Fuzzy logic application for short term energy consumption forecasting in one shopping centre at Cirebon city

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Abstract. Short-term forecasting is often used to predict with calculations using time, hour, day or week. This study aims to compare the accuracy of the results of the method. many choices of methods used for conventional forecasting (moving average, exponential smoothing, linear regression, and ARIMA) for artificial intelligence there are artificial neural network algorithms and fuzzy logic. A fuzzy logic method is a method used in research to predict energy consumption in one shopping centre in the city of Cirebon because as is well-known shopping centres are users of considerable energy consumption. The data used in this study is the cooling system which is the biggest user of energy consumption in shopping centres. It is hoped that this research can prove the accuracy of the fuzzy logic method for estimating energy consumption.

1. Introduction
Electricity energy saving must be a national concern because that is knowledge about the energy consumption of buildings is one of the solutions to the problem of saving electricity [1]. Building energy consumption contributes to an important proportion in the world. In European Union countries, energy consumption consumes 40%. In China, 28% in 2011, and statistical data estimated to reach 35% in 2020 [2]. Building or residence is one of a fairly large part of the current demand for electrical energy, therefore it is necessary to analyse alternative designs to decide and decide which is the most efficient in saving costs [3]. Obtain energy consumption of buildings or buildings that are important in energy savings that benefit individual communities. With basic knowledge about building construction, it needs to be improved for building approval [4].

Energy consumption forecasting has been studied in developed countries which is generally divided into two conventional categories and artificial intelligence-based methods (AI) [5]. Conventional forecasting methods include time series, analysis regressions, etc., but do not meet the accuracy predicted in practical communities [6]. Artificial intelligence-based methods (AI) are currently more widely used because of the ability to solve nonlinear problems [5]. A fuzzy logic method is one of the easiest to understand among various techniques (AI). The use of fuzzy logic is very much. Fuzzy has three main systems, namely: fuzzification, interference and defuzzification [7].

Fuzzy inference, proposed in 1993 which combines fuzzy if-then rules into a network structure [8]. The ability to consider non-linear relationships between inputs and outputs, fuzzy time series has major advances in various applications, including forecasting energy consumption [9]. Fuzzy can be classified into three main categories, Mamdani, Takagi Sugeno and Tsukamoto [10]. This study will discuss
forecasting short-term energy consumption in a shopping centre building using the fuzzy logic method [11].

2. Research methods
Data is taken from the building of a shopping centre in the city of Cirebon which has an area a total of 21,930 m² there are 4 floors, with the complete address of Doctoral Road Cipto Mangunkusomo, Pekiringan, Kesambi, Pekiringan, Kec. Kesambi, Cirebon City, West Java Indonesia 45131. Data collected is the time of use of the chiller, temperature, power of the chiller in March 2020.

2.1. Data processing method
To analyse the short-term energy consumption data in the study, several techniques were used, the first using fuzzy logic and MATLAB software. A fuzzy logic method with 3 stages in the first fuzzy logic fuzzification the process of forming the fuzzy set and membership function, fuzzy inference making rules based on the relationship of variables, and the last stage is defuzzification which has several types selected in the study this Mamdani out the results of forecasting fuzzy logic methods. Then compare with the conventional ARIMA (autoregressive integrated moving average) forecasting method using Microsoft Excel software.

2.2. Simulation using fuzzy logic
Data management in this study was carried out using the fuzzy logic method available in MATLAB software. Using MATLAB software to do energy consumption, some things must be done in the process, namely:

- Analysis of the data needed then, determine the variables that will be used in forecasting the energy consumption of buildings in the regional studio. This variable will be used as a fuzzy logic input method.
- Data must first be changed to fuzzy set because not all data can be entered into fuzzy logic. Meeting function (the membership function to be used is the triangle function), time or time variable, temperature or temperature variable, charge or load variable, and for the condenser output variable each function consists of 5 sets of fuzzy.
- After that, the data can be directly worked on in MATLAB. Change the input and output in the initial display fuzzy logic adjust to what has been determined seen from Figure 1.

![Figure 1. First Display of fuzzy logic.](image-url)
• Enter the membership function for each input and output variable, range, and parameter. then enter in Figure 2. current variable and current membership function

**Figure 2.** Current variable and current membership function.

• Then do the composition of the rules, to obtain the smallest forecast. The composition of the rules must be arranged based on the interrelationships between variables

• The next stage is defuzzification, at this stage, the data is changed back in the actual data form (crips). The Mamdani defuzzification method used in the study is the centroid.

• Get the best forecast results from each method of defuzzification based on the rules compiled

3. **Results and discussion**

This study aims to forecast short-term energy consumption in the case study area for the next week. The method used is an artificial intelligence that is fuzzy logic, and as a comparison using conventional ARIMA (autoregressive integrated moving average). Before forecasting the fuzzy logic method, first make input variables according to the data, then make the rules so that it produces the expected predictions, the results of the predicted fuzzy output are compared with the actual data on electricity consumption on March 8-14. The conventional method is used as a comparison of artificial intelligence fuzzy logic methods and conventional ARIMA to know which is better in forecasting short-term energy consumption.

3.1. **Energy consumption in the case study area**

This research was conducted on normal days and holidays. Pick season occurs when returning from work or from school, and also holidays. So that visitors who come will surge and affect the use of cooling systems that produce high energy consumption. The case study area is a sector that must be maintained by electricity supply at all times because there is food storage that must be protected using refrigeration, air must use refrigeration so visitors are comfortable, and there is also a theme park. if the air conditioner or cooling system does not work well then it makes a huge loss, therefore the air conditioner and the cooling system contribute most of the energy consumption. For this reason, shopping centres are among the highest electricity consumers Figure 3. is the chiller cooling load curve in March 2020 in the study area.
Figure 3. Chiller loads March 2020.

Figure 4. is proof of the explanation above accordingly. seen on holidays on the 1st, 7th, 8th, 14th, 15th, 21th, 22th. the use of chiller cooling power is higher than other normal days, after that date the power drops due to COVID-19 virus so that social restrictions and gatherings are held.

3.1.1. Time. Time according to the Big Indonesian Dictionary 1997 is a condition that takes place today or the length of time an event lasts. The definition of noon is when the time is in positions 12.01 to 14.00. evenings are between 19:00 - 00:00. Morning is a term that starts all the time in Indonesian culture in the use of time at 01.00 - 10.00, Afternoon or evening is the time afternoon connecting the night, in the geographical area of the tropical climate in the afternoon at 15.00 - 18.00 when the sun begins to fall towards the west. The first input variable used in the fuzzy logic method of this research is time data before the data is entered in the membership function the data must be converted into a fuzzy set. This fuzzy set is determined by the above explanation, chosen into 5 membership functions, namely midnight, morning, noon, evening, and night. To be processed using the fuzzy logic method. After inputting the membership function, it is shown in Figure 4.

Figure 4. Membership function time.

3.1.2. Temperature. Chiller temperature data in the study area is the lowest at 0.7 °C and the highest at 5.2 °C, the temperature based on the Big Indonesian Dictionary is body heat or air, while the temperature is in quantitative terms, something measured by a thermometer. Temperature itself has 4 units most often used are Celsius, Reaumur, Fahrenheit, and Kelvin. The Celsius unit is a unit that is designed so that the freezing point of water is at 0 degrees and the boiling point at 100 degrees. The 0-degree temperature used as freezing point of water can also be used as a food preservative so it lasts longer. For the term cold, cold is almost the same as cold, which is cold, only to the extent that it is almost cold. so the linguistic value included in the membership function is divided into 5 which are very cold, cold, very cold, cold, and normal. Shown in Figure 5.
3.1.3. Load. In Figure 6 (a) Can be seen on Sunday, March 8, 2020, from the beginning at 0.00 - 7.00 in the morning there has been no significant change between 3 kW - 7 kW. Then it starts to rise at 08:00 to 09:00 and continues to pass while operating at 10:00 then rises again at 22:00 when the operation hour ends. To load the chiller load on holidays can be seen in Figure 7 (b) the increase in load on Sunday the 8th, Friday the 13th and Saturday the 14th, the high surge can reach more than 600 kW. For monitored working days or working days, it is not much different to load every time I join 300 Kw.

![Membership function temperature](image)

**Figure 5. Membership function temperature.**

Fuzzy set which is used in fuzzy logic is chosen 5, very low, low, medium, high and very high. Because this linguistic value can explain when the load goes down and the load goes up clearly so it is easy to understand. After inputting the membership function, it can be seen in Figure 7.
3.2. Forecasting results using fuzzy logic method

Forecasting energy consumption using the artificial intelligence method of fuzzy logic using MATLAB software, several steps must be done to get the forecast results.

3.2.1. Fuzzification. Fuzzification is the process of converting sharp numerical values into degrees of membership function with the appropriate fuzzy set so that it can be further processed with each fuzzy variable must be represented by the fuzzy membership set.

3.2.2. Formation of fuzzy set. Fuzzy logic toolbox in MATLAB software is used for fuzzy inference design. The display that must be filled with variable input and variable output appears in Figure 8.

3.2.3. Fuzzy rule. The step after determining the membership function is the rule evaluation. Fuzzy rules are the most important part of all fuzzy logic, heurometric knowledge of the understanding is stored in the form of the rules "IF-THEN". This information is sent to the fuzzy inference system obtained by the information obtained to obtain the results of load thinking. Some rules as follows: If (time is MID NIG) and (temperature is VERY COLD) and (load is VERY LOW) then (composer is VERY HIGH).

- If (time is MID NIG) and (temperature is VERY COLD) and (load is LOW) then (composer is VERY HIGH)
- If (time is MID NIG) and (temperature is VERY COLD) and (load is MEDIUM) then (composer is VERY HIGH)
- If (time is MID NIG) and (temperature is VERY COLD) and (load is HIGH) then (composer is VERY HIGH)
- If (time is MID NIG) and (temperature is VERY COLD) and (load is VERY LOW) then (composer is VERY HIGH)

125 fuzzy rules are arranged based on the data obtained. Fuzzy rules or rules that are good can be seen from the gradations set by permission. Can be seen from Figure 9.
3.2.4. Defuzzification. The last stage in the fuzzy system function is to change the output of the membership function in the form of fuzzy logic into real value (chip) again. There are several defuzzification methods in the Mamdani type, but for this study, using the centroid method. The centroid method of the fuzzy output seen from the input junction looking for the centroid point shows the estimated value of energy consumption. Figure 10 shows the Rules views.

3.2.5. Analysis of forecasting results using fuzzy logic. Table 1 is the result of defuzzification on March 8, 2020, one of the results of this study conducted for one week starting March 8 - 14, 2020. Before the previous accuracy, we must know the error generated by fuzzy logic average error or MAPE (Mean Absolute Percentage Error) can be seen with the formula.

\[
\frac{1}{N} \sum \left( \frac{\text{actual} - \text{forecasted}}{\text{actual}} \right) \times 100\%
\]

With the results for 2.55% MAPE for the accuracy of the fuzzy calculation system with actual data that is 97.45% obtained from the formula, Accuracy = 100% - MAPE.
Table 1. Fuzzy logic forecasting results for March 8.

| Date-Time       | Condensor | Fuzzy | Error (%) |
|-----------------|-----------|-------|-----------|
| 08/03/2020 00:00:00 | 16.6      | 17.5  | 5.4       |
| 08/03/2020 01:05:00 | 17.1      | 17.10 | 0.0       |
| 08/03/2020 02:05:00 | 17        | 17.50 | 2.9       |
| 08/03/2020 03:05:00 | 16.9      | 16.90 | 0.0       |
| 08/03/2020 04:05:00 | 17.2      | 17.10 | 0.6       |
| 08/03/2020 05:05:00 | 17.3      | 17.20 | 0.6       |
| 08/03/2020 06:05:00 | 17.4      | 16.30 | 6.3       |
| 08/03/2020 07:05:00 | 17.6      | 17.30 | 1.7       |
| 08/03/2020 08:05:00 | 17.1      | 16.40 | 4.1       |
| 08/03/2020 09:05:00 | 17.2      | 17.00 | 1.2       |
| 08/03/2020 10:05:00 | 18.2      | 17.20 | 5.5       |
| 08/03/2020 11:05:00 | 16.7      | 16.10 | 3.6       |
| 08/03/2020 12:05:00 | 16.8      | 16.70 | 0.6       |
| 08/03/2020 13:05:00 | 16.3      | 15.70 | 3.7       |
| 08/03/2020 14:05:00 | 16.8      | 16.20 | 3.6       |
| 08/03/2020 15:05:00 | 17.3      | 16.50 | 4.6       |
| 08/03/2020 16:05:00 | 16.9      | 17.20 | 1.8       |
| 08/03/2020 17:05:00 | 16.9      | 17.40 | 3.0       |
| 08/03/2020 18:05:00 | 17.4      | 17.40 | 0.0       |
| 08/03/2020 19:05:00 | 17.1      | 17.30 | 1.2       |
| 08/03/2020 20:05:00 | 17.4      | 17.10 | 1.7       |
| 08/03/2020 21:05:00 | 17.2      | 17.10 | 0.6       |
| 08/03/2020 22:05:00 | 17.5      | 17.20 | 1.7       |
| 08/03/2020 23:05:00 | 16.9      | 16.40 | 3.0       |

It can be seen that the resulting error is very small. That means a very good level of accurate forecasts of energy consumption using fuzzy logic and compared to actual data, the difference can be seen using the curve of Figure 11. For comparison in 7 days for straight black lines, it explains for fuzzy and for grey lines broken ash explains the condenser or actual data used. From the curve, it can be seen clearly that the majority lines are very closely packed, even there are several lines attached.

![Figure 11. Real curve data and fuzzy logic data.](image)

One of the most important factors is the methodology for estimating short-term load using fuzzy logic. decide the variables used in forecasting methods such as temperature, humidity [11]. Fuzzy logic provides an intuitive and easy way to include heuristics in load forecasting. In the fuzzy logic approach, preference calculation is based more on the entire membership function profile than based on point values. This approach is much closer to the decision-making process of people in real life [12].
3.3. Comparison results using ARIMA and fuzzy logic

Table 2. one of the results of forecasting energy consumption on March 13 and 14 2020 between the two fuzzy logic methods and the conventional ARIMA method. Forecasting is done for one week starting on March 8-14, 2020. The results obtained are the smallest error value displayed on the fuzzy logic method with an error rate of 2.55%, which means an accuracy rate of 97.45% while for forecasting using an error rate is at 18.96% with 81.04% accuracy. seen from the forecast of energy consumption error using fuzzy logic is more accurate than ARIMA (autoregressive integrated moving average) because the smaller the error of eating the better the level of accuracy.

| Date-Time      | Condenser | ARIMA | Fuzzy | Error Fuzzy Logic (%) | Error ARIMA (%) |
|----------------|-----------|-------|-------|-----------------------|-----------------|
| 13/03/2020 01:05:00 | 17.30     | 21.59 | 17.10 | 1.16                  | 24.82           |
| 13/03/2020 02:05:00 | 16.90     | 21.63 | 16.30 | 3.55                  | 27.97           |
| 13/03/2020 03:05:00 | 17.00     | 21.66 | 17.10 | 0.59                  | 27.41           |
| 13/03/2020 04:05:00 | 16.90     | 21.69 | 15.80 | 6.51                  | 28.36           |
| 13/03/2020 05:05:00 | 16.00     | 21.73 | 17.10 | 6.88                  | 35.78           |
| 13/03/2020 06:05:00 | 17.20     | 21.76 | 17.10 | 0.58                  | 26.50           |
| 13/03/2020 07:05:00 | 16.90     | 21.79 | 17.10 | 1.18                  | 28.94           |
| 13/03/2020 08:05:00 | 17.10     | 21.82 | 16.10 | 5.85                  | 27.63           |
| 13/03/2020 09:05:00 | 17.10     | 21.86 | 17.10 | 0.00                  | 27.82           |
| 13/03/2020 10:05:00 | 17.30     | 21.89 | 16.70 | 3.47                  | 26.54           |
| 13/03/2020 11:05:00 | 17.60     | 21.92 | 17.10 | 2.84                  | 24.57           |
| 13/03/2020 12:05:00 | 17.50     | 21.96 | 16.00 | 8.57                  | 25.47           |
| 13/03/2020 13:05:00 | 16.10     | 21.99 | 16.20 | 0.62                  | 36.59           |
| 13/03/2020 14:05:00 | 17.00     | 22.02 | 17.20 | 1.18                  | 29.55           |
| 13/03/2020 15:05:00 | 17.30     | 22.06 | 17.10 | 1.16                  | 27.49           |
| 13/03/2020 16:05:00 | 17.20     | 22.09 | 17.20 | 0.00                  | 28.43           |
| 13/03/2020 17:05:00 | 17.60     | 22.12 | 17.00 | 3.41                  | 25.70           |
| 13/03/2020 18:05:00 | 18.00     | 22.16 | 17.10 | 5.00                  | 23.09           |
| 13/03/2020 19:05:00 | 17.10     | 22.19 | 17.30 | 1.17                  | 29.76           |
| 13/03/2020 20:05:00 | 17.10     | 22.22 | 16.30 | 4.68                  | 29.95           |
| 13/03/2020 21:05:00 | 16.90     | 22.26 | 17.10 | 1.18                  | 31.69           |
| 13/03/2020 22:05:00 | 17.40     | 22.29 | 17.10 | 1.72                  | 28.09           |
| 13/03/2020 23:05:00 | 16.50     | 22.32 | 17.50 | 6.06                  | 35.28           |

The curve in Table 2 shows the forecast of energy consumption on March 8-14, 2020, explained that for the actual data (gray straight line), fuzzy logic data (solid black with dashed lines), and ARIMA data (grey) dashed ash line). Judging by the estimated curve using conventional ARIMA, the curve away from the actual data, while for fuzzy logic, the curve is almost close to the actual data.
Fuzzy has more accuracy and better results conventionally for predicted results. Also, short-term fuzzy forecasting can save a lot of money by reducing errors in forecasting [13]. Percentage error of less than ± 3%. Comparisons of what has been predicted have been done between conventional methods and fuzzy methods. Fuzzy-based load forecasting is much closer to the actual load [14].

4. Conclusion
Forecasting energy consumption using artificial intelligence with fuzzy logic methods proved to be very good. The accuracy for forecasting lies in the rules (rules) made from input data, so making the right rules allows for better forecasting results. For the determination of input variables in fuzzy logic, solid changes go hand in hand with the required input data consider with other variables. Forecasting energy consumption with fuzzy logic results in a smaller MAPE (mean absolute percentage) compared to conventional ARIMA (autoregressive integrated moving average) methods, seen from very small errors and accuracy approaching 100% while for ARIMA results in only around 80%. With this proving that the fuzzy logic method has good accuracy compared to ARIMA (autoregressive integrated moving average), ARIMA, if used for long-term forecasting accuracy of forecasting, is not good because the results will tend to be constant or flat for long periods.

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