An Evaluation Approach Enhancing Apartment Building Comfort through Artificial Intelligence

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Abstract — **Background: In the last two decades, there has been a growing interest in intelligent management systems capable of strengthening numerous industries. This study uses fuzzy sets to analyse and enhance the comfort levels of apartment dwellers.**

Objective: The primary objective of this project is to create an intelligent system which focuses on both statistical and subjective elements of living comfort. This article aims to help readers understand the difficulties and possible conflicts caused by insufficient data and the various subjective preferences of apartment purchasers.

Methods: A fuzzy Petri net is a fundamental solution to the conflict between fuzzy knowledge and logical reasoning. The model combines numerous indicators such as neighbourhood, neighbouring area, home, unit reviews, price formulation, and value fixation to assess apartment building comfort fully.

Results: The findings show that the suggested approach effectively handles the multidimensional character of comfort assessment. Using fuzzy systems and various indicators adds a nuanced viewpoint to the evaluation, accounting for physical and intangible variables contributing to pleasant living in apartment complexes.

Conclusion: The current study sheds light on the possibilities of artificial intelligence and fuzzy systems for improving apartment building comfort. It underlines the need for novel methodologies and intelligent management systems to tackle the complexity and subjectivities of assessing and enhancing apartment living comfort.

I. Introduction

In recent years, with the rapid development of information technologies, interest in various aspects of intelligent management, which had the strength to enter various branches of production, has grown sharply. Many complex problems are solved with the help of these systems.

Today, this topic is quite relevant for research. The authors of this article identified the main factors that affect comfortable accommodation in such types of homes, namely:

- pedestrian accessibility (of the micro-district);
- pedestrian accessibility (of the home territory);
- comfortable living in an apartment building;
- comfortable living in the apartment;

So, today, the main direction in solving problems with intelligent management is the use of fuzzy systems, with the help of which it is possible to build a fuzzy management system for various situations; these sets include fuzzy sets, fuzzy logic, and fuzzy modelling.

Fig. 1 shows the basic levels of comfortable living for future apartment residents. These hierarchical levels of these factors will be used in this study to model a fuzzy system called «Apartment» [1]. A detailed description of all comfort factors is presented in Table I.

TABLE I. KEY CHARACTERISTICS OF APARTMENT COMFORT

Property	Description
Size and Spaciousness	This characteristic refers to the presence of a roomy balcony or loggia and the total area of the apartment.
Living Space Comfort	It encompasses isolated rooms and spacious kitchens, providing a comfortable living experience.
Layout Convenience	This factor considers factors such as the amount of sunlight the apartment receives and its humidity levels.
Floor Location	Refers to the positioning of the apartment on the middle floors, with desirable scenic features.

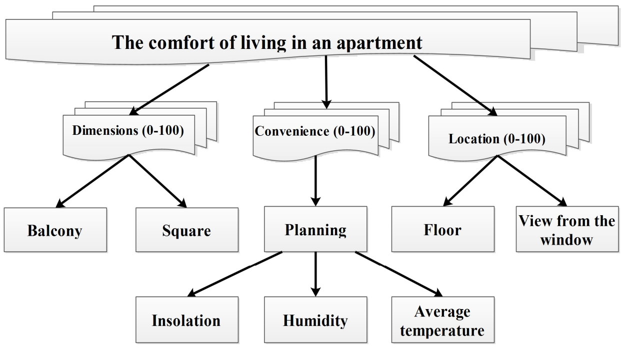

Fig. 1. Evaluation of the comfort of life in the apartment

So, we considered the following basic parameters:

Dimensions, which lie on the interval from 0 to 100. Moreover, with the help of the belonging function {small, medium, large}, you can determine whether it is comfortable to live in this apartment.

Spaciousness lies in the interval from 0 to 100. Furthermore, with the help of the belonging function {small, medium, large}, you can determine whether living in this apartment is comfortable according to this indicator.

The location lies at the interval from 0 to 100. With the help of the function of belonging {convenient, unsuccessful, average}, you can determine whether a comfortable living in this apartment is by this indicator [2].

A. *Aim of the Article*

This article aims to examine the potential of artificial intelligence (AI) in enhancing the comfort and livability of apartment complexes. This thorough evaluative methodology explores several facets of artificial intelligence's use in real estate and urban life.

The study aims to meet several significant goals. The primary objective of this study is to illustrate the potential of AI-driven systems in improving temperature management, lighting, and overall energy efficiency in apartment buildings. It may enhance inhabitants' comfort while decreasing energy consumption and associated expenses. Furthermore, it aims to assess the practicality and expandability of these artificial intelligence systems inside various construction categories and dimensions.

Moreover, this article aims to provide insight into the possible social and environmental advantages of using AI-Driven methods to boost comfort, particularly emphasising the significance of sustainable urban development. The primary objective of this article is to provide a complete assessment framework that may assist stakeholders in the real estate and urban planning sectors in making well-informed choices about the integration of artificial intelligence technology. The ultimate goal is to increase the comfort and livability of apartment buildings. The study contributes to the broader academic conversation about using AI to pursue enhanced efficiency and sustainability within urban settings.

B. *Problem Statement*

The article's primary focus is to address the issues that arise when attempting to optimise apartment complexes' comfort levels via artificial intelligence (AI) solutions. In the contemporary urbanised society, the prevalence of apartment living is widespread, yet the challenge of guaranteeing the welfare and contentment of inhabitants remains intricate. Several elements influence residents' comfort, including temperature regulation, lighting conditions, noise levels, and security measures. It renders the issue complex in nature.

Conventional building management systems often fail to deliver tailored and energy-efficient comfort solutions. The article aims to analyse the current deficiencies in comfort management in apartment buildings and provide an assessment methodology that utilises artificial intelligence. The primary concerns are the insufficiency of adaptation, inefficiency in energy use, and the absence of a comprehensive strategy towards enhancing comfort. This study aims to use AI technology to augment personal comfort, minimise energy usage, and boost the overall efficiency of buildings. The primary objective of this study is to transform the residential living experience in apartment complexes while simultaneously addressing urgent environmental issues.

II. METHODOLOGY

In Fig. 2, an ambiguous set based on the "dimensions" parameter represents the apartment's description. This fuzzy set contains three membership functions shaped like triangles. These membership functions describe the linguistic variable by aligning terms with the graphical representation.

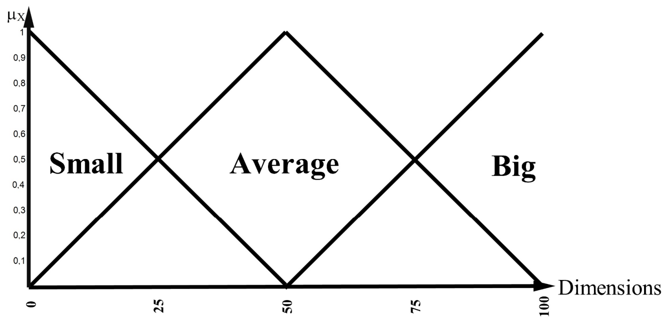

Fig. 2. View of the vague plural of the description of the apartment "Dimensions"

TABLE II. ESCRIPTION OF THE LINGUISTIC VARIABLE "APARTMENT."

The term linguistic variable		X	
	Interval	μ(x) =1	μ(x) =2
Small	0 – 50	0	50
Average	0 – 100	50	0-100
Big	50-100	100	50

The main levels of comfort factors were selected for the fuzzy Petri net for managing the comfort of an apartment building, which consists of the following elements:

- P={p1, p2, p3....p24} – finite set of positions, detailed description in table 3;
- T={t1, t2, t3....p8} – finite set of transitions, detailed in Table 4.

TABLE III. ASSIGNING FUZZY PETRI NET POSITIONS

Positions	Description
P_1	Selected apartment
P_2	Walking distance from the neighbourhood is "close."
P_3	The walking distance of the neighbourhood is "remote."
P_4	The walking distance of the neighbourhood is "far."
P_5	Pedestrian accessibility of the premises is "close."
P_6	Pedestrian accessibility of the premises is "remote."
P_7	Pedestrian accessibility to the premises is "far."
P_8	The noise level is "comfortable."
P_9	The noise level is "tolerable."
P_{10}	The noise level is "unbearable."
P_{11}	The technical condition of the house is "perfect."
P_{12}	The technical condition of the house is "satisfactory."
P_{13}	The technical condition of the house is "bad."
P_{14}	The dimensions of the apartment are "large."
P_{15}	The size of the apartment is "average."
P_{16}	The size of the apartment is "small."
P_{17}	The location of the apartment is "convenient."
P_{18}	The location of the apartment is "average."
P_{19}	The location of the apartment is "unfortunate."
P_{20}	The convenience of the apartment is "good."
P_{21}	The convenience of the apartment is "average."
P_{22}	The convenience of the apartment is "bad."
P_{23}	Price for a "premium" apartment
P_{24}	Price for a "comfort" apartment
P_{25}	Price for an "economy" apartment
P_{26}	Evaluation completed

TABLE IV. DESCRIPTION OF THE TRANSITIONS OF THE FUZZY PETRI NET

Transitions	Description
T1	Review of the neighborhood
T2	Consideration of the home territory
T3	Review of the house
T4	Consideration of the apartment
T5	Price formation
T6	Fix value

Fig. 3 depicts the operation of the fuzzy Petri net, beginning with the initial state P1. After the transition (t1) is complete, the surrounding area is considered. The system then advances to positions (P2, P3, P4), where the decision maker (DPO) evaluates the current distance and records the values provided [3].

The activated transition (t2) then evaluates the native territory. This results in positions (P5, P6, P7) where the OPR evaluates the distance based on living conditions. Upon completion of the assessments, a transition to the subsequent marking (P8, P9, P10) occurs, allowing the OPR to evaluate the extant noise level and adjust the corresponding data values [4].

Another transition (t3) is activated, concentrating on the apartment building's convenience factors. The OPR examines positions (P11, P12, and P13), assesses the technical condition, and records these values [5].

The subsequent transition (t4) examines the flat itself.

The OPR initially analyses positions (P14, P15, and P16) to evaluate the apartment's dimensions. Then, at positions (P17, P18, P19), the location is reevaluated to determine the optimal choice. The final stage in this block is positions (P20, P21, and P22), where the OPR evaluates the extant apartment's convenience and records these values, as shown in Fig. 3.

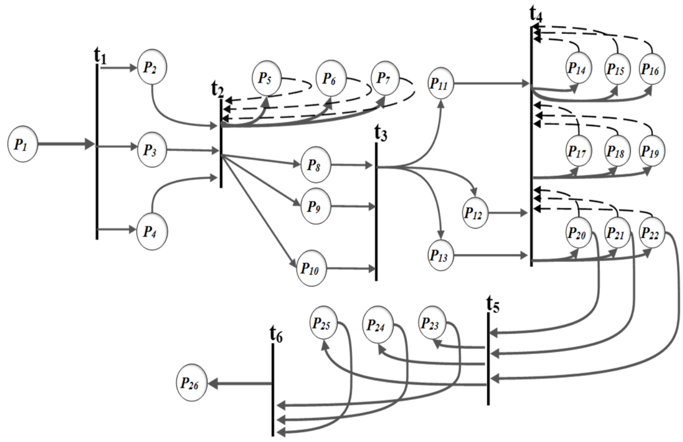

Fig. 3. Fuzzy Petri net of the general scheme without taking into account the preferences of the buyer

Using the extended fuzzy Petri net (Figure 4), flat evaluation entails a series of transitions and assessments based on the client's preferences. Each transition activates distinct evaluation criteria; the resulting data is stored for further examination [6], [7].

One method for evaluating an apartment is as follows: neighbourhood (P1), adjacent territory (P2), house (P5), and the apartment itself (P8); based on these evaluations, the initial price of the apartment is determined (t3). The client's preferences determine the evaluation sequence, ensuring that the most important factors are considered first [8].

Another evaluation scenario begins with the neighbouring land (P1), then the house (P2), and finally, the flat (P5). This sequence is founded on the client's preferences and leads to the apartment's provisional pricing formulation (t4).

A third strategy begins with the flat itself (P1), focusing initially on its dimensions (P14). Next, the evaluation focuses on the pollution level in the neighbouring territory (P8). Then, the apartment's convenience factors (P14) are revisited, followed by a neighbourhood evaluation (P20). Next, the neighbourhood's walkability is considered (P5), followed by an evaluation of the home (P11). Lastly, the apartment's location (P17) is evaluated prior to the execution of the provisional price formulation (t5) [9].

Because each client has distinct preferences, it becomes difficult to account for all conceivable situations. The authors suggest using artificial intelligence, specifically the genetic algorithm, to simplify and expedite this procedure. The flat evaluation can be optimised and tailored to the specific requirements of each client using this method, resulting in more efficient and accurate price formation [10].

Ultimately, the extended, hazy Petri net provides a structured and systematic method for evaluating apartments, accommodating various assessment sequences based on customer preferences. Due to the intricacy of contemplating all potential scenarios, artificial intelligence, specifically the genetic algorithm, offers a viable solution for streamlining and optimising the flat evaluation process. Integrating technology and expert knowledge will result in more accurate and individualised assessments, enhancing client satisfaction and facilitating real estate market decision-making [11].

TABLE V. THE PROPORTIONAL FITNESS SELECTION METHOD

The individual	Adaptation f	Fraction	The new value of the function f f*
A	20	9,80	50
B	23	11,27	65
C	26	12,75	80
D	30	14,71	100
E	29	14,21	95
F	20	9,80	50
G	26	12,75	80
H	30	14,71	100
∑	204	100	

So, eight individuals in the population have different degrees of adaptation, ranging from 20 to 30. Moreover, in the future, they will be transferred to the range from 50 to 100 using the following formulas:

$$\begin{cases} a * f_{min} + b = d_{min} \\ a * f_{max} + b = d_{max} \end{cases} \quad (1)$$

Where f_min=20, f_max=30 – the minimum and maximum values of adaptation of individuals in the population; d_min=50; d_max=100 – the minimum and maximum value of the range.

So, using a linear equation, we find the coefficients a, b:

$$a = \frac{d_{min} - d_{max}}{f_{min} - f_{max}} \quad (2)$$

$$b = d_{min} - a * f_{min} \quad (3)$$

Therefore, the transition to the next stage is carried out, where the values from [20-30] are transferred to the new range [50-100] using a mathematical formula [7, 300]:

$$f^* = a * f + b \quad (4)$$

The next step is to present the research as a pie chart with sectors, with a size corresponding to each share.

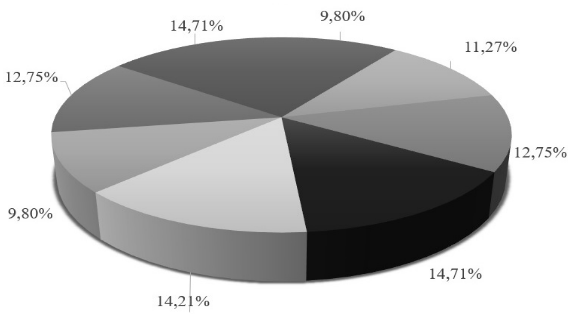

Fig. 4. Plotting a pie chart for the f value

As can be seen from Fig. 5 and 6, thanks to this method, the rank relativity fraction is calculated (it is it, and no other characteristics of the genetic algorithm) [8,73], due to which each of the sector fractions has a more uniform appearance, and thus parents from the population have equal chances of selection from the population [9,100].

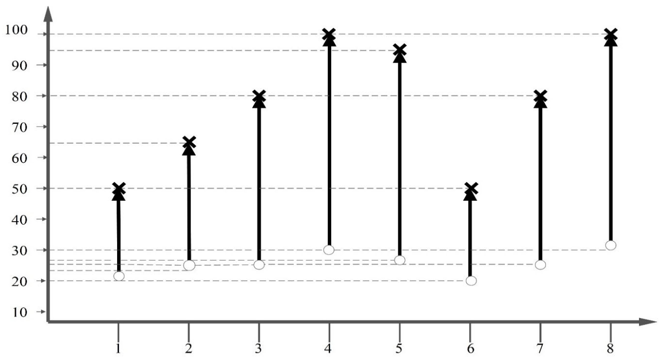

Fig. 5. Mapping previous f values into the new f* range

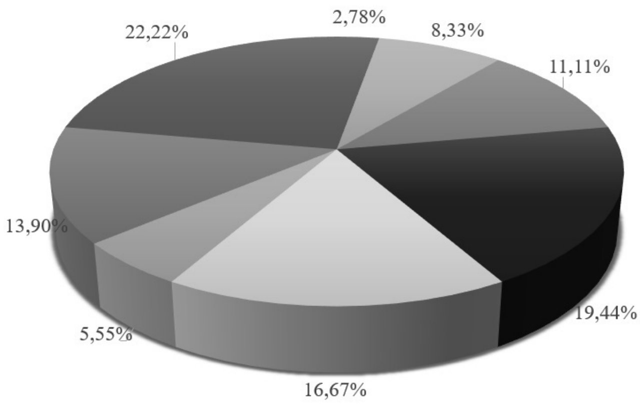

Fig. 6. Plotting a pie chart after scaling

Operations with the selected parents are carried out with the help of crossover, the graphic representation of which is disclosed in Fig. 7.

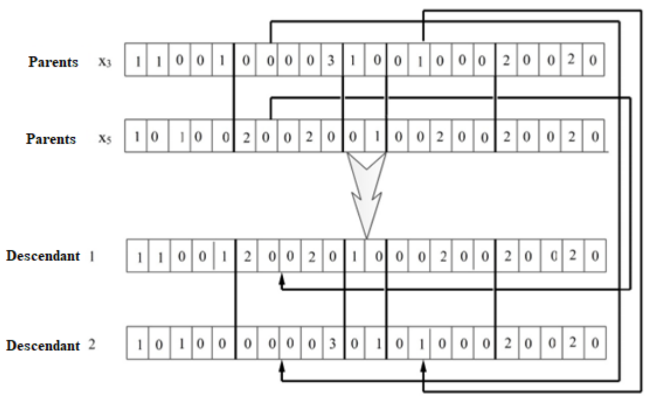

Fig. 7. Plotting a pie chart after scaling

1) Enhancing Precision: The Application of Fuzzification and Defuzzification Phases

According to Fig. 8, there are the following values of the membership function of the operation of the fuzzy Petri net:

$\mu 1 = 0.24$; $\mu 2 = 0.26$; $\mu 3 = 0.24$; $\mu 4 = 0.74$; $\mu 5 = 0.26$; $\mu 6 = 0.14$; $\mu 7 = 0.14$; $\mu 8 = 0.14$; $\mu 9 = 0.64$; $\mu 10 = 0.26$; $\mu 11 = 0.14$; $\mu 12 = 0.14$; $\mu 13 = 0.36$; $\mu 14 = 0.26$.

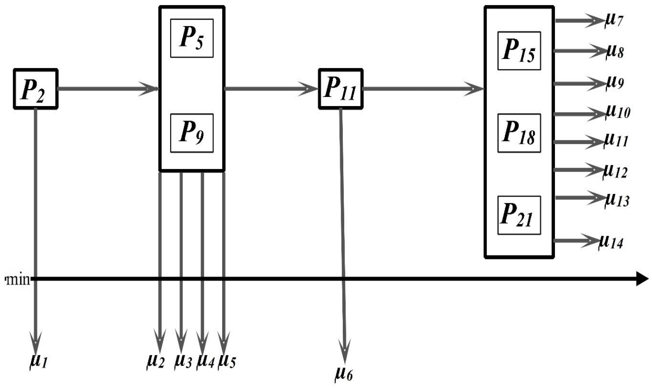

Fig. 8. The structure of Mamdani's fuzzy derivation

The intermediate result, "Comfort", which has the following linguistic meanings: best, average, and insignificant for an apartment, is presented in the form of fuzzy production rules:

1. If overall dimensions = large and location = convenient and convenience is good, then comfort = the best.

2. If overall dimensions = large and location = convenient and convenience is average, then comfort = best.

3. If overall dimensions = large and location = convenient and convenience is bad, then comfort = average.

4. If overall dimensions = large and location = average and convenience is good, then comfort = best.

5. If overall dimensions = large and location = average and convenience is average, then comfort = average.

6. If overall dimensions = large and location = average and convenience is poor, then comfort = insignificant.

7. If dimensions = large and location = bad and convenience is good, then comfort = average.

8. If overall dimensions = large and location = poor and convenience is average, then comfort = insignificant.

9. If overall dimensions = large and location = unsuccessful and convenience is bad, then comfort = insignificant.

10. If overall dimensions = average and location = convenient and convenience is good, then comfort = best.

11. If overall dimensions = average and location = convenient and convenience average, then comfort = average.

12. If overall dimensions = average and location = convenient and convenience is bad, then comfort = insignificant.

13. If overall dimensions = average and location = average and convenience is good, then comfort = insignificant.

14. If overall dimensions = average and location = average and convenience is average, then comfort = insignificant.

15. If overall dimensions = average and location = average and convenience is bad, then comfort = insignificant.

16. If dimensions = average and location = bad and convenience is good, then comfort = average.

17. If overall dimensions = average and location = poor and convenience is average, then comfort = insignificant.

18. If overall dimensions = average and location = unsuccessful and convenience is bad, then comfort = insignificant.

19. If overall dimensions = small and location = convenient and convenience is good, then comfort = average.

20. If overall dimensions = small and location = convenient and convenience is average, then comfort = insignificant.

21. If overall dimensions = small and location = convenient and convenience is bad, then comfort = insignificant.

22. If overall dimensions = small and location = average and convenience is good, then comfort = average.

23. If overall dimensions = small and location = convenient and convenience is bad, then comfort = insignificant.

24. If overall dimensions = small and location = average and convenience is bad, then comfort = insignificant.

25. If dimensions = small and location = bad and convenience is good, then comfort = insignificant.

26. If overall dimensions = small and location = poor and convenience is average, then comfort = insignificant.

27. If overall dimensions = small and location = unsuccessful and convenience is bad, then comfort = insignificant.

The result of the work of fuzzy logical deduction according to the Mamdani algorithm for the component of the Petri net [10, 55], which describes the position of "Comfort" according to the home territory, is presented in Fig. 9.

$$y = \frac{\sum y' * \mu(y')}{\sum \mu(y')} \quad (5)$$

By substituting the value from Fig. 9 into formula 5, the following defuzzification value is obtained:

$$y = \frac{0*0,26+0,26*11,9+0,5*25+0,74*36,9+0,74*64,6+0,5*75+0*100}{0,26+0,26+0,5+0,74+0,74+0,5+0} = \frac{91,06}{3} = 30 \quad (5)$$

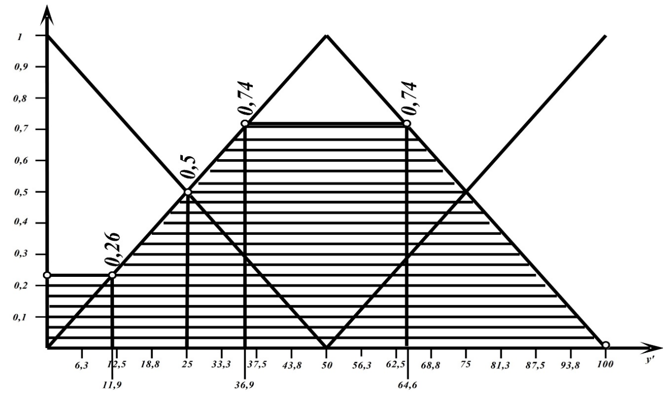

Fig. 9. The stage of defuzzification of the surrounding area (P5) and noise level (P9)

III. Results

The article results prove the presence of a complex system for assessing the comfort of residential apartments in new buildings, which indicates the presence of elements of the system that are difficult to assess using standard precise mathematical methods, one of which is the subjective opinion of each buyer. In order to solve this problem, it was given a more quantitative character, which was determined using a genetic algorithm, the main ideas of which were highlighted in point 2 of the previous section. In addition, comfort itself needs a more apparent scale for working with it. That is why the model of a fuzzy system was practically implemented, which in more than 90% of practical applications allows researching the qualitative nature of problems, which are currently little researched. In particular, this applies to the construction industry as a whole and the problem considered in this article. Mamdani's fuzzy derivation, the authors succeeded in narrowing the blur using accumulation and aggregation, which is a combination of defuzzification, by almost 96%. Comparing the results of the work of the genetic algorithm, which describes the selection of the position of Ri, it is possible to reach such results as:

- raising the status of a specific developer, which is reflected in the frequency of choosing his apartments from new buildings.

- the speed of processing offers from different buyers applying for the same apartment in a new building, on the one hand, and the preferences that a specific client chose for himself for different apartments that he liked.

IV. Discussion

Incorporating artificial intelligence (AI) into the domain of enhancing building comfort and energy efficiency has gained significant importance within the sustainability and user happiness framework. In this discourse, we assess the article considering contemporary articles and advancements in the domain.

This research acknowledges the importance of tenant comfort in apartment buildings since it directly influences their overall quality of life. AI technologies, including machine learning and Internet of Things sensors, have shown the potential to enhance the optimisation of indoor environmental conditions [12]. Artificial intelligence can adjust heating, cooling, and lighting systems in response to real-time data, guaranteeing occupants a pleasant and comfortable living environment.

Recent studies, such as Chiara Bedon et al. [13], underscored the significance of human-centric design, which examined human emotions and psychological comfort in glass buildings. Artificial intelligence can assess the behaviour and preferences of occupants in order to customise building settings, hence improving psychological comfort.

The authors, Valinejadshoubi et al., conducted a study on the integration of the Internet of Things and BIM in order to measure thermal comfort [12]. Integrating artificial intelligence with building information modelling may provide a comprehensive perspective on building performance, facilitating the identification of potential areas for enhancement and optimising energy use.

The research conducted by Tian, Shi, and Hong focuses on the use of data-driven approaches in the design of energy-efficient buildings, explicitly emphasising the significance of quantifying the effects of building envelopes [14]. AI has the potential to make significant contributions to data analysis, particularly in the context of developing ideal envelope designs that prioritise both comfort and energy economy.

The study conducted by Gao, Li, and Wen [15] demonstrates the use of reinforcement learning in achieving energy-efficient thermal comfort management, as shown in their "DeepComfort" technique. Artificial intelligence can consistently modify heating, ventilation, and air conditioning (HVAC) systems, effectively managing the trade-off between maintaining optimal comfort levels and dynamically maximising energy efficiency.

The study conducted by Cotrufo et al. [16] showcases the actual implementation of AI-driven predictive control in the context of commercial buildings, highlighting its effectiveness in optimising the management of building systems. These methodologies may be modified for residential complexes to guarantee occupant comfort and energy efficiency.

The article conducted by Rijal, Yoshida, Humphreys, and Nicol [17] on adaptive thermal comfort models has significance in the context of artificial intelligence (AI)-driven systems that can adjust according to various user preferences and fluctuations in ambient variables.

The study by Zhang, Wen, Tseng, and Jin [18] examines the significance of transparency and comprehension in artificial intelligence (AI) systems, explicitly concerning thermal comfort in intelligent buildings. The authors emphasise that these factors are pivotal in ensuring user adoption of such systems.

The research conducted by Narahara and Yamasaki [19] on predicting subjective functionality and comfort in apartment floor designs aligns with the article's primary objective, which is to explore the use of AI to improve user comfort. Artificial intelligence has the potential to assist individuals in making well-informed decisions about their residential environments [Mykola Tsiutsiura, 2022 #538].

The energy consumption prediction model developed by Kim and Suh [20] places significant emphasis on using AI to enhance energy optimisation in high-rise apartment complexes. Artificial intelligence can predict energy consumption and optimise building systems to save expenses and mitigate environmental consequences.

The article contributes to the expanding corpus of research in AI-driven building comfort and sustainability. The statement above highlights the significance of incorporating user-centric design, data-driven optimisation, and transparency into artificial intelligence systems. By leveraging current research findings and using established methodologies, AI has the potential to assume a crucial function in the development of energy-efficient apartment buildings that prioritise occupant well-being and minimise ecological footprint.

V. Conclusion

The article results prove the presence of a complex system for assessing the comfort of residential apartments in new buildings, which indicates the presence of elements of the system that are difficult to assess using standard precise mathematical methods, one of which is the subjective opinion of each buyer. In order to solve this problem, it was given a more quantitative character, which was determined using a genetic algorithm, the main ideas of which were highlighted in point 2 of the previous section. In addition, comfort itself needs a more precise scale for working with it. That is why the model of a fuzzy system was practically implemented, which in more than 90% of practical applications allows researching the qualitative nature of problems, which are currently little researched. In particular, this applies to the construction industry as a whole and the problem considered in this article. As shown in Fig. 10, which presents Mamdani's fuzzy derivation, the authors narrowed the blur using accumulation.

Furthermore, aggregation, a combination of defuzzification, by almost 96%. Comparing the results of the work of the genetic algorithm, which describes the selection of the position of Ri, it is possible to reach such results as:

- the speed of processing offers from different buyers applying for the same apartment in a new building, on the one hand, and the preferences that a specific client chose for himself for different apartments that he liked;

- raising the status of a specific developer, which is reflected in the frequency of choosing his apartments from new buildings.

The choice of a fuzzy Petri net for assessing the comfort of housing in a new building is justified. A dynamic model was implemented based on the practical results of the study, which simplifies the assessment of the comfort of a particular apartment.

Experimentally determined steps of comfort assessment for building the above model through the mathematical apparatus of system analysis and artificial intelligence.

A fuzzy model has been implemented and extended by an expert genetic algorithm system for determining the price of one or another apartment.

This article described the network operation, which starts from the initial position P1, where marking is used in the transition (t1) and ends activation through the transition (t6) and marking the position P26. Also, the presentation of the fuzzy Petri net has been extended by adding the feature of considering the buyer's preferences in the form of improved chains. Considering that each client has his subjective wishes concerning determining the priority of one factor of comfortable living in a residential building, it is practically established that it is generally only possible to consider some possible options. Therefore, the article's authors suggested considering the assessment of comfortable living in an apartment building using a genetic algorithm. The first step of this method is forming the initial population (IP), which corresponds to the process that determines whether the selection of parents from eight individuals took place. The PP is built using a random selection mechanism. The second step is to assess the quality of chromosomes in the population. This genetic algorithm (GA) stage decodes the current population into a decimal number. After that, each of the eight chromosomes from the above population is evaluated regarding suitability for further evolution. In the third step of GA, selection is considered, that is, the selection of parents using the roulette method. After crossing over and mutation, we will get a sequence of steps to operate a fuzzy Petri net. Applying fuzzy derivation according to the Mamdani algorithm, it is possible to determine the initial price of the apartment based on the obtained model data. This corresponds to the solution of one of the main problems posed by the authors when studying the comfort of living in a residential apartment building.

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