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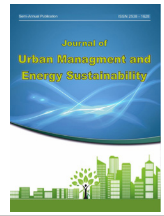

ORIGINAL RESEARCH PAPER

Explanation of indicators affecting the improvement of indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation using the fuzzy Delphi method

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ABSTRACT

Houses located in hot and humid climates, such as those in Iran, greatly benefit from having a central courtyard, which fulfills both functional and aesthetic roles. The incorporation of natural ventilation, particularly through central courtyards, is acknowledged as an effective method for enhancing indoor air quality while reducing energy consumption. By strategically situating windows and openings around the courtyard, architects can utilize prevailing wind patterns, thereby facilitating the movement of fresh air throughout the living spaces. This study employs a descriptive-analytical approach with a focus on development, particularly in elucidating the theoretical foundations, proposed models, and frameworks relevant to this topic. Following a thorough examination of theoretical foundations and a review of the existing literature, alongside an emphasis on clearly defining objectives without redundancy, key factors were identified. These were derived from the research framework and were validated through the Delphi method, resulting in a model of final indicators. The findings indicate that experts and stakeholders identified the size of the courtyard, the number and configuration of rooms, and the design of the roof as the most significant factors affecting indoor air quality in central courtyard houses. These elements received high average scores of 4.30, 4.28, and 4.27, respectively, underscoring their impact on promoting natural ventilation. Future research may focus on exploring the interrelationships among these indicators in specific case studies, allowing for broader generalization of the results.

Running Title: Indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

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INTRODUCTION

Houses in hot and humid climates like those found in Iran benefit significantly from the inclusion of a central courtyard, which serves both functional and aesthetic purposes. The courtyard not only provides a private outdoor space for residents but also plays a critical role in facilitating natural ventilation. In hot and humid areas, the use of cross-ventilation becomes essential for maintaining comfortable indoor temperatures. The design of the courtyard encourages air movement, allowing cooler breezes to penetrate interior spaces, while simultaneously offering shade and reducing the thermal load on surrounding walls. Research has shown that buildings designed with central courtyards outperform those without in terms of maintaining thermal comfort and air quality (Klepeis et al., 2022). Natural ventilation, particularly in the context of a central courtyard, has been recognized as an effective strategy for improving indoor air quality while minimizing energy consumption. By strategically placing windows and openings around the courtyard, architects can harness wind patterns and promote the flow of fresh air. The central courtyard acts as a thermal chimney, where warm air rises and escapes, creating a pressure difference that pulls cooler air from outside into the building (Basu & Khanna, 2023). This design approach is particularly significant in hot and humid climates, as it allows for passive cooling, thereby reducing reliance on mechanical ventilation systems, which can be energy-intensive. In the context of Iranian architecture, the significance of central courtyards in enhancing natural ventilation cannot be overstated. They not only improve thermal comfort but also contribute to the overall aesthetic of the living space. The integration of vegetation within these courtyards further improves air quality by acting as a natural filter, absorbing pollutants and releasing oxygen (Tzoulas et al., 2023). This interplay of architecture, nature, and climate illustrates how traditional design methods can effectively address modern environmental challenges, making central courtyards a vital component in the architectural landscape of hot and humid regions in Iran.

indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

Factors influencing indoor air quality and comfort in buildings involve a comprehensive and multifaceted examination of various components that play a crucial role in the design and evaluation of residential spaces. The proportion and dimensions of the central courtyard are one of the primary factors to consider, as suitable courtyards can effectively improve natural air circulation and help control temperature and humidity. The size of the courtyard can allow residents to utilize outdoor space while enhancing their connection with nature and the positive effects on mental health (Klepeis et al., 2022). Additionally, the type and number of openings, including windows and doors, are other key factors that affect ventilation and natural light. Properly designing these elements can reduce the need for mechanical ventilation systems and consequently save energy. In fact, using large windows and operable openings can give residents control over indoor conditions and facilitate the entry of light and fresh air (Basu & Khanna, 2023). The relationship between the area of transparent surfaces and opaque surfaces highlights the importance of natural light and proper ventilation. The more transparent surfaces there are, the higher the likelihood of natural light and air circulation. Natural light not only enhances the quality of life and reduces darkness but also decreases the need for artificial light during the day, which can lower energy costs (Harrison & Lee, 2022). Furthermore, the orientation of the building is another influential factor that, through the angles of sunlight and wind, assists in optimizing energy consumption and thermal comfort. Research has shown that buildings designed towards the sun can be more successful in capturing natural light and heat, while protecting the interior from cold winds is also important (Miller et al., 2023). This subject is also influenced by the geographical and topographical position of the area. Geological features can affect wind patterns and temperature, contributing to the optimal design of buildings. In fact, areas with favorable topography can enhance natural ventilation and provide beautiful views for residents (Tzoulas et al., 2023). Additionally, the building materials used and their types significantly impact temperature and humidity retention. Materials such as wood, concrete, and brick each have their own specific properties and can contribute to creating a better quality indoor environment. Improper thermal insulation can lead to unwanted heat and humidity entering the building, while a well-designed roof can improve natural ventilation and light entry into the space. Sloped roofs or specially designed roofs can effectively direct wind flow and assist with natural ventilation (Klepeis et al., 2022). The vegetation of the courtyard, including the type and distribution of plants, helps improve air quality and maintain environmental moisture. Additionally, the presence of water features can increase humidity and cool the indoor air.

Research has shown that water features can help reduce indoor temperatures and improve residents' comfort. A suitable combination of plants and water features can contribute to creating a sustainable ecosystem in urban spaces (O'Connor, 2023). The number and type of rooms also shape the spatial division and impact ventilation. Room designs should be based on residents' needs to ensure fresh air reaches all areas. In this regard, the use of natural ventilation systems is an effective method for improving indoor air quality, which requires attention to the climatic conditions of the location and the temperature and humidity levels. Therefore, the design of natural ventilation systems should consider weather conditions and seasonal variations (Harrison & Lee, 2022). Environmental pollutants can significantly affect indoor air quality, as the emission of pollutants from various sources can lead to their infiltration into interior spaces. For example, the presence of busy roadways or polluting industries near a building can severely impact indoor air quality, necessitating effective solutions to mitigate these effects (Basu & Khanna, 2023). In this context, the wind flow and its status around the building are also important. Wind can serve as a natural factor for ventilating and displacing polluted air into the interior, but if not properly considered, it can create problems. Proximity to water sources such as rivers or seas also has a direct relationship with environmental humidity and can influence building design. Buildings located near water sources typically experience higher humidity, which can aid in temperature control and comfort, but specific considerations are needed to prevent issues like mold growth (Miller et al., 2023). Additionally, passive control systems using awnings and curtains can help regulate natural light and temperature. These systems allow users to adjust lighting and temperature to enhance comfort. Moreover, these systems can contribute to reducing energy consumption, thus aiding environmental resource conservation (Tzoulas et al., 2023). Ultimately, residents' experience and awareness play an important role in managing and maintaining indoor air quality. Residents equipped with sufficient knowledge about air quality improvement techniques and resource management can contribute to creating a healthier and more comfortable environment. Educating and providing useful information about air quality, effective ventilation methods, and the care of indoor spaces can increase residents' awareness and sensitivity to their environment (O'Connor, 2023). Operable openings also play a key role in controlling indoor conditions. This capability allows residents to easily draw in fresh air or expel polluted air according to their needs and changing conditions. These fundamental principles should be integrated as part of sustainable design strategies in residential spaces. Overall, investing in the design and creation of these components can lead to improved quality of life, comfort, and health for residents. Consequently, enhancing indoor air quality is not only beneficial for residents but also holds significant long-term importance in sustainable design and natural resource management. Furthermore, considering the interactions among these factors and adopting an integrated approach to achieve better living spaces lead to optimizing human experiences and preserving the environment (Zasepa et al., 2023). The connections and dependencies among all mentioned factors emphasize the importance of a tailored and guided design based on a thorough understanding and analysis of the natural and human requirements and conditions. (Tab. 1) In this table, each of the 20 factors affecting indoor air quality in central courtyard houses in hot and humid climates is listed as follows: (Tab. 1)

Tabel. 1: Input Factors in in indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

Factor	Description	Practical examples	Positive effects	Negative impacts
Geographical location and topography	Impact on temperature and wind in the area	Residences in coastal areas	Cooler air and more humidity	Strong winds in open areas
Characteristics of building materials	Impact on maintaining temperature and humidity	Using insulating materials in buildings	Reducing energy costs and improving comfort	High cost for materials with unique characteristics
Thermal insulation	Preventing heat and humidity from entering	Houses with strong thermal insulation	Reducing energy costs and indoor temperature	Need for repairs and maintenance
Roof design	Impact on ventilation and light entry	Buildings with sloping roofs	Effective ventilation and more natural light	Construction and design costs
Yard vegetation	Impact on air purification and temperature reduction	Local gardens and ornamental trees	Improving air quality and environmental beauty	Need for maintenance and irrigation
Using a fountain	Impact on humidity and coolness	Designing gardens with suitable water features	Increasing humidity and beautifying the space	Maintenance and water costs
Number and type of rooms	Impact on ventilation and living space	Houses with open rooms	Increasing ventilation and the feeling of space	Design challenges and higher costs
Natural ventilation systems	Helping with energy-efficient ventilation	Open-plan buildings	Reducing energy consumption and increasing air quality	Dependence on weather conditions
Ambient temperature and humidity	Influential weather conditions	Building projects in hot and humid areas	Designing in line with climatic conditions	Climate changes
Natural light	Impact on lighting and environmental quality	Using large, light-filled windows	Optimizing use of light and reducing the need for artificial light	Direct radiation and high heat
Environmental pollution	Impact on air quality	Buildings close to traffic	Noise and air pollution	Health challenges that come with pollution
Wind flow	Wind conditions and their effect on ventilation	Buildings designed for natural wind flow	Effective ventilation and reducing energy costs	Unwanted flows
Distance to water sources	Impact on humidity and indoor air	Building projects close to the sea or lake	Maintaining natural humidity and cooling	May result in high costs
Passive control systems	Using awnings and curtains to control light and heat	Using awnings to block direct radiation	Improving comfort and reducing energy costs	Need for annual adjustments

Factor	Description	Practical examples	Positive effects	Negative impacts
Resident experience and awareness	Residents' awareness of optimizing energy consumption	Educational programs for residents	Improving resource management and quality of life	Lack of knowledge
Animated pop-ups	Ability to open and close to control ventilation	Houses with smart and adjustable windows	Effective indoor air control and improving comfort	High cost of installation and maintenance
Sound pollution	Amount of noise pollution and its effect on residents' comfort	Locations close to busy streets	Reducing concentration and stress	Need for sound insulation
Ratio of transparent to opaque surfaces	Ratio of transparent to walls and rooms	Buildings wall open moveable spaces	Improving quality of Air Conditions	Energy concumption ratio
Building orientation	Orientation direction up to the site	Urban fabric buildings axis	Environmental benefits	Wind flow uncontrol issue

Methodology

This research is of a descriptive-analytical type, which has a development aim, but its fundamental characteristic can be pointed out, especially in explaining the depth of the theoretical foundations, the proposed model and framework. The method of collecting information is in the form of a library and field from references such as the architecture department of academic institutions and international data and at the field level. First, after examining the theoretical foundations as well as the history of the research in the two dimensions of procedure and content, where there is an emphasis on clarifying the aim, not repeating it, factors are extracted as the result of the research framework and using the Delphi method as the final indicators proposed in the form of a model. In the Delphi method, in successive courses, by forming an elite board consisting of specialists in the field of architecture, university professors, researchers in the field of architecture in the number of 15 people1, in the form of a digital questionnaire using Google tools and sending the answers in the form of a link. is received, the type of answers is also set based on the Likert spectrum as very low, low, medium, high and very high impact. The number of influencing factors on the subject of the perception of the architectural form is mentioned with regard to the fall of the shadow, which after going through stages including the specified average limit and also calculating the Kendall coefficient for the answers, polling is stopped when a certain average is reached and the final indicators are proposed as a research framework. It will be given. In the following, the extracted indicators are explained as the main model of the research as a result using intermediate analysis.

1. The panel of elites and experts includes 15 faculty members of Tehran University, Tabriz University of Arts, Isfahan University of Arts, as well as researchers of Islamic Azad University and Karaj University of Arts Research Institute.

DISCUSSION AND FINDINGS

Description of the Delphi method

The Delphi method is known as a qualitative research method for solving complex problems and reaching consensus in various fields, including sustainable development and policy making (Zarghami et al., 2019; Manoliadis et al., 2006; Chan et al., 2010; Shi et al., 2015). This method has been well implemented especially in the review and evaluation of factors in research related to sustainable and low-carbon buildings in other countries and has obtained acceptable results (Kamaruzzaman et al., 2019; Alawneh et al., 2019). The fuzzy Delphi method is a research technique that aids in analyzing and gathering expert opinions across various fields. This method is particularly useful for examining complex and multifaceted issues. In the context of indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation, the fuzzy Delphi method can help identify and prioritize the factors that impact the design and construction of these types of buildings. As defined, this method involves multiple rounds of questionnaires where expert opinions are collected and analyzed (Hsu & Sandford, 2007). Utilizing the fuzzy Delphi method allows researchers to achieve a consensus on the importance and necessity of specific factors while evaluating diverse opinions. This method accounts for the uncertainties stemming from varied perspectives by employing fuzzy techniques, thus facilitating decision-making under conditions of ambiguity (Deng, 2011).. Research focusing on identifying selected factors affecting indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation can achieve a more precise understanding through the application of the fuzzy Delphi method. These factors may encompass various aspects of design, construction materials, and renewable energy technologies (Gao et al., 2021). For instance, studies that investigate challenges in zero carbon construction reveal that expert opinions can significantly influence the development of new and effective solutions (Malekzadeh et al., 2022). This approach enables researchers to gather diverse viewpoints and reach comprehensive conclusions. Ultimately, the fuzzy Delphi method serves as an effective tool for identifying and prioritizing the factors that influence zero carbon buildings. This method allows researchers to thoroughly consider the insights and experiences of experts and contribute to the development of strategies aimed at achieving indoor air quality in central courtyard houses in a hot and humid climate (Zheng et al., 2022).

Steps to implement the Delphi method

The Delphi method involves a series of questionnaires or stages that are carried out sequentially with controlled feedback. These stages generally include five steps. In each stage of the research, the Delphi panel members, consisting of experts in the field of low-carbon building design, respond to questions. One notable feature of this method is the anonymity of the panel members, which allows them to express their opinions freely without being influenced by friendly or competitive judgments. In practice, Delphi panel members participate more than once in answering questions. This repetition provides them with an opportunity to reconsider their decisions by reviewing feedback from other experts on each indicator. The exchange of data between panel members is controlled by the researcher. The researcher collects individuals' responses and, after evaluating them, passes the results on to the next round. This process prevents personal discussions among individuals and thus helps facilitate and streamline the work and research process.

Implementation of the Delphi method

After identifying the areas and factors that affect indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation, the Delphi process for evaluating these factors began. The Delphi process includes several fundamental stages and each of the stages will be described. In the first step of the research, factors and areas were identified through a literature review, followed by the initial classification of these factors. After this stage, the first round questionnaire was prepared. To ensure the validity of the questionnaire, copies were delivered in person before final distribution. In this meeting, discussions and exchanges of views regarding the factors mentioned in the questionnaire took place. After analyzing the first round questions, the second round questionnaire was prepared and sent to those individuals. The results confirmed the validity of the questionnaire. For assessing the reliability of the questionnaire, Cronbach's alpha coefficient was used, with a value of 0.982 indicating high reliability.

In the second step, based on the characteristics mentioned in the previous section, the Delphi panel members were identified, and they were invited to participate. In the first meeting, they were given the necessary explanations regarding their responsibilities to respond to the questionnaires in several stages and to continue their collaboration until the end of the process. They were also assured that their responses would remain confidential throughout all stages. In the third step, the first round questionnaire was distributed among 30 panel members, and all individuals responded to the questionnaire. The panel members evaluated the factors derived from the literature review based on their importance in the design of low-carbon buildings in Iran using a Likert scale (from 1 to 5, including very low importance, low, medium, high, and very high). To facilitate brainstorming, the questionnaire included the option for panel members to add their suggested factors based on their professional backgrounds. Additionally, panel members could propose that some factors be combined and presented as a single overall indicator. After collecting and analyzing the responses with SPSS software, statistical factors such as mean, standard deviation, and interquartile range were extracted for each indicator. In the fourth step, the second round questionnaire was prepared based on the feedback received from the first round questionnaire. The aim of this questionnaire was to reassess the factors that achieved consensus as well as to reach consensus on factors that did not, and to evaluate the factors raised by the panel members in the first round questionnaire. This questionnaire was similar to the first round, with the difference that the mean responses were listed for each indicator. Experts could evaluate the importance of each indicator and revise their responses based on the opinions of other experts. It is an important step of the Delphi method. Consensus means the agreement of opinion among experts on a specific topic, and its achievement is measured using data dispersion measurement methods.

Interquartile range

Interquartile Range (IQR) is one of the most commonly used methods for measuring data dispersion in assessing the level of consensus in the Delphi method. The interquartile range indicates the distance between the third quartile (Q3) and the first quartile (Q1) and is calculated using the following formula: IQR = Q3 − Q1 (Relation 1) The acceptable range in the interquartile range depends on the spectrum of responses from the Delphi panel. In this research, experts evaluate each indicator based on a 7-point Likert scale from 1 to 5 according to its importance. In studies where responses are provided on a five-point Likert scale, an interquartile range of IQR ≤ 1 indicates the establishment of consensus.

Standard Deviation

To determine the level of consensus and demonstrate data dispersion relative to the mean for each indicator, the standard deviation (SD) is also calculated. The standard deviation is the square root of the average squared distance of values from the mean and is calculated using the following formula:

$SD = \sqrt{\sum(X_i - \bar{X})^2 / n}$ (*Relation 2*)

Where in this relation:

- SD: Standard Deviation
- Xi: Value of data point i
- $\bar{X}$: Mean of the data
- n: Number of data points

These two tools (interquartile range and standard deviation) help researchers easily assess the level of consensus among respondents and obtain a more precise analysis of the data.

$SD(x) = \sqrt{\sum(X_i - \bar{X})^2 / (n - 1)}$ (*Relation 2*)

In this research, two factors of standard deviation and interquartile range were used to evaluate the consensus of Delphi panel members. This approach helped us to determine which factors were agreed upon by the Delphi panel members in achieving low-carbon buildings and which should be removed from the list of factors.

Importance evaluation of factors

In this research, the mean was calculated to measure the importance of each indicator. The weighted average of each indicator is also reported in the findings section. This criterion was used as a key tool for understanding the relative value of each indicator in in indoor air quality in central courtyard houses in a hot and humid climate. This approach allows us not only to assess consensus among panel members but also to aid in the evaluation and prioritization of key factors, leading to more informed and efficient decision-making in this area. (Tab. 2)

Based on the consensus among the Delphi panel, the factors for indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation were classified into seven areas and 20 factors as shown in Tab. 2.

Findings of primary evaluation step

According to the consensus among the Delphi panel, the factors for indoor air quality in central courtyard houses in a hot and humid climate, emphasizing the concept of natural ventilation were classified into three phases and 20 factors.

Tabel. 2: Factors in in indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

Phases	Indexes ads.	Index	Consensus evaluation
Environemtal	9	Proportion of yard size	
		Building orientation	
		Geographical location and topography	
		Environmental pollution	
		Ambient temperature and humidity	
		Wind flow	
		Yard vegetation	
		Using a fountain	
		Natural light	
Technical	8	Type and number of openings	
		Ratio of transparent to opaque surfaces	
		Characteristics of building materials	
		Thermal insulation	
		Roof design	
		Natural ventilation systems	
		Passive control systems	
		Animated pop-ups	
Human	3	Number and type of rooms	
		Residents’ experience and knowledge	
		Distance to water sources	

Human Phase

This phase focuses on human and social impacts. It means understanding the needs, comfort, and well-being of residents. This phase includes human elements such as residents' experiences, awareness of ventilation systems, individual behaviors, and their ability to manage their living space. The assessment of this phase is carried out using surveys and studying human behaviors in relation to the indoor air quality of a building. In the human phase, experts emphasized that " Residents' experience and knowledge " (average: 4.08) is of great importance for indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation Factors such as proximity to Number and type of rooms, Distance to water sources can be considered. (Fig. 1)

Environmental Phase

This phase refers to environmental and climatic conditions that significantly impact indoor air quality and residents' well-being. Factors such as temperature, humidity, weather conditions, soil type, and the building's exposure to natural resources (like water and vegetation) are among the aspects analyzed in this phase. To assess the importance of this phase, attention is given to factors that directly affect the environment and natural air quality. According to the evaluation of experts, " Proportion of yard size " (average 4.98) and " Building orientation" (average 4.78) are regarded as highly important. (Fig. 2)

Technical Phase

This phase relates to the technologies, equipment, and systems used in buildings. It includes ventilation technologies, insulation, and architectural designs that contribute to improving air quality and reducing energy consumption. To assess the importance of this phase, technical factors affecting building systems and their efficiency are examined, including the capability and effectiveness of ventilation and energy management systems. Experts emphasized that " Type and number of openings " (average: 4.98), "Roof design" (average: 4.89), and "Natural ventilation system" (average: 4.87) are highly (Fig. 3)

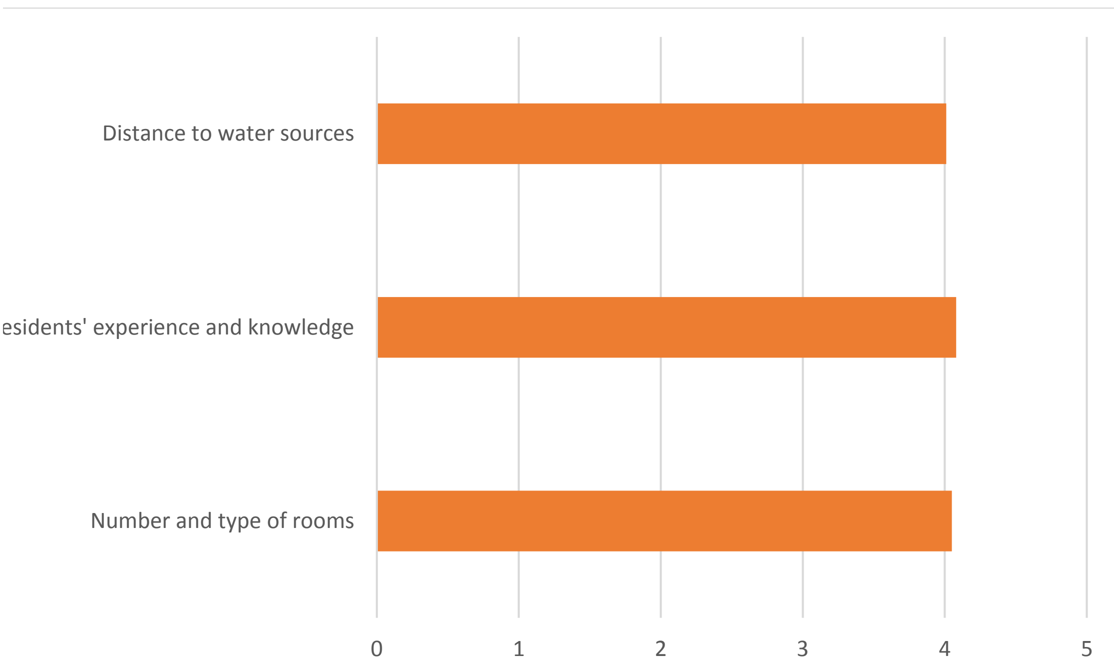

Fig. 1: Average weight of human phase factors according to the importance of the indicator in indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

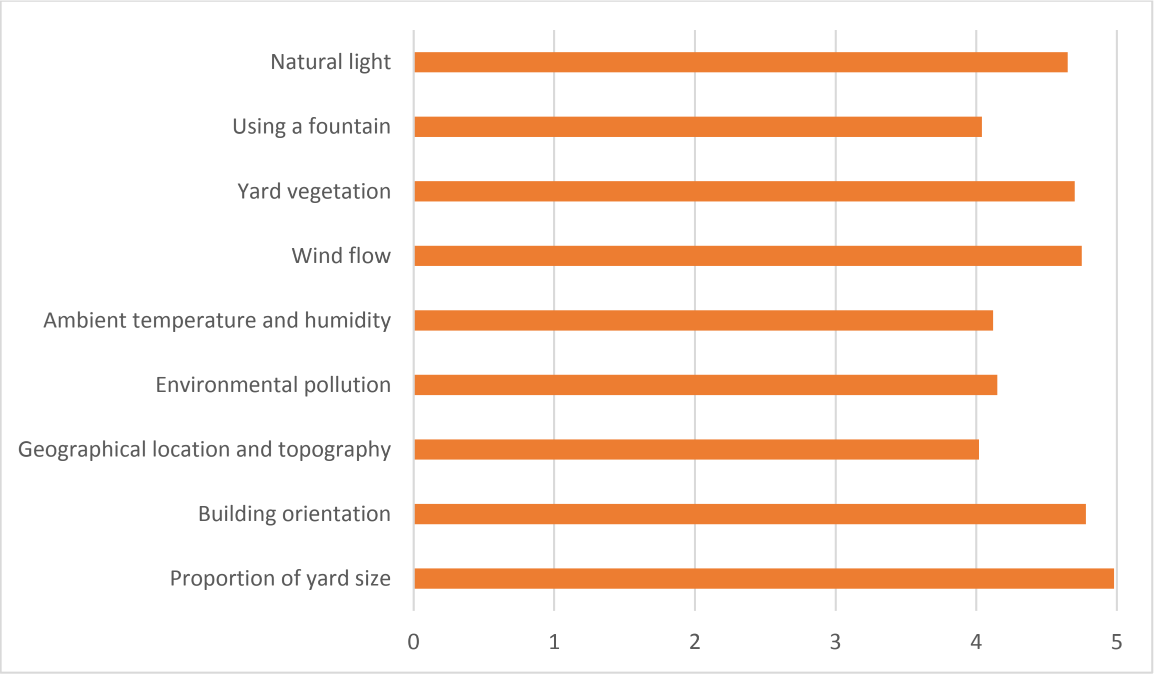

Fig. 2: Average weight of environmental phase factors according to the importance of the indicator in indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

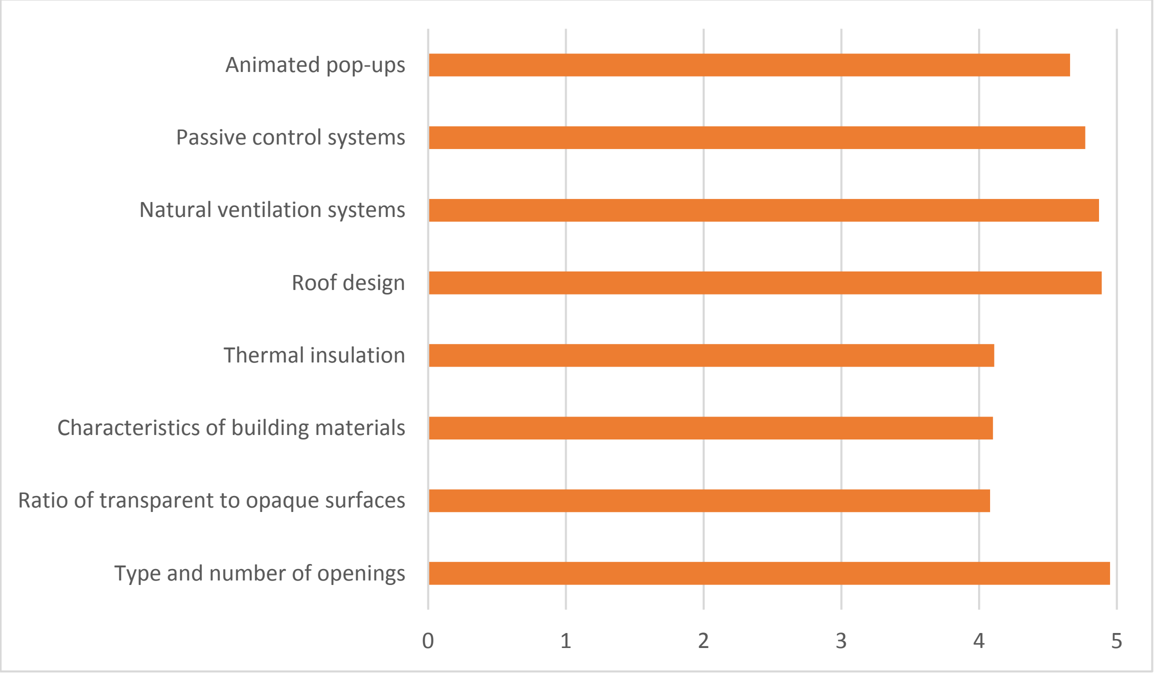

Fig. 3: Average weight of technical phase factors according to the importance of the indicator in indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

Findings of the implementation of the Delphi method

In the first round, the panel members identified 15 factors of 20 factors that were extracted from successful researches as having a great and very great effect in formulating the framework of the indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation. The detailed and extended results related to the implementation of the first stage of questionnaire distribution are given in the following table. The factors of Distance to water sources, Type and number of openings, Using a fountain, Characteristics of building materials and Geographical location and topography has been removed have from the Delphi process due to their average importance of less than 2.5. (Table 3)

After the implementation of the first stage of investigation and evaluation of the opinion of the experts of the panel regarding the factors proposed and extracted from the theoretical bases and also receiving the suggestions of the panel members, in this round, in order to observe caution, all the factors extracted from the theoretical bases are again Together with the average opinion of the members in the first round and the previous opinion of the same member, it was provided to all the experts of the panel. The panel members identified 15 factors out of 20 factors that were presented in the second round as having a high and very high impact (with an average greater than 3) on the proposed framework of the concept of the role of shadows on the perception of architectural form. The detailed and extended results related to the implementation of the second stage of questionnaire distribution are given in the following table. Kendall's coefficient of coordination for the members' answers about the order of the factors that had a high and very high influence in this round was 0.765, among which the factor of Ratio of transparent to opaque surfaces, Thermal insulation, Yard vegetation, Ambient temperature and humidity, Natural light, Environmental pollution, Passive control systems , Residents' experience and knowledge and Animated pop-ups has been removed. (Tab. 4)

Tab. 3: Round 1 of the fuzzy method in compiling the proposed indicators of indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Proportion of yard size	18	3/98	0/35	1	5
2	Building orientation	19	3/78	0/37	1	5
3	Environmental pollution	22	3/15	0/55	1	3
4	Ambient temperature and humidity	18	3/12	0/37	1	4
5	Wind flow	20	3/75	0/40	1	4
6	Yard vegetation	23	3/70	0/25	1	5
7	Natural light	22	3/65	0/45	1	4
8	Ratio of transparent to opaque surfaces	21	3/08	0/38	1	5
9	Thermal insulation	23	3/11	0/47	1	5
10	Roof design	21	3/89	0/60	1	4
11	Natural ventilation systems	22	3/87	0/28	1	5
12	Passive control systems	24	3/77	0/41	1	5
13	Animated pop-ups	21	3/66	0/32	1	5
14	Number and type of rooms	22	3/95	0/35	1	5
15	Residents' experience and knowledge	19	3/08	0/69	1	4

In the third round of compiling the framework of the proposed indicators, the indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate, together with the average opinion of the members in the second round and the previous opinion of the same member, was provided to all panel experts. The detailed and extended results related to the implementation of the third stage of questionnaire distribution are given in the table below. Kendall's correlation coefficient for members' answers about the order of the six factors was 0.790. (Tab. 5)

RESULT AND CONCLUSION

Reasons for stopping polling

The results of the three rounds of implementing the Delphi method in the research show that a consensus has been reached among the panel members for the following reasons and the repetition of the rounds can be ended:

- In the second round, more than 50% of the members, 15 influential factors in developing the framework of the proposed indicators, chose the indicators of indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation, which had an average greater than 2.5 among their factors.
- The standard deviation of the members' answers about the importance of the factors in the third round has decreased significantly compared to the previous rounds.
- Kendall's coordination coefficient for members' answers about the order of factors in the third round is 0.790. Considering that the number of panel members was more than ten people, this amount of Kendall's coefficient is considered quite significant.
- Kendall's coordination coefficient for the arrangement of the 6 influential factors in compiling the proposed indicators of the role

Table. 4: Round 2 of the fuzzy method in compiling the proposed indicators of indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Proportion of yard size	18	4/10	0/38	2	5
2	Building orientation	19	3/91	0/32	2	5
3	Wind flow	20	3/87	0/45	2	5
4	Roof design	21	4/03	0/42	2	5
5	Natural ventilation systems	22	4/01	0/32	2	5
6	Number and type of rooms	22	4/08	0/31	2	5

Table. 5: Round 3 of the fuzzy method in compiling the proposed indicators of indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation

No.	Factors	Number of responses	Average	Standard deviation	Min.	Max.
1	Proportion of yard size	18	4/30	0/25	3	5
2	Building orientation	19	4/21	0/30	3	5
3	Wind flow	20	4/17	0/28	3	5
4	Roof design	21	4/27	0/36	3	5
5	Natural ventilation systems	22	4/25	0/32	3	5
6	Number and type of rooms	22	4/28	0/24	3	5

of cast shadow on the perception of architectural form in the third round compared to the second round only increased by 0.025. This coefficient or the degree of consensus between the panel members Consecutive rounds do not show significant growth.

- The points given to the factors by the experts and elites indicate that the indicators of Proportion of yard size, Number and type of rooms and Roof design have the highest score and as a result the most impact in explaining the indicators affecting of indoor air quality in central courtyard houses in a hot and humid climate emphasizing the concept of natural ventilation in the process of developing the framework of indicators. There are suggestions in form perception, which can be based on the structural model and the research framework.

According to the research process and examination of the theoretical foundations, as well as the use of the research background in the Delphi method to achieve the effective factors on indoor air quality in central courtyard houses in a hot and humid climate, it is possible to predict the extent of the limitation of this type of structure. But in general, the effects of the final indicators on the type of perception clearly have an effect in addition to the type of example based on the psychology of the viewer, the level of awareness and the level of the specialized advertisement. This type of impact on a person's mind can also be investigated according to the type of observer and the environment. Finally, the proposed indicators can provide a specific structure of the type of analysis for the role of indoor air quality in central courtyard houses in a hot and humid climate in the first stage. In future studies, methods such as HSE It was used to check the qualitative conditions of the respondents as well as the type of interview and testing and evaluated the results in a certain way.

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