl	1-2
5	Alpha-Glucose	Acarbose	100 - 300 mg/dl	2-3
		Miglitol	25-100 mg/dl	2-3
6	GLP-1	Liraglutide	0.6 - 1.8 mg/dl	1-2
		Lixisenatide	10 - 20 mg/dl	1-2
7	SGLT2	Dapagliflozin	5 - 10 mg/dl	1-2
		Empagliflozin	10 - 25 mg/dl	1-2
8	DPP-4	Vildagliptin	50-100 mg	1-2
		Sitagliptin	25-100 mg	1-2
9	Insulin	Lispro	0.1 - 1 Unit/Kg	1-2
		Aspart	0.05 - 1Unit/Kg	1-2

G. The domain of Medicine Dosage

Determination of the dose using the parameters in Figure 4 (a). Each parameter becomes an input variable, divided by 2 (two) in linguistic and domain variables. The environment's output is a dose calculated using Tsukamoto's FIS to calculate a more appropriate dosage.

TABLE VIII
DOMAIN PARAMETERS FOR DETERMINES DRUGS DOSAGE

Id	Parameters	Linguistic Variable	Domain	Output (Dosage)
1	HbA1c	Normal	0-9	
		Abnormal	6.5-12	
2	Age	Young	0-65	
		Old	60-100	Low
3	BMI	Low	0-27	[0-600]
		High	24-30	
4	Renal	Normal	0-1.5	High
		Abnormal	1.2-3.0	[500-
5	Liver	Normal	0-100	1000]
		Abnormal	40-100	
6	Hypoglycemia	No	0-70	
		Yes	50-120	

TABLE IX
THE DOSAGE DOMAIN OF THE DRUG IS BIGUANIDE

Type	Drugs	Dosage (mg/dl)	Domain	
			Low	High
Biguanide	Metformin	500 - 1000	0-600	500-1000

Based on Table IX. The next step is to make a curve for each parameter presented in Fig. 3-5, and the output curves for drug dosages are shown in Fig. 6.

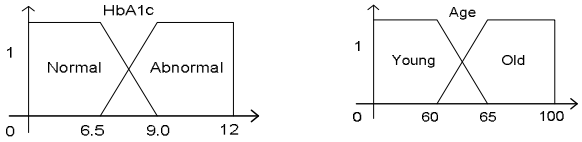


Fig. 3 Curv membership function for HbA1C and Age

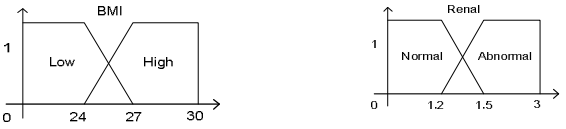


Fig. 4 Curv membership function for BMI and Renal

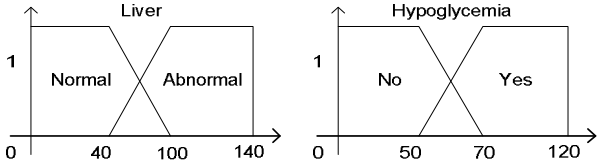


Fig. 5 Curve membership function for Liver and Hypoglycemia

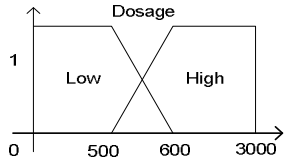


Fig. 6 Curve membership function for dosage

Each parameter's membership value is then calculated based on the membership curve and function, as in Table X.

TABLE X
MEMBERSHIP VALUES FOR PARAMETER

Parameters	Data	Linguistic Variables	
		Normal	Abnormal
HbA1c	6.9	0.84	0.16
Age	62	0.8	0.2
BMI	24	0	1
Renal	2.3	0	1
Liver	54	0.76	0.23
Hypoglycemia	60	0.50	0.50

H. Fuzzy Implication Rules for Dosage

Monotonous fuzzy rules are used as a basis for fuzzy implication techniques. The number of practices used is calculated based on the number of criteria and sub-criteria [28]. The parameters used are 6 (six) as HbA1c, Age, BMI, Renal, Liver, Hypoglycemia, and sub-criteria of each criterion are 2 (two), so the number of rules use is $2^6 = 64$ rules. Examples of the use of practices as follows:

"[R13]If HbA1c= Normal and Age=Young and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;"
"[R29]If HbA1c= Normal and Age=Old and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;"
"[R30]If HbA1c= Abnormal and Age=Young and BMI=Low and Renal=Normal and Liver=Normal and Hypoglicemia=Yes Then High dosage;"
"[R45]If HbA1c= Abnormal and Age=Young and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then High dosage;"
"[R61]If HbA1c= Abnormal and Age=Old and BMI=High and Renal=Abnormal and Liver=Normal and Hypoglicemia=No Then Low dosage;"
"[R64]If HbA1c= Abnormal and Age=Old and BMI=High and Renal=Abormal and Liver=Abnormal and Hypoglicemia=Yes Then Low dosage;"

Then value z calculation will be performed to look for output using FIS Tsukamoto from each rule given explicitly (crisp) based on α-predicate (fire strength). In this calculation, not all α and $z_{1\text{-}64}$ rules are displayed. The final result is obtained using a weighted average. Examples of the use of practices as follows:

$\alpha\text{-predicat}_{13}$ = μHbA1c Normal ∩ μAge Young ∩ μBMI High ∩ μRenal Abormal ∩ μLiver Normal ∩μHypoglycemia No Then Low dosage;
= Min (0.84; 0.8; 1; 1; 0.76; 0.5)
= 0.5

Z_{13} = High - (α_{13} * (High-Low))
= 3000 - (0.5 * (3000-500))
= 1750

$\alpha\text{-predicat}_{29}$ = μHbA1c Normal ∩ μAge Old ∩ μBMI High ∩ μRenal Abormal ∩ μLiver Normal ∩μHypoglycemia No Then Low dosage;
= Min (0.84; 0.2; 1; 1; 0.76; 0.5)
= 0.2

Z_{29} = High - (α_{29} * (High-Low))
= 3000 - (0.2 * (3000-500))
= 2500

α-predicat$_{30}$ = µHbA1c Normal ∩ µAge Old ∩ µBMI High ∩ µRenal Abormal ∩ µLiver Normal ∩µHypoglycemia Yes Then Low dosage;
= Min (0.84; 0.2; 1; 1; 0.76; 0.5)
= 0.2
Z_{30} = High - (α_{30} * (High-Low))
= 3000 - (0.2 * (3000-500))
= 2500
α-predicat$_{45}$ = µHbA1c Abormal ∩ µAge Young ∩ µBMI High ∩ µRenal Abormal ∩ µLiver Normal ∩ µHypoglycemia No Then High dosage;
= Min (0.16; 0.8; 1; 1; 0.76; 0.5)
= 0.16
Z_{45} = α_{45} * (High-Low) + Low
= 0.16 * (3000-500) + 500
= 900
α-predicat$_{61}$ = µHbA1c Abnormal ∩ µAge Old ∩ µBMI High ∩ µRenal Abnormal ∩ µLiver Normal ∩ µHypoglycemia No Then Low dosage;
= Min (0.16; 0.2; 1; 1; 0.76; 0.5)
= 0.16
Z_{61} = High - (α_{61} * (High-Low))
= 3000 - (0.16 * (3000-500))
= 2600
α-predicat$_{64}$ = µHbA1c Abnormal ∩ µAge Old ∩ µBMI High ∩ µRenal Abnormal ∩ µLiver Abnormal ∩ µHypoglycemia Yes Then Low dosage;
= Min (0.16; 0.2; 1; 1; 0.23; 0.5)
= 0.16
Z_{64} = High - (α_{64} * (High-Low))
= 3000 - (0.16 * (3000-500))
= 2600

TABLE XI
MEMBERSHIP VALUE FOR ALL A_{1-64} AND Z_{1-64} FROM PARAMETERS

Id	HbA1c	Age	BMI	Renal	Liver	Hypo	Min (α_{1-64})	Z_{1-64}
13	0.84	0.8	1	1	0.76	0.5	0.5	1750
29	0.84	0.2	1	1	0.76	0.5	0.2	2500
30	0.84	0.2	1	1	0.76	0.5	0.2	2500
45	0.16	0.8	1	1	0.76	0.5	0.16	900
61	0.16	0.2	1	1	0.76	0.5	0.16	2600
64	0.16	0.2	1	1	0.23	0.5	0.16	2600

I. Determining Dosage

After a combination of forming rules, the next step is doing a calculation to get the value of defuzzification by adding the rules to regulations 64 to get the weighted average values *(Weight Average)*

$$z\,(Dosage) = \frac{(a1*z1)+(a2*z2)+(a3*z3)+(a4*z4)+\cdots(a64*z64)+}{a1+a2+a3+a4\ldots a64} \quad (4)$$

z (Dosage) = 2160 mg/dl. Based on the name of the drug Metformin with the lowest dose of 500 ml/gl and the highest dosage of 3000 ml/dl in Table XI, based on the results of the system recommendations for the correct dosage given by patients as many as 2160 mg/dl.

TABLE XII
DIFFERENCES IN RECOMMENDED DOSAGES BETWEEN DOCTORS AND THE SYSTEM

Id	Input						Type and drugs	Output	
	HbA1c	Age	BMI	Renal	Liver	Hypo glycemia		The daily dose recommended by the doctor	Daily dose obtained from the system
1	6.5	39	25	0.7	78	6.5	Insulin/Lispro	1 Unit/mL	6 Unit/mL
2	6.9	62	24	2.3	54	60	Biguanide/Metformin	500 mg/dl	2160 mg/dl
3	8.3	60	20	0.8	33	55	Biguanide/Metformin	500 ml/dl	1703 mg/dl
4	6.65	40	30	0.8	98	65	Thiazolidinedione/ Pioglitazone	15 mg/dl	28 mg/dl
5	6.8	37	27	2.1	100	66	Biguanide/Metformin	500 mg/dl	1571 mg/dl
6	11	44	29	0.6	140	70	Biguanide/Buformin	50 mg/dl	50 mg/dl
7	7.9	50	27	3.8	130	68	Biguanide/Buformin	50 mg/dl	78 mg/dl
8	11.6	62	20	2.7	130	0	Biguanide/Metformin	500 mg/dl	1300 mg/dl
9	9.8	37	27	3.8	80	40	Insulin/Aspart	1 Unit/mL	5 Unit/mL
10	6.8	65	20	0.6	0	55	Alfa-Glucosidase/ Miglitol	25 mg/dl	56 mg/dl

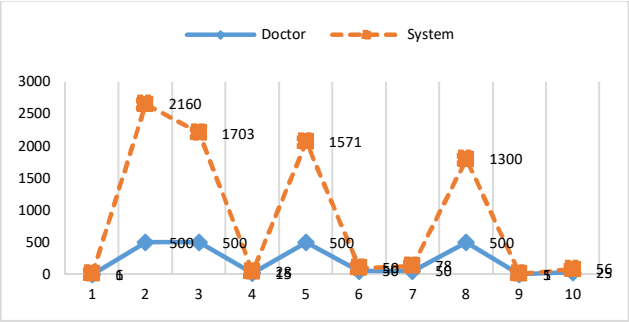


Fig. 7 The daily dose of medicine recommended by doctor and system

Fig. 7 shows the system recommendations can provide daily dosage according to the patient's severity, while the doctor's recommended dosage begins using a low dosage [29]. Giving too low a dosage can result in suboptimal results [17], and recovery is prolonged for up to 1 year. However, for patients receiving the system's recommended daily dose, recovery duration is shorter to ≤3 months [30].

J. Determine Drugs Frequency

The low frequency of use will result in a healing process and have an extended usage interval frequency of drug use that can cause side effects that can worsen the patient's condition. The dose should consider the HbA1c level <8% to determine the drug dosage and frequency [18]; we need proper consideration in determining the dosage and frequency. The frequency of administration of antidiabetic drugs using IF-Then about HbA1c levels shown in Table XIII.

TABLE XIII
DETERMINING FREQUENCY BASED ON HBA1C

HbA1c	Frequency	Value
>9	Frequency high	3
>7.5	Frequency middle	2
>6.5	Frequency low	1

Algorithm
Input: HbA1c;
Output: Frequency;
Variable
REAL: HbA1c, Frequency;
Begin
If HbA1C >9 Then Frequency = High

```
Else
  If HbA1C >9 Then Frequency = Middle
Else
  Frequency = low;
End;
```

K. Expert System Application

This application uses fuzzy-profile matching, which was built using the Pascal programming language with the Delphi IDE. The application interface can be seen in Fig. 8.

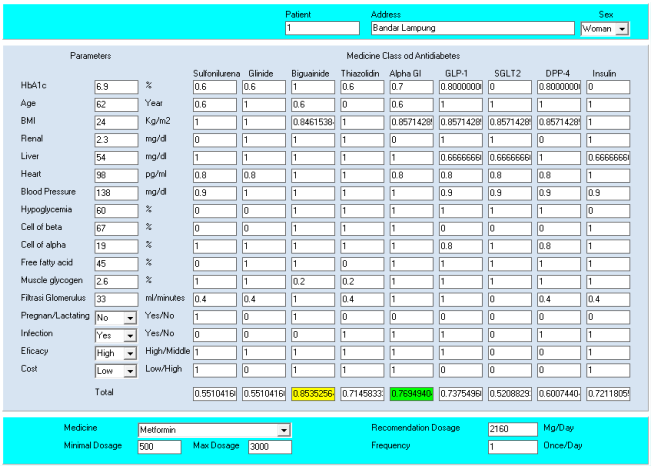


Fig. 8 The developed interface system

Fuzzy logic calculates the value of the match between the patient's condition with the type of drug and profile matching as an inference to display the total amount of each kind of medication. The dose was calculated using the FIS Tsukamoto for inputting low dosage, and high dosage calculated the weighted average value. Determination of frequency using the IF-Then function. Doctors or medics will use this application by inputting several parameters, and the system will display the match values of each antidiabetic drug. Also, the system can communicate as well as the frequency of administration of the appropriate medication

L. Comparison with Existing System

Table XIV shows the differences between several studies of antidiabetic drug recommendations with this study. The difference between this study and previous research is that this study uses more complex parameters to recommend the type of drug and its name. Also, being able to calculate the dosage and frequency based on parameters so that the dose and frequency are more precise and consider the price and efficacy of the drug

TABLE XIV
COMPARISON WITH EXISTING SYSTEMS RECOMMENDATION DRUGS

Parameter	Authors					
	Rung Chin Chen et al [12]	Shyi-Ming Chen et al[13]	Rung Ching Chen et al[14]	M. Eghbali et al.[31]	Switi et al.[32]	**This research**
Years	2012	2013	2017	2018	2019	2020
Method	SWRL/ JESS	Fuzzy	Fuzzy TOPSIS	Fuzzy Multimoora	GA	Fuzzy – PM
Number of Parameters	6	6	8	5	7	17
Number of class medicine	6	6	7	7	2	9
Class of medicines	Yes	Yes	Yes	Yes	Yes	Yes
Medicine	No	No	No	No	No	Yes
Recommend levels	No	Yes	Yes	Yes	Yes	Yes
Dosage	No	No	No	No	No	Yes
Frequency dosage	No	No	No	No	No	Yes
Cost	No	No	Yes	No	No	Yes

III. RESULTS AND DISCUSSION

A. Recommendation Doctor with System

The data used were 20 test data taken from patients' medical record data at the Bumi Waras Hospital in Bandar Lampung, Lampung, Indonesia, in 2019. Medical record data were calculated using the ordinal scale 1 and 0, as shown in Figure 9. in mapping the suitability of the patient's condition with antidiabetic drugs. The calculation uses a database query by creating a table; then, the selection is based on each patient's condition stored in the view. Data in the next statement is calculated using a query formula to get the total. The results of the query calculation in Figure 10

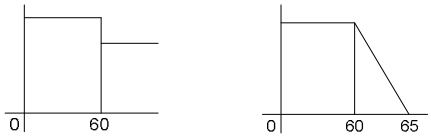


Fig. 9. Weight comparison curve using Ordinal scale and Fuzzy

Calculations using an ordinal scale have weaknesses because they do not produce flexible values to affect the quality of drug recommendations [16]. For example, antidiabetic Sulfonylurea is used for ≤60 years. If calculated using an ordinal scale, patients who are 61 years old cannot be given the type of Sulfonilurena drug, even though up to 65 years of age can still be given the medication. Therefore we need a more flexible calculation using Fuzzy logic [16].

Compared with Ordinal scale calculations, the application of fuzzy logic produces drug recommendations that approach the dataset; this is because fuzzy logic can provide flexible values to provide better anti-diabetic drug recommendations. Based on the number of recommended first-line antidiabetic drugs, Biguanide (Metformin), while for the second-line Insulin. This is according to management guidelines for type 2 Diabetes Mellitus [18].

TABLE XV
DATA COMPARISON OF RECOMMENDED SCALE ORDINAL, FUZZY AND DATASET DRUGS

Hb	Age	BMI	Renal	Liver	Heart	BP	Hypo	Cb	Ca	FFA	Muscle	FG	PL	If	Ef	Price	Medicine 1			Medicine 2		
																	Ordinal	Fuzzy	Dataset	Ordinal	Fuzzy	Dataset
6.9	62	24	2.3	54	98	138	60	67	19	45	2.6	33	No	Yes	High	Low	Biguanide	Biguanide	Biguanide	Thiazolidine	Alpha-Glucose	Alpha-Glucose
9	40	22	0.6	18	100	145	70	45	22	28	3.2	26	No	No	High	Low	Sulfonilurena	Sulfonilurena	Sulfonilurena	Glinide	Glinide	Glinide
8.3	60	20	0.8	33	90	110	55	50	17	45	1.7	40	No	No	High	Low	Biguanide	Biguanide	Biguanide	Alpha-Glucose	Alpha-Glucose	Alpha-Glucose
10	57	24.5	1.8	80	90	105	48	75	25	57	2.1	45	No	Yes	High	Low	Insulin	Insulin	Biguanide	Biguanide	Biguanide	Insulin
6.8	37	27	2.1	100	120	120	66	60	30	46	1.1	56	Yes	No	High	Low	Alpha-Glucose	Biguanide	Biguanide	SGLT-2	Alpha-Glucose	Alpha-Glucose
11	44	29	0.6	140	130	140	70	57	18	50	0.87	37	No	No	High	Low	Alpha-Glucose	Biguanide	Biguanide	Biguanide	Alpha-Glucose	Alpha-Glucose
6.5	39	25	0.7	78	95	130	65	80	35	45	2.5	28	Yes	Yes	High	Low	Insulin	Insulin	Insulin	Alpha-Glucose	Alpha-Glucose	Alpha-Glucose
7.9	50	27	3.8	130	97	100	68	67	28	32	1.9	32	No	No	High	Low	Biguanide	Biguanide	Biguanide	Alpha-Glucose	Insulin	Insulin
7.2	45	21	1.5	80	105	135	40	55	17	58	0.6	55	No	Yes	High	Low	Alpha-Glucose	Insulin	Biguanide	Biguanide	Biguanide	Insulin
11.6	62	20	2.7	130	100	117	0	46	20	47	2.1	46	No	No	High	Low	Glinide	Biguanide	Biguanide	GLP-1	GLP-1	GLP-1
9	68	24.8	2.1	78	90	125	48	54	22	28	1	50	No	No	High	Low	Biguanide	Biguanide	Biguanide	Insulin	Insulin	Insulin
7.85	55	23	0.6	100	98	150	55	70	27	35	3.7	29	No	Yes	High	Low	Insulin	Insulin	Insulin	Alpha-Glucose	Alpha-Glucose	Alpha-Glucose
6.65	40	30	0.8	98	97	137	65	52	18	55	2.9	31	Yes	No	High	Low	Alpha-Glucose	Thiazolidine	Thiazolidine	Biguanide	Alpha-Glucose	Alpha-Glucose
9.8	37	27	3.8	80	130	145	40	78	32	60	1.4	27	Yes	Yes	High	Low	Insulin	Insulin	Insulin	Alpha-Glucose	Thiazolidine	Thiazolidine
6.75	41	30	2.1	18	125	157	60	56	26	45	0.91	36	No	Yes	High	Low	Biguanide	Biguanide	Biguanide	Alpha-Glucose	Alpha-Glucose	Alpha-Glucose
7.85	57	26	2.6	140	110	142	65	48	21	58	0.85	55	No	No	High	Low	GLP-1	Biguanide	Biguanide	SGLT-2	GLP-1	GLP-1
10	60	22	0.7	78	89	100	46	75	17	50	2.6	40	No	No	High	Low	Insulin	Biguanide	Biguanide	Biguanide	Insulin	Insulin
7.78	52	21	3.9	100	94	140	68	82	28	35	3	28	No	No	High	Low	Biguanide	Biguanide	Biguanide	Insulin	Insulin	Insulin
6.8	65	20	0.6	0	105	120	55	65	23	27	0.76	30	No	Yes	High	Low	Thiazolidine	Alpha-Glucose	Alpha-Glucose	Alpha-Glucose	Thiazolidine	Thiazolidine
6.5	43	22.5	1.8	130	95	127	48	78	22	34	2.3	45	No	No	High	Low	Biguanide	Biguanide	Biguanide	Insulin	Insulin	Insulin

Information: Hb (HbA1C), BP (Blood pressure), Hypo (Hypoglicemia), Cb (Cell of Betha), Ca (Cell of Alpha), Mc (Muscle), FG (Filtrasi Glomerulus), PL (Pregnant/Lactating), If (Infection), Ef (Eficacy), Sul (Sulfonilurea), TZ (Thiazolidine), AG (Alpha Glucose), GL (GLP-1), Ins (Insulin)

B. *Evaluation of drugs administration*

In Antidiabetic drug recommendations, the accuracy of the system is crucial [33]. The course will display all the results, and the doctor will choose the best based on expertise. Evaluate the suitability of drugs recommendations based on the system, and the doctor, True Positive (TP) is used, which means the doctor approves the recommended drug. The dataset (DS) is the total amount of data, the formula shown in Table XVII. The first stage of testing compares drug recommendations using the Ordinal scale, and the second stage will be carried out to compare drug recommendations using fuzzy logic. The results of drug recommendations using the Ordinal scale can be seen in Table XVI.

TABLE XVI
THE ESTIMATION OF ANTIDIABETIC DRUGS SYSTEM

Parameter	Definition
True positive rate (TP)	The system recommends, and the doctor agrees
Dataset (DS)	The total amount of record

$$Accuracy = \frac{TP}{DS} \quad (4)$$

$$\text{Accuracy} = \frac{Tatal\ number\ of\ recommend\ drugs}{Total\ Dataset}\ x100\%$$

TABLE XVII
COMPARISON OF ACCURACY ORDINAL SCALE AND FUZZY

Scale	First medicine	Second medicine	Average
Ordinal	$\frac{11}{20} * 100\% = 50\%$	$\frac{9}{20} * 100\% = 45\%$	47.5%
Fuzzy	$\frac{18}{20} * 100\% = 90\%$	$\frac{20}{20} * 100\% = 90\%$	90%

The recommendation to use Fuzzy does not have much difference with the dataset doctor. The difference lies in the number of Biguanide recommendations that the dataset recommends as many as 14, but the system only recommends 12. Based on the accuracy value calculation, the fuzzy logic application has better accuracy, with an average difference of 43%. The application of fuzzy logic was high-speed and lower cost in recommending reliable drugs [26].

IV. CONCLUSION

Based on the description, explanation, and testing that have been done, we get a few conclusions. This study

applied antidiabetic drugs' suitability based on the patient's health condition using the Profile Matching and Fuzzy Logic methods. Based on the evaluations Fuzzy Logic can recommend antidiabetic drugs that are better than using the Ordinal scale. In addition to the recommendation of the type of medicine, the system can also recommend the dosage and frequency of using Tsukamoto's FIS so that it is more precise and reduces the errors of medical staff in recommending drugs and can have a positive impact on patients in terms of time, the healing process, and lower costs. This study provides knowledge that antidiabetic drug determination requires as many as 17 parameters, while other courses only use 4-8 parameters. This study also describes the number of drugs that drug companies can produce. Usually, companies only make low and high dosage. This research shows that creating various dosages of the drug is more efficient for patients. However, this research still needs to be reviewed and continued considering that it still has some weaknesses and shortcomings from the dataset to the number of parameters.

ACKNOWLEDGMENTS

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