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Environment indoor air quality assessment using fuzzy inference system

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Abstract

Environment indoor quality (EIQ) is a significant aspect of the built environment to maintain occupant health, comfort, prosperity and productivity. One of the most critical issues on EIQ is the environment of indoor air quality (EIAQ). Indoor air pollution has a big impact on the degradation quality of human life due to harmful chemicals and other toxic materials that it is worsened by ten times than the outdoor air pollution. Environment indoor air quality index (EIAQI) does a crucial role in determining the EIAQ that is good for a healthy human life by combining indoor air quality index (IAQI) and thermal comfort index (TCI). This research presents an EIAQ monitoring and controlling system based on fuzzy logic controller (FLC) to identify, classify and calculate the EIAQI value expressed in four categories: excellent, good, bad and worst. Additionally, the clustering technique is used to categorize the air pollutants according to the similarities characteristics and human health impact. EIAQI values are used as index references to set the control system automatically. The control system is used as a system that can notify the status level and reduce indoor air and thermal comfort pollutants and is in the form of fans, inlet–outlet exhaust, and buzzer and LED. Therefore, these models are an appropriate tool for identifying, classifying, assessing, providing guidance to increase the quality of human life.

Keywords: Fuzzy inference system (FIS); Clustering technique; Environment indoor air quality index (EIAQI); Environment indoor air quality (EIAQ); Indoor air quality index (IAQI); Thermal comfort index (TCI)

1. Introduction

Recently, environmental issues concerning pollution and resource exhaustion have become big social aspects. Health problems from the environment point of view are generally ascribed to air contamination, climatic pollution, water contamination, climate change, ozone exhaustion, as well as harmful, chemical, and hazardous waste management [1,2]. Environment indoor quality is the most significant aspect because people spend about 90% of their time indoors [3]. The environmental parameters that determine the environment indoor quality (EIQ) are quality of indoor air, thermal comfort, visual, lighting and acoustic comforts [4]. Environment indoor air quality (EIAQ) presents a system by combining indoor air quality (IAQ) which focuses on air pollutants that are harmful to humans and thermal comfort quality which focuses on air pollutants that can interfere with the comfort of people in the room [5–7]. Over the last two decades, there are many health hazards places associated with many kinds of air pollution such as CO, CO_2, NO_2, O_3, particulate matter, VOC, temperature, and humidity. It would affect human health by causing dizziness, fatigue, respiratory and cardiovascular diseases even cancer and there are 4.3 million deaths per year worldwide because of air pollution [8–10].

Indoor air quality monitoring and controlling are the important factors to be able to find out the air pollutants inside the room and able to reduce the pollutants. Low-cost indoor air quality serves to monitor and detect air quality to improve the health with real-time monitoring using air sensors such as MQ-135, MQ-7, MQ-9, DHT11 to detect CO, CO_2, NO_2, O_3, PM

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$_{2.5}$, temperature and humidity [11–14]. The ventilation system is used as a supporting system to maximize the air quality system to control and mitigate the pollution using a chimney, ventilation, exhaust fan, and water sprinkler [15,16]. Human passable limits are in ranges set and utilized to determine the indoor air quality index (IAQI). IAQI is defined as the sum pollutants concentration ratio of toxicity level tests and calculates the effect of polluted air on the people's health as a whole [17–19]. Meanwhile, IoT technology can be used as a refinement of the system because it can improve efficiency and make it easier for users to monitor and control the system remotely [20–22]. Integrated smart system will produce a sensitive, effective and has better response output than the normal system in dealing with some of the more complex issues [23–25].

Recent works for indoor air quality (IAQ) assessment using fuzzy logic with reasoning methods have been developed, providing different solutions with different kinds of air pollutants. The fuzzy logic controller is used to calculate comfort and air quality index by combining some air pollution parameters such as $PM_{2.5}$, PM_{10}, CO, NO_2, NOP (number of passengers) and temperature. Furthermore, this index is used to provide information to users about permissible air quality with various pollutants toxicity [26–29]. Besides that, the fuzzy logic controller is used to determine the output action response in the form of an on/off exhaust van hot water valve, fresh air dumper, air conditioner, and DC motor control speed based on several toxicity levels of air pollutants [30–33]. Simulation of fuzzy logic indoor environment quality that integrating with lighting and windows as a control system is proposed that causes by thermal comfort pollutants (temperature and humidity) [34]. Indoor environmental quality (IEQ) based on fuzzy logic can improve the quality of the building that focuses on indoor air pollutants [35]. Those works provide a good solution for evaluating the environment indoor air pollutants; moreover, the main gap is the lack of reasoning process to calculate the value of the index that can classify indoor air pollutants and thermal comfort pollutants separately. Also, using only a few types of air pollutants as environment air quality parameters, where the air quality is influenced by many parameters of air pollutants that have different characteristics and human health impacts.

In this research, the authors used environment indoor air quality index (EIAQI) as the main reference index status level that contains four indoor air pollutants (IAP) and four thermal comfort pollutants (TCP). The clustering technique is used to divide the results of the fuzzy logic controller of IAQI and TCI values. This classification is carried out because the two indexes have different characteristics and human health effects in each type of pollutants. Fuzzy inference system (FIS) using the reasoning process will identify, classify, assess, and provide guidance on IAP and TCP. This system is integrated with the control output consisting of inlet exhaust, outlet exhaust, fan, buzzer and LED that automatically run based on EIAQI value. The author's contribution is to develop an EIAQ system to produce the EIAQI as the standard quality using a fuzzy logic controller that can classify indoor air and thermal comfort pollutants separately because it has different characteristics and has different human health impacts.

2. Environment indoor air quality requirements

Poor environment indoor quality (EIQ) conditions are caused by poor indoor air pollutants and poor thermal comfort [36]. EIQ system combined monitoring mode, ventilation flow, hazard index and cancer risk evaluation are used to estimate the risk of indoor air pollutants and even to reduce it using the ventilation [37]. The models of indoor air quality are integrated with numerous EIQ parameters into a single number and endeavor to relate tenant fulfillment with objective estimations. An EIQ index, i.e. a numerical rating, is a result of an EIQ model [38]. AQI based on fuzzy logic helps deal with the complexity of combined effects of more than one pollutants [26]. Therefore, several systems from previous research will be combined in this study which will be explained as follows:

2.1. Environment indoor air quality system

The monitoring and controlling of environment indoor air quality are designed with a fuzzy controller to conform with regulations of indoor air quality (IAQ) and thermal comfort. The input signals are the main four elements of IAQ involving the concentration of carbon dioxide (CO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and ozone (O_3), and four main elements of thermal comfort incorporating volatile organic compounds (VOC), particulate matter ($PM_{2.5}$), temperature and humidity. The output signals are the value of EIAQ that is divided into four status levels namely excellent, good, bad and worst. The output control signals which can drive the fan control relay, outlet and inlet exhaust control relay, buzzer and LED control to switch the power ON/OFF are shown in Fig. 1.

The seven sensors collect the input signals which then, are transferred, and converted from analog into digital data by the microcontroller. In the function of the environment indoor air quality index fuzzy logic is divided into 4 clusters namely cluster index 1 (IAQI 1) that contains CO and CO_2, cluster index 2 (IAQI 2) that contains NO_2 and O_3, cluster index 3 (TCI 1) that contains VOC and $PM_{2.5}$ and cluster index 4 (TCI 2) that contains temperature and humidity. After gathering data from sensors, the first stage is to check all inputs values for further process on the fuzzy logic block. The fuzzyfication of digitized input data is done by the predefined input fuzzy sets. Later on, the fuzzy rule will infer the fuzzified data and then the inferred data will be defuzzified to obtain IAQI 1, IAQI 2, TCI 1, and TCI 2 values. Finally, the EIAQI value will be summed by the four cluster index values. The output system will be turned ON/OFF according to the EIAQI value. The working principle of the EIAQI system is depicted in Fig. 2.

2.2. Environment indoor air quality classification

Environment indoor air quality (EIAQ) is the most important parameter that affects human health, comfort, and even sick building symptoms. Poor EIAQ can reduce work productivity and indeed cause symptoms of sick building syndrome (SBS) like lethargy, headaches, and mental fatigue [39,40].

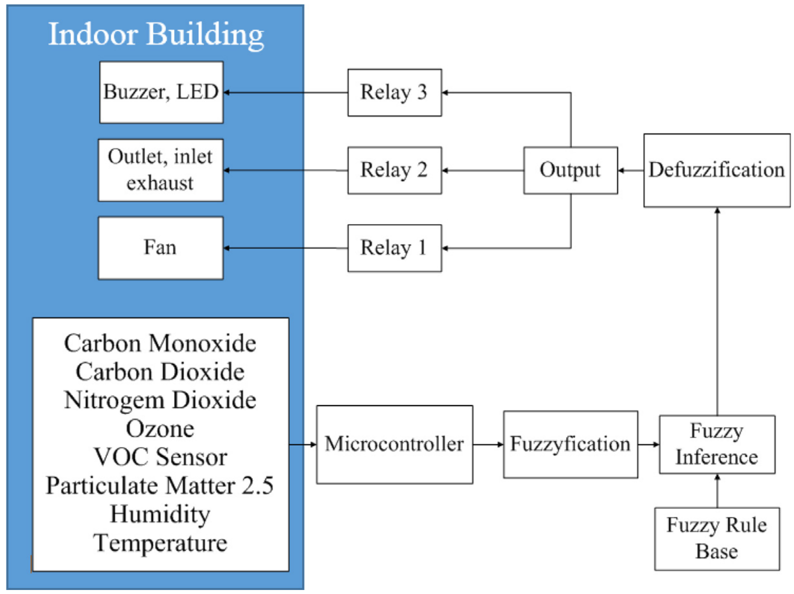

Fig. 1. Block Diagram System.

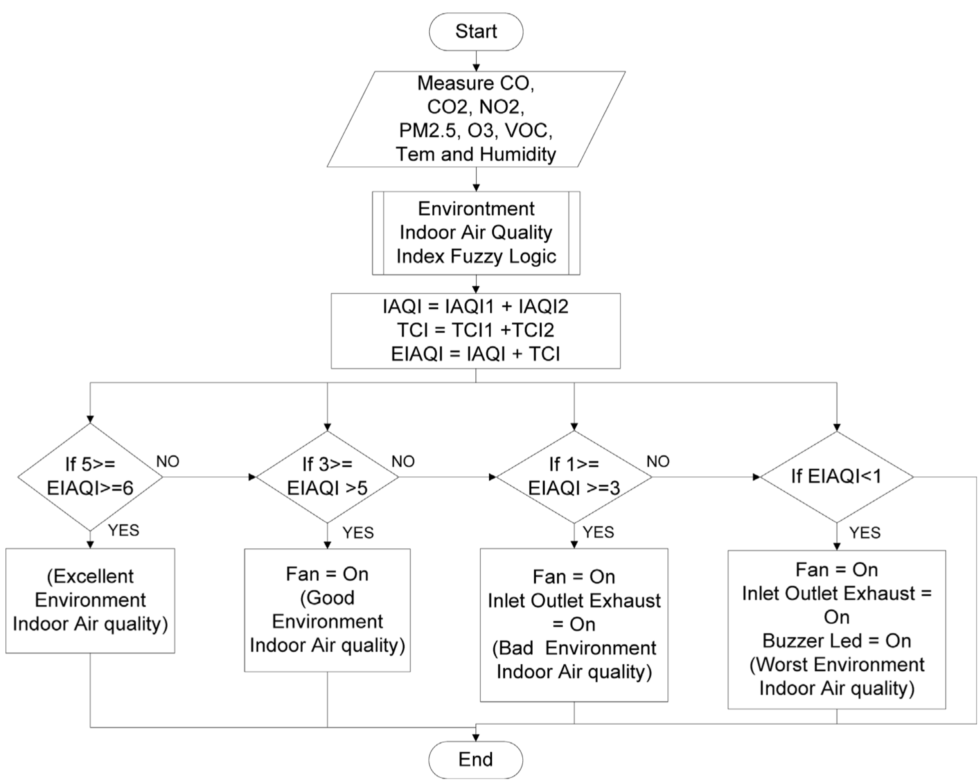

Fig. 2. Working principle of environment indoor air quality (EIAQ) system.

Air pollutants represent a variety of biological, chemical, and physical agents that point a health risk for humans and the environment [41]. Air pollutants can exist in solid particles or gases form and are usually monitored to minimize negative effects on the health of populations [42]. Therefore, environmental parameters are evaluated based on their toxicity levels and negative impacts related to the good air quality which are considered as the assessment criteria of the air quality [43]. There are four indoor air pollutants (IAP) and four thermal comfort pollutants that have become the major air pollutants which are directly linked to human health hazard [7,9,10] as shown in Table 1.

According to environment indoor air quality standards [7], the index is calculated by several pollutants by assigning their classification level. In this concept, four groups have been presented to evaluate air quality as shown below:

Table 1
Environment indoor air quality parameters importance.

Environment indoor air parameter	Human health effect
CO_2	Psychological effects, cardiac arrhythmias, seizures, cerebral disease & trauma patients, diminished performance, pulmonary, coronary disease and respiratory infection [44–46]
CO	Headache, dizziness, weakness, nausea, vomiting and loss of consciousness and enter fetal circulation and developing through the brain placenta [47,48]
NO_2	Respiratory infections such as asthma, pneumonia bronchial reactivity, asthma and aggravation of chronic respiratory diseases [48–50]
O_3	Respiratory infection (asthma, emphysema, bronchitis), skin cancer (melanoma and non-melanoma), eyes (blindness, cataract) and human immunity [51,52]
VOC	Asthma, anaphylactic, cardiovascular and cancer diseases [53,54]
$PM_{2.5}$	Asthma attack, chronic bronchitis, cardiovascular disease, diabetes and restricted activity and premature death [55,56]
Temperature	Perspiration, eyestrain, dizziness, accelerated respiration, accelerated heart rate and warm discomfort [57,58]
Humidity	Eyes become dry and irritated, skin gets flaky, dries out the mucous membrane lining the respiratory tract and increases heat disease admissions [59–61]

- Excellent: The EIAQI range for a society is 5 to 6. Air quality in this range is satisfied, and polluted air poses small or even no risk.
- Good: The EIAQI range is between 3 and 5. The air quality is worthy accepted; nevertheless, for a few toxins, there may be a medium health concern for a small number of individuals. For instance, individuals who are curiously delicate to ozone may encounter respiratory side effects.
- Bad: When EIAQI values are between 1 and 3, individuals of delicate groups may encounter health impacts. This implies they are likely to be influenced at lower levels than the public.
- Worst: Values below 1. It triggers a health alarm, meaning everybody may encounter genuine health impacts. This would trigger health notices of crisis conditions.

3. Fuzzy inference systems (FIS)

Fuzzy inference system is utilized in arrange to analyze, classify the indoor polluted air according to the reasoning operation (rules). Rule-based fuzzy logic is executed in this method on collected data that is received from various sensors. The main role of the fuzzy inference system is to develop an environment indoor air quality index (EIAQI) utilizing the theory of fuzzy, that improving the efficiency air quality appraisal and coordination specific concentration levels in a fuzzy index.

The proposed architecture of the fuzzy inference system is to combine eight pollutants that will be detected and classified pollution levels of each pollution, identify cluster index by using the fuzzy logic controller to produce cluster indexes 1, 2, 3 and 4 is shown in Fig. 3. After getting the value of the four clusters, will be known the values of the indoor air quality index (IAQI) and thermal comfort index (TCI). This index is divided because air pollution has different effects on human health and the environment. Finally, adding up IAQI and TCI we will get the EIAQI score divided into four levels, namely excellent, good, bad and worst.

3.1. Membership functions

For the construction of an integrated air quality assessment, it is significant to assess independently every pollutant, determining its concentration level that agrees to an individual run and characterizes a negative impact in air contamination and the health of individuals. In this regard, it is critical to recognize how a specific pollutant can create numerous negative impacts. Another option to solve this issue is by utilizing uncertainty to decide how much a concentration relates to a defined condition; this value is determined by employing a membership function. [43]. Membership functions (μ) are a graphical curve that digitizes the real input measurements into [0, 1] format and they specify the level that a concentration is related to a defined range [62]. Each membership function associates to eight air quality parameter classification and four output cluster indexes shown in Figs. 4 and 5 based on the indoor air and thermal comfort pollutants concentration level proposed in Tables 3 and 4.

The proposed fuzzy inference system (FIS) uses two types of membership functions, namely triangular and trapezoidal to determine the level that a concentration is related to a defined range. The trapezoidal function was selected to determine the highest value or the lowest value of air pollutants concentration. Triangular function was selected for the intermediate levels of air pollutants concentration. There are four cluster indexes, each with two input membership function parameters and one output membership function. For input membership functions, the Sigma operator is utilized as a membership function because it assesses statistically the concentrations of air parameter in a [0, 1] range, utilizing their individual toxic levels as presented in Tables 2 and 3 (good/most comfort, moderate/comfort, unhealthy/not comfort and hazardous/least comfort).

3.2. Inference rules (Reasoning)

When the fuzzy parameters and membership functions have been assigned, the if-then fuzzy rule base can be presented.

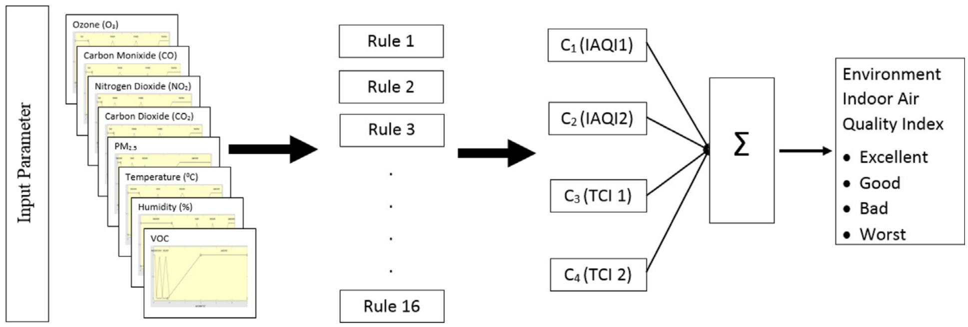

Fig. 3. Architecture of fuzzy inference environment indoor air quality index (EIAQI).

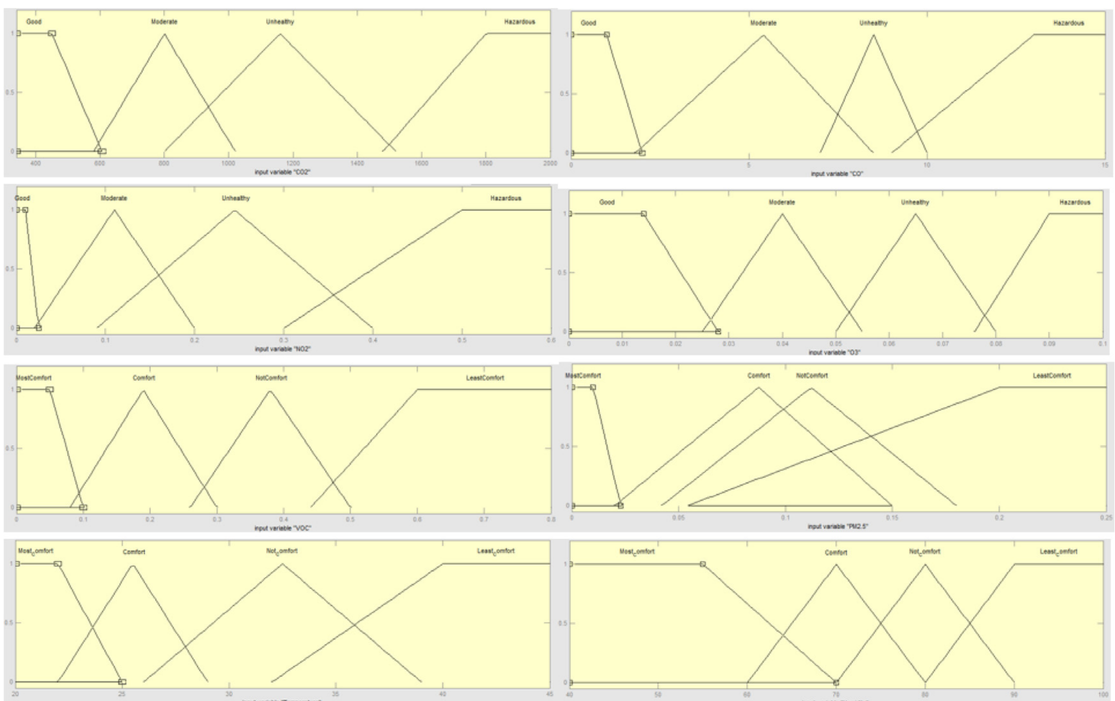

Fig. 4. Membership function for environment indoor air quality and measured pollutants: CO_2, CO, NO_2, O_3, VOC, $PM_{2.5}$, temperature and humidity.

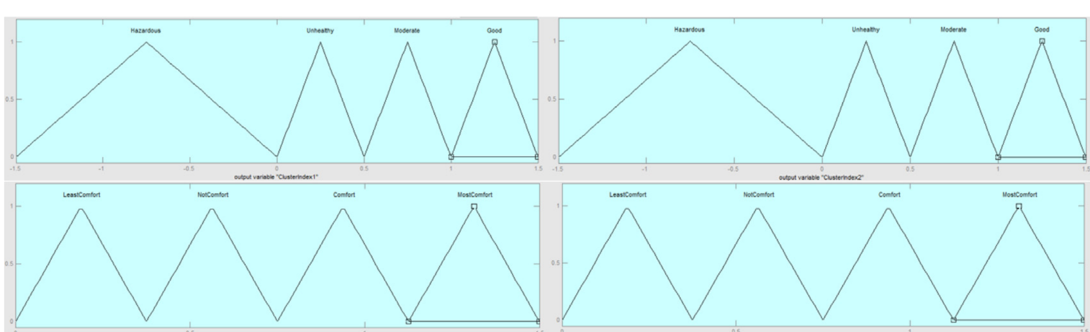

Fig. 5. Membership function for indoor air quality index (IAQI 1 and 2) and thermal comfort index (TCI 1 and TCI 2).

The number of defined fuzzy rules relies on the potential combination of membership functions [63]. A reasoning operation can be well-set as the way to utilize preservationist terms utilized by specialists for changing the information into mathematical forms that can be actualized in a computational framework. Once the membership functions are selected, the fuzzy rules are defined simply. The interpreted rule is constructed by considering the combinations of air quality parameters index. Based on how perilous the indoor polluted air is, the selection of constructed rule relies on air quality conditions. Moreover, if concentrations can specify other air quality parameters (essential or auxiliary parameters), the air

Table 2
Threshold point for indoor air pollution.

CO_2 (ppm)	CO (ppm)	NO_2 (ppm)	O_3 (ppm)	IAQI	IAQI status
0–606	0–2	0–0.025	0–0.028	2–3	Good
580–1020	1.8–8.5	0.02–0.2	0.025–0.055	1–2	Moderate
800–1520	7–10	0.09–0.4	0.05–0.08	0–1	Unhealthy
1480–5000	9–50	0.3–5	0.076–0.1	0–(−3)	Hazardous

Table 3
Threshold point for thermal comfort pollutants.

PM (gm/m^3)	VOC (ppm)	Temp (°c)	Humidity (%)	TCI	TCI status
0–0.023	0–0.1	18–25	40–70	2.25–3	Most comfort
0.02–0.15	0.08–0.3	22–29	60–80	1.5–2.25	Comfort
.042–0.18	0.26–0.5	26–39	70–90	0.75–1.5	Not comfort
0.054–0.6	0.44–3	32–45	80–100	0–0.75	Least comfort

Table 4
Rules base Cluster Index 1 and Cluster Index 2 (IAQI 1, IAQI 2).

	CO_2/O_3 status level				
	IAQI status	Good	Moderate	Unhealthy	Hazardous
CO/NO_2 status level	Good	Good	Moderate	Moderate	Unhealthy
	Moderate	Moderate	Moderate	Unhealthy	Unhealthy
	Unhealthy	Moderate	Unhealthy	Unhealthy	Unhealthy
	Hazardous	Unhealthy	Unhealthy	Unhealthy	Hazardous

Table 5
Rule base Cluster Index 3 and Cluster Index 4 (TCI 1, TCI 2).

	VOC/humidity status level				
	TCI status	Most comfort	Comfort	Not comfort	Least comfort
$PM_{2.5}$/temperature status level	Most comfort	Most comfort	Comfort	Comfort	Not comfort
	Comfort	Comfort	Comfort	Not comfort	Not comfort
	Not comfort	Comfort	Not comfort	Not comfort	Not comfort
	Least comfort	Not comfort	Not comfort	Not comfort	Least comfort

quality condition is defined. In this respect, the size of the rule set relies on how numerous rules are required to represent the dynamical ecosystem. The fuzzy rules are most broadly and commonly utilized for elucidation. According to the proposed threshold point for each pollutant, there are four rules base to describe the level of indoor air pollution namely cluster index 1 (IAQI 1), cluster index 2 (IAQI 2), cluster index 3 (TCI1) and cluster index 4 (TCI 2) and is shown in Tables 4 and 5. There are 16 total rules for the clustered index that consist of one good/most comfort level, five moderate/comfort levels, and nine unhealthy/no comfort levels and one hazardous/least comfort level.

Each rule base contains two indoor air pollutants or thermal comfort pollutants and for levels condition thereby resulting in $4^2 = 16$ rules for each clustered index. The conditions of parameter concentrations will be considered in the rules of our FIS evaluating environmental conditions for indoor air pollutants and thermal comfort. Consequently, the fuzzy inference system will be capable to identify the potential emergency, awful changes in parameter concentrations or conceivable results in sensitive individuals in case that the rules are constructed correctly.

3.3. Defuzzification

After completing the inference rules rule process, the final process of the fuzzy inference system of conversion of the fuzzy output into a crisp output is known as defuzzification, where the index is determined to utilize the method of the centroid. The centroid method is used to determine the output using the center of gravity possibility which is one of the most common methods [64]. The centroid defuzzification result presents the best output response than the other defuzzification method [65,66]. The outputs are the IAQI 1, IAQI 2, TCI 1 and TCI 2 values.

4. Simulation results and discussions

A set of simulations were performed to investigate the performance of the presented EIAQI system. Fig. 6 illustrates the surface view of the three-dimensional view of the relationship between the inputs (indoor air pollutants and thermal comfort pollutants) and the output (indoor air quality and thermal comfort index). X and Y-axis represent the input value of indoor air and thermal comfort pollutants, and Z-axis represents the output value of IAQI and TCI. Therefore, when the air pollutant inputs concentration is low (close to 0),

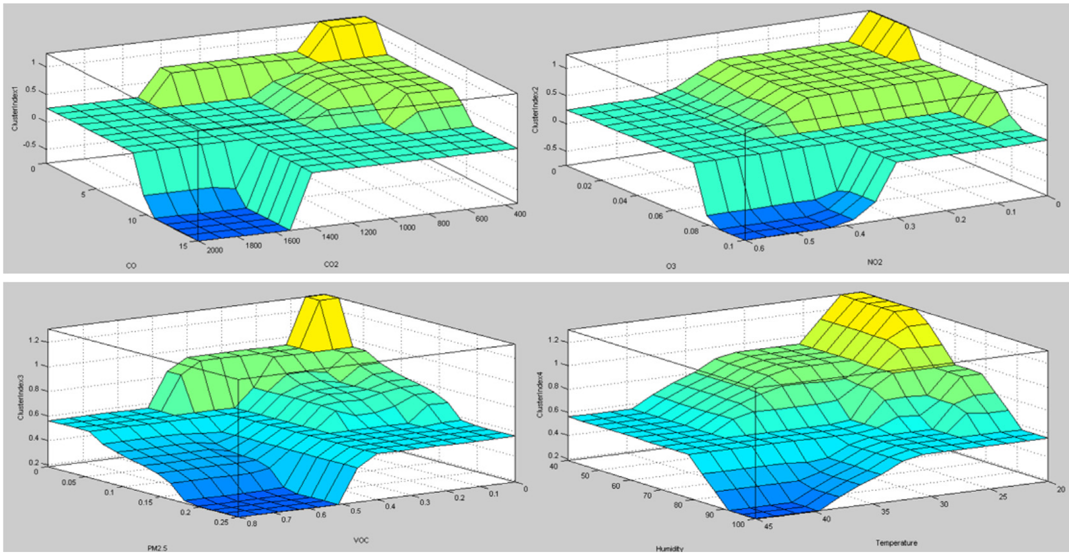

Fig. 6. Output surface area of four cluster indexes (IAQI 1, IAQI 2, TCI 1 and TCI 2).

Table 6
Results of input value of indoor air pollutants, thermal comfort pollutants and EIAQI value and status.

CO_2 (ppm)	CO (ppm)	NO_2 (ppm)	O_3 (ppm)	VOC (ppm)	$PM_{2.5}$ (ppm)	Tem (°C)	Hum (%)	IAQI	TCI	EIAQI	Status
944	7.78	0.0101	0.026	0.536	0.116	23.6	70	1.531	1.334	2.865	Bad
1600	12	1.2	0.09	0.05	0.11	20.5	65	−1.5	2.035	0.5346	Worst
369	1.2	0.015	0.014	0.055	0.015	20	45	2.499	2.625	5.124	Excellent
641	5.4	0.031	0.065	0.085	0.24	25	90	1	1.445	2.445	Bad
441	1.9	0.022	0.021	0.155	0.062	20	40	2.326	2.114	4.44	Good
1259	9.2	0.67	0.094	0.16	0.07	21	42	−0.49	2.097	1.597	Worst
1900	21	0.4	0.08	2.1	0.25	39	70	−1.5	0.75	−0.75	Worst
430	1.85	0.1	0.015	0.09	0.022	23	45	1.952	2.305	4.257	Good
1020	0.1	0.56	0.06	0.42	0.034	39	90	1.001	0.75	1.751	Bad
630	4	0.001	0.033	0.095	0.048	22	65	1.5	1.887	3.387	Good

the index value will be high (IAQI/TCI) based on clustering inference rules.

After completing the design on the fuzzy inference system, Simulink is performed to get the EIAQI value from the added value of IAQI 1, IAQI 2, TCI 1, and TCI 2. Simulink consists of eight constant blocks that show eight air pollutants, four fuzzy block parameters that show four process index clusters and displays to show the value of a process. From the Simulink result, the index values are obtained from each cluster, IAQI, TCI and EIAQI that shown in Fig. 7. The IAQI value contains two cluster indexes that are cluster index 1 (IAQI 1) and cluster index 2 (IAQI 2). The TCI value contains two cluster indexes that are cluster index 3 (TCI 1) and cluster index 4 (TCI 2). The value of EIAQI is 2,865 which means the index level is Bad. The EIAQI value is used as a basis for determining the output to be used as an action to reduce indoor air pollution and improve air quality. The greater the EIAQI value, the better the air quality in the room, while the smaller EIAQI value indicates the poor air quality and that air can therefore impact people's health.

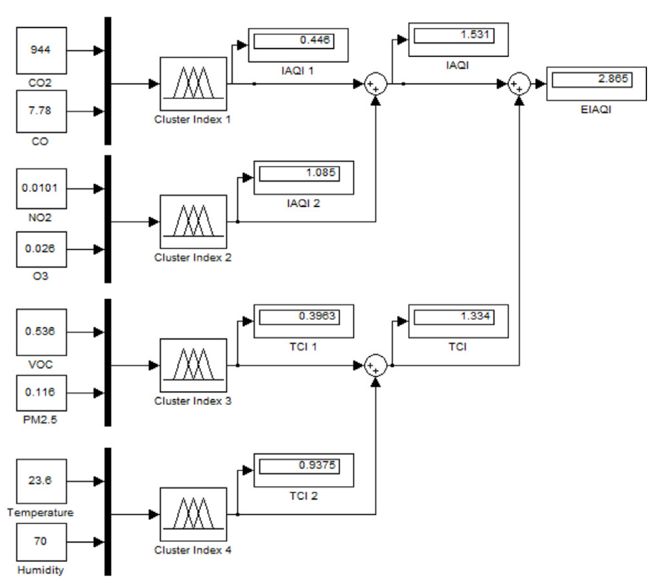

Fig. 7. Environment Indoor Air Quality Index (EIAQI) Result Value.

Table 6 shows the eight inputs, three index values and EIAQI status of Simulink results with different input values. Ten results were tried in fuzzy logic simulation to find the value of EIAQI. The ten values are taken randomly to determine whether the effects occur when the input values (indoor

Table 7
Output status and action based on EIAQI level.

EIAQI level	Output status and action
5–6	Excellent EIAQI status
3–5	Good EIAQI status Fan ON
1–3	Bad EIAQI status Fan ON, inlet–outlet exhaust ON
Below 1	Worst EIAQI status Fan ON, inlet–outlet exhaust ON, LED Buzzer ON

air pollutants and thermal comfort pollutants) are changed to IAQI, TCI, and EIAQI values. EIAQI value is the sum of IAQI and TCI values. IAQI is one of the important effects because IAQI values have a range of output values from −3 to 3 which can reduce the value of EIAQI if there is the higher value of indoor air pollutants (CO_2, CO, NO_2, and O_3). Besides the IAQI, TCI is also an important index that is used as a support index because it can measure indoor air based comfort on thermal comfort pollutants (VOC, PM2.5, temperature, and Humidity) with a range of output values from 0 to 3. So if IAQI value is negative (−3) while the TCI has a large positive value (3), the results of EIAQI will be reduced (0). Table 7 shows the output action to give the notification and reduce the indoor air and thermal comfort pollutants that will be executed automatically based on the EIAQI value.

The proposed method for assessing environment indoor air quality (EIAQ) provides a good approach in air monitoring and controlling management. Table 8 shows the fuzzy inference system for air quality assessment previous research; nevertheless, the proposed model presents eight input pollutants parameter that divided into two index contain indoor air quality index (IAQI) and thermal comfort index (TCI). Thermal comfort index (TCI) used as a support index to have a more accurate index value to improve the quality of life. Moreover, this system used clustering systems to calculate indoor air quality (IAQI) and thermal comfort index (TCI) values separately, as these two index parameters have different characteristics and human health impact. Proposed model makes a treatment to the input parameter based on the characteristic similarity that significantly increases the performance of the environment indoor air quality assessment.

5. Conclusion

Environment indoor quality (EIQ) is one of the important aspects to increasing the quality of life because most people spend the majority of their time in various indoor spaces. Environment indoor air quality (EIAQ) system for indoor air and thermal comfort pollutants has been constructed to evaluate, assess and protect humans in indoor environmental areas. The presented EIAQ operated in multi-steps. Firstly, the toxicity of measured concentrations set involved in indoor air pollutants (CO_2, CO, NO_2, and O_3) and thermal comfort pollutants (VOC, $PM_{2.5}$, temperature, and humidity) is classified into four status levels and divided into four cluster indexes based on the characteristic similarity and human health effect. Secondly, the indoor air quality index (IAQI 1 and 2) and thermal comfort index (TCI 1 and TCI 2) values are calculated in order to determine environment indoor air quality index (fuzzy inference system); third, the output notification and action are automatically run based on the EIAQI value. This monitoring and controlling system based on EIAQI is approved to help decision-makers in detailing the status of environmental indoor air quality, and examining both spatial and temporal changes.

CRediT authorship contribution statement

Brainvendra Widi Dionova: Data curation, Writing - original draft, Visualization, Investigation. **M.N. Mohammed:** Conceptualization, Methodology, Supervision. **S. Al-Zubaidi:** Writing - review & editing. **Eddy Yusuf:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 8
Fuzzy inference previous research inputs and result.

No	Title (year)	Input parameter	Fuzzy inference systems output
1	Assessment and prediction of air quality using fuzzy logic and autoregressive models (2012)	O_3, NO_2, SO_2, CO, and PM_{10}	Air quality index
2	Air quality assessment using a weighted Fuzzy Inference System (2016)	O_3, NO_2, SO_2, CO, $PM_{2.5}$, and PM_{10}	Air quality index
3	Unifying Fuzzy controller for Indoor Environment Quality (2013)	CO_2, temperature, and humidity	Indoor environment quality index
4	Indoor Air Quality Monitoring and Controlling System based on IoT and Fuzzy Logic (2019)	CO_2 and PM_{10}	Indoor air quality index
5	AQI Classification using CO and NO_2 pollutants: A Fuzzy-based Approach (2019)	CO and NO_2	Air Quality Index

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