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Sustainable Development Goal for Industrialization and Innovation (SDG-9): Education sector deploying Fuzzy Logic Approach for Pattern matching

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Abstract: Sustainable Development Goals (SDGs) are given first priority among the initiatives of the government throughout the world. The United Nations (UN) has set targets for global development measuring the progress towards sustainability. SDGs are primarily a worldwide data base concerned with tracking the data responsible for sustainable growth via official statistical indicators leading to advancement in economics, sustainable environment, legislation, industry, innovation, research and academics. The famous goals of the SDG 9 are to build a resilient infrastructure, promote inclusive and sustainable industrialization and encourage innovation. UN has figured out eight targets with twelve indicators to achieve SDG 9. This work focuses on sustainable development to provide high quality, reliable, sustainable and flexible infrastructure to support economic development and human welfare affordability and equity in access to all. The multi-dimensional initiative offered by our Government for accomplishing the milestones of SDG-9 is addressed here. In addition, for comprehending the relationship among the observed indicators of SDG 9, fuzzy logic is used. A significant outcome based on the degree of mapping with the related parameters using Fuzzy Associative Mapping (FAM) in the measurement of objectives of SDG 9 is achieved using fuzzy logic. The predicted results on CO_2 levels in proportion to industries under operation will provide assistance to the central bodies to take preventive measures during the modification of the existing policies connected to SDG 9 goals, which also will consequently support the decision correlated with other SDGs using interactive visualization.

Keywords: *Sustainable Development Goals (SDGs , Industrialization , Innovation , Fuzzy logic , minimal CO_2 emissions*

1. Introduction

The effort taken by the government of India to upgrade the infrastructure and retrofit the industries so that they become self sustained, with increased resource usage efficiency using clean and intelligent technology. Expenses for Research and Development (R&D) include fundamental research, practical research and experimental research. Research ambitions to promote sustainable industries in the year 2030 are primarily reflected in SDG 9 which is aimed to guarantee modernization of industries equipped with state of the art technologies to support innovation and facilitate sustainable infrastructure [1].

There has been only a partial recovery and survival of various manufacturing industries after the pandemic COVID-19 in the year 2020. Globally, the manufacturing capacity has decreased from 7.4% to 3.3% in the year 2021-2022. Considering the progress made by Less Developed Nations (LDNs), it is highly difficult to achieve the objective of doubling-up the manufacture

share in the gross value of the domestic product by 2030.

However, robust increase in the growth rate is encountered by moderate and high technology industries. As of now, nearly 98% of the world's total population is using a mobile broadband network within the limits, even though there exists some network coverage issues [2].

The combustion process in industries contribute to 0.9% of CO_2 and other green house gas emissions globally which figure outs to be as high as 36.8 billion metric tons in order to take action within their respective capabilities comparable with the norms of pollution control board without affecting the economic growth [3]. The achievement of SDN-9 by 2030, is very vital for the LDNs to sustain by investing their resources to develop and incorporate advanced state of the art technologies, enabling low carbon emissions with increased broadband access to mobile networks [4].

The employment in core industries started to decline worldwide from 14.3% to 13.6% in the year 2022-2023. As of now, 96% of the world's total population is not within the reachable limits of the mobile broadband network. Currently, the expenditure on R&D has increased from 1.67% to 1.94% in 2023. Similarly, innovation in

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medicine has reduced the child mortality rate and improvement in life expectancy. As a key role, the technology progress is creating a change in the daily life enabling life-saving and affordable innovations even for a common man [5]. Though the transformation in technology takes place continuously, these developments do not show positive impact all the times. So, Artificial Intelligence (AI) is incorporated for technological advancements.

2. Milestones

The objectives of SDG-9 are as follows

I. Scrutinize the approach of SDG 9 to construct adaptable framework, upgrade inclusive, environmentally conscious industrialization and stimulate innovation.

II. Examine the present state with the outcomes for the improvement of SDG 9.

III. Use Fuzzy logic approach to determine the degree of pattern matching with the various indicators of SDG 9 based for Indian scenario.

3. Manuscript Overview

This manuscript is divided as follows; Literature survey includes an outline of research work and survey in connection to the sustainable development goals, with a milestone on SDG-9 and its related challenges. Firstly, the work associated with this study is carried out in two episodes. In episode 1, the insights of SDG-9 and the different steps taken for the accomplishment of SDG-9 in India were emphasized. Specifically, episode 1 includes the following divisions; SDG section puts forth the schematic for the establishment of the SDGs laid by UN to encourage development of peace globally. The division on present scenario of SDG-9, indicates the systematic procedure for implementation and attainment evaluation of measures carried out by the government, worldwide. The critical measures to attain sustained development in R&D are discussed in the preceding content. In episode 2, the primary objectives for analysing the SDG-9 dataset is done by extracting useful pattern to design an association among the indicators of SDG-9 for the Indian scenario. Analysis and methodology subsection explains the procedure behind the data collection and the pre–processing technique used to filter the noisy data. The graphical interpretation combined with the outcomes of statistical analysis is elaborately discussed in the Results and Discussion module. Apart from that, the last division is the conclusion and future scope which summarizes the achievement of this work along with the future directions for development in the proposed area.

4. Literature survey

Many researchers have contributed to the issues of sustainability and controlled green house gas emissions to prevent climate change. The authors have used linguistic variables like low, medium and high to demarcate the achievement of the objectives and targets made by a particular country [1], while others use colour indicators or numbers [2,3] to denote them. The purpose of this work is to design a mathematical model. Once the mathematical model is developed, the main aim is to categorize the countries based on their achievement of SDGs.

The entire states in UN have scheduled the SDGs from 2015 to 2030. The SDGs speculate that all the states have a cooperative awareness and accountability to make sure that the most susceptible people in the total population are not lagging in financial, societal status, and ecological development. The SDGs portray a collective schedule which is applicable to all the countries in the entire world [2]. It is challenging to develop real time tools for data analysis and computation of its related performance metrics [2]. This problem can be solved by (i) organizing the governance and education (ii) offering a progress card which contains a detailed report so as to track and guarantee the responsibility and (iii) serving as a supervision tool. Fuzzy logic is used for result analysis [2, 4, 5].

Mathematical analysis must be made to achieve sustainability and face challenges in climate change by offering admissible solutions. The indicators for describing the SDGs are assigned with linguistic variables [6] like low, medium and high. A common rule is followed to combine these linguistic variables to infer a single true value. This method is adopted by fuzzy logic [2, 7]. An overall value is derived for each target associated with SDGs and they are categorized into three parts by simple multiplication. The attainment of the criteria by a target is initiated by multiplication to emphasize that the particular goal has scored a high value. The mathematical operation, multiplication is equivalent to performing a t-norm [8]. Ranking the countries are indicated using different colors ranging deep blue to orange and red indicating the order of ranking in descending order right from high to average and poor respectively. Aggregation is used to denote the averaging function in fuzzy logic. The similar inferences made by fuzzy engine are converted to a single true value based on the statistical methods like area of decision analysis and uncertainty in comparison with the suggestions given by an expert based on the SDGs [8, 9].

In this paper, the focus is inclined towards the prediction of the targets corresponding to the various goals pertaining to SDG 9. There are seven targets that need to be achieved so as to accomplish the goals. The percentage of achievement of these goals pertaining to SDG 9 is assigned any value in the range [0, 1] for Educational institutions [10]. Thus sustainability using fuzzy logic [11-15] is rightly pointed

out by few researchers. Any number of fuzzy aggregations can be done. The SDG-9 denotes building a resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation and their corresponding targets are listed as follows

T1: Develop quality, reliable, sustainable and resilient infrastructure

T2: Promote inclusive and sustainable industrialization

T3: Increase the access to small-scale industries

T4: Improve industrial infrastructure for reconstruction

T5: Augment systematic investigation

5. Fuzzy logic Applied to SDG 9

In this section, interpretations are made to determine the single unique number that measures achievement of SDG 9 for the educational institution, Dr. MGR Educational and Research Institute, Maduravoyal, Chennai, Tamil Nadu, India. The SDG 9 and its targets for educational institution under study are specifically aligned in line with the indicators of the international ranking in cooperation with the nation's SDG 9. The initial coefficients or weights were randomly selected and updated in due course using fuzzy logic approach. The marks summed to a value of 100 for all the five targets by considering a maximum marks of 20 for each target to be attained. The mathematical relationship between the SDG 9 and the targets is expressed in Equations 1-6.

$$SDG\ 9.1 = 0.3T_1 + 0.4T_2 + 0.03T_3 + 0.05T_4 + 0.22T_5 \quad (1)$$

$$SDG\ 9.2 = 0.5T_1 + 0.22T_2 + 0.02T_3 + 0.06T_4 + 0.3T_5 \quad (2)$$

$$SDG\ 9.3 = 0.4T_1 + 0.5T_2 + 0.04T_3 + 0.03T_4 + 0.03T_5 \quad (3)$$

$$SDG\ 9.4 = 0.22T_1 + 0.6T_2 + 0.08T_3 + 0.06T_4 + 0.04T_5 \quad (4)$$

$$SDG\ 9.5 = 0.03T_1 + 0.04T_2 + 0.3T_3 + 0.5T_4 + 0.13T_5 \quad (5)$$

The individual marks for actually attained for each target were divided by 100 so that the values are normalized and the total of all the values is equal to one.

Table 1. Original Data for SDG 9 and its target values

SDG 9 Vs Target	T_1	T_2	T_3	T_4	T_5	Total (T)
SDG 9.1	0.6	0.5	0.8	0.6	0.5	3
SDG 9.2	0.8	0.5	0.5	0.5	0.5	2.8
SDG 9.3	0.8	0.5	0.5	0.5	0.6	2.9
SDG 9.4	0.6	0.4	0.4	0.8	0.5	2.7
SDG 9.5	0.5	0.5	0.5	0.5	0.5	2.5

The averages $A_{SDG\ 9.1}$, $A_{SDG\ 9.2}$, $A_{SDG\ 9.3}$, $A_{SDG\ 9.4}$ and $A_{SDG\ 9.5}$ are calculated using the formula in Equation 2 and recorded in Table 2.

$$A_{SDG\ 9.1}/A_{SDG\ 9.2}/A_{SDG\ 9.3}/A_{SDG\ 9.4}/A_{SDG\ 9.5} = (T_1+T_2+T_3+T_4+T_5)/T \quad (6)$$

Table 2. Weighted Averages

SDG 9 Vs Target	T_1	T_2	T_3	T_4	T_5
$A_{SDG\ 9.1}$	0.2	0.167	0.267	0.2	0.167
$A_{SDG\ 9.2}$	0.286	0.179	0.179	0.179	0.179
$A_{SDG\ 9.3}$	0.276	0.172	0.172	0.172	0.207
$A_{SDG\ 9.4}$	0.222	0.185	0.185	0.296	0.185
$A_{SDG\ 9.5}$	0.2	0.2	0.2	0.2	0.2

5.1 Fuzzification

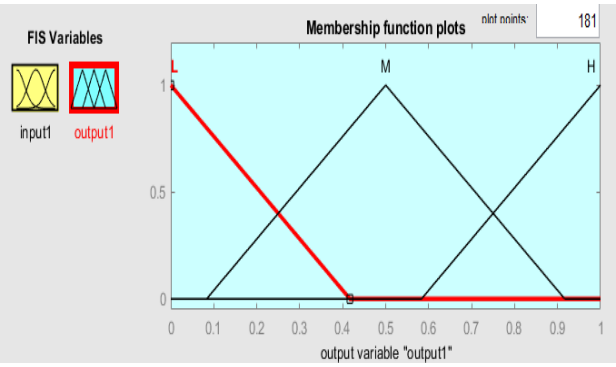
The following procedure is adapted to convert the input-output variables into fuzzy values (Figure 1(a) and Figure 1(b)) respectively.

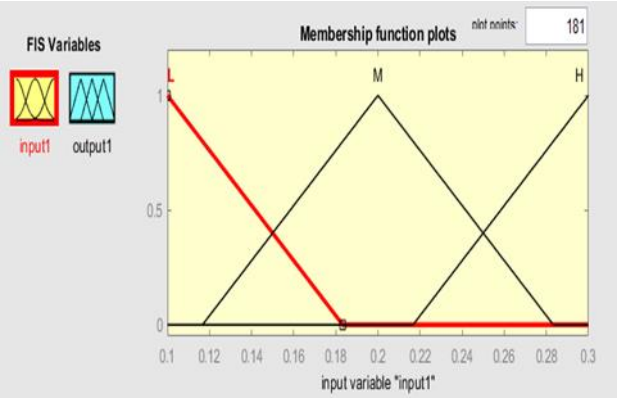
1. Identify the various input-output variables

2. Assign a suitable membership function (triangular) to the input output variables

3. Identify and assign the linguistic variables (Low-L, Medium-M and High – H) for the inputs and outputs.

4. Find the correct universe of discourse for each support value.





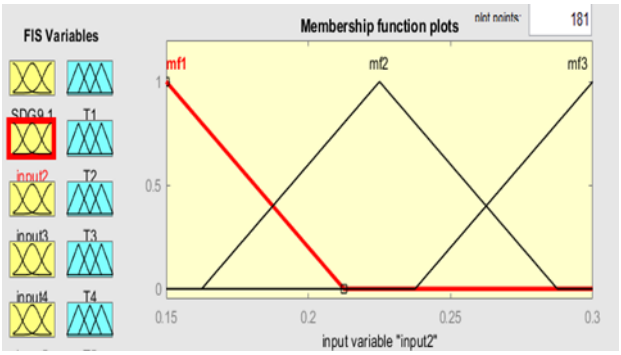


Fig. 1. Membership function for Input and output variables

5.2. Rule base and Knowledge base

The knowledge base includes the data set where the five goals (SDG 9.1, SDG 9.2, SDG 9.3, SDG 9.4, SDG 9.5) in SDG 9 are the inputs with five outputs corresponding to the targets T_1, T_2, T_3, T_4 and T_5. The rule base consists of 'IF THEN' statements. Nearly, 31 rules are framed using various possible combinations of the goals and targets and pictorial representation is given in Figure 2.

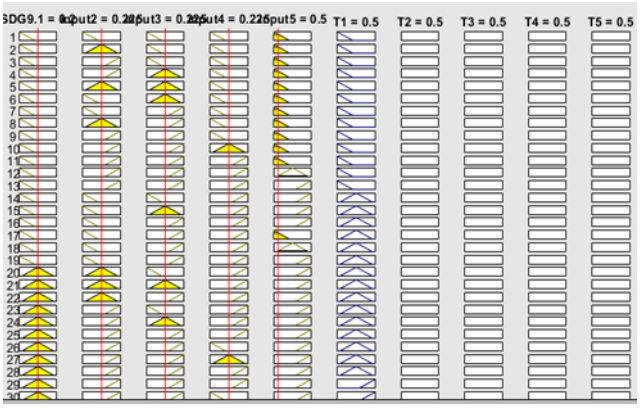


Fig. 2. Display for Rule Viewer

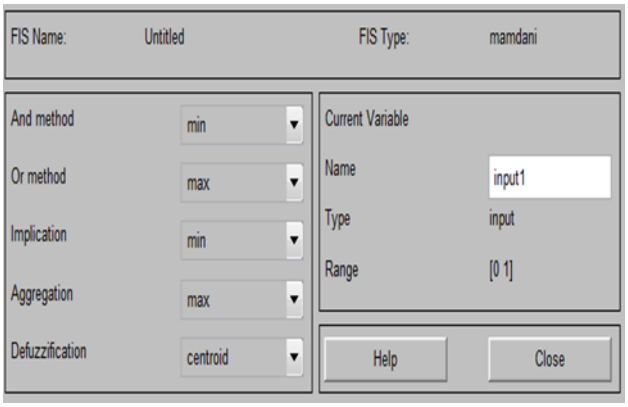


Fig. 3. Specification of Fuzzy Classifier

5.3. Decision Making Logic

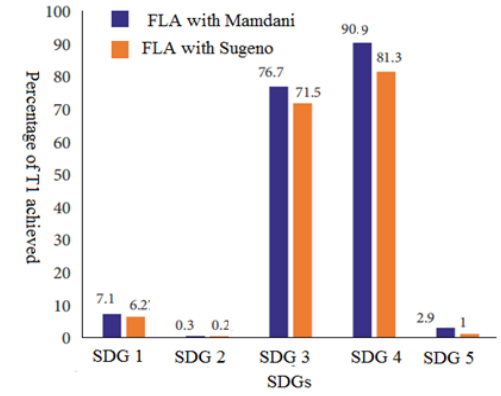
This facilitates the inference of single truth value from the rule base. Min Max criterion is used to infer the single true value. Equation 7 denotes the logic behind this criterion.

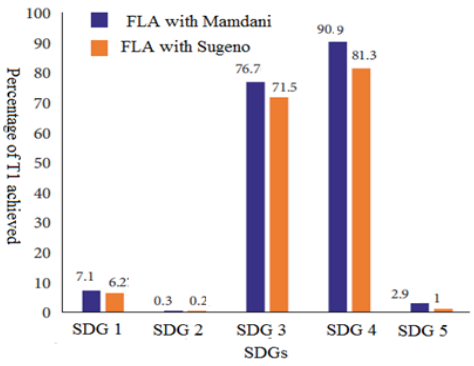
$$M = \text{Min}\{\text{Max}(X_1, X_2, X_3,...)\} \quad (7)$$

The specifications for the proposed Fuzzy classifier are displayed in Figure 4.

6. Results and Discussion

Measuring the level of attainment of sustainable development is a tedious task. The major motive is specified broadly as social, economical and environmental domains. Hence, the important factor impacting the classification result by fuzzy logic is by identifying the unique set of variables for analysis and the extent to which it encompasses the sustainability in various dimensions. Comparing the results presented in Figure 4, studies reveal that there are some similarities and differences in measuring the sustainable development for SDG 9 with various indicators. Each target for SDG 9 was evaluated for its appropriateness, feasibility and transformative nature [3]. Fuzzy logic with two different complements like 'Mamdani' and 'Sugeno' was implemented and the scores were evaluated for each of the targets attained corresponding to the 5 objectives in SDG 9 as depicted in Figure 4 [3]. According to Figure 5, it is inferred that the percentage of accuracy, sensitivity, precision, specificity, recall and F1 score measure for various classifiers, the fuzzy logic with Mamdani complement has the highest percentage values of the performance measures. Conversely, ANN classifier, decision tree and Euclidean distance classifiers have the lowest values for sensitivity and precision, while Euclidean distance classifier has the lowest accuracy and specificity. Hence, the fuzzy logic with Mamdani complement seems yield optimal output for the dataset considered, as it has the best parameter when compared to the other four methods.





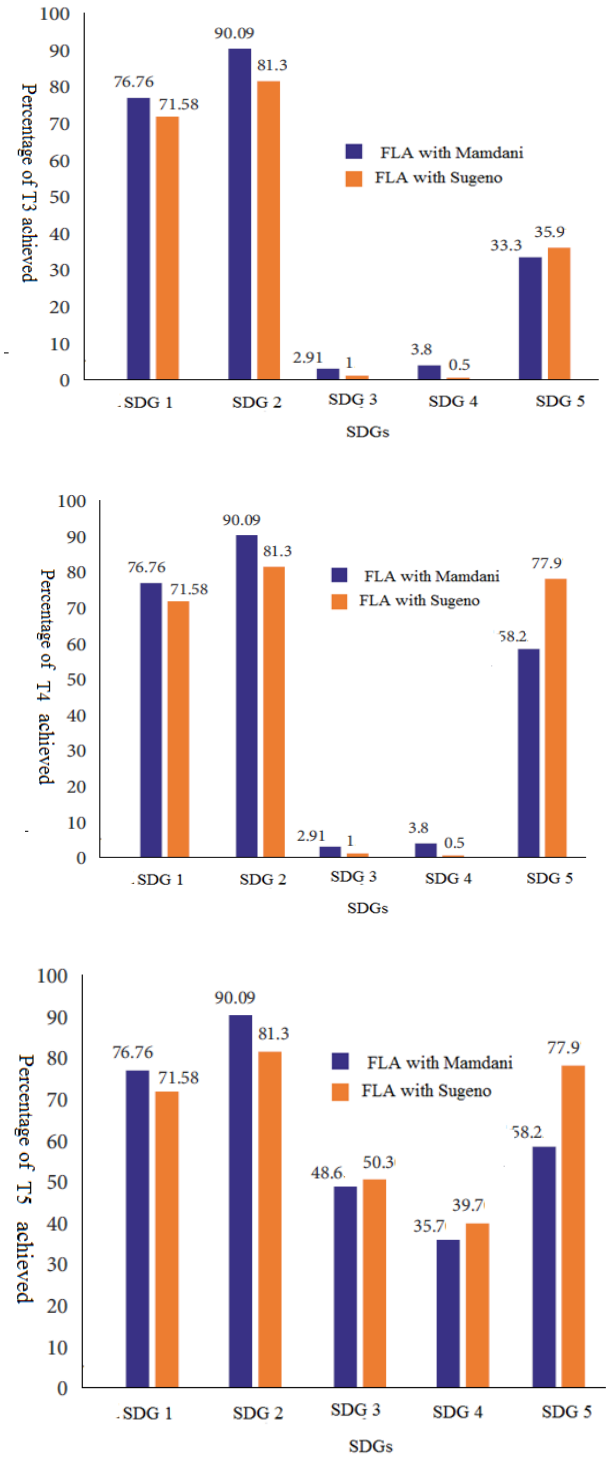


Fig. 4. Level of Target Attainment using Fuzzy classifier – Mamdani and Sugeno Complements

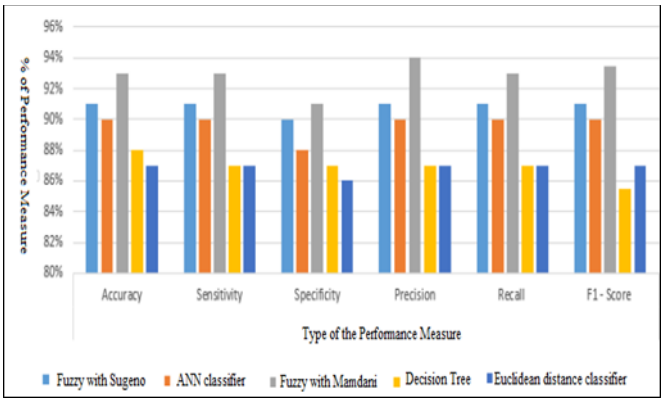


Fig. 5. Comparison of the Performance Measures for various classification schemes

7. Conclusion

This work is focused on the evaluation of the attainment of the targets corresponding to the goals in SDG 9. A prediction statistics is carried out using fuzzy logic for evaluation of the attainment of the targets. This is done by assigning linguistic variables to the random numbers in the closed interval [0, 1] which indicates the scores achieved. Defuzzification was done using centroid method which effectively displayed the original values of the targets in its crisp form for SDG 9. Evaluation measures were used to identify how well the goals were achieved for SDG 9. It is inferred that by using Mamdani complement function in the fuzzy logic and with triangular membership function the highest ranks for targets were achieved for various goals in SDG 9.

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