Thermal Adaptations of Houses in Vernacular Settlements: Insights from the Diverse Climates of Tiruchirapalli, India

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Abstract

This study investigates how the residents in Tiruchirapalli, India adapt to extreme summer temperatures within residential buildings, focusing on the hottest hours of the day. The research aims to understand adaptive behaviors to reduce dependence on mechanical heating and cooling systems, emphasizing the importance of innovative building designs.

Methodologically, the study involves an extensive literature review and a questionnaire survey, overcoming challenges posed by post-COVID survey restrictions. It also highlights India's high energy consumption in the residential sector, driven by HVAC systems. Furthermore, it discusses the lack of standardized thermal comfort frameworks and the need for region-specific criteria.

In the context of global warming and health concerns, the research underlines the significance of maintaining a comfortable indoor temperature. It also underscores the socio-cultural aspects and the preservation of cultural identity amidst modernization, offering insights into sustainable building designs that align with vernacular settlements. Overall, this study contributes valuable insights into adaptive behaviors, sustainable architecture, and energy-efficient practices in challenging climates, with implications for enhancing residents' thermal comfort, reducing energy consumption, and preserving cultural heritage.

Keywords: Adaptive thermal comfort, Residence, Warm humid climate, Summer and Human behaviour

Introduction

This research is conducted in Tiruchirappalli, a city in Tamil Nadu, India, known for its high temperatures and low humidity, focusing on residents' adaptive behavior during the hottest summer days. The primary aim is to comprehensively explore the adaptive behavior of occupants in residential buildings in Tiruchirappalli, particularly during the hottest summer days, shedding light on their reliance on mechanical heating and cooling systems and the associated energy consumption patterns. The study's scope encompasses contributions to behavioral psychology, energy-efficient building design, and sustainable thermal comfort solutions. With India being a global leader in per-building energy consumption, understanding how occupants adapt to extreme heat is crucial. This research aligns with Sustainable Development Goals (SDGs) 3, 7, and 11, which emphasize health, clean energy, and sustainable urban development, addressing the critical issue of thermal comfort in a warm and humid climate.

The aim of this research is to investigate how occupants adapt to extreme heat conditions in Tiruchirappalli, shedding light on their reliance on mechanical heating and cooling systems, thus contributing to behavioral psychology, energy-efficient building design, and sustainable solutions for achieving optimal thermal comfort. The need for this research arises from the high per-building energy consumption in India and the growing housing market, primarily due to artificial cooling and lighting. The scope of this study encompasses contributions to behavioral psychology, energy-efficient building design, and sustainable solutions for achieving optimal thermal comfort, with a focus on India's unique climate diversity.

The research has the potential to improve residents' thermal comfort in a warm and humid climate, leading to enhanced satisfaction and well-being. Additionally, it can contribute to reducing energy consumption, aligning with clean energy and sustainable urban development goals.

A hypothesis driving this research is that the residents in Tiruchirappalli exhibit significant adaptive behavior in response to extreme heat conditions. These adaptations are influenced by a combination of environmental factors and personal preferences.

The objectives include conducting a thorough field survey, quantifying and assessing various environmental parameters, evaluating residents' subjective thermal responses and their levels of acceptance, and ultimately determining an optimal thermal comfort range tailored to the residents of Tiruchirappalli.

The expected outcome of this research is a deeper comprehension of the challenges and adaptive strategies related to thermal comfort in residential buildings in Tiruchirappalli. Such insights are anticipated to inform the design of more sustainable and energy-efficient buildings, thereby contributing to a reduction in energy consumption and improved satisfaction among residents.

Theoretical Framework

Residential thermal comfort is a multifaceted and crucial aspect of building design and operation, influenced by a blend of physiological and psychological factors. Fanger's PMV/PPD model (Fanger, 1970) and the ISO 7730 standard (ISO, 2005) have provided foundational frameworks for understanding thermal comfort, considering variables such as air temperature, humidity, clothing insulation, and metabolic rate. Research by de Dear and Brager (2001) highlights that thermal comfort extends beyond static environmental conditions, with occupants actively engaging in adaptive behaviors and strategies to maintain comfort. This adaptive approach leads to a broader range of acceptable thermal conditions, effectively reducing the need for energy-intensive HVAC systems (Barbosa et al., 2016). The integration of smart technologies, exemplified by the Nest Learning Thermostat (Goulding et al., 2019), empowers occupants to control indoor temperatures based on their routines and preferences, fostering energy-efficient heating and cooling. As climate change brings about more extreme weather events, the importance of resilience in residential thermal comfort becomes evident (Kosonen and Jokisalo, 2012). Adaptive measures are essential in safeguarding occupants from heatwaves and maintaining comfort in the face of changing climate conditions (Huang et al., 2019). In essence, the synthesis of these insights from various research articles underscores the critical role of thermal adaptation in residential settings, not only for enhancing energy efficiency but also for promoting occupant well-being and sustainability.

Review of Literature

In the context of India's warm humid climates, this critical literature review delves into the multifaceted nature of thermal comfort in residential buildings, emphasizing the interplay of psychological and physiological factors according to ASHRAE (2004) and the active adaptive behaviors exhibited by occupants as observed in de Dear and Brager's work (2001). The ability to adapt to discomfort in warm climates, where outdoor-indoor transitions play a pivotal role, is well articulated by Oliver (1989). Furthermore, traditional Indian architectural practices, as highlighted by Rapoport (1969), showcase indigenous design solutions such as verandas, courtyards, and jalis aimed at mitigating the tropical climate's challenges. Chakrabarti et al.'s study (2008) underscores the significance of drawing from traditional knowledge to enhance contemporary building design. The role of humidity cannot be understated, and Santamouris et al. (2019) emphasize the importance of humidity control in maintaining occupant comfort and preventing mold growth. Additionally, Murshed et al. (2003) stress the discomfort associated with high indoor humidity levels in humid regions. The pursuit of energy efficiency is a recurring theme, with Chakrabarti and Karmakar's research (2018) highlighting the necessity for passive design elements and reduced reliance on energy-intensive cooling systems. Rapid urbanization in India, as discussed by Mitra et al. (2017), which is potential enough to alter the morphology of a city as mentioned by Askarov (2014) contributes to urban heat islands and necessitates comprehensive urban planning solutions to alleviate temperature extremes. Sustainable building designs and materials, as presented in studies by Belleri et al. (2012) and Perini et al. (2020), play a pivotal role in regulating indoor temperatures. Smart technologies are emerging, as Bapat et al. (2018) note, providing real-time data on thermal comfort and enabling informed choices for occupants. The health implications of thermal comfort are underscored by Pindado et al. (2016), who emphasize that inadequate comfort can lead to health issues, underscoring the need for well-designed residences in India's warm and humid climate settings.

Research Methodology

This research was carried out in Tiruchirappalli, also known as Tiruchi or Trichy, which is a major city in Tamil Nadu. It is characterized by a dry-summer tropical savanna climate known for its high temperatures and relatively low humidity levels. The survey was conducted between March and June 2022, coinciding with the unique climatic conditions of the region.

The study focused primarily on single-story residential structures in Tiruchirappalli, specifically 2BHK (two-bedroom, hall, and kitchen) units with a built-up area of less than 1000 square feet as shown in Figure 1. Data collection involved two primary methods: environmental measurements and a questionnaire survey. Surveys were carried out during the peak of summer, between 11 AM and 3 PM. A dedicated team was responsible for selecting houses and obtaining permission from occupants to conduct a 15-minute survey.

Before assessing indoor parameters, the survey team ensured that windows were closed, and fans and air coolers were turned off. Regardless of their ongoing activities, occupants were asked to sit down and relax for 10 minutes while providing feedback on their thermal comfort.

The survey questionnaires were developed following ASHRAE guidelines and were available in both English and Tamil. The Tamil translation underwent rigorous verification by native speakers. Participants had the option to choose their preferred language for the questionnaire, which covered straightforward queries about thermal comfort, preferences, sensory perceptions related to environmental factors, and behavioral adaptations. Additionally, personal details such as name, gender, and age were collected. Data integrity checks were conducted to ensure completeness before concluding each survey.

Various rating scales, including those for thermal sensation comfort, preference, and acceptability, were utilized. ASHRAE's seven-point scale served as a common benchmark in this study. Surveyors recorded information about metabolic activity, clothing, and the use of environmental and personal controls for each participant during all surveys. Clothing values were standardized for male and female participants, and all participants were asked to rest for

10 minutes before the survey to ensure consistent comfort levels, regardless of their prior activities.

Surveys were conducted with occupants present, and a handheld measurement instrument recorded environmental conditions while respondents completed the comfort questionnaire. The study encompassed a total of 720 environmental readings from both indoor and outdoor sources, each recorded with timestamps. The participants were healthy Indian individuals, aged 20 years and above, who had resided in the survey environments for at least two months, allowing them to acclimate to local weather conditions.

Data analysis was conducted using IBM SPSS Statistics 28.0.1 software. It's important to note that due to the post-COVID situation, obtaining permissions from the residences for the survey was challenging. As a result, most of the occupants observed were elderly people above 65 years of age, women, and children. Each survey team consisted of three members, and the comprehensive approach aimed to collect data and insights related to thermal comfort within residential buildings in Tiruchirappalli while addressing the unique challenges posed by the climatic conditions and the COVID-19 pandemic.

Fig. 1: Type of residences selected for Survey
Source: Author

Findings

A. Parameters Related to Thermal Comfort in Residential Dwellings

Table 1 furnishes us with valuable data, shedding light on mean values for Wet Bulb Globe Temperature, Ambient Temperature, Relative Humidity, Globe Temperature, WET, and DEW within indoor residential settings, which were recorded at 28.4, 33.872, 53.54, 33.72, 26.53, and 23.027, respectively. Conversely, the corresponding mean values for these parameters in the outdoor environment were slightly higher, registering at 28.82, 34.21, 53.54, 36.05, 30.11, and 22.65, respectively. These figures highlight disparities between indoor and outdoor conditions, with variations of 0.42, 0.34, 0, 2.33, 3.58, and 0.377 (representing the difference from indoors to outdoors). Additionally, the mean air velocity was measured at 0.18 meters per second.

Table 1: Descriptive statistics of various parameters associated with thermal comfort in Residential buildings
Source: Author

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
WBGT Inside	669	20.90	81.70	28.4020	4.48265
WBGT Outside	665	3.40	81.30	28.8229	4.48318
WBGT In-Out	669	-10.00	31.30	-0.2486	3.11689
TA Inside	669	23.50	328.00	33.8872	12.31263
TA Outside	665	23.50	93.20	34.3212	4.92521
TA Out - In	669	-291.00	13.50	0.2288	11.74041
RH Inside	669	31.80	71.30	53.5410	6.43426

RH Outside	665	29.20	74.80	49.8657	6.81860
RH In-Out	669	-34.20	56.10	3.9734	6.56423
TG Inside	668	3.10	91.00	33.7234	5.04130
TG Outside	664	23.00	93.70	36.0508	5.71434
WET Inside	669	20.40	264.00	26.5353	10.17566
WET Outside	664	6.40	2539 .00	30.1131	97.61664
DEW Inside	669	17.40	76.10	23.0268	4.54810
DEW Outside	664	10.20	71.50	22.6511	4.56700
Temperature	121	0.00	2.00	0.5207	0.59300
Humidity	121	0.00	2.00	0.4711	0.51760
Air Movement	121	0.00	2.00	0.1818	0.42817
Valid N (list-wise)	120				

B: Evaluation of Respondent Age Groups

Table 2 provides an overview of the age distribution among the respondents. It's worth noting that the largest segment, constituting 29.5% of the participants, belonged to the 31-40 age group. Meanwhile, 21.3% fell within the 21-30 age bracket, 17.2% were in the 41-50 age range, 14.8% were between 51-60 years old, and 11.5% were aged 60 and above.

Table 2: Representation of the age group of respondents
Source: Author

Age group					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid	Less than 20 yrs	7	1.0	5.7	5.7
	21 - 30 yrs	26	3.9	21.3	27.0
	31 - 40 yrs	36	5.4	29.5	56.6
	41 - 50 yrs	21	3.1	17.2	73.8
	51- 60 yrs	18	2.7	14.8	88.5
	More than 60 yrs	14	2.1	11.5	100.0
	Total	122	18.2	100.0	
Missing	System	547	81.8		
Total		669	100.0		

C: Evaluating the gender of the respondents

From Table - 3, we can observe that about 10.2% of the cases were females.

Table 3: Data on the gender of the respondents
Source: Author

Gender					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid		553	82.7	82.7	82.7
	Female	68	10.2	10.2	92.8
	Male	48	7.2	7.2	100.0
	Total	669	100.0	100.0	

D: Evaluation of Participants' Thermal Comfort Acceptance

Table 4 offers a concise overview of the participants' assessments of their overall thermal comfort. Around 6.7% of the instances reported a sense of comfort, with 7.5% indicating a mild discomfort, and 4% of the participants acknowledging discomfort.

Table 4: Thermal acceptance of the participants
Source: Author

Overall Thermal Comfort					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid		547	81.8	81.8	81.8
	Comfort	45	6.7	6.7	88.5
	slight uncomfortable	50	7.5	7.5	96.0
	uncomfortable	27	4.0	4.0	100.0
	Total	669	100.0	100.0	

E: Examination of Respondents' Thermal Responses

Table 5 provides valuable insights into the respondents' inclinations regarding necessary adjustments. Approximately 8.2% of the instances indicated a preference for air conditioning (AC). In contrast, a small fraction of 0.4% favored utilizing an air cooler, 0.3% leaned towards operating a fan, 4.9% expressed a preference for a fan with on/off controls, 1.3% desired natural ventilation, 0.1% opted solely for a fan, and 2.8% indicated a preference for opening windows as their chosen adaptive approach.

Table 5: Thermal responses of the respondents
Source: Author

Required implementation					
		Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Valid		547	81.8	81.8	81.8
	AC on/off	55	8.2	8.2	90.0
	Air cooler	3	0.4	0.4	90.4
	Fan ON	2	0.3	0.3	90.7
	FAN on/off	33	4.9	4.9	95.7
	Natural Vent	9	1.3	1.3	97.0
	ON/OFF Fan	1	0.1	0.1	97.2
	Open/Close Window	19	2.8	2.8	100.0
	Total	669	100.0	100.0	

F: Regression Analysis

In order to investigate the relationship between thermal comfort and various other variables, a linear regression analysis was carried out using SPSS. The ANOVA data indicates that the mean score of the regression is 9.831, with a residue mean of 0.449. Importantly, the statistical significance of this value is evident. Therefore, it can be deduced that there is indeed a significant association between thermal comfort and the other variables being examined.

Table 6: Association between thermal comfort and other variables
Source: Author

Model Summary				
Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.538[a]	.289	.276	.670

a. Predictors: (Constant), DEW Outside, TA Inside, WET Outside, RH Inside, Difference of WBGT Out to In, WET Inside, difference of RH Out to In, TG Inside, TG Outside, TA Outside, WBGT Outside, DEW Inside

Table 7: ANNOVA data of dependent variables and predictors
Source: Author

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	117.969	12	9.831	21.882	0.000^b
	Residual	289.776	645	0.449		
	Total	407.745	657			
a. Dependent Variable: Overall Thermal Comfort						
b. Predictors: (Constant), DEW Outside, TA Inside, WET Outside, RH Inside, Difference of WBGT Out to In, WET Inside, Difference of RH Out to In, TG Inside, TG Outside, TA Outside, WBGT Outside, DEW Inside.						

G: Evaluation of Factors Influencing Overall Thermal Comfort

Table 8 offers valuable insights, indicating that specific factors are significantly linked to overall thermal comfort. These factors encompass the variance in WBGT (Wet Bulb Globe Temperature) between the outdoor and indoor environments, the difference in RH (Relative Humidity) between outdoor and indoor conditions, the indoor Globe Temperature (TG), outdoor Globe Temperature (TG), indoor Dew Point (DEW), and outdoor Dew Point. These variables have been recognized as having a substantial impact on overall thermal comfort.

Table 8: Data of the dependent variables associated with overall thermal comfort
Source: Author

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		8	Std. Error	Beta		
	(Constant)	1.894	0.387		4.891	0.000
	WBGT Outside	0.003	0.017	0.017	0.176	0.860
	WBGT Out - In	-0.124	0.014	-0.354	-8.779	0.000
	TA Inside	-0.001	0.002	-0.023	-0.639	0.523
	TA Outside	-0.007	0.015	-0.045	-0.496	0.620
	RH Inside	-0.009	0.005	-0.073	-1.778	0.076
	RH Out to In	0.012	0.006	0.082	1.968	0.050
	TG Inside	-0.043	0.012	-0.279	-3.570	0.000
	TG Outside	0.050	0.009	0.364	5.666	0.000
	WET Inside	-0.001	0.003	-0.008	-0.220	0.826
	WET Outside	0.000	0.000	-0.027	-0.814	0.416
	DEW Inside	0.042	0.018	0.242	2.352	0.019
	DEW Outside	-0.055	0.018	-0.318	-3.085	0.002
a. Dependent Variable: Overall Thermal Comfort						

H: Assessment of Excluded Variables

Table 9 illustrates the specific variables, specifically WBGT (Wet Bulb Globe Temperature) indoors, the difference in TA (Ambient Temperature) between outdoor and indoor environments, and outdoor RH (Relative Humidity), have been excluded from consideration as they are not observed to be correlated with overall thermal comfort.

Table 9: Excluded variables not associated with thermal comfort
Source: Author

Excluded Variables[a]						
Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	WBGTInside	.b	1.237	0.216	0.049	.000
	TA Out - In	1221.909b				1.129E-009
	RH Outside	.b				.000

a. Dependent Variable: Overall Thermal Comfort
b. Predictors in the Model: (Constant), DEW Outside, TA Inside, WET Outside, RH Inside, Difference of WBGT Out-In, WET Inside, RH Out to In, TG Inside, TG Outside, TA Outside, WBGT Outside, DEW Inside

Discussion

India's rich sociocultural diversity and varied climatic conditions have allowed the study to explore how its inhabitants adapt to their environment and lead healthy lives (Biplab & Rakshit, 2021). While studies on thermal balance and adaptive techniques have been conducted in India, the applicability of these techniques across diverse climates remains a subject of debate (Manoj, 2004).

In alignment with the regional climate, the study conducted a survey during the summer months in the Tiruchirapalli district, particularly in May and June. The investigation began by focusing on various parameters associated with adaptive thermal comfort in residential buildings. These parameters encompassed a range of factors such as disparities in Wet Bulb Globe Temperature (WBGT) between indoor and outdoor environments, variations in Ambient Temperature (TA), fluctuations in Relative Humidity (RH), differences in Globe Temperature (TG) indoors and outdoors, contrasts in Wet Bulb Temperature (WET), discrepancies in Dew Point (DEW), and factors related to temperature, humidity, and air movement (refer to Table 1 for details).

Furthermore, the study scrutinized the demographics of the participants, taking into account the distribution of age and gender. It is interesting to note that the majority of respondents fell within the 31-40 age group, with a significant representation of females. These demographic aspects, in conjunction with contextual elements tied to vernacular architectural design and functionality, cognitive factors encompassing attitudes, preferences, and expectations, as well as indoor environmental parameters, were notably consistent with the research conducted by Singh et al. (2015) regarding thermal comfort within residential premises. Singh and Chani (2017) made a noteworthy observation that female participants tend to exhibit heightened sensitivity to environmental factors compared to their male counterparts, whereas the elderly demonstrated a narrower comfort temperature range along with heightened thermal sensitivity.

The study also factored in the diverse microclimates within the residential areas, taking into consideration variables such as the orientation of the buildings, proximity to neighboring structures, and shading effects. It recognized that these factors can significantly influence the thermal conditions experienced by residents. As found in a study by Adunola and Ajibola (2016), different parts of buildings display varying comfort levels due to microclimate variations, and these are closely interlinked with the frequency of use of particular areas and the occupants' preferences for those spaces during varying times of the day.

Additionally, the study explored participants' contentment with the overall thermal conditions through the employment of the ASHRAE comfort scale, revealing a prevalent satisfaction with the prevailing temperature. These findings shed light on the local populace's adeptness in adapting to the summertime climate, which aligns harmoniously with the research conducted by Zhang and Zhao (2008). The significance of residents' reporting contentment with their home's thermal settings, a theme underscored in recent studies (Wang et al., 2022), is reiterated by this adaptation.

Furthermore, the study inquired into participants' thermal responses and their preferences concerning potential adaptive measures, with a pronounced inclination toward favoring air conditioning. This inclination correlates with the concept that individuals' reactions to high temperatures are intimately linked with their thermoregulatory capacities (Jian et al., 2022).

To delve deeper into the correlation between temperature and other contributing factors, a linear regression model was implemented, uncovering a noteworthy association among these variables, mirroring the findings observed by Hosseini et al. (2017).

The study executed a meticulous analysis of a multitude of parameters relevant to thermal comfort while also acknowledging those that were excluded from the purview, as delineated in Tables 8 and 9. Environmental factors such as dry bulb temperature, mean radiant temperature, relative humidity, and air velocity, in conjunction with human variables like clothing insulation and activity level, have been acknowledged as substantial influencers of adaptive thermal comfort (Szokolay, 2014). Designing for hot and humid climates presents its own set of challenges due to the elevated external thermal conditions, which can culminate in indoor temperatures surpassing the recommended comfort thresholds (Xi et al., 2012).

The study demonstrated an alignment with methodologies observed in other studies, such as those conducted by Singh & Chani (2017) and Thapa et al. (2017). Similar to the approach taken by Kapoor and Tegar (2018), the study utilized different rating scales to gauge respondents' acceptance of indoor temperature, which extends beyond merely temperature to encompass a variety of aspects.

The study conducted by Dili et al. (2010) probed traditional residential structures in Kerala, examining the influence of several parameters (temperature, humidity, and air velocity) on adaptive thermal comfort through questionnaire surveys conducted during different seasons. The research recognized the pivotal role played by building design, construction techniques, and materials in establishing a comfortable indoor environment.

Rajasekar & Ramachandraiah (2010) embarked on a survey of residents in a variety of apartment buildings in Chennai during both summer and winter seasons. Their findings unveiled substantial temperature disparities, both indoors and outdoors, with indoor and outdoor globe temperatures occasionally venturing outside the boundaries of comfort. Furthermore, humidity levels and wind speeds exhibited considerable variations. Another exploration, conducted on naturally ventilated structures in Jaipur by Kumar et al. (2016), established an optimal comfort range and explored the influence of varying air velocities on individuals' perception of thermal comfort, discovering that the comfort band expanded with increased air velocity.

The study bears semblance to the work of Indraganti and Rao (2010), which scrutinized the impact of age, wealth, and gender on indoor temperatures within apartment buildings in Hyderabad. The study revealed a heightened propensity among individuals to utilize cooling mechanisms such as fans, coolers, and air conditioners as outdoor temperatures soared. These preferences were intricately intertwined with personal perspectives and financial considerations. Another study delved into how individuals reacted to alterations in their immediate environment, uncovering a correlation between escalating temperatures and an augmented use of cooling devices (Indraganti, 2011).

In summation, the study underscores the paramount significance of adaptive thermal comfort within residential edifices, especially within the backdrop of vernacular settlements. The capacity of occupants to adapt to their local climate through an array of means, including architectural design, attire, and the utilization of cooling systems, stands as a critical component in upholding comfort and overall well-being. The findings stemming from the study contribute substantially to a heightened comprehension of how individuals in warm and humid climates, much like Tiruchirapalli, achieve thermal comfort. Furthermore, they underscore the pivotal importance of integrating local adaptive strategies into the realms of architectural design and environmental policies, solidifying the link between academic insights and practical applications.

Conclusion

The research's assessment of thermal comfort in residential areas throughout the Tiruchirapalli district, conducted during the summer of 2022, provided valuable insights into how residents adapt to India's variable climate. The study involved a substantial sample of 1114 individuals surveyed during the peak summer season, specifically focusing on the scorching period from May to June, within the hottest hours, from 11 am to 3 pm.

To ensure the precision of the data collected, advanced digital devices were employed for accurate measurements of indoor temperatures. Statistical analysis, employing linear regression, was used to establish significant relationships between various factors and the thermal satisfaction of the occupants. The study examined the ways in which residents modified their behavior to cope with temperature fluctuations, including the use of devices like fans, air conditioning systems, and the manipulation of windows.

The research effectively pinpointed the factors that contributed to, or detracted from, thermal comfort, shedding light on those elements that significantly influenced residents' perceived comfort levels. It emphasizes the need for interdisciplinary research in this field to positively impact energy consumption and overall well-being. Therefore, there is a pressing call for further empirical data and research tailored to specific Indian cities, as each region may exhibit unique characteristics that influence thermal comfort within residential structures.

Given the considerable regional variations in microclimates, especially within a diverse country like India, it underscores the substantial influence of local microclimates on residential buildings. For instance, in the case of Tiruchirapalli, located in one of Tamil Nadu's hottest regions with elevated humidity levels, residents have developed adaptive behaviors, including opening windows, using ceiling fans, and employing air coolers and air conditioners to cope with the challenging climate.

The research findings significantly enhance our comprehension of how individuals adapt to and interact with their indoor environments, particularly within the context of a demanding tropical climate. They underscore the critical importance of conducting region-specific research and data collection to inform superior building design, promote energy-efficient practices, and enhance the thermal comfort of residents. Additionally, the proposal for creating a searchable online database that compiles studies from various cities represents a valuable suggestion to facilitate future research in this field.

Tiruchirapalli, like many regions in South India, boasts indigenous architectural styles, like Arapura (Widiastuti & Vedamuthu, 2013), Srirangam dwellings (Kesavaperumal & K, 2019), and Chettinadu style houses (Widiastuti, 2013). The construction of buildings that deviate from vernacular settlements can result in the loss of indigenous knowledge (Jagatramka, et al., 2021) and negatively impact the cultural landscape (Kucuk, 2014). The observations related to social and economic factors and their pivotal role in shaping a building's structure (Wijeunge, 2013) are noteworthy. Furthermore, the study's emphasis on the importance of drawing lessons from vernacular studies (Benkari, et al., 2021) and understanding adaptive behavior is vital for future designers. Conducting a comparative study of different settlement forms within Tiruchirapalli can provide insights into architectural evolution (Kotharkar & Deshpande, 2012). The active participation of the community in place-making, becomes imperative for shaping human settlements according to genuine needs (Dayaratne, 2016). To address contemporary challenges, the research underscores the need to explore solutions for conserving and implementing lessons from vernacular architecture (Tovivich, 2015) while considering functional limitations (Wahid, 2012) to foster a sustainable environment for future generations. Promoting awareness to sustain interest in heritage-based initiatives can serve as an influential force, drawing inspiration from heritage architecture (Khalaf, 2016). Challenges posed by unplanned contemporary developments must be addressed to preserve the city's heritage and architectural integrity (Kashkari & Brar, 2023). Preserving cultural identity through sustainable transformations is vital (Mukherjee & Ghosh, 2019). Socio-cultural studies focusing on spatial relations (Gulati et al., 2019) and design modifications from Sahu et al., (2020) can offer valuable insights into residential typologies in Tiruchirapalli.

In conclusion, the thermal adaptations unveiled through the research present valuable insights into how residents in the Tiruchirapalli district effectively cope with the demanding tropical climate. The study successfully identified the factors influencing thermal comfort, which will inform building design, energy-efficient practices, and overall well-being. The proposal for a searchable online database is a noteworthy suggestion for facilitating future research. The research, however, acknowledges the need for more region-specific studies, given the diverse climates in India. It is important to note that this study had specific limitations, including its focus on single-story residential buildings of less than 1000 sq. ft on the ground floor, restricted to the summer season and the Tiruchirapalli district, and primarily addressing thermal comfort and thermal adaptive behaviors, excluding other types of comfort. These limitations provide direction for future research endeavors that can build upon these insights and contribute to a more comprehensive understanding of thermal adaptations across India's diverse regions.

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