

# Body Mass Index Classifier Using Type-1 Fuzzy Logic: Case Study of Mexico

Cinthia Peraza\*, Patricia Ochoa

Tijuana Institute of Technology/TECNM,  
Division of postgraduate studies and research,  
Mexico

{cinthia.peraza, martha.ochoa18}@tectijuana.edu.mx

**Abstract.** Fuzzy logic offers significant benefits for solving real-world problems in various fields of knowledge. The main objective of this article is to design a system based on the theory and concepts of Type-1 fuzzy logic to determine the Body Mass Index (BMI) category of an adult population in Mexico. The World Health Organization (WHO) establishes certain parameters for this calculate, based on the data presented in the Body Mass Index table published on the official website of the Mexican Social Security Institute (IMSS). According to the data presented by the IMSS, the body mass index can be determined by knowing a person's weight and height. This understanding serves as the basis for creating the inputs, outputs, and rules of the Type-1 fuzzy system, with the goal of validating the correct classification based on a person's BMI. The results will be validated using the Body Mass Index Table to assess the performance and accuracy of the proposed fuzzy system.

**Keywords.** Body mass index, fuzzy logic, health.

## 1 Introduction

Obesity has become one of the main public health problems in Mexico in recent decades. This phenomenon did not arise suddenly, but rather because of a combination of social, economic, and cultural factors that have profoundly altered the population's eating habits and physical activity levels [1-3]. Obesity is one of the main public health problems in Mexico and has shown sustained growth over the last few decades. This phenomenon arises because of a nutritional transition characterized by the progressive abandonment of traditional dietary patterns and the increased consumption of processed foods, rich in

sugars, fats, and sodium. Added to this is a decrease in physical activity and an urban environment that promotes sedentary lifestyles, which has led to a notable increase in overweight and obesity rates across the population.

The study entitled "Obesity in Mexico, prevalence and trends in adults. ENSANUT 2018-19" analyzes a sample of 16,256 adults. The prevalence of obesity was reported to be 39.1%, obesity 36.1%, and abdominal adiposity 81.6%. Between 2000 and 2018, the prevalence of obesity increased by 42.2% and that of morbid obesity by 96.5%. [4] This source is good because it bases its data on multiple rounds of the ENSANUT national survey (2000, 2006, 2012, 2018-19), thus allowing for the observation of trends over time. [4] For children and adolescents, the study "Overweight and obesity in children and adolescents, 2016 Halfway National Health and Nutrition Survey update" indicates that in children under 5 years of age, the prevalence of overweight/obesity was 5.1% in girls and 6.5% in boys; in children aged 5-11 years, it was ~33% (32.8% girls, 33.7% boys); and in adolescents, 39.2% in girls and 33.5% in boys [5]. Another source, "Trends in overweight and obesity in children under 24 months of age in Mexico (2012-2020)", indicates that in children under 12 months, the prevalence of overweight and obesity is 10.3%, and in the 12-23-month range, it is 26.1% [6]. Also, a systematic review entitled "Obesity and Its Association with Micronutrient Deficiency Among Mexican Children and Adolescents" indicates that between 2020 and 2022, the prevalence of overweight or obesity in school-aged children was ~37% and in adolescents ~41% [7].

With technological advancements around fuzzy logic sets, the aim is to classify the obesity status of an individual, based on the table provided by the Mexican Social Security Institute. Type-1 fuzzy logic, proposed by Lofti Zadeh in 1965 [8]. In this article, we focus on the problem of obesity in a population of adults in Mexico.

This article is distributed as follows: Section 2 Fuzzy logic sets, Section 3 Case study, Section 4 Proposed Fuzzy Logic Classifier, Section 5 Experiments and results, and finally Section 6 where the conclusions are presented.

## 2 Fuzzy Logic Sets

Fuzzy logic (FL) is a branch of artificial intelligence that allows for the handling of imprecise, uncertain, or gradual information, mimicking the way humans reason in ambiguous situations. In the medical field, it is especially useful, since many diagnoses and clinical decisions are not strictly “true” or “false,” but rather depend on levels or ranges [9-20].

In the context of obesity, FL offers a powerful tool for evaluating factors that cannot be defined with rigid boundaries, such as the degree of obesity. Instead of classifying a patient solely by fixed categories—for example, “obese” or “not obese”—fuzzy logic allows for the description of intermediate states and the combination of multiple variables to obtain more flexible assessments [21-29].

In this study, triangular and trapezoidal membership functions are used due to their simplicity, computational efficiency, and ability to clearly represent the inherent uncertainty of system variables. These functions are widely used in fuzzy controller design because they allow for smooth transitions between different membership levels and facilitate the interpretation of fuzzy sets.

The triangular function is distinguished by its simple form, defined by three parameters that generate a linear rise and fall around a maximum point. Equation 1 presents its mathematical expression, while Figure 1 shows its graphical representation:

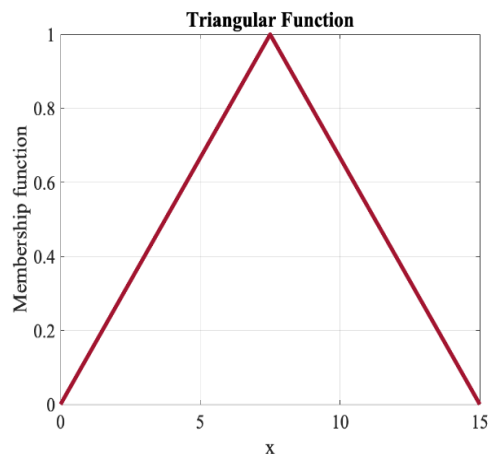


Fig. 1. Triangular function

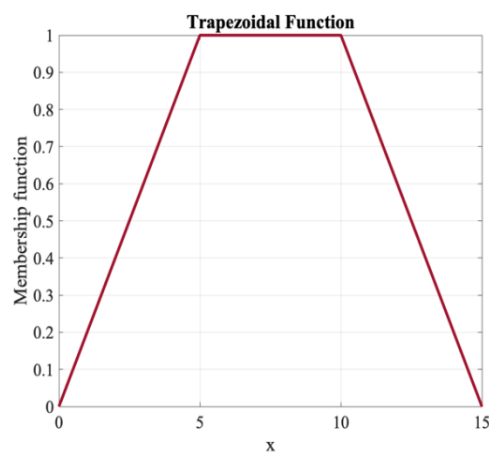


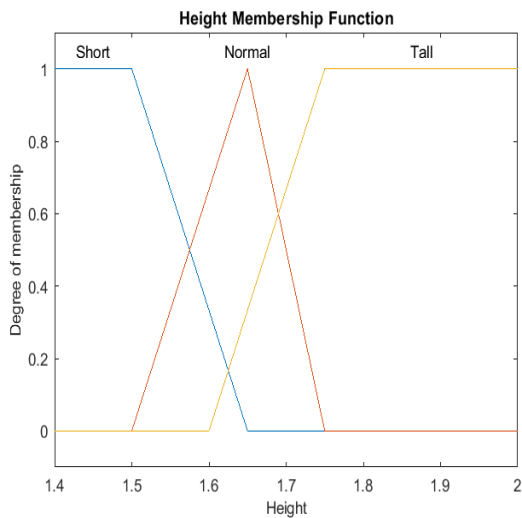
Fig. 2. Trapezoidal function

$$\text{trimf}(x, pa, pb, pc) = \begin{cases} 0, & x \leq pa, \\ \frac{x - pa}{pb - pa}, & pa \leq x \leq pb, \\ \frac{pc - x}{pc - pb}, & pb \leq x \leq pc, \\ 0, & pc \leq x \end{cases} \quad (1)$$

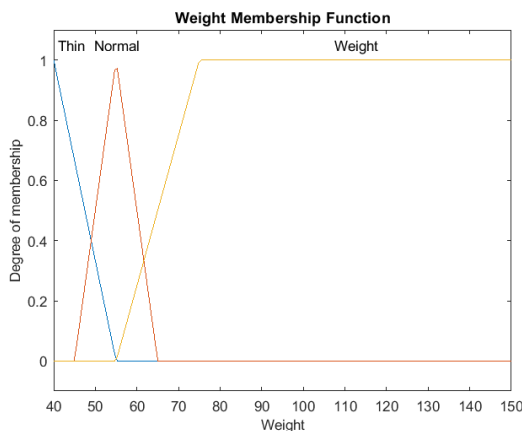
The trapezoidal function, on the other hand, extends this concept by incorporating a flat region where membership remains at its maximum value, which is especially useful for modeling intervals where a variable can be considered fully representative of a fuzzy set. Equation 2 shows its mathematical formulation, and Figure 2 illustrates its graphical representation:

**Table 1.** BMI Classification

BMI Range	Weight Classification
<18.5	Under
18.5-24.9	Normal
25-29.9	Over
30-34.9	Mild Obesity
35-39.9	Moderate Obesity
≥40	Morbid Obesity



**Fig. 3.** Input 1: "Height"



**Fig. 4.** Input 2: "Weight"

$$\begin{aligned}
 & trapf(x, pa, pb, pc, pd) \\
 &= \begin{cases} 0, & x \leq pa, \\ \frac{x - pa}{pb - pa}, & pa \leq x \leq pb, \\ 1, & pb \leq x \leq pc, \\ \frac{pd - x}{pd - pc}, & pc \leq x \leq pd, \\ 0, & pc \leq x. \end{cases} \quad (2)
 \end{aligned}$$

The fuzzy system discussed in the following section is composed of these membership functions; therefore, the importance of each membership function is emphasized. We aim to validate the difference between strictly mathematical or statistical methods and fuzzy logic, which allows for the integration of human reasoning through linguistic rules that mimic how specialists describe symptoms, risks, or degrees of severity.

### 3 Case Study

The body mass index (BMI) It is a measure that indicates the relationship between weight and height, which allows for the identification of overweight and obesity in adults.

The way to calculate it is as follows: Divide a person's weight into kilograms by the square of their height in meters [30]:

$$BMI = \frac{BodyWeight}{(BodyHeight)^2}. \quad (3)$$

The following Table 1 can be used to interpret the person's condition [30].

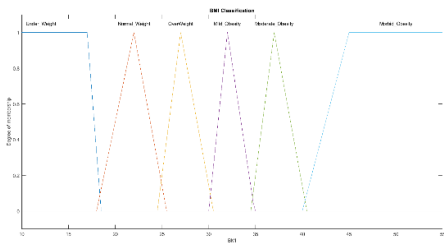
Based on this knowledge of a real-world problem, the aim is to model this behavior using a type-1 fuzzy system which allows us to handle the uncertainty and imprecision of the problem. Our fuzzy system proposal seeks to be an aid in the calculation of the BMI, avoiding traditional calculations, where the user simply enters their weight and height to obtain their BMI classification as a result.

### 4 Proposed Fuzzy Logic Classifier

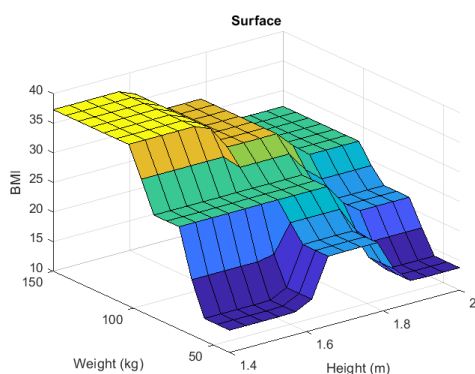
Design a system based on the theory and concepts of Type-1 fuzzy logic to determine the BMI category of an adult population of Mexico.

**Table 2.** Validation of rules of the BMI fuzzy system

Validati on	Heig ht (m)	Weig ht (kg)	BMI real = Weig ht/ Heig ht <sup>2</sup>	Estimated Classification( Fuzzy Output)
1	1.70	40	13.84	Under_weight 16.6
2	1.70	55	19.03	Normal_weight 21.8
3	1.65	64	23.50	Overweight 28.5
4	1.60	85	33.20	Mild Obesity 34.5
5	1.55	90	37.46	Moderate Obesity 35.7
6	1.50	95	42.22	Morbit Obesity 48.8



**Fig. 5.** Output: "BMI"



**Fig. 6.** Surface

The proposed fuzzy system structure consists of two inputs and one output, granulated into triangular and trapezoidal membership functions. The inputs were granulated into 3 membership

functions, and the output was granulated into 6 membership functions, each with its own linguistic labels, as shown in Figures 3, 4, and 5. The surface of the BMI fuzzy controller is shown in Figure 6.

Figure 6 represents the behavior of the BMI classification output surface, between the relationship of the weight and height inputs with the rules proposed in the fuzzy system to generate the output.

The fuzzy rules were constructed based on the ranges in Table 1; a total of 9 were used:

1. If (Height is Short) and (Weight is Thin) then (BMI is Under)
2. If (Height is Short) and (Weight is Normal) then (BMI is Moderate\_Obesity)
3. If (Height is Short) and (Weight is Weight) then (BMI is Morbid\_Obesity)
4. If (Height is Normal) and (Weight is Thin) then (BMI is Normal)
5. If (Height is Normal) and (Weight is Normal) then (BMI is Over)
6. If (Height is Normal) and (Weight is Weight) then (BMI is Mild\_Obesity)
7. If (Height is Tall) and (Weight is Thin) then (BMI is Under)
8. If (Height is Tall) and (Weight is Normal) then (BMI is Normal)
9. If (Height is Tall) and (Weight is Weight) then (BMI is Over)

## 5 Validation and results

To verify the correct classification of the proposed fuzzy system, six validations were performed using values for each of the fuzzy system's inputs to evaluate the output.

Table 2 presents the results obtained. Table 2 shows the result of the actual BMI calculation using Equation 3 and mentions the result of the evaluation of the proposed fuzzy system's output.

## 6 Conclusions

Fuzzy logic has become a widely used tool in various disciplines, where it complements traditional methods for handling uncertainty and variability in data.

This study is no exception: a fuzzy system was implemented to determine Body Mass Index (BMI). To this end, a type 1 fuzzy system was developed based on the ranges and reference values provided by the Mexican Social Security Institute (IMSS). This approach allows for a more flexible analysis of BMI, integrating smooth transitions between categories and offering an evaluation closer to human reasoning.

To validate the performance of the fuzzy system, the real BMI was calculated, and the output obtained by the fuzzy system is shown. A variation between the estimated and real parameters can be observed, but the fuzzy system successfully classifies the BMI. As future work, the values of the input, output, and rule functions can be optimized with metaheuristics. Also, other applications could be considered [31].

## Acknowledgments

We appreciate the support of TECNM and Tijuana Institute of Technology.

## References

1. Faradisa, I. S., Muhammad, R. P., Girindraswari, D. A. (2022). A design of body mass index (BMI) and body fat percentage device using fuzzy logic. *Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics*, 4(2), 94-106.
2. Flores-Payan, L., Hernández-Corona, D. M., González-Heredia, T. (2021). Multidimensional analysis of health in Mexico: implementation of fuzzy sets. *BMC Public Health*, 21(1), 944.
3. Grande-Ramírez, José Meza-Palacios, Ramiro & Lasserre, Alberto Flores Asis, Rita. (2024). Intelligent fuzzy system to assess the risk of type 2 diabetes and diagnosis in marginalized regions. 99. 1-10.
4. Barquera S, Hernández-Barrera L, Trejo-Valdivia B, Shamah T, Campos-Nonato I, Rivera-Dommarco J. (2020) Obesidad en México, prevalencia y tendencias en adultos. *Ensanut 2018-19* [Obesity in Mexico, prevalence and trends in adults. *Ensanut 2018-19*]. *Salud Publica Mex.* 2020 Nov-Dec;62(6):682-692. Spanish. doi: 10.21149/11630. PMID: 33620965
5. Shamah-Levy, T., Cuevas-Nasu, L., Gaona-Pineda, E. B., Gómez-Acosta, L. M., del Carmen Morales-Ruán, M., Hernández-Ávila, M., Rivera-Dommarco, J. Á. (2018). Sobrepeso y obesidad en niños y adolescentes en México, actualización de la Encuesta Nacional de Salud y Nutrición de Medio Camino 2016. *Salud pública de México*, 60(3), 244-253.
6. Cárdenas-Villarreal, V. M., Hernandez-Barrera, L., Castro-Sifuentes, D., Guevara-Valtier, M. C., & Trejo-Valdivia, B. (2023) Trends in overweight and obesity in children under 24 months of age in Mexico (2012-2020): analysis of four national health surveys. *Cadernos de Saúde Pública*, 39, e00046123.
7. Herrera-González, A., Gutierrez-Gómez, Y. Y., Moreno-García, C. F., Aceves-Martins, M. (2025). Obesity and Its Association With Micronutrient Deficiency Among Mexican Children and Adolescents: A Systematic Review and Meta-analysis. *Nutrition reviews*, naaf148.
8. Zadeh, L. A. (1965). Fuzzy sets. *Information and control*, 8(3), 338-353.
9. Yin, P.Y. (2000). A tabu search approach to polygonal approximation of digital curves. *International Journal of Pattern Recognition and Artificial Intelligence*, 14(2), 243-255.
10. Khushal, R., Fatima, U. (2025). A novel fuzzy three-valued logic computational framework in machine learning for medicine dataset. *Computers in Biology and Medicine*, 186, 109636.
11. Ennab, M., Mcheick, H. (2025). A novel convolutional interpretability model for pixel-level interpretation of medical image classification through fusion of machine learning and fuzzy logic. *Smart Health*, 35, 100535.
12. Grob, M., Liepold, J., Hauptfeld, L., Weich, C., Kreinovich, V., Jenders, R. A., Adlassnig, K. P. (2025). Fuzzy Arden syntax connectives in clinical medicine. In *Global*

- Healthcare Transformation in the Era of Artificial Intelligence and Informatics (pp. 36-40). IOS Press.
13. **Zheng, W., Turner, L., Kropczynski, J., Ozer, M., Nguyen, T., Halse, S. (2025).** LLM-as-a-Fuzzy-Judge: Fine-Tuning Large Language Models as a Clinical Evaluation Judge with Fuzzy Logic. arXiv preprint arXiv:2506.11221.
  14. **Zheng, W., Turner, L., Kropczynski, J., Ozer, M., Nguyen, T., Halse, S. (2025).** LLM-as-a-Fuzzy-Judge: Fine-Tuning Large Language Models as a Clinical Evaluation Judge with Fuzzy Logic. arXiv preprint arXiv:2506.11221.
  15. **Yağız, S., Karabulut, D., Sandal, B., Salihoğlu, Z., Yağız, N. (2025).** Medical Ethics-based Intensive Care Unit Admission Evaluation Using Fuzzy Logic for COVID-19-like Pandemic. *Bagcilar Medical Bulletin*.
  16. **Okpor, M. D., Osakwe, G., Emekume, S. O., Okpu, O. E., Obruché, C. O., OvieOkpor, D. (2025).** Enhancing meningitis diagnosis accuracy through the integration of fuzzy logic and random forest: A conceptual framework.
  17. **Basu, A., Chaudhury, C. L. (2025).** An Introduction to Fuzzy Logic in Real Time Application Paradigm. In *Applications of Fuzzy Logic in Decision Making and Management Science* (pp. 1-18). Cham: Springer Nature Switzerland.
  18. **Abdalla, A. Y., Abdalla, T. Y., Chyaid, A. M. (2024).** Internet of things based fuzzy systems for medical applications: A review. *IEEE Access*.
  19. **Razaq, A., Maghrabi, L. A., Ahmad, M., Aslam, F., Feng, W. (2024).** Fuzzy logic-based substitution-box for robust medical image encryption in telemedicine. *IEEE Access*, 12, 7584-7608.
  20. **Byker Shanks, C., Bruening, M., Yaroach, A. L. (2025).** BMI or not to BMI? debating the value of body mass index as a measure of health in adults. *International Journal of Behavioral Nutrition and Physical Activity*, 22(1), 23.
  21. **Montoya Castillo, M., Martínez Quiroz, W. D. J., Suarez-Ortegon, M. F., Higuíta-Gutiérrez, L. F. (2025).** Waist-to-height ratio, waist circumference, and body mass index in relation to full cardiometabolic risk in an adult population from Medellin, Colombia. *Journal of Clinical Medicine*, 14(7), 2411.
  22. **Annunziata, G., Verde, L., Grillo, A. R. A., Stallone, T., Colao, A., Muscogiuri, G., Barrea, L. (2025).** Association among measurements obtained using portable ultrasonography with sex, body mass index, and age in a large sample of adult population. *Journal of Translational Medicine*, 23(1), 236.
  23. **Pratt, J., Narici, M., Boreham, C., De Vito, G. (2025).** Dual-energy x-ray absorptiometry derived body composition trajectories across adulthood: Reference values and associations with body roundness index and body mass index. *Clinical Nutrition*, 46, 137-146.
  24. **Okawa, Y., Mitsuhashi, T., Tsuda, T. (2025).** The Asia-Pacific body mass index classification and new-onset chronic kidney disease in non-diabetic Japanese adults: a community-based longitudinal study from 1998 to 2023. *Biomedicines*, 13(2), 373.
  25. **Mandic, M., Safizadeh, F., Schöttker, B., Holleczeck, B., Hoffmeister, M., Brenner, H. (2025).** Body mass index across adulthood, weight gain and cancer risk: a population-based cohort study. *BMC cancer*, 25(1), 488.
  26. **Gianfredi, V., Nucci, D., Lattanzio, R., Piccinelli, S., Cicconi, G., Farfan, S. J. S., ... Soysal, P. (2025).** Food insecurity and body mass index among older people: A systematic review and meta-analysis. *Archives of gerontology and geriatrics*, 128, 105606.
  27. **Agbaje, A. O. (2025).** Body mass index triples overweight prevalence in 7600 children compared with waist-to-height ratio: the ALSPAC study. *Obesity and Endocrinology*, 1(1), wjaf002.
  28. **Kim, J. H., Baek, J. Y., Han, K. D., Kim, B. S., Kwon, H. S. (2025).** Higher body mass index increases the risk of shoulder adhesive capsulitis in young adults: a nationwide cohort study. *Journal of Shoulder and Elbow Surgery*, 34(1), 26-32.
  29. **McElfish, P. A., Ayers, B. L., Hawley, N. L., Caldwell, A., Porter, A., Macechko, M. D., ...**

- Brown, C. C. (2025).** Gestational weight gain and increased risk of cesarean delivery across body mass index categories. *AJOG Global Reports*, 5(1), 100445.
- 30. Instituto De Seguridad y Servicios Sociales de los Trabajadores del Estado (2018).** ¿Qué es el índice de masa corporal? [gob.mx. https://www.gob.mx/issste/es/articulos/que-es-el-indice-de-masa-corporal?idiom=es/1000](https://www.gob.mx/issste/es/articulos/que-es-el-indice-de-masa-corporal?idiom=es/1000)
- 31. Ramirez, E., Melin, P., Prado-Arechiga, G. (2019).** Hybrid model based on neural networks, type-1 and type-2 fuzzy systems for 2-lead cardiac arrhythmia classification, *Journal of Expert Systems with Applications*, 126, 295-307, <https://doi.org/10.1016/j.eswa.2019.02.035>

*Article received on 31/10/2025; accepted on 15/12/2025.*

*\*Corresponding author is Cinthia Peraza.*