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Investigating designers' perceptions of thermal comfort: A Q-methodology study in residential design

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Abstract

This study employs a robust mixed methods approach—anchored in Q-methodology and semi-structured interviews—to explore how architects in Ilam, Iran, conceptualize thermal comfort as both technical and cultural discourse. A concourse of 78 statements, refined to 43, was sorted by 20 senior designers. Factor analysis using PQMethod revealed four distinct perception types: (1) passive climate responsiveness, (2) reliance on smart HVAC systems, (3) prioritization of insulation materials, and (4) management of natural light and solar exposure. These viewpoints highlight methodological hybridity, combining subjective discourse with analytical rigor, and reveal how cultural and professional logics shape design priorities. Findings indicate that thermal comfort is a cultural and cognitive construct, shaped by professional judgment, local climate, and social expectations. Q-methodology integrates qualitative interpretation with quantitative categorization to reveal subjective viewpoints with analytical rigor. By situating comfort within cultural and cognitive frameworks, this study demonstrates how Q-methodology enriches sustainability research, guiding climate-responsive design and fostering critical dialogue on energy efficiency and occupant well-being.

Keywords: Q-methodology, Thermal comfort, Energy efficiency, Climate-responsive design, Residential architecture.

1 Introduction

Thermal comfort is not a fixed condition; it is a state of mind. While the definition of thermal comfort does not explicitly outline this state of mind or level of satisfaction, it highlights that the evaluation of comfort is a cognitive process. This process is influenced by a variety of physical, physiological, psychological, and other factors [26]. Thermal comfort is the subjective satisfaction with the thermal environment, influenced by psychological and physiological factors [37,51]. In residential architecture, understanding how occupants experience thermal comfort is essential for designing spaces that promote well-being and energy efficiency [4, 22,25]. Against the backdrop of global energy challenges, achieving thermal comfort is not only a matter of occupant satisfaction but also a pathway to reducing energy demand and mitigating environmental impacts [16]. Residential buildings provide diverse adaptive strategies—ranging from behavioral adjustments to architectural interventions—that can enhance comfort while minimizing energy loss [43,44]. Such strategies are central to climate-responsive design and indoor environmental quality, linking occupant health, productivity, and sustainable resource use [1]. Recent studies highlight how occupant behavior influences both comfort and energy use [8,21,26]. Comfort is shaped by architectural, psychological, and social factors, making it central to energy-efficient building design [2,19,24]. This makes thermal comfort a cornerstone of sustainable building design, where energy efficiency and human experience converge. Historically, research on thermal comfort emerged in the 20th century through the heating, ventilation, and air-conditioning (HVAC) industry, but its contemporary relevance extends far beyond technical optimization [6,8]. Today, thermal comfort is situated within broader sustainability discourses, informing building energy strategies, climate-responsive architecture, and interdisciplinary debates on how environments can support both ecological responsibility and human flourishing [49].

Q-methodology provides a systematic framework for analyzing subjectivity by identifying and categorizing individual viewpoints [29,42]. It enables researchers to quantify shared perspectives within a group [32], making it especially effective for evaluating thermal comfort in residential architecture. Unlike conventional survey methods, Q-methodology captures nuanced perceptions with qualitative sensitivity, while its theory-driven statement selection ensures a broad and relevant discourse [34,35]. Within the broader paradigm of mixed methods research, which integrates both quantitative and qualitative data to enhance explanatory power [14], Q-methodology is often classified as a “hybrid” or “integrative” approach. The process typically begins with qualitative data collection—through interviews, literature reviews, or focus groups—to generate a concourse of statements that reflect diverse opinions on a topic. These statements are then subjected to a structured sorting process (Q-sorting), where participants rank-order them according to subjective criteria. The resulting data are analyzed via factor analysis to reveal shared viewpoints [10,29]. This integrated process exemplifies mixed methods principles by merging subjective insight with statistical rigor [14]. Scholars like [41] highlight its compatibility with the transformative and pragmatic paradigms of mixed methods research, especially when the aim is to shape policy, design, or practice based on insights driven by stakeholders.

This study employs Q-methodology to interrogate how professionals construct and negotiate meanings of thermal comfort within residential architecture. Rather than treating comfort as a neutral technical condition, the approach foregrounds subjectivity, discourse, and cultural context. Developed by William Stephenson in the 1930s, Q-methodology exemplifies methodological hybridity by combining qualitative sensitivity with quantitative rigor. Its capacity to surface shared viewpoints, mental models, and typologies of perception makes it particularly valuable for critical inquiries into how professional knowledge and cultural assumptions shape design practice [42,47]. By integrating subjective insights with analytical precision, Q-methodology provides a robust framework for interrogating how architectural decisions intersect with cultural discourse, environmental responsibility, and the pursuit of sustainable residential design.

The primary objective of this methodology was to gain a nuanced understanding of designers' perceptions, moving beyond mere numerical representation of differing opinions [32]. This study applied Q-methodology to explore how architects and designers in Ilam perceive thermal comfort in residential architecture, combining qualitative depth with quantitative structure. Through structured interviews and Q-sorting, it uncovered nuanced patterns in professional judgment, revealing both shared and divergent conceptualizations. A literature review informed the initial set of 78 design-related statements, which were refined to 43 through expert validation. A purposive sample of 20 experienced professionals was selected from a pool of 54 based on their expertise in architecture, design, and construction. Participants engaged in structured interviews and Q-sorting, providing qualitative insights into their design philosophies and ranking rationale [29,47]. By integrating qualitative and quantitative data, the study revealed both shared and divergent mental patterns, offering a nuanced understanding of how thermal comfort is conceptualized in architectural practice.

This study interrogates how residential designers in Ilam, Iran, construct meanings of thermal comfort within a rapidly urbanizing and climatically diverse context. Moving beyond conventional quantitative approaches, it employs Q-methodology to foreground subjectivity and reveal the cultural, cognitive, and professional logics shaping design practice. By integrating qualitative interpretation with quantitative categorization, the research bridges architecture, environmental psychology, and urban studies, offering a culturally situated framework for stakeholder analysis. Q-sort data were analyzed with PQMethod software, a specialized tool for Q studies that computes factor arrays, z-scores, and correlation matrices to interpret subjective viewpoints [28]. Consistent with Q-methodology standards, the analysis prioritizes factor arrays for clearer interpretation of statement significance [34, 48]. Using Q-methodology and PQMethod analysis, it explores how designers prioritize comfort-related factors and how these views shape architectural decisions. The research addresses two key questions:

(1) What distinct perceptions do Ilam's residential designers hold about thermal comfort?
(2) How do these perceptions form identifiable patterns that influence design priorities and decision-making?

2 Methods

Q-methodology represents a mixed methods approach that bridges constructivist and post-positivist paradigms, enabling researchers to examine subjective viewpoints through structured sorting and statistical analysis [9,11,47]. This dual character—qualitative in developing the Q-sample and interpreting factors, and quantitative in applying correlational and factor-analytic techniques—renders Q-methodology inherently mixed [29]. Unlike conventional surveys with fixed categories, Q-methodology captures nuanced beliefs and groups them into shared perspectives, thereby enhancing interpretive depth and explanatory power [14]. Q-methodology combines qualitative depth with quantitative rigor through tools like principal component analysis [48].Participants sort structured statements in two stages: initial “hard grouping” into sentiment categories, followed by placement in a forced-choice, quasi-normal distribution.This process uncovers consensus and divergence, revealing how subjective judgments are culturally and professionally constructed [45].

2.1 Review Methodology and Concourse Development

To examine designers’ perceptions of thermal comfort in Ilam’s residential buildings, this study applied Q-methodology to identify and categorize subjective viewpoints [50]. From over 420 complexes housing 6,317 residents, a purposive sample of 20 architecture and construction experts was selected. An unstructured Q-sampling approach ensured diversity in statement selection. Of 78 statements derived from interviews and literature, 43 were refined for the Q-sort based on clarity and uniqueness, without thematic coding. As shown in Appendix A, Table 1 presents a sample of the original statements; the complete set, reflecting the most salient perceptions from the concourse phase, is also provided therein.

This study employed Q-methodology to explore the subjective perceptions of residential building designers regarding thermal comfort. The analysis was conducted using PQMethod 2.35, which is specifically designed for Q studies and provides robust tools for factor extraction, z-score computation, and interpretation of factor arrays [39,48]. To construct the concourse—the universe of possible statements about thermal comfort—data were gathered from diverse sources including academic articles, books, specialized journals, theses, and media reports. A discourse space was formed using both textual and visual materials relevant to the topic. Semi-structured interviews were conducted with 20 experienced designers and architects in Ilam, Iran. These interviews allowed for open-ended responses while maintaining consistency across participants.

2.2 Q-sample Construction and Participant Selection

Q-methodology provides a structured way to examine complex issues through participants’ subjective rankings of statements, enabling the identification of shared and divergent viewpoints even in small samples [17]. In this study, 78 statements from interviews and literature were refined to 65, then narrowed to 43 by experts to ensure clarity and diversity. These were printed on uniform Q cards and coded for analysis. A purposive sample of 20 architects and builders (12 men, 8 women) as participants (P-set) was selected from 54 Ilam-based experts based on qualifications and experience in residential design. Q-methodology was used to explore their subjective views on thermal comfort. The statements, developed through literature and semi-structured interviews,

were sorted on a quasi-normal distribution from –5 (strongly disagree) to +5 (strongly agree). This process emphasized personal relevance over standardized metrics, allowing Q-methodology to capture subjective meaning holistically and reveal how designers conceptualize thermal comfort in practice.

All methods were carried out in accordance with relevant guidelines and regulations for research involving human participants Interviews were conducted in person and audio-recorded with participants permission. All procedures involving partcipants were conducted in accordance with relevant institutional and national guidelines and regulations. The study protocol was reviewed and approved by the Ethics Committee of Islamic Azad University, Ilam Branch (Ethical Approval Code: IR.IAU.ILAM.RES. 1404.012). Before participation, all designers received an explanation of the study aims, procedures, and data-handling practices. Informed consent was obtained from all participants prior to the interviews and Q-sorting sessions. Participants voluntarily agreed to take part in the study and provided explicit consent for the use of their anonymized statements and, where applicable, their images in research outputs and publications.

2.3 Q-sample Development and Sorting Procedure

Q-sorting is a technique where individuals rank statements to create evaluative profiles. These Q-sorts serve as datasets analyzed via factor analysis to uncover shared perspectives, known as factors. [23] explain that R methodology is commonly utilized in social sciences to evaluate traits or variables across populations. Unlike R methodology, which focuses on variables, Q-methodology centers on individuals and their subjective viewpoints. Through this ranking process, researchers can identify patterns of shared perception across participants [17].The analytical procedure begins with the collection of Q-sorts, which are then subjected to factor analysis to uncover clusters of individuals who share similar evaluative profiles, thereby highlighting collective viewpoints within diverse subjectivities.

After data collection, Q-methodology applies factor analysis to group participants with similar statement priorities. [48] stress that meaning emerges from each item’s position within the overall configuration, emphasizing thought patterns over isolated scores. Q-sorts were processed using PQMethod software, which applies principal components and varimax rotation to generate factor arrays that reveal shared perspectives [34]. Unlike general statistical tools, PQMethod is specifically designed for Q-methodology.To perform factor analysis, specialized software such as PQMethod [39] or Ken-Q Analysis [7] is commonly used. The software facilitates centroid factor extraction and varimax rotation, enabling the identification of latent factors and the generation of factor arrays and z-scores. Factors were retained based on eigenvalues greater than 1 and at least two significant Q-sorts [40,47]. A conservative significance threshold of $p < 0.01$ was applied, meaning that Q-sorts with loadings of 0.413 or higher were considered statistically significant [38]. Final interpretations relied on crib sheets documenting key rankings, distinguishing statements, and consensus items [3,47].

To explore designers' perceptions of thermal comfort in residential buildings in Ilam, a series of statements was created based on a literature review and semi-structured interviews with experienced professionals. Participants were intentionally chosen for their expertise in thermal comfort design. Out of 78 initial statements, four architectural experts refined this list to 43 statements, ensuring clarity, diversity, and thematic breadth. These statements were printed on standardized Q cards, each uniquely coded to prevent bias in format, typography, or layout, thereby enhancing the methodological rigor and interpretive validity of the study. Participants were instructed to sort the cards according to the following conditions of instruction: *"Please sort the following statements based on how important you believe each factor is in achieving thermal comfort in residential buildings, considering your professional experience and design philosophy."* This instruction was designed to elicit subjective judgments about the relative importance of each item, even though many of the statements were phrased in technically objective terms. This focused prompt ensured that the Q-sort reflected each participant's personal perception rather than assumptions about residents. Using a forced quasi-normal distribution grid ranging from strongly disagree (–5) to strongly agree (+5), participants first categorized the cards into Agree, Disagree, and Neutral piles, then placed them on the Q diagram accordingly. Each participant's sorting pattern was recorded using a standardized form designed for this study. An example of how Q cards were distributed on a Q-sort diagram, the "Q chart diagram," using the forced-choice instruction condition, completed by one of the participants, is shown in Figure 1. It is worth noting that Forced distribution involves participants using a graded scale to place cards in each grade, with the researcher determining the number of cards in each column. This uniformity allows for a deeper understanding of participants' mindsets, as they pay more attention to examining statements placed at both ends of the scale, making it more challenging to determine their position on the scale [11]. Figure 2, available in Appendix A, shows photographs of several participants actively engaged in the Q card sorting process, highlighting their involvement during the activity.

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
18	34	25	32	10	21	2	23	11	4	15
	14	9	35	42	27	8	16	1	12	
		20	23	6	33	3	13	24		
		38	17	5	30	36	7	43		
			39	31	28	37	29			
				26	40	41				
					19					

Fig. 1 An example of Q-sorting.

The study area of this research is Ilam. Ilam Province is located in western Iran and shares a border with Iraq. It is known as one of the hottest regions in the country; however, the mountainous areas in the north and northeast of Ilam experience relatively cooler

temperatures. Ilam city serves as the provincial capital and is the third-largest Kurdish city in Iran. The Kabir Kouh mountain range lies to the east of the city, while the border with Iraq is situated to the west. The majority of Ilam's residents are Kurdish, and Kurdish is the primary language spoken in the region. Figure 3[1] illustrates the location of Ilam Province within Iran and shows the distribution of residential complexes in Ilam city, marked with numbers 1 to 4. These complexes typically consist of five- or six-story buildings, with each floor containing four residential units. Amenities such as parking spaces, play areas, and green spaces are commonly provided Figure 4[1] presents satellite imagery of Ilam city, highlighting the spatial distribution of residential complexes across the urban landscape.

The validity of the test refers to the ability to infer from the sampling behavior [13]. In Q-methodology, validity focuses on accurately capturing hidden traits through qualitative analysis rather than statistical generalization [33]. The aim is to ensure the Q set reflects diverse mentalities, requiring critical evaluation of its representativeness [15]. This study achieved strong content and face validity via literature review, expert input, and participant feedback. Academics and bank executives contributed to content validity, while formal validity was confirmed through participant-guided Q-sorting. Interviews and surveys with university professors refined phrasing and keywords, enhancing clarity and relevance for evaluating the research topic.

3 Results

This research phase employed a quantitative approach to identify shared mindsets, complementing earlier qualitative inquiry. Q factor analysis focused on factor arrays—idealized Q-sorts—rather than individual loadings, with tools such as z-scores structuring interpretation. Rooted in interpersonal solidarity, Q-methodology categorizes participants by shared perspectives rather than variables, underscoring its distinctiveness despite statistical parallels with traditional factor analysis [31]. Interview data were distilled into 43 concise statements on thermal comfort, directly converted into Q-sample phrases without thematic coding, ensuring representative clarity for analysis.The finalized Q phrases used in the study are presented in Table 2.

Table 2 Q-Phrases from the conducted interviews

Q final phrases from the interview	Sources
01. Adjusting the amount of clothing according to the temperature	interviews (1)(7)(12)
02.Adjusting the amount of window opening according to the air temperature	interviews (1)(2)(4)(17)
03.Individual characteristics (height, weight, age, population)	interviews (6)(7) 13)
04. Ventilation and air conditioning	interviews (2)(3)(13)
05.Sleep quality	interviews (6)(10)(14)(15)(17)(20)
06.Ability to use natural energy	interviews (7)(9)(16)(19)
07.Using the color of the walls according to the air temperature	interviews (2)(9)
08.Using awning for openings	interviews (3)(12)(18)(20)
09.The effect of the amount of noise in the space	interviews (6)(12)(17)

[1] Figures 3 & 4 are available in Appendix A. for readers seeking visual context and additional geographic detail.

10.The use of vegetation in people's living areas	interviews (6)(7)(11)
11.The effect of mental factors on the thermal comfort of people	interview (19)
12.The amount of moisture in the air	interviews (1)(4)
13.Air flow speed	Interviews (4)(9)(11)
14.Furniture arrangement form	interviews (3)(6)(7)
15.Air temperature	interviews (2)(6)(11)(13)(14)(17)(19)
16.Effect of body skin surface temperature	Interviews (1)(6)(12)
17.Satisfaction with people's living space	interviews (6)(7)
18.The fabric of the curtains	interviews (1)(3)(9)(12)
19.Adjust the number of curtains according to the air temperature	interview (6)
20.Setting the number of lights on and off	interviews (7)(11)(12)(13)(16)(18)(20)
21.Use of electrical household appliances based on air temperature	interviews (6)(10)
22.Change in the state or position of people in space	interviews (2)(5)(9)(12)(15)(18)
23.Changes in the individual's metabolism by consuming hot and cold drinks	interviews (3)(5)(15)(19)
24.Choosing hot and cold food according to the temperature	interviews (2)(6)(13)
25.The number of people traveling in space	interviews (12)(20)
26.getting used to the space	interviews (12)(14)(17)(19)
27.Duration of presence of people in space	interviews (4)(6)(14)(18)
28.Adjusting the amount of activity of people in the space	interviews (7)(11)(13)
29.Choosing the activity time of people in the space according to the air temperature	interviews (2)(4)(7)(8)(14)(17)(18)
30.Mental state of people	interviews (1)(3)(8)(20)
31.Having a sense of belonging to a place	interviews (6)(9)(18)(20)
32.Adjusting the opening ratio and the location of doors and windows	interviews (1)(12)(14)(16)(17)
33.The number of direct and indirect light in the space	interviews (4)(7)(15)(11)
34.Density of objects and guests in space	interviews (2)(3)(7)(11)(20)
35.The number of people in space	interviews (5)(8)(9)(10)(13)(15)(18)(19)
36.Controlling the radiation of the opening through the use of the radiation band and the outer awning	interviews (3)(6)(13)(16)
37.Use of appropriate thermal insulation in the building	interviews (6)(13)(18)
38.Type and material of window	interviews (3)(4)(8)(10)(12)(18)(20)
39.Adjusting the height of the ceiling according to the climatic conditions	interviews (6)(12)(17)(19)
40.Using materials suitable for the region's climate	interviews (15)(18)(20)
41.Orientation of the building according to the climatic conditions	interviews (7)(11)
42.Attention to the geometry and form of the building	Interviews (4)(14)(17)(20)
43.Air quality	Interviews (1)(4)(8)(13)

3.1 Data Analysis and Interpretation Framework

The study utilized PQMethod 2.35 for analyzing Q-sorts, applying centroid factor extraction and varimax rotation to clarify factor structures [39]. Factor retention was guided by eigenvalues >1.00, scree plot analysis, cumulative variance, and theoretical coherence [30,40]. A significance threshold of ±0.413 ($p < 0.01$) was used to identify defining participants [38]. Centroid extraction revealed latent factors through correlation coefficients, followed by varimax rotation to ensure strong single-factor loadings [9,47]. Varimax rotation was then applied to maximize explained variance and ensure each Q-sort loaded strongly onto a single factor [47]. A conservative significance level of $p < 0.01$ was maintained, with factor loadings of 0.413 or higher considered statistically significant [46]. Eigenvalues indicated explained variance, with the final solution accounting for over 35%, meeting interpretive standards [40,47]. Z-score arrays and crib sheets helped

identify distinguishing and consensus statements [3], aligning with Q-methodology norms [34,48].

Interpretation involved analyzing ranked statements to uncover core beliefs, supplemented by mid-ranked and consensus items for thematic coherence [47]. Factor arrays, scaled from –5 to +5, revealed shared and divergent views. Crib sheets synthesized these into narratives, enriched by demographic links [23]. The four retained factors were labeled according to their dominant themes: *passive climate responsiveness, technological control via smart HVAC systems, material-centric thermal regulation, and solar exposure and daylighting management.* The four extracted factors represent distinct perceptions of thermal comfort among Ilam's residential architecture, reflecting varied design logics and priorities. Table 3[2] displays participant loadings, showing Factor 1 supported by 12 individuals, Factors 2 and 3 by three each, and Factor 4 by two. This distribution reinforces both the interpretive coherence and statistical reliability of the factor solution.

Table 4 revealed four distinct factores (denoted by F_i: for i=1,2,3,4) regarding thermal comfort in residential design. The first factor (F_1), labeled "Passive climate responsiveness," reflects a shared emphasis on passive thermal regulation strategies among participants 2, 4, 7, 11, 12, 13, 15, 16, 17, and 19. Key statements ranked highest include "Air temperature" (z = +2.14), "The amount of moisture in the air" (z = +1.98), and "The use of vegetation in living areas" (z = +1.76), along with others related to spatial openness and adaptive clothing. Additional supporting phrases include Statement 32, "Adjusting the opening ratio and the location of doors and windows" (z = +1.53), Statement 1, "Adjusting the amount of clothing according to the temperature" (z = +1.47), and Statement 19, "Adjust the amount of curtains according to the air temperature" (z = +1.42). These rankings reflect a shared emphasis on passive thermal regulation strategies, particularly those related to air temperature, humidity, and spatial openness. In contrast, statements like "Setting the number of lights on and off" (z = –1.89), "Getting used to the space" (z = –1.74), and "Density of objects and guests in space" (z = –1.61) were ranked lowest, indicating their perceived irrelevance. These rankings support the factor's label and align with climate-responsive design principles. Table 4 shows participant alignment, with four types classified by highest factor loadings at 99% confidence.

Table 4 Rotated factor arrays

Participants No.	Factors scores			
	F_1	F_2	F_3	F_4
1	-0.016	0.676	0.511	0.239
2	0.685	0.388	-0.142	-0.223

[2] To view the extracted components related to the factor coefficients of each participant, refer to Appendix A.

3	0.280	0.096	0.607	0.275
4	0.698	0.047	-0.222	0.372
5	0.126	0.128	0.803	-0.094
6	0.011	0.749	-0.143	0.210
7	0.595	0.361	0.464	-0.339
8	-0.102	0.166	0.335	0.855
9	0.216	0.871	0.186	-0.091
10	0.206	0.540	0.255	0.594
11	0.526	0.453	0.332	-0.423
12	0.650	0.149	0.372	-0.116
13	0.835	0.104	0.217	-0.115
14	0.466	0.647	0.252	-0.076
15	0.751	0.265	0.168	0.062
16	0.635	0.078	0.278	0.114
17	0.819	0.093	0.083	-0.076
18	0.386	0.714	0.237	-0.216
19	0.624	0.516	0.370	-0.138
20	0.128	0.184	0.784	0.189

Extraction method: Principal component analysis Rotation method: Varimax with Kaiser normalization.

3.2 Q Factor Analysis and Interpretation Framework

Following Q-sorting, data were analyzed using PQMethod 2.35, which applies principal component analysis and varimax rotation to extract factors and generate z-scores [11, 39, 47]. Each factor represents a shared viewpoint, with scores converted to the original Q-sort scale (−5 to +5) to form composite arrays for group comparison [5]. Typically, one factor is extracted per six to eight participants, and valid factors must explain at least 35% of variance and include two significant Q-sorts [47]. Final solutions rely on eigenvalues, variance, and loading patterns [23]. PQMethod supports both automated and manual rotation, with post-rotation matrices guiding factor clarity and merging. Interpretation demands statistical insight, exploratory logic, and theoretical alignment [29]. The software's manual provides detailed guidance for newcomers to Q-methodology.

Q factor analysis identified distinct perception types that reflect how designers conceptualize thermal comfort in residential architecture. Using PQMethod-generated factor arrays as idealized Q-sorts, the study holistically interpreted prioritization patterns by grouping participants based on subjective rankings. Through principal component analysis and varimax rotation, four latent perception types were extracted. Table 5 summarizes each factor's eigenvalue and explained variance, illustrating their contribution to overall variance. This focus on factor arrays provides a comprehensive view of collective perceptions and design priorities.

Table 5 Total variance explained

Factors	Extraction sums of squared loading			Rotation sums of squared loading		
	Total	% of variance	% of Cumulative	Total	% of variance	% of Cumulative
F_1	8.488	42.442	42.442	5.311	26.557	26.557
F_2	2.505	12.523	54.965	3.956	19.779	46.336
F_3	1.666	8.331	63.296	3.070	15.348	61.685
F_4	1.326	6.632	69.928	1.649	8.243	69.928

Extraction method: Principal component analysis.

In Q factor analysis with varimax rotation, factors with eigenvalues above 1 are emphasized for their explanatory value, reflecting variance from squared loadings [40]. Yet, Q-methodology prioritizes interpretive coherence over rigid thresholds. [30] propose calculating eigenvalues by adjusting explained variance with participant count, integrating statistical and qualitative insights. Four perception types emerged, accounting for 69.92% of variance, with scree plot analysis confirming their significance [40, 47]. As shown in Figure 5, the scree plot confirms the retention of four factors with eigenvalues greater than 1, supporting their interpretive significance with respective variances of 26.55%, 19.77%, 15.34%, and 8.24% consistent with what is seen in Table 5. These represent distinct perceptions of thermal comfort.

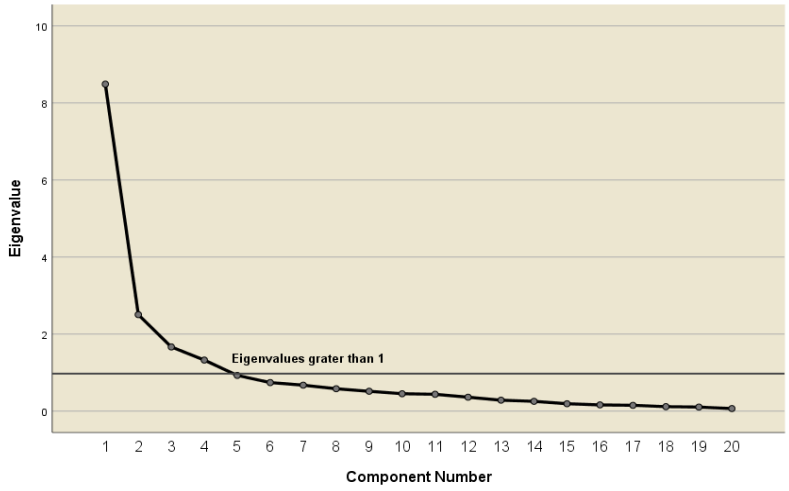


Fig. 5 Scree plot of extracted factors.

3.3 Factor arrays and Factor z-scores

In Q-methodology, factor arrays serve as interpretive tools that visualize data patterns and shared meanings [3]. Although the design and analysis of Q studies are well established, guidance on factor interpretation remains limited [47, p. 147]. Watts & Stenner [47] emphasize the use of “crib sheets” to analyze arrays by identifying top and bottom-ranked items, uniquely positioned statements, and those central to a factor’s viewpoint, while also allowing space for researcher insight. Interpretation relies on both arrays and z-scores, ensuring each statement is examined for its potential significance [47, pp. 153–155]. In this study, crib sheets were expanded beyond Watts and Stenner’s framework to include distinguishing items unique to each factor, consensus items shared

across factors, and responses from post-sort questions linked to participants. Factor arrays generated by PQMethod thus represent idealized Q-sorts, capturing collective viewpoints and situating them within cultural and professional contexts.

Q-methodology revealed four distinct interpretive positions among Ilam's residential designers. The first emphasizes passive climate‑responsive strategies—insulation, shading, and natural ventilation—highlighting air temperature as central to comfort. The second privilege of smart HVAC systems is advocating programmable and adaptive technologies as markers of modern efficiency. The third centers on insulation materials, ranking wall composition and roof conductivity as decisive for thermal regulation. The fourth foregrounds daylight and solar exposure, stressing the need to balance natural light with thermal control to avoid glare and overheating. Together, these factors illustrate how professional judgments construct thermal comfort as both technical and cultural discourse, situating design practice within broader methodological hybridity and critical inquiry.

Following Q-sorting, factor analysis revealed four distinct mental frameworks among 20 residential designers regarding thermal comfort. Interpretation centered on factor arrays—idealized Q-sorts derived from ranked statements and z‑scores—rather than individual loadings, consistent with Watts and Stenner's emphasis on arrays as interpretive tools [47, pp. 147-155]. Visualized as Q diagrams, these arrays represent collective prioritizations of the 43 Q-sample items, ranging from strong agreement (+5) to strong disagreement (–5). They capture shared professional viewpoints and situate them within broader cultural and methodological contexts [3]. To deepen understanding, selected statements from each array were organized in Table 6, bridging statistical analysis with qualitative insight and highlighting which elements of thermal comfort and environmental design emerge as central or peripheral to each perception type. To enhance interpretation, z-scores were computed for all statements, with those exceeding ±1.00 deemed significant and used to construct narrative profiles. This method emphasizes distinctive viewpoints over statistical metrics, ensuring participant perspectives guide interpretation. This Table highlights the most salient statements for each factor, which played a central role in shaping the thematic labels and conceptual clarity of the findings.

Table 6 Factor arrays Q-sort values and z-scores (Selected statements)

Statements	Q-sort value F_1	z-score F_1	Q-sort value F_2	z-score F_2	Q-sort value F_3	z-score F_3	Q-sort value F_4	z-score F_4
Air temperature	+5	+2.14	+4	+2.14	+1	+1.92	+3	+1.67
Moisture in air	+4	+1.98	+3	+1.76	+3	+1.84	+2	+1.53
Vegetation use	+4	+1.76	–1	–0.94	0	+1.63	–1	–0.88
Ventilation & AC	+1	+1.53	+5	+2.35	+3	+1.88	+3	+1.72

Radiation control	+2	+1.34	+2	+1.41	+2	+1.56	+5	+2.41
Building orientation	+1	+1.12	0	+0.87	+3	+1.44	+4	+2.18
Lighting control	–5	–1.89	–2	–1.42	–2	–1.67	–3	–1.94
Mental factors	+3	+1.63	–4	–1.94	–1	–0.88	+3	+1.76
Furniture arrangement	-2	-1.61	-3	-1.88	-2	-1.74	-4	-2.05

Note: Z-scores ≥ ±1.00 were used to interpret factor meaning, in line with Q-methodology standards.

To interpret perception patterns, the study used PQMethod software to process Q table data and factor loadings. Factor labeling was based on ranked statements—distinguishing, consensus, and mid-range—reflecting broader participant views. z-scores, as weighted averages of aligned Q-sorts, were converted into integer scores to reconstruct each factor's ideal Q-sort. Factor weights were calculated using the formula: $W = f/(1 - f\text{^}2)$, then multiplied by initial ranks to derive scores. Principal component analysis with varimax rotation was conducted via PQMethod to identify underlying dimensions of subjective perspectives. Automatic flagging ($p < 0.01$) identified defining Q-sorts. Interpretation emphasized significant z-score patterns over factor size or variance, consistent with Q-methodology's focus on clustering subjective viewpoints. In the following Table 7 summarizes the key metrics for each factor, including eigenvalues, explained variance, and the number of defining participants. Then, based on these ranks, it was determined in which region of the spectrum of the Q-diagram each of the expressions is placed. Full reconstruction of factorial arrays according to factorial scores and their sorting and assigning numbers between -5 and +5 according to factorial scores are shown in Table 8[3].

Table 7 Factor extraction and rotation summary

Rotation Method: Varimax with Kaiser Normalization

Factors	Eigenvalue	% Variance explained	Participants No. defining factor
Passive climate responsiveness	5.311	26.56%	2, 4, 7, 11, 12, 13, 15, 16, 17, 19
Smart HVAC systems	3.956	19.78%	1, 6, 9, 10, 14, 18
Insulation material priority	3.070	15.35%	3, 5, 20
Solar exposure & daylighting	1.649	8.24%	8, 10

The statement numbers shown in the diagrams correspond to the original Q-sample phrases developed during the concourse phase. The full Q Diagram for four perception types, shown in Tables 9-12[3]. These Q diagrams provide a visual representation of how each perception type prioritizes thermal comfort factors. The rankings reflect the shared professional judgments of participants within each group and serve as the foundation for the interpretive analysis presented in the following section.

4 Discussion

[3] See Appendix A.

This study employed Q-methodology to interrogate how residential designers in Ilam, Iran construct and negotiate meanings of thermal comfort within architectural practice. By integrating qualitative sensitivity with quantitative rigor, Q-methodology provides a systematic framework for exploring subjectivity [47]. The analysis of 43 curated statements, processed through Q-sorts and PQMethod 2.35, revealed four distinct perception types, each reflecting divergent design priorities. As McKewon & Thomas [29] argue, Q-methodology exemplifies methodological hybridity by beginning with qualitative Q-sample development and culminating in quantitative factor analysis, thereby uncovering shared viewpoints without reducing them to variables. This dual structure bridges narrative depth and statistical precision, aligning method with research questions to illuminate complex human perspectives [14]. In this study, four interpretive positions emerged: (1) passive climate responsiveness, privileging natural ventilation, shading, and greenery; (2) reliance on smart HVAC systems, emphasizing programmable and adaptive technologies; (3) material-centric regulation, focusing on insulation and envelope performance; and (4) solar exposure management, balancing daylight aesthetics with thermal control. These varied perspectives underscore Q-methodology's capacity to capture nuanced design logics and situate professional judgments within broader cultural and environmental discourses, rather than enforcing a singular architectural approach.

This study highlights the transformative role of qualitative inquiry in examining architects' culturally situated perceptions of thermal comfort. Using Q-methodology, comfort is reframed as a contested construct shaped by diverse professional logics. Four distinct perception types—ranging from passive climate responsiveness to technologically mediated control—illustrate the multiplicity of worldviews in architectural practice. The approach demonstrates methodological innovation and reflexivity, revealing underlying belief systems and challenging dominant paradigms in environmental design. Findings extend across disciplinary boundaries, offering practical insights, acknowledging limitations, and informing future planning. Moreover, the research highlights the interpretive value of library-based exploration and participant subjectivity in enriching conceptual frameworks for sustainable design. In climate-responsive architecture, where design decisions are shaped by personal experience, cultural context, and environmental awareness, this methodological hybridity is particularly valuable. By combining semi-structured interviews with Q-sorting, the study elicited nuanced viewpoints from practicing architects and distilled them into coherent typologies using PQMethod software. This approach aligns with [14] advocacy for methodological complementarity in complex social inquiries, demonstrating how qualitative depth can be systematically structured without compromising interpretive richness. The resulting typologies—ranging from passive design advocates to technology-oriented practitioners—reflect the multifaceted nature of thermal comfort strategies and underscore the utility of Q-methodology in bridging epistemological divides within architectural discourse [34,40]. Thus, the study contributes to the advancement of mixed methods research by offering a replicable model for exploring professional cognition in environmentally responsive design.

In response to the first question of this research, it should be stated that Q factor analysis revealed four distinct perception types among residential designers in Ilam, each reflecting a unique mental model of thermal comfort. Importantly, these perspectives are

not ranked by statistical dominance; Q-methodology values interpretive richness over prevalence. Type 1 emphasized passive climate responsiveness, with high z-scores for air temperature (+2.14), humidity (+1.98), and vegetation (+1.76), and low scores for lighting control (–1.89) and spatial density (–1.61), indicating a preference for natural design solutions. *Designers aligned with this factor prioritize passive design strategies—natural ventilation, humidity control, and spatial openness—as key to thermal comfort.* Type 2 prioritized technological control through smart HVAC systems, ranking ventilation (+2.35) and airflow speed (+1.88) highly, while downplaying noise (–2.01) and mental factors (–1.94), reflecting a precision-driven approach. *This group favors engineered solutions—automated HVAC systems and airflow management—over behavioral or spatial interventions.* Type 3 focused on material-centric regulation, valuing insulation and wall composition (air temperature z = +1.92), with low emphasis on behavioral factors like sleep quality (–2.04). *This group Focused on building envelope performance—insulation, material selection, and thermal conductivity—as the foundation of comfort.* Finally, Type 4 centered on solar exposure and daylighting, with strong preferences for radiation control (+2.41) and building orientation (+2.18), while deprioritizing air quality (–2.22) and appliance use (–2.05). *Designers aligned with this factor Emphasizes managing solar gain and daylighting through orientation and shading to optimize comfort.* These findings highlight diverse design logics and demonstrate how Q-methodology captures subjective priorities, revealing multiple approaches to conceptualizing and addressing thermal comfort in residential architecture.

In addressing the second research question on how perception patterns shape architectural decision-making, it becomes clear that each viewpoint identified through Q-methodology directly informs design practice. Designers who emphasize passive climate strategies focus on natural ventilation, landscape integration, and sustainable spatial layouts. Those oriented toward smart HVAC systems promote programmable technologies and energy-efficient appliances, while material-centered perspectives influence insulation standards and construction detailing. Solar-oriented designers, in turn, prioritize building orientation, shading devices, and daylight management—particularly significant in Ilam's variable climate. Collectively, these distinct logics extend beyond individual design choices to shape broader frameworks, policies, and planning approaches. Recognizing such mental models enables the development of targeted interventions and context-sensitive solutions that balance occupant comfort with environmental psychology.

The four perception types identified in this study show both alignment and divergence with existing research on thermal comfort. Perception Types 1 and 3, which emphasize air temperature, humidity, and material-based strategies, align with climate-responsive approaches found in studies by Abdollahzadeh et al. [1], and Hashemi [20], who also highlighted climate-responsive and material-based strategies in hot and dry regions. Similarly, the focus on solar control and building orientation in Perception Type 4 echoes the work of Fedorczak-Cisak et al. [18], who examined the impact of shading and daylighting on thermal comfort. The prioritization of smart HVAC systems in

Perception Type 2 is consistent with Maher et al. [27], who emphasized airflow and temperature distribution in engineered environments. However, the study diverges from research centered on physiological, behavioral, and sociocultural factors—such as those by Aqilah et al. [6], Zhang et al. [51], and Hitchings [21]—as statements related to individual traits, movement, and emotional context were consistently ranked low. This suggests that designers in Ilam prioritize spatial and technical solutions over occupant physiology, underscoring the need for future research that incorporates resident feedback and post-occupancy evaluations to bridge the gap between design intent and lived experience. Similarly, Zhang [52] and Zhou et al. [53], highlight the role of physical activity and metabolic variation in shaping comfort. Yet, Statements 25 and 29—related to movement and activity timing—were also ranked low, suggesting a divergence from Zhang's behavioral emphasis. Although Statement 11 was included in the Q-sample, it did not emerge as central to any of the identified perception types, reflecting the more design-oriented scope of this study.

By integrating qualitative sensitivity with quantitative rigor, Q-methodology enables factor-based analysis of subjectivity and offers a systematic lens for interpreting professional worldviews [36]. While not intended for statistical generalization, it facilitates substantive inference, generating broader insights into population-level phenomena. The perceptions noted among designers align with technical and architectural literature but differ from studies that emphasize physiological or behavioral aspects of thermal comfort. This divergence highlights the disciplinary boundaries separating physiological research, sociocultural inquiry, and professional design perspectives. In this regard, Q-methodology proves valuable in capturing the logic of architectural practice and establishes a foundation for comparative studies that may incorporate residents or other stakeholder groups. Such methodological hybridity highlights how professional subjectivity can be systematically examined while remaining attentive to cultural and contextual complexity.

5 Conclusions

This study demonstrates that thermal comfort in residential design is not a universal technical condition but a culturally embedded construct shaped by professional judgment, local climate, and social expectations. By applying Q-methodology, we revealed four distinct perception types among designers in Ilam, Iran, highlighting how disciplinary logics and socio-material practices inform climate-responsive strategies. These findings advance sustainability research by merging subjective discourse with analytical rigor, situating thermal comfort within cultural and cognitive frameworks that enrich debates on energy-efficient architecture.

This study underscores the value of integrating structured qualitative methodologies—such as Q-methodology—into architectural research to surface the often-overlooked subjectivities that shape design practice. By situating Q-methodology within the cultural and climatic context of Ilam, the study demonstrates how thermal comfort is not merely a technical condition but a culturally mediated construct. Comfort emerges as a contested terrain where professional subjectivities, disciplinary traditions, and socio-material practices converge. The implications extend beyond local practice: they underscore the need for interdisciplinary approaches that integrate architecture, environmental psychology, and sustainability studies to foster resilient and inclusive design. By connecting occupant well-being with ecological responsibility, the study offers practical insights for reducing energy demand while enhancing quality of life. This research contributes to critical dialogue on sustainable futures, demonstrating how culturally situated perspectives can guide climate-responsive residential design and inform broader sustainability strategies.

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Author contributions
Mohammad Tohidi wrote the main manuscript, provided conceptualization, contributed to writing—original draft preparation, writing—review and editing, software development, methodology design, investigation, data curation, and formal analysis; **Karen Fatahi** contributed to writing—original draft preparation, writing—review and editing, supervision, provision of resources, methodology design, funding acquisition, validation, data curation, investigation, and conceptualization; **Ali Omranipour** supervised the writing process, reviewed the manuscript, and investigation; **Maryam Beigi** reviewed the manuscript, and managed research project and contributed to funding acquisition. All authors have read and approved the final manuscript.

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Data availability
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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Ethical approval and consent to participate
Not applicable.

Ethical Considerations
In accordance with research ethics, informed consent was obtained from all participants prior to the interviews. This study was approved by the Ethics Committee of the Islamic Azad University, Ilam Branch, under the ethics [code No. IR.IAU.ILAM. RES.1404.012].

Consent to publication
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Competing interests
The authors declare no competing interests.

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Not applicable.

Supplementary Material

Supplementary material for this article is available in Appendix A.

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