Evaluation Setup

To comprehensively test this fuzzy system, we created five different scenarios. We then compared these five scenarios with a thermometer set at a constant temperature of 21°C in the living room. We entered the parameters (humidity, ecology, temperature, etc.) from these scenarios into our fuzzy system and then included the results in the survey for participants to compare.

The conditions covered by our scenarios are generally as follows:

- A very cold room and a user who feels freezing
- A slightly cool room where the user feels very hot
- A very hot day with an eco-minded user
- A slightly chilly but very humid evening
- A warm and humid situation with an eco-minded user

The parameters we used in the survey and our fuzzy system are as follows, and we use each as follows:

- Room Temperature: The measurement unit is calculated in degrees Celsius (17°C)
- Humidity: The measurement unit is calculated in percentiles. (20%)
- Feeling: The scale parameter in the fuzzy system ranges from 0 to 10. Instead of entering a parameter out of 10 to convey feelings to participants in the survey, we used linguistic descriptions such as "I feel extremely cold, I feel very hot, I feel okay (not extremely hot), I feel more or less okay" based on the scenarios.
- Ecology: The scale parameter in the fuzzy system ranges from 0 to 10. To explain what these values mean to users in the survey, we used linguistic descriptions such as "comfort first," "eco (strongly care about energy saving), and "medium (care about energy saving but not strongly)."

In the survey, we first described the five scenarios we created with a short story appropriate to the scenario, provided the parameters, and then asked participants to compare this fuzzy system (System B) with a fixed system (System A). We made this comparison as follows: If you were to give a score from 0 to 5 (they can give float values as 3.5, 4.2, etc.), to what extent would you prefer System B over System A? In this comparison, 0 means "I clearly prefer System A," while 5 means "I clearly prefer System B." For this survey, total of 13 people participated in this survey.

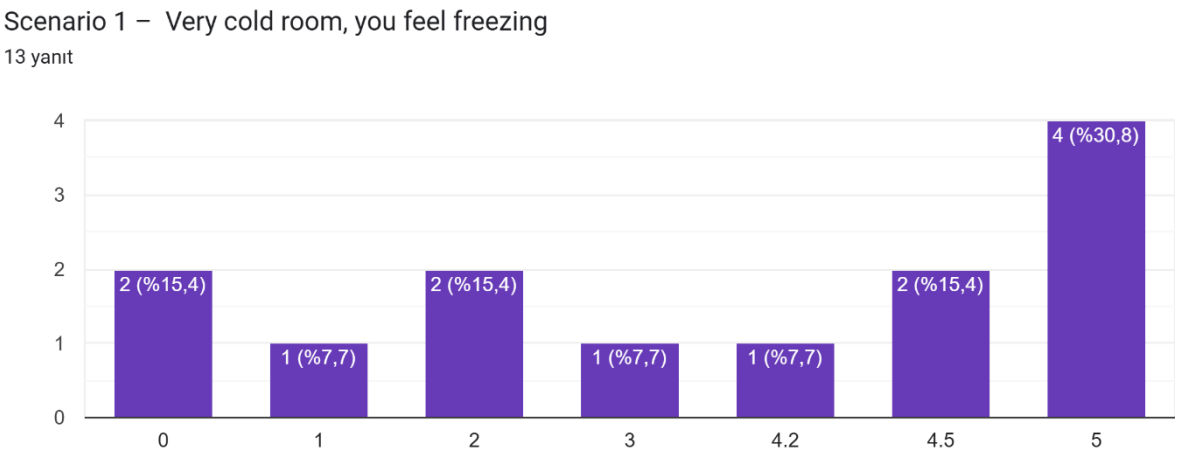
Quantitative Results

For each scenario, we collected a total of 13 ratings, ranging from 0 to 5. As previously mentioned, a score of 0 indicates that the participant chose the fixed thermostat (system A), while a score of 5 indicates that the participant preferred the fuzzy system (system B).

We calculated the mean and standard deviation scores for each scenario. A mean value above 2.5 indicates that the fuzzy system was more preferred by the participants.

Scenario 1 – Very cold room, user feels "I'm freezing"

In this scenario, the room is 17 degrees Celsius (17 degrees Celsius), which is quite cold, and the user describes themselves as "I feel extremely cold." The humidity level in the room is 20%, making the air dry. The user also values comfort over environmental concerns. In this scenario, the fuzzy system we created decided on a temperature of 25°C.



The mean and standard deviation values found for this scenario are:

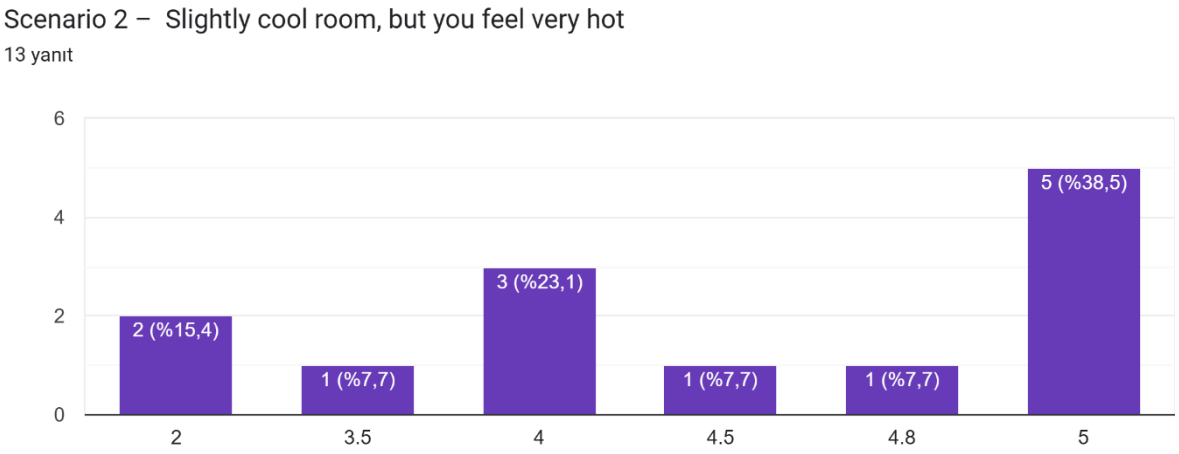
- M = 3.16
- SD = 1.87
- N = 13

Although the mean value we obtained is slightly above the neutral point (2.5), we understand that users generally prefer the fuzzy system for this scenario, this preference is a weak one.

The relatively high standard deviation value we obtained indicates that the responses were quite diverse. Some preferred the fuzzy system, which heats the room to 25 degrees Celsius (5 points), while others chose the fixed thermostat, which heats the room to 21 degrees Celsius (0 points).

Scenario 2 – Slightly cool room, user feels very hot

In this scenario, the room is 18 degrees Celsius and slightly cool, and the user says, "I feel very hot." The humidity level in the room is 40%. The user considers ecology more important than comfort. In this scenario, the fuzzy system we created settled on a temperature of 18.5°C.



The mean and standard deviation values found for this scenario are:

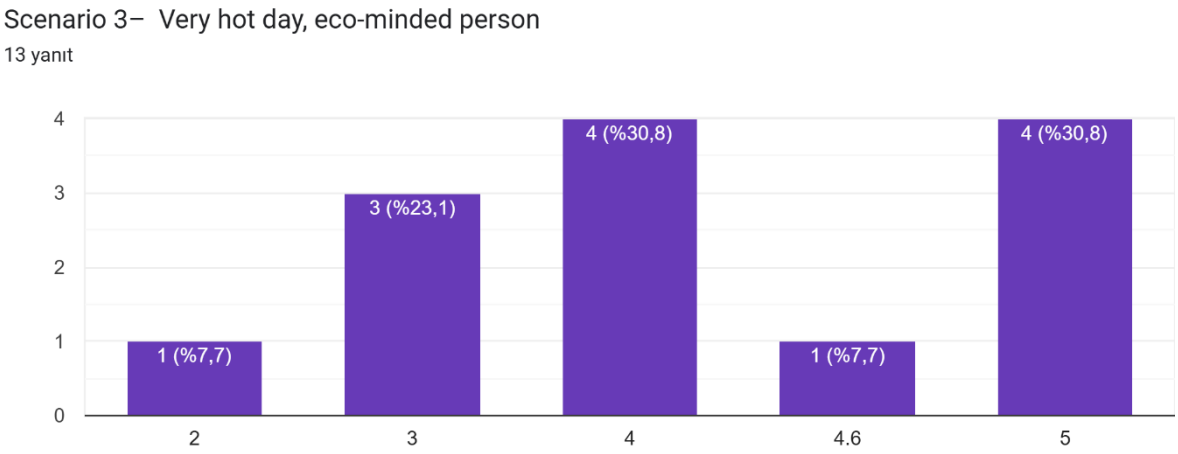
- M = 4.13
- SD = 1.03
- N = 13

The mean value we obtained tells us that in this scenario, users mostly preferred the fuzzy system we created. In other words, because the user already felt too hot, they considered it more reasonable to heat the room to 18.5 degrees Celsius rather than 21 degrees Celsius.

The standard deviation we obtained shows that while there was some variation in the responses, it wasn't very large.

Scenario 3 – Very hot day, user who cares about environmental issues

In this scenario, the room temperature is very high at 29 degrees Celsius, and the user expresses themselves as "I feel okay, not extremely hot." The humidity in the room is 40%. The user values environmental issues over comfort. In this scenario, the fuzzy system we created decided on a temperature of 24.1°C.



The mean and standard deviation values for this scenario are:

• M = 3.96

• SD = 0.93

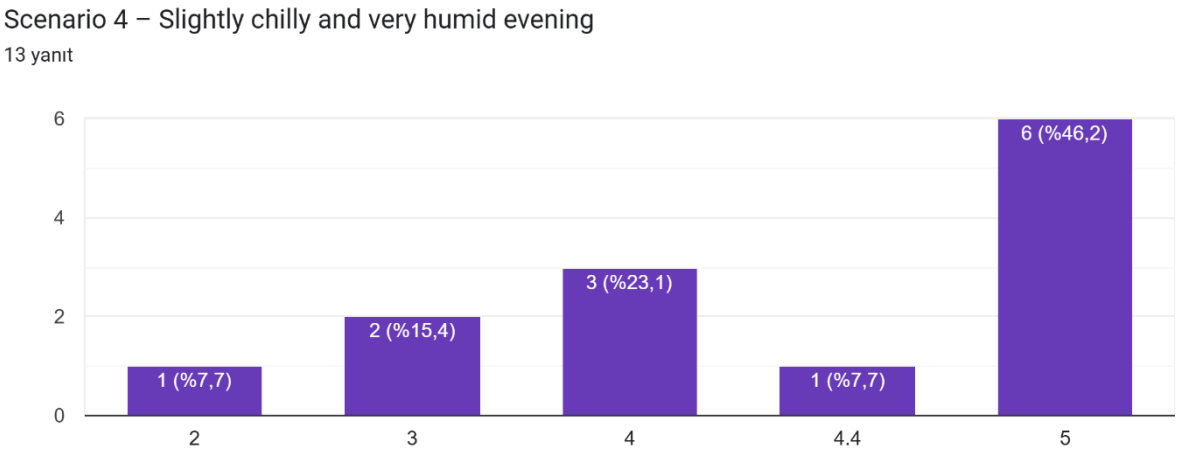
• N = 13

When we examine the mean value, we can say that participants generally prefer the fuzzy system. In this scenario, instead of a strong cooling system that drops to 21 degrees Celsius, users opted for a more ecologically conscious and gentler cooling system.

The standard deviation we obtained is relatively low, indicating that this preference is more consistent among participants.

Scenario 4 – Slightly Cool but Very Humid Evening

In this scenario, the room temperature is 18 degrees Celsius, making it slightly cool. The humidity in the room is high, around 80%. The user expresses their feelings as "I feel mostly okay, but the air feels a bit uncomfortable." The user also has a moderate level of ecological importance. In this scenario, the fuzzy system we created settled on a temperature of 19.5°C.



The mean and standard deviation values found for this scenario are:

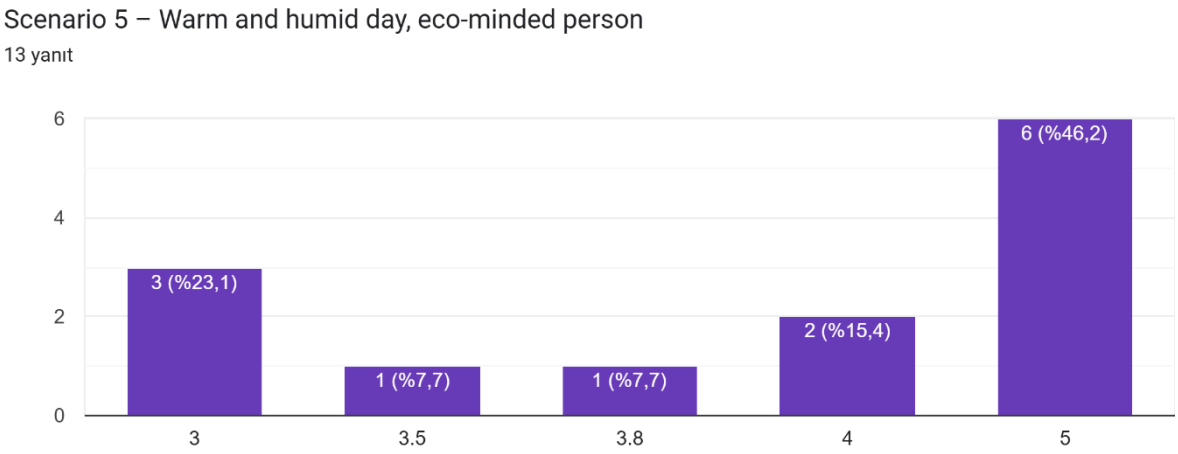
- M = 4.17
- SD = 0.94
- N = 13

When we examine the mean values we obtained, we can say that the participants clearly preferred the fuzzy system. Here, instead of raising the temperature to 21 degrees Celsius, the fuzzy system slightly warms the room to 19.5 degrees Celsius.

The standard deviation we obtained also indicates that there were only a few variations in the user responses we obtained.

Scenario 5 – Hot and humid day, user who prioritizes environmental friendliness

In this scenario, the room temperature is 25 degrees Celsius, making it slightly warm. The humidity in the room is high at 70%. The user expresses himself as "I feel more or less okay." He prefers environmental friendliness to comfort. In this scenario, the fuzzy system we created decided on a temperature of 24°C.



The mean and standard deviation values found for this scenario were:

- M = 4.18
- SD = 0.82
- N = 13

This value was chosen as the highest mean and lowest standard deviation among all scenarios.

When we examine the mean value, we see that participants overwhelmingly preferred a system that only slightly cools the room over a fixed thermostat that strongly cools the room.

When we examine the standard deviation value, it is relatively low, indicating that almost all users agree on this.

Overall, the mean scores across all five scenarios are above 2.5.

This indicates that in all tested situations, the fuzzy system is preferred over the fixed 21°C thermostat. However, the strength of this preference and the distribution of responses vary from scenario to scenario.

Interpretation

When we examine the overall results, we can say that users prefer the fuzzy system to the fixed thermostat system in every scenario, as the average temperature is 2.5 degrees higher than the average in every scenario. This suggests that designing and using a system that considers factors such as user feelings, humidity levels, room temperature, and ecological preferences, rather than a system based solely on temperature, is meaningful and convincing for the survey participants.

The survey results highlight two points in particular:

- In situations where users feel significantly too hot or too cold, the fuzzy system deviates from the fixed thermostat's set temperature of 21 degrees Celsius, setting it to a more suitable temperature.
- Another point is that in scenarios where ecological importance is emphasized, users prefer the fuzzy system, which provides less heating or cooling. However, despite this, in the "Very cold room, user feels "I'm freezing" scenario, the fuzzy system's suggestion of a relatively high temperature of 25 degrees Celsius resulted in more diverse opinions among participants, based on the mean and standard deviation values.

These results can be considered useful feedback, demonstrating that the fuzzy system's overall approach is working, but the rule set should be reconsidered for extremely cold conditions.

Limitations & Future Work

This study has several important limitations. First, it was conducted with 13 users, and second, it was based entirely on imaginary scenarios. Survey participants did not physically feel the temperature and only responded to textual descriptions. Furthermore, our constant use of 21 degrees Celsius as the default thermostat may have created a perception among participants that this temperature was the absolute correct temperature, potentially leading to bias among survey participants.

Technically, all of our rules were individually designed and tailored to each situation, and were tested only in the living room context. These tests revealed that the rules designed for very cold weather may not have fully met user expectations in some scenarios.

Future studies would benefit from testing this system with a larger number of users and in different room types (bedroom, bathroom, kitchen, etc.). However, it would be appropriate to revise the rule set for very cold scenarios. Finally, designing an adaptive system that learns users' personal preferences from their feedback in the long term could be a study that would take this system and the project one step further.