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Diagnosis of Diabetes Mellitus Symptoms Using Simple Additive Weighting and Weighted Product Methods

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Abstract: Diabetes Mellitus is a disease when the body has abnormalities in insulin secretion, insulin performance or both, maintaining excess sugar in the blood. Diabetes Mellitus is caused by an imbalance between the supply and demand of insulin facilitating the entry of glucose into cells. Reduced or absent insulin makes glucose retained in the blood and leads to an increase in blood sugar, while cells become deficient in glucose badly needed for cell survival and function [8]. The frightening consequence of diabetes mellitus is that patients are at a high risk of cardiovascular disease, kidney disease, rupture of blood vessels, heart attack, stroke, leg ulcers, infection, amputation and all risks. Diabetes Mellitus is also a disease that shows an increase in glucose due to insulin deficiency which can cause macrovascular, microvascular and neurological complications. Considering those as described above, this study is intended to provide a decision support system for public to get informed of the risk of diabetes militus so as to take an immediate action. The methods used in this research are the SAW(Simple Additive Weighting) and WP (Weighted Product) methods to diagnose the diabetes militus symptoms.

Keywords: *Diabetes Melitus; Decision Making Support System; Simple Additive Weighting (SAW), Weighted Product (WP).*

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1 Introduction

Diabetes is a disease familiar in the world of medicine and society. Diabetes mellitus usually affects various social classes and public circles. Diabetes mellitus is a chronic metabolic disease characterized by increased blood glucose (hyperglycemia) due to an imbalance between the supply and demand of insulin facilitating the entry of glucose into cells so that it can be used for cell metabolism and growth. Reduced or absent insulin makes glucose retained in the blood and causes an increase in blood sugar, while cells become deficient in glucose very much needed for cell survival and function [8].

Diabetes or commonly called 'kencing manis' (in Bahasa Indonesia) is a dangerous disease that can lead to the death of patients. Diabetes mellitus is a chronic disease that may last a lifetime. The frightening consequence of diabetes mellitus is that patients are at a high risk of cardiovascular disease, kidney disease, rupture of blood vessels, heart attack, stroke, leg ulcers, infection, amputation and all risks. Diabetes Mellitus is also a disease that shows an increase in glucose due to insulin deficiency which can cause macrovascular, microvascular and neurological complications.

Most people are often unaware of the bad effects caused by diabetes and do not know that they may be at the risk of suffering from this disease [5]. The reason for this is the lack of information for people regarding diabetes mellitus, their limited funds and time to consult a doctor [4]. Considering the several problems above, enough information is needed to help solve those problems. For this, an effective analysis tool is required. That is a decision making support system, information system used to make decisions effectively and efficiently on structured and unstructured problems.

The decision support system is intended to overcome the problems and to assist people in diagnosing diabetes symptoms. The benefits of the decision support systems include providing solutions that deliver faster and more reliable results, increasing decision makers' confidence in their decisions, and saving time, effort, and money with on-demand decision support system. It is very much needed to solve problems, especially the problems that are very complex and unstructured [12]. In this research, we need a method reliable and effective to solve the existing problems. The methods used are the Simple Additive Weighting (SAW) Method and the Weighted Product (WP) Method to be applied with the Matlab application. The basic concept of the SAW method is to find a weighted sum of performance ratings for each alternative on all attributes. Meanwhile, the WP method uses multiplication to connect attribute ratings, of which the rating of each attribute must be raised to the power of the weight of the attribute in question.

Both of these methods are simple methods to provide a more accurate assessment because they are based on predetermined criteria values and preference weights used to complete the decision-making process and choose the best alternative. Therefore, to assist the process of determining the results of the diagnosis of the diabetes mellitus symptoms in this study, the SAW method and the WP method were used. The use of these two methods is expected to help people find out whether they have diabetes mellitus or not with a fast and precise process. As a result, the community immediately knows and it is not too late to handle it.

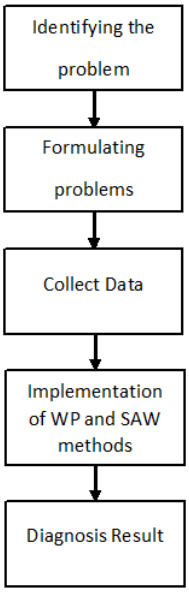

Figure 1: Research Flowchart.

2 Method

2.1 Research flow chart

The flow of this research began with identifying the problem of diabetes mellitus with many criteria required, followed by the formulation of the problem. Through existing problems such as determining the criteria for diagnosing diabetes mellitus symptoms, solutions can then be determined. Further, to assist in finding out solutions, this can be resolved through observation and interviews in the data collection process, then from the data obtained, analyzed and implemented into the SAW method and the WP method. After all these processes have been conducted, conclusions can be drawn in the form of the results of the diagnosis of diabetes mellitus symptoms.

2.2 Data collection method

This research was conducted by applying data collection techniques of questionnaires made with the Google form. If you want to get the data being convincing and real, the authors review it for direct interviews with people with diabetes mellitus. For the literature study at this stage, the researcher collects information and data from several different sources such as journals, e-journals, proceedings, books, e-books and the internet, after which the researcher studies them in order to get valid results. From this data collection technique, the researcher needs several research objects because if only one sample is taken, then it cannot be used as a conclusion in this study, therefore severalty of research objects are needed and later used as comparisons when carrying out later calculations.

3 Theoretical Framework

3.1 Diabetes Mellitus

Diabetes mellitus is a condition in which the body cannot produce insulin effectively, resulting in excessive sugar in the blood. Based on the results of collecting information from several sources and those of interviews with experts in the health field, it can be concluded that diabetes mellitus can be risky due to several factors, including heredity, overweight, unhealthy lifestyles, and age. This disease can also be triggered by the presence of other diseases such as hypertension and cholesterol due to high blood pressure which can make the sugar distribution to cells not run optimally so that it leads to accumulation of sugar and cholesterol in the blood. On the contrary, if the condition of blood pressure is within the normal range, then blood sugar is maintained within the normal range since the insulin is working properly. Considering the factors causing diabetes mellitus, they are used as a criterion determinant in this study, which is essentially expected to assist in the decision-making process.

3.2 Decision Making Support System (SPK)

Decision Support System is an information system that is used to assist in decision making by using data and several decision models effectively and efficiently to solve semi-structured and unstructured problems. The Decision Support System usually does not change the function of decision makers but only provides support or strengthens the results in making decisions. The purpose of the Decision Support System is to provide information, forecasts, and guidance for information users so that they can make decisions by doing the calculations using predetermined methods so that the results obtained are more accurate.

3.3 Simple Additive Weighting (SAW) method

The SAW (Simple Additive Weighting) method is often called the weighted sum method. The basic concept of the SAW method is to find a weighted sum of performance ratings for each alternative of all attributes. The SAW method requires the process of normalizing the decision matrix (x) to a scale that can be compared to all existing alternative ratings. This method requires the decision maker to determine the weight for each attribute. The rating of each attribute must be dimension-free in the sense that it has gone through the previous normalization process. The SAW method recognizes the existence of two attributes, that is, the profit criterion and cost criterion.

The formula for doing the normalization is as follows :

$$r_{ij} \begin{cases} \frac{x_{ij}}{Max\ x_{ij}} \ if\ j : atribute\ of\ benefit, \\ \frac{Min\ x_{ij}}{x_{ij}} \ if\ j : atribute\ of\ cost, \end{cases} \tag{1}$$

where r_{ij} is the normalized performance rating, x_{ij} is the attribute of each criterion, $Max\ x_{ij}$ is the highest value of each criterion and $Min\ x_{ij}$ is the lowest value of each criterion.

Preference value for each alternative (V_i) is given as

$$V_i = \sum_{j=1}^{n} w_j r_{ij}, \tag{2}$$

where V_i is the final value of the alternative, w_j is the predetermined weight, r_{ij} is the normalised matrix. The higher value of V_i indicates that the alternative A_i is preferred.

3.4 Weighted Product (WP) method

The Weighted Product (WP) method is a multi-criteria decision analysis, and it is a multi-criteria decision-making method. The WP method is a set of decision alternatives described in terms of several criteria. The weighted product method uses multiplication to link attribute ratings, of which the rating of each attribute must be raised first to the power of the attribute weight in question. This process is the same as the normalization process. In the WP method, matrix manipulation is not required because this method multiplies the results of the assessment of each attribute. The multiplication results have not been compared to (divided by) the standard value, in this case, the ideal alternative is often used as the standard weight value. The weight for the benefit attribute functions as a positive rank in the multiplication process between attributes, while the cost weight functions as a negative rank. This process is the same as the normalization process. The preference for the Ai alternative is given as follows:

$$S_i = \prod_{j=1}^{n} X_{ij}^{w_i}; i = 1, 2, \ldots, m, \tag{3}$$

where $\Sigma w_j = 1$, w_j is the power of positive value for the benefit attribute and of negative value for the cost attribute.

Then the ranking process uses the vector v, and the vector v can be obtained by applying the following formula:

$$V_i = \frac{\prod_{j=1}^{n} X_{ij}^{w_i}}{\prod_{j=1}^{n} \left(X_j^*\right)^{w_i}}; i = 1, 2, \ldots, m. \tag{4}$$

4 Discussion

4.1 Determining criteria (C_i)

The data obtained from the questionnaire of the Google form are evaluated then used as a reference for the decision making process criteria for the cases of diabetes mellitus symptoms, see Table 1.

No.	Criteria	Description
1	C_1	Hereditary
2	C_2	Age
3	C_3	BMI
4	C_4	Diet
5	C_5	History of other diseases

Table 1: Criteria.

4.2 Determining the criterion value based on the weight value

For each criterion of heredity, age, difference of ideal body weight, diet, history of other diseases, the value of the criterion is determined with the reference to the value of the variable given to each criterion. Then this value is considered as an indicator criterion which later becomes the value determining factor. For reference, see Table 2.

No.	Value	Description
1	1	Low risk
2	2	Average risk
3	3	High risk

Table 2: Weight value reference.

1. Hereditary Criterion
   The criteria for heredity (offspring of diabetics) are categorized into three types: first, neither father nor mother have diabete, second, either father or mother has diabete, and third, both father and mother have diabetes. When converted with reference to the weight value determination, the values are as follows:

No.	Heredity(C_1)	Value
1	Neither	1
2	Either father or mother	2
3	Both father and mother	3

Table 3: Heriditary Criterion.

2. Age Criterion
   The age category is converted into the weight value, and the weight value determining reference is shown in Table 4.

No.	Age(C_2)	Value
1	0-30	1
2	31-45	2
3	> 45	3

Table 4: Age Criterion.

3. BMI Criterion
   The BMI is obtained by using the BMI formula, that is, $BMI = \frac{berat\ badan\ (kg)}{tinggi\ badan\ (m^2)}$. The obtained result is converted into the weight value, and the weight value determining reference is shown in Table 5.
4. Diet Criteria
   The diet criterion is converted into the weight value, and the weight value determining reference is shown in Table 6.

No.	BMI (C_3)	Value
1	18-25	1
2	< 18	2
3	> 25	3

Table 5: BMI Criterion.

No.	Diet (C_4)	Value
1	1-2 times a day	1
2	3 times a day	2
3	> 3 times a day	3

Table 6: Diet Criterion.

5. Other disease history Criterion
   The criterion of the other disease history is converted into the weight value, and the weight value determining reference can be seen in Table 7.

No.	Other Disease History (C_5)	Value
1	Not suffering any other disease	1
2	Suffering an internal disease	2
3	High blood tension or high cholesterol	3

Table 7: Criterion of other disease history.

4.3 Determining the weight of each criterion applied

The next step is to determine the weight for each criterion as shown in Table 8.

No.	Criteria (C_i)	Attribute	Value
1	Heredity (C_1)	Benefit	$45\% = \frac{45}{100} = 0,45$
2	Age (C_2)	Benefit	$25\% = \frac{25}{100} = 0,25$
3	BMI (C_3)	Benefit	$15\% = \frac{15}{100} = 0,15$
4	Diet (C_4)	Benefit	$10\% = \frac{10}{100} = 0,10$
5	History of other disease (C_5)	Benefit	$5\% = \frac{5}{100} = 0,05$

Table 8: Determining the weight of each criterion.

Each criterion in this study has a benefit attribute because all types of criteria prioritize the highest value as a reference for selection.

4.4 Determining the alternatives

Determining the alternatives is done by taking the data based on the criteria predetermined by the researcher. The data were obtained from 15 respondents who filled out the Google form. The following is a table for each alternative determined based on the determined criteria, that is, hereditary, age, BMI, diet, and history of other diseases as shown in Table 9.

No.	Name	Parents With Diabete	Age	BMI	Diet	Disease History
1	SI	1	2	1	2	1
2	AN	2	3	3	2	2
3	SK	1	3	1	2	1
4	ST	1	3	1	2	3
5	PL	2	3	1	2	1
6	AZ	1	3	3	1	3
7	AS	1	3	1	2	1
8	E	2	3	1	2	1
9	MY	2	3	3	1	2
10	MT	1	2	3	2	1
11	KT	2	3	3	1	2
12	SA	1	2	1	2	1
13	KS	1	3	3	3	3
14	S	2	2	3	2	1
15	SD	2	2	3	2	1

Table 9: Determining alternatives.

4.5 Normalizing the matrix by the SAW method

The following is a decision matrix formed in accordance with the value of each alternative obtained by the researchers by calculation as follows:

$$X = \begin{pmatrix} 1 & 2 & 1 & 2 & 1 \\ 2 & 3 & 3 & 2 & 2 \\ 1 & 3 & 1 & 2 & 1 \\ 1 & 3 & 1 & 2 & 3 \\ 2 & 3 & 1 & 2 & 1 \\ 1 & 3 & 3 & 1 & 3 \\ 1 & 3 & 1 & 2 & 1 \\ 2 & 3 & 1 & 2 & 1 \\ 2 & 3 & 3 & 1 & 2 \\ 1 & 2 & 3 & 2 & 1 \\ 2 & 3 & 3 & 1 & 2 \\ 1 & 2 & 1 & 2 & 1 \\ 1 & 3 & 3 & 3 & 3 \\ 2 & 2 & 3 & 2 & 1 \\ 2 & 2 & 3 & 2 & 1 \end{pmatrix}.$$

The next step is to normalize the matrix based on the types of attributes predefined so as to get the normalized matrix results by calculation as follows:

$$r_{11} = \frac{1}{2} = 0,5; r_{21} = \frac{2}{2} = 1; r_{31} = \frac{1}{2} = 0,5.$$

Proceed up to r_{155} to get the results of the normalized matrix as follows:

$$X = \begin{pmatrix} 0.500 & 0.667 & 0.333 & 0.667 & 0.333 \\ 1.000 & 1.000 & 1.000 & 0.667 & 0.667 \\ 0.500 & 1.000 & 0.333 & 0.667 & 0.333 \\ 0.500 & 1.000 & 0.333 & 0.667 & 1.000 \\ 1.000 & 1.000 & 0.333 & 0.667 & 0.333 \\ 0.500 & 1.000 & 1.000 & 0.333 & 1.000 \\ 0.500 & 1.000 & 0.333 & 0.667 & 0.333 \\ 1.000 & 1.000 & 0.333 & 0.667 & 0.333 \\ 1.000 & 1.000 & 1.000 & 0.333 & 0.667 \\ 0.500 & 0.667 & 1.000 & 0.667 & 0.333 \\ 1.000 & 1.000 & 1.000 & 0.333 & 0.667 \\ 0.500 & 0.667 & 0.333 & 0.667 & 0.333 \\ 0.500 & 1.000 & 1.000 & 1.000 & 1.000 \\ 1.000 & 0.667 & 1.000 & 0.667 & 0.333 \\ 1.000 & 0.667 & 1.000 & 0.667 & 0.333 \end{pmatrix}.$$

4.6 Ranking process by SAW method

The next process is to have the sum of the matrix R, and later it is multiplied by the weight of each criterion, then the obtained value is used as a benchmark in determining the diagnosis of diabetes mellitus symptoms. The following is the alternative ranking based on the calculation results as shown in Table 10.

No.	Alternative	Reference	Diagnosis Results
1	SI	0.52	Low risk
2	SA	0.52	Low risk
3	SK	0.60	Fair risk
4	AS	0.60	Fair risk
5	MT	0.62	Fair risk
6	ST	0.64	Fair risk
7	AZ	0.70	Fair risk
8	KS	0.77	High risk
9	E	0.83	High risk
10	PL	0.83	High risk
11	S	0.85	High risk
12	SD	0.85	High risk
13	MY	0.91	High risk
14	KT	0.91	High risk
15	AN	0.95	High risk

Table 10: The Results of the Ranking by the SAW method.

4.7 Determining the preference and alternative ranking by WP method

Because the total weight is equal to 1, the next step is to determine the preference for each alternative.

$$\begin{aligned} S_1 &= (1^{0,45})(2^{0,25})(1^{0,15})(2^{0,1})(1^{0,05}) = 1,274561, \\ S_2 &= (2^{0,45})(3^{0,25})(3^{0,15})(2^{0,1})(2^{0,05}) = 2,352158, \\ S_3 &= (1^{0,45})(3^{0,25})(1^{0,15})(2^{0,1})(1^{0,05}) = 1,410533. \end{aligned}$$

Proceed up to S_{15}. Then, it is followed by the calculation of the relative preference.

$$\begin{aligned} V_1 &= \frac{1,274561}{26,533754} = 0,048035, \\ V_2 &= \frac{2,352158}{26,533754} = 0.088648, \\ V_3 &= \frac{1,410533}{26,533754} = 0.053160. \end{aligned}$$

And it is continued up to V_{15}. The following is the alternative ranking determined based on the calculation results as shown in Table 11.

No.	Alternative	Reference	Alternative Preference	Diagnosis Results
1	SI	1.274561	0.048035	Low Risk
2	SA	1.274561	0.048035	Low risk
3	SK	1.410533	0.053160	Low risk
4	AS	1.410533	0.053160	Fair risk
5	MT	1.502895	0.056641	Fair risk
6	ST	1.490182	0.056162	Fair risk
7	AZ	1.639474	0.061788	Fair risk
8	KS	1.829855	0.068963	High risk
9	E	1.926845	0.072619	High risk
10	PL	1.926845	0.072619	High risk
11	S	2.053015	0.077374	High risk
12	SD	2.053015	0.077374	High risk
13	MY	2.194641	0.082711	High risk
14	KT	2.194641	0.082711	High risk
15	AN	2.352158	0.088648	High risk

Table 11: Results of Preference and Ranking by the WP method.

5 Conclusion

Based on the calculation results as seen above, there were 8 people indicated to have high risk of suffering from diabete mellitus, that is, KS, E, PL, S, SD, MY, KT, and AN due to the high values of heredity, body weight, and diet criteria. And, there were 5 people indicated to be at medium risk of suffering from diabetes mellitus, they are SK, AS, MT, ST, AZ. Meanwhile, there were 2 people indicated to be at low risk of suffering from

diabetes mellitus, they are SI and SA. Thus, the decision support system for diabetes mellitus symptoms was effectively done by using the Simple Additive Weighting (SAW) method, or by the Weighted Product (WP) method, with the aim of providing information for the public regarding the risk of diabetes mellitus for their immediate action to take.

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References

[1] K. G. Alberti and P. Z. Zimmet. Definisi, Diagnosis dan Klasifikasi Diabetes Mellitus dan Komplikasinya, Bagian 1: Diagnosis dan Klasifikasi Diabetes Mellitus Lporan Sementara Konsultasi WHO. *Pengobatan Diabetes* **15** (7) (1998) 239–553.

[2] B. D. Prasetyo, E. Daniati and S. Sucipto. Implementasi Metode Simple Attidive Weighting Untuk Diagnosis Gejala Diabetes Melitus. *Jambura Journal of Electrical and Electronics Engineering* **3** (2) (2021) 72–77.

[3] C. R. Nalsa. Penerapan Metode Simple Additive Weighting (SAW) pada Sistem Pendukung Keputusan Pemilihan Lokasi Untuk Cabang Baru Took Pakan UD. Indo Multi Fish. *Jurnal INTENSIF* **1** (2) (2017) 102–107.

[4] H. T. Sihotang. Perancangan Aplikasi System Pakar Diagnose Diabetes Dengan Metode Bayes. *Jurnal Mantik Penusa* **1** (1) (2017) 36–41.

[5] K. Khairani. Pengetahuan Diabetes Mellitus Dan Upaya Pencegahan Pada Lansia Di Lam Bheu Aceh Besar. *Idea nursing Journal* **5** (3) (2014) 58–66.

[6] S. Kusumadewi and S. Hartati. *Fuzzy Multi-Attribute Decision Making (FUZZY MADM)*. Graha Ilmu, Yogyakarta, 2006.

[7] T. Herlambang, S. Suryowinoto, I. Kurniastuti, H. Nurhadi, and K. Oktafianto. Performance Comparison of Sliding Mode Control and Sliding PID for Rescue ROV. *Nonlinear Dynamics and Systems Theory* **23** (5) (2023) 519–537.

[8] M. I. Derek, J. V. Rottie and V. Kallo. Hubungan Tingkat Stres dengan Kadar Gula Darah pada Pasien Diabetes Mellitus Tipe II di Rumah Sakit Pancaran Kasih GMIM Manado. **5** (1) (2017).

[9] R. Helilintar, W. W. Winarno and A. F. Hanif. Penerapan Metode SAW dan Fuzzy Dalam Sistem Pendukung Keputusan Penerimaan Beasiswa. *Creative Information Technology Journal* **3** (2) (2016) 89–101.

[10] T. Herlambang, H. Nurhadi, S. Suryowinoto,D. Rahmalia and K. Oktafianto. Motion Estimation of Third Finger Using Ensemble and Unscented Kalman Filter for Inverse Kinematic of Assisive Finger Arm Robot. *Nonlinear Dynamics and Systems Theory* **23** (4) (2023) 389–397.

[11] S. Imelda. Faktor-Faktor Yang Mempengaruhi Terjadinya Diabetes Melitus Di Puskesmas Harapan Raya Tahun 2018. *Scientia Journal* **8** (1) (2019) 28–39.

[12] W. Setiyaningsih and M. Kom. *Konsep Sistem Pendukung Keputusan*. Yayasan Edelweis, 2015.