INTERNATIONAL SCIENTIFIC JOURNAL GEOGRAPHICA PANNONICA

A Qualitative Approach for Investigating Thermal Discomfort in the Outdoor Environment of a World Heritage Site: A Case Study of Hampi, India

Tanaya Paul[A*], Srinivas Daketi[A], Kailasa Rao M[A], Faiz Ahmed Chundeli[A]

[A] School of Planning and Architecture, Vijayawada, India; ORCID TP: 0009-0003-9165-798X; SD: 0000-0002-5995-9457, FAC: 0000-0003-1556-2375

Received: March 24, 2025| Revised: June 25, 2025| Accepted: August 12, 2025

doi: 10.5937/gp29-57738

Abstract
The outdoor thermal environment affects visitors' thermal comfort and overall experience. This study investigates the application of photographic analysis as a qualitative tool for evaluating thermal discomfort in outdoor environments at a World Heritage Site. Thermal discomfort is a key concern in public settings as global temperatures continue to rise. At the same time, traditional approaches rely on microclimate measurements and user feedback. However, this study takes a more subjective, visual approach to capturing and interpreting how visitors experience thermal comfort or discomfort in large-scale archaeological sites. This research uses photographic data to identify and analyze the primary visual signs of thermal discomfort. Results reveal that visitors in the heritage site experience strong heat stress during the winter season. Despite the study area experiencing strong heat stress and visitors feeling hot and warm, the majority of the visitors are satisfied with the thermal conditions of the heritage site. Photographic analysis reports that the most common signs of thermal discomfort are mostly related to intense solar radiation and the absence of shade. The research findings can be used to develop strategies for reducing thermal discomfort while maintaining the cultural and historical integrity of heritage places. The research underscores the importance of visual data in comprehending the interplay between thermal comfort, environmental design, and visitor experiences in culturally significant sites.

Keywords: thermal discomfort; photographic analysis; qualitative research; World Heritage Site

Introduction
Climate change, caused by global warming, has a wide range of consequences on human life. As temperatures rise, stresses from heat and heat-related mortality increase (Kleerekoper et al., 2012). In the years ahead, designers and planners will face the difficulty of creating the conditions required for outdoor thermal comfort, or "that state of mind which expresses satisfaction with the thermal environment" (ISO, 2005). Earlier studies focused on the physiological aspects of thermal comfort, while recent ones have highlighted psychological factors (Hirashima et al., 2016). Qualitative and quantitative studies are essential for gaining a deeper understanding of people's subjective experiences. Numerous studies on outdoor heat perception have integrated these approaches (Ali & Patnaik, 2018; Banerjee et al., 2022;

* Corresponding author: Tanaya Paul; tanaya@spav.edu.in

Kumar & Sharma, 2021; Manavvi & Rajasekar, 2020). Studies on microclimate and outdoor thermal comfort have primarily focused on environments such as residential neighborhoods (Colter et al., 2019; Singh et al., 2024; Zhang & Liu, 2021), parks and open spaces (Ali & Patnaik, 2018; Aram et al., 2020; Johansson et al., 2018; Niu et al., 2022; Yuan et al., 2023), university campuses (Eslamirad et al., 2022; Ghaffarianhoseini et al., 2019; Jing et al., 2024; Othman et al., 2021), street canyons (Abdollahzadeh & Biloria, 2021; Deng & Wong, 2020; Miao et al., 2023; Mohite & Surawar, 2024), traditional vernacular settlements (Huang et al., 2018; Sözen & Koçlar Oral, 2019) and low income settlements (Banerjee et al., 2020, 2022). The existing literature reports numerous studies on thermal comfort in urban microclimates; however, limited studies have focused on enhancing tourist sites. According to Kumar and Sharma (2020), only 4% of studies have dealt with outdoor thermal comfort in tourist sites, based on research conducted between 2001 and 2019. Tourists are highly vulnerable to heat exposure, as heat-related health hazards are becoming increasingly complex and severe (Hondula et al., 2017). Thus, it becomes increasingly important to study its climatic characteristics and outdoor thermal comfort analysis. Considering thermal comfort analysis in tourist site planning and development can enhance the comfort condition and improve visitor experience (Nikolopoulou & Steemers, 2003). Outdoor thermal comfort studies on tourist sites mainly focused on beaches (Rutty & Scott, 2014, 2015; Zhang et al., 2023), parks (Wei et al., 2022), and heritage sites (Binarti et al., 2021; Fabbri et al., 2020; Manteghi et al., 2020; Manteghi & Mostofa, 2022; Nasrollahi et al., 2017). Furthermore, in countries like India, despite having a large number of heritage sites, there is a lack of adequate studies on outdoor thermal comfort in tourism settings. Most of the world heritage sites are large protected areas, and after the excavations, the areas appear like barren land. As many tourists visit these places and consider the projected rise in temperatures, improving Outdoor Thermal Comfort (OTC) is essential and worthy of investigation because tourists are exposed to the harsh climate year-round.

World Heritage Sites (WHS) are designated for cultural, historical, and architectural significance. These locations draw millions of visitors annually, who enjoy both the aesthetic appeal and the environmental conditions in these areas. Thermal discomfort caused by extreme temperatures or humidity is one of the most serious issues in outdoor environments, as it impacts visitor comfort, well-being, and overall satisfaction. However, measuring thermal discomfort in such scenarios is challenging, as it involves considering both environmental factors and individual sensations of discomfort (Fabbri et al., 2020). Thermal discomfort in outdoor environments refers to situations that make people feel uncomfortably hot or cold, generally caused by environmental elements such as air temperature, humidity, wind, and exposure to the sun. This phenomenon is significant at heritage sites, where preserving cultural and architectural integrity must be maintained with visitor comfort and health.

The International Council on Monuments and Sites (ICOMOS) recommends that tourism activities prioritize visitor comfort, safety, and well-being while preserving significant features and ecological characteristics (ICOMOS, 2002). However, the factors contributing to thermal discomfort in outdoor heritage sites include climate and weather conditions, a lack of green spaces, and limited design options. Heritage site planning and redevelopment often focus on historical and aesthetic value, while neglecting thermal comfort. Researchers used visual research techniques in various academic disciplines, including urban studies. Historically utilized in ethnography and architectural studies, photographic analysis has proven to be a valuable qualitative tool for documenting a site's physical and social elements (Pink, 2015). Based on the theory of semiotics, photographic analysis is employed to investigate the processes of visual interpretation of built and vegetated environments related to people's outdoor thermal adaptation. Semiotics is the study of signs. Anything that creates meaning or can represent something else is a sign. Photographs are the signs in this case (Shooshtarian, 2019). Based on this theory, Cortesão et al. (2020) evaluated the outdoor thermal environment using photographic comparison, where participants interpreted the photographs. According to the researcher, signs of thermal comfort or discomfort can be visible in photographs, such as vegetation, shading, and predominant colours. Results show that photographic comparison (visual appraisal) confirmed the conclusions from the verbal method (field survey) (Cortesão et al., 2020). However, this method may not apply to the respondents in the tourist group.

Existing literature suggests that heritage sites are subject to high heat stress, as indicated by microclimate analysis. Binarti et al. (2021) conducted a thermal comfort survey at the World Heritage Archaeological Park (Prambanan Temple) in a tropical climate. Their study reveals that the andesite stone structures in the heritage site contribute to an increase in air temperature due to the thermal properties of the stones. The radiative properties of the stones cause thermal discomfort, making the outdoor environment uncomfortable for visitors. Moreover, the limited shading and large open areas in archaeological sites exacerbate the high temperatures. Fabbri et al. (2020) evaluated the role of vegetation in archaeological regions and its impact on visitors' thermal comfort using Physiologically Equivalent Temperature (PET) and microclimate analysis. They studied different scenarios with ENVI-met software and concluded that although PET values were high, scenarios with more vegetation and green areas improved thermal comfort. They report that vegetation cools the environment due to shading and the process of evapotranspiration. Vegetation lowers the air temperature, making the outdoor environment more comfortable for visitors. Lam et al. (2018) reported that foreign visitors experienced different thermal sensations and preferences than local visitors during hot weather. They also noted that visitors perceived the thermal environment as hot, yet 36.8% of European visitors preferred no change in thermal conditions.

Additionally, the presence of cooling elements, like shaded areas or water features, can alter the perception of thermal conditions, even if the actual microclimate remains unchanged. Furthermore, Manteghi et al. (2020) reported that in the Malacca heritage site, PET values exceeded the comfort range (<30°C). Despite the high air temperature, relative humidity, and higher PET range indicating an uncomfortable thermal environment, about 76% of foreign visitors were satisfied with the thermal conditions. Several studies on heritage sites report that visitors are psychologically compatible with the conditions despite the high heat stress (Karimi & Mohammad, 2022; Nasrollahi et al., 2017). Hence, this research aims to validate the visitors' responses from the thermal perception survey by analyzing the thermal environment using photographic analysis.

From the existing literature, we identified a need to explore the OTC use of tourists in large-scale archaeological sites. Previous research in India has focused on urban streets, neighbourhoods, parks, and open spaces. However, current narratives lack the discussion of tourism sites or heritage sites. As heritage sites or archaeological sites reveal a distant microclimate and spatial pattern for the outdoor spaces, they require special attention during revitalization. Therefore, there is a need for a contextual approach, which is lacking in heritage sites, particularly in India. The key signs of thermal comfort and discomfort can help designers and planners visualize the existing site conditions more effectively. We report that no comprehensive framework exists to explore the existing OTC conditions of tourists in heritage sites in India. Therefore, this study aims to explore the OTC use of tourists in heritage sites in India (Bsh Koppen) through photographic analysis, microclimate measurement, and a questionnaire survey.

Furthermore, we investigate the match between the respondents' behaviour and their thermal comfort votes through semiotic logic. It is a first-of-its-kind study that uses photographic analysis to assess outdoor thermal comfort conditions. We examine how photographic analysis validates qualitative outdoor thermal perception surveys by interpreting visual data.

Data and Methods

The present study utilized photographic data to analyze outdoor thermal comfort in a tourist destination. A pilot test was conducted on sunny days in multiple locations to evaluate the thermal conditions within a large-scale archaeological setting. The investigation aimed to identify thermal comfort issues in a large-scale archaeological site and further intends to yield more information on the spatial and behavioural patterns of the visitors.

Study Area

The Group of Monuments in Hampi (15°20′N and 76°28′E) is one of the UNESCO World Heritage Sites in India, with a tourist footfall of 9.9 lakh (990,000) domestic and 21,900 foreign tourists, according to the India Tourism Data Compendium 2024. Hampi is a small village with temples and ruins of the Vijayanagara kingdom, situated on the banks of the Tungabhadra river and bounded by hills on three sides. Hampi has two centres: the sacred center and the royal center. The sacred centre is situated along the river and consists of numerous temples, while the royal center is mainly the urban core of the Vijayanagara rulers. The site exhibits a semi-arid climate (Koppen Bsh). Hampi has an annual mean air temperature (T_a) of 32°C. Summers are very hot and dry, with an average temperature (T_a) of 37°C and an average relative humidity (RH) of 35-40%. During the summers, the T_a often exceeds 40°C. This higher T_a causes thermal discomfort during summer. Thus, tourist visitation declines during the summer season from March to May. Winters are generally the peak season when T_a ranges from 15 to 30°C. Tourist visitation increases from October to February. Tourists typically explore this World Heritage Site from 10:00 AM to 4:00 PM. Thus, we consider this heritage site a case study due to its large-scale archaeological setting, comprising more than 1600 monuments, and its significant tourist footfall, situated in an extreme climate to ensure year-round tourist footfall and enhance the tourist experience.

An outdoor thermal comfort survey was conducted at four key locations within a large-scale archaeological site in Hampi, India. We selected four famous locations for our research, namely Hampi Bazaar Street (study area A), Vittala Bazaar Street (study area B), the Royal Centre (study area C), and Kampa Bhupa's Path (study area D) (Figure 1). We conducted the study during the high tourism season in November to analyze a large number of visitors. Photographs were collected during the same time. Figure 2 shows the study framework. Table 1 tabulates the detailed description of the survey locations. We chose these four study areas to capture the spatial, behavioural and microclimatic differences due to variations in vegetation cover, exposure to climatic variables, availability of shade, and the morphology of the ruins. The Archaeological Survey of India (ASI) maintains these chosen heritage sites.

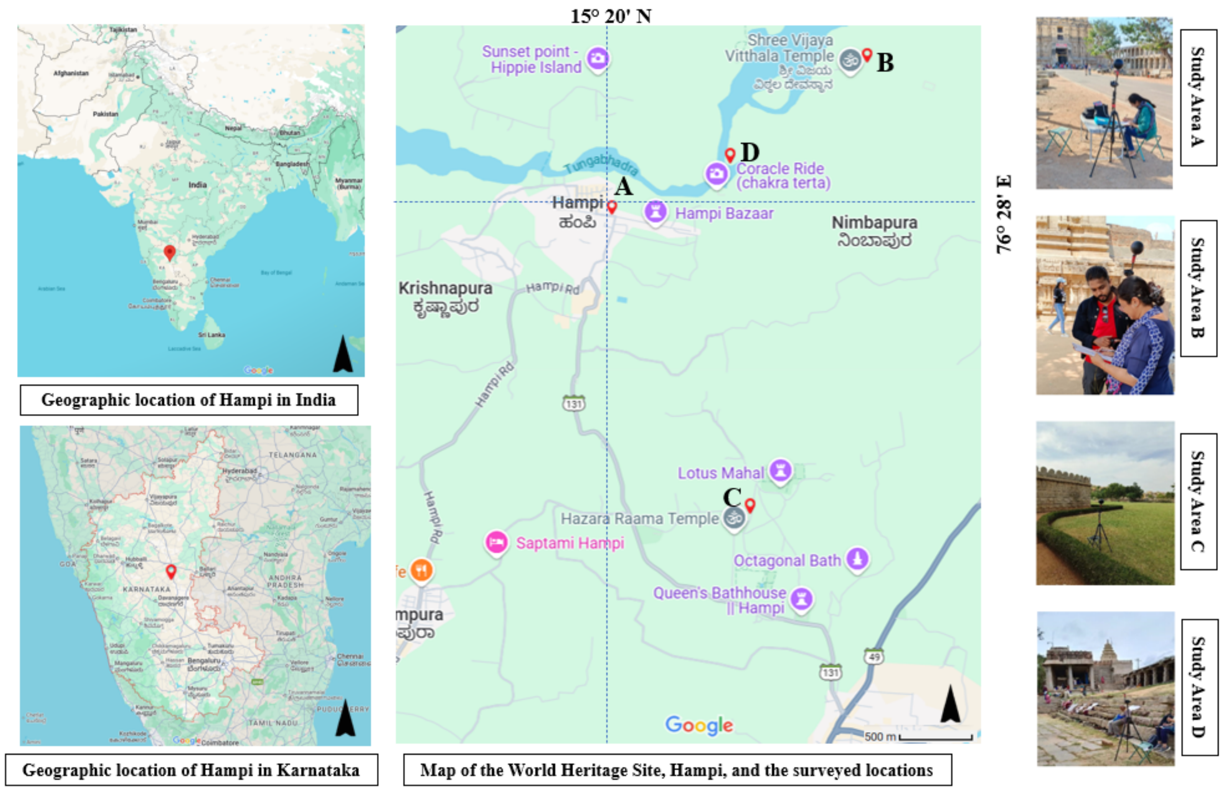

Figure 1. Location of Hampi in Karnataka, India and Survey locations
Study area A – D (Study area A - Hampi Bazaar Street (Partially shaded pathway), Study area B - Vittala Bazaar Street (Unshaded pathway), Study Area - C Royal Centre (Picturesque approach), Study Area D - Kampa Bhupa's path (Riverfront))

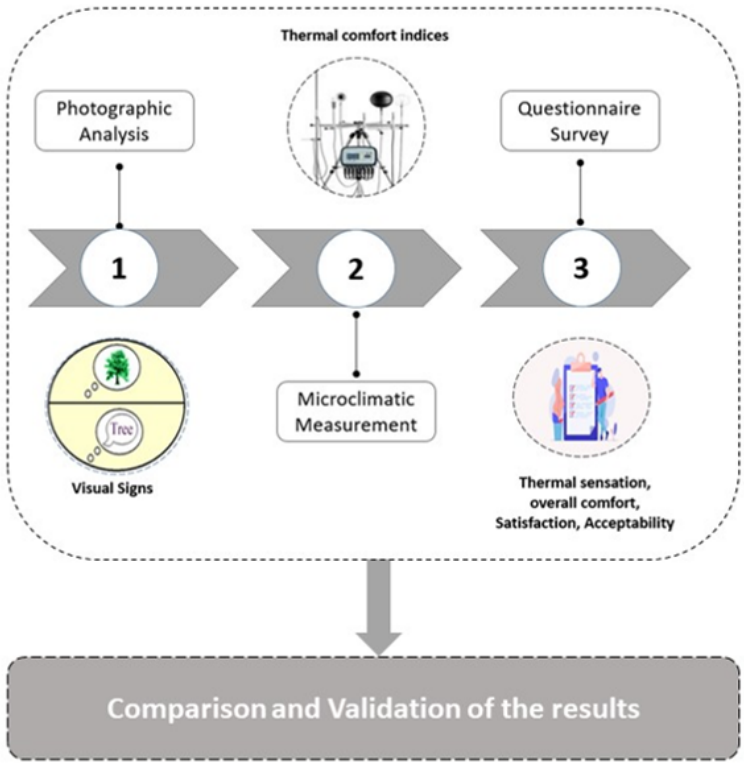

Figure 2. The study framework

Source: Authors

Table 1. Description of the study areas

Study area	Pavement	Vegetation	Distance from waterbody	Influencing factor
Study area A- (Hampi Bazaar Street)	Hard paved (Concrete)	Little vegetation along the walkway	100m	Partially exposed to all climatic variables
Study area B- (Vittala Bazaar Street)	Soft paved (Dry Sandy Soil)	Very nominal vegetation	200m	Fully exposed to all climatic variables
Study area C- (Royal Centre)	Soft paved (Grass & dry sandy soil) and Hard paved (Granite)	Vegetation on the periphery of the boundaries	2km	Fully exposed to all climatic variables
Study area D- (Kampa Bhupa's Path)	Soft paved (Sandy soil) and Hard paved (Granite)	Scattered vegetation	50m	Partially exposed to all climatic variables and presence of granite blouders

Microclimate Measurement

We measured the microclimatic conditions of the World Heritage Site in Hampi at four locations on four sunny days from November 2nd to 5th, 2023. Survey days exhibit a maximum daily T_a of about 30°C, with clear skies, no precipitation, and intense solar radiation. We chose measurement locations which are famous attractions in Hampi: a) Study area A (Hampi bazaar street in front of Virupaksha temple), b) Study area B (Vittala bazaar street in front of Vittala temple), c) Study area C (Royal Centre) and d) Study area D (Kampa Bhupa's path along Tungabhadra river) (Figure 1).

We employed Testo 645 (Temperature and Humidity probe), Testo 625 (thermal flow probe), and Testo 480 with (Globe probe Ø 150mm, TC Type K) to obtain microclimate measurements of air temperature (T_a), Relative Humidity (RH), Wind speed (V_a), and Globe Temperature (T_g) at a height of 1.2-1.5 m above ground level. We set the instruments at least 15 minutes before the measurement was recorded, to allow the sensors to stabilise to the ambient conditions. We recorded these microclimate parameters at 30-minute intervals. All the instruments and sensors (Figure 3) have a measuring range and accuracy that comply with the International Organisation for Standardisation (ISO) 7726 standards (Ergonomics of the Thermal Environment-Instruments for Measuring Physical Quantities, 1998).

Table 2. Instruments and sensors used for collecting microclimate data

Meteorological data	Instrument	Measuring Range	Accuracy/Resolution
T_a (°C)	Testo 645 (Temperature probe)	-20 to +70 °C	±0.4 °C (+0.1 to +50 °C)
RH (%)	Testo 645 (Humidity probe)	0 to +100 % RH	±2 %RH (+2... +98 %RH)
V_a (m/s)	Testo 425 (Thermal flow probe)	0 to +20 m/s	±(0.03 m/s +5% of m.v.), 0.01 m/s

T_g (°C)	Testo 480 (Globe probe Ø 150mm, TC Type K)	0 to +50 °C	±0.1 °C, 0.01°C

Figure 3. Instruments and sensors used in the study

We calculated T_{mrt} according to Thorsson et al. (2007) from the measured data of T_a, T_g, and V_a:

$$\mathrm{Tmrt} = \left[(Ta + 273.15)^4 + \frac{1.1 \cdot 10^8 \cdot v^{0.6}}{\varepsilon \cdot D^{0.4}} \cdot (tg - ta)\right] 1/4$$

Where *D* is the globe diameter in mm and *ε* is globe emissivity.

We employed the RayMan model to calculate the Universal Thermal Climate Index (UTCI) using the T_{mrt} values (Błazejczyk et al., 2013; Matzarakis et al., 2007). Numerous studies have utilised RayMan for calculating UTCI across various climatic conditions, particularly those focused on hot and semi-arid climates (Dhariwal et al., 2019; Kumar & Sharma, 2022a, 2022b; Su et al., 2024). This encouraged us to use RayMan as an appropriate model and UTCI as thermal comfort indices for our current research. According to Bröde et al. (2012), UTCI can be defined as "the air temperature of the reference conditions causing the same model response as actual conditions." The input provided in the RayMan software included date, time, location, microclimate data, and personal details of the respondents, such as age, gender, clothing, and metabolic rate (Matzarakis et al., 2010). The thermal stress categories of UTCI can be seen in Table 3.

Table 3. UTCI ranges and thermal stress categories

UTCI range	Thermal stress categories
Above 46°C	Extreme heat stress
38 to 46°C	Very strong heat stress
32 to 38°C	Strong heat stress
26 to 32°C	Moderate heat stress
9 to 26°C	No thermal stress
9 to 0°C	Slight cold stress
0 to -13°C	Moderate cold stress
-13 to -27°C	Strong cold stress
-27 to -40°C	Very strong cold stress
Below -40°C	Extreme cold stress

Questionnaire Survey

Subjective parameters, such as personal and physiological factors (age, gender, activity, clothing, position, exposure to sunlight, etc.), are collected through a questionnaire survey and photographic analysis.

The survey was conducted during peak hours, from 10:00 AM to 2:00 PM, over four days in November 2023. We collected photographs for photographic analysis. The target population was all visitors to Hampi. A simple random sampling technique was used to select samples. However, visitors are not directly involved in photographic analysis; the researchers do not contact them. The main aim is to map the users' spatial and behavioural patterns through visual methods (photographs) without interfering with real-life situations.

We collected 160 questionnaires during the questionnaire survey across the four study areas. The survey locations are predetermined based on the visitor's path towards the monuments. The questionnaire was prepared based on the existing research on outdoor thermal comfort (Nikolopoulou et al., 2001; Nikolopoulou & Lykoudis, 2006). Each questionnaire consisted of 20 closed-ended questions, taking 5-8 minutes to complete. According to thermal comfort standards ISO 7730 (ISO, 2005), we structured the questions and used the ASHRAE seven-point scale to interpret the thermal sensation vote. The questionnaire consisted of three sections: thermal comfort judgment scales, visitor responses to materials and vegetation, and preferred adaptation strategies for thermal comfort.

Photographic analysis

Shooshtarian (2019) stated that applying different theories can contribute to the development of more effective and innovative assessment methods to yield valid results. According to semiotic analysis theory, researchers analyse photographs on two levels: denotations and connotations within photographs (Langmann & Pick, 2017). The first level deals with the immediate meaning of the photograph (Aiello, 2006), and the second level interprets the photographs in a more abstract sense (Pennington, 2017).

Penn (2000) provided a detailed guideline for semiotic analysis using photographs. In the first step of this method, the researchers should choose the photographs to have a representative sample (going for quantity). However, selecting purposeful images to convey meaning (going for quality). Secondly, the researcher must denote the photographs. Thirdly, the connotations in the photographs are identified, and finally, the research questions are answered.

We collected the photographs on the same day during the microclimate measurement and questionnaire survey. A high-quality camera captured the real-time scenario in a standing eye-level position. The viewing angles primarily included pedestrian areas connecting the iconic monuments, with more relevant signs highlighting spatial and behavioural features. We chose two photographs from each location. We took one photograph at 10:00 AM and another at 12:00 PM to depict the peak hours of tourist visits. One set of researchers took the photographs, while others took surveys and microclimate measurements. Respondents who took part in the survey were not involved in the photographs. We took the photographs without involving the visitors to record the actual behavioural patterns and adaptation strategies.

We denoted the photographs with spatial and behavioural signs; further detailed connotations were made for each photograph. The parameters selected for the photographic analysis are primarily divided into two categories: spatial and behavioural. These main categories were further subdivided into subcategories. Spatial categories include vegetation, light, shade, and colour, as well as water, furniture, paving, and the sky view factor. Meanwhile, behavioural categories encompass posture and expression, position, motion, and accessories used. We followed Cortesão et al. (2020) for selecting the parameters and categorization of the signs (Cortesão et al., 2020). Respondents' votes on the judgmental scale (thermal sensation, overall thermal comfort, and satisfaction level) were recorded on paper. The recorded responses in the questionnaire survey were verified through photographic analysis, which was used as a qualitative method to assess the thermal environment.

We also employed photographic analysis as a visual method to validate the findings from the questionnaire survey, specifically the information respondents provided about a particular thermal environment. A few standard questions about outdoor thermal experiences can reasonably interpret the thermal condition of a space. However, analyzing these random photographs of the same place would help identify thermal comfort issues and enable the researcher to analyse the people's votes, confirming their reliability. Therefore, we intended the photographic analysis to add to verbal responses and enrich interpretations. We employed this method along with a field survey to verify certain assumptions related to the thermal comfort of the respondents.

Results

The microclimate characteristics

We conducted microclimate measurements in all four study areas during the winter. The following parameters were measured on-site: Air Temperature (T_a), Relative Humidity (RH), Wind Speed (V_a), and Globe Temperature (T_g). Mean Radiant Temperature (T_{mrt}) was calculated using RayMan. In study areas A and C, the average T_a during the survey was 31.68°C, and the average RH, V_a, and T_{mrt} were 54.57%, 0.9 m/s, and 51.5°C, respectively. In study areas B and D, the average T_a during the survey was 30.7°C, the average V_a was 1.5 m/s, and the average T_{mrt} was 49.3°C. However, there is a difference in relative humidity (RH) between study areas B and D. The average RH recorded in study areas B and D was 54.4% and 60.73%, respectively. It is worth noting that due to overcast and windy conditions in study areas B and D during the survey days, T_{mrt} was significantly lower than in study areas A and C. The maximum recorded T_a during the survey was 32.9°C at study area A, while the minimum recorded T_a was 29.2°C. The maximum and minimum T_a show a range of 3°C.

The average UTCI for the study areas ranged from 32°C to 39°C (μUTCI = 36.24°C). Figure 4 shows the hourly variation in average UTCI across all the study areas from 10:00 am to 4:00 pm. Study areas A and C reported high UTCI throughout the day, ranging from 35.3°C to 39.1°C. Study areas B and D reported high UTCI values ranging from 35.6°C to 38.4°C during the mid-afternoon hours.

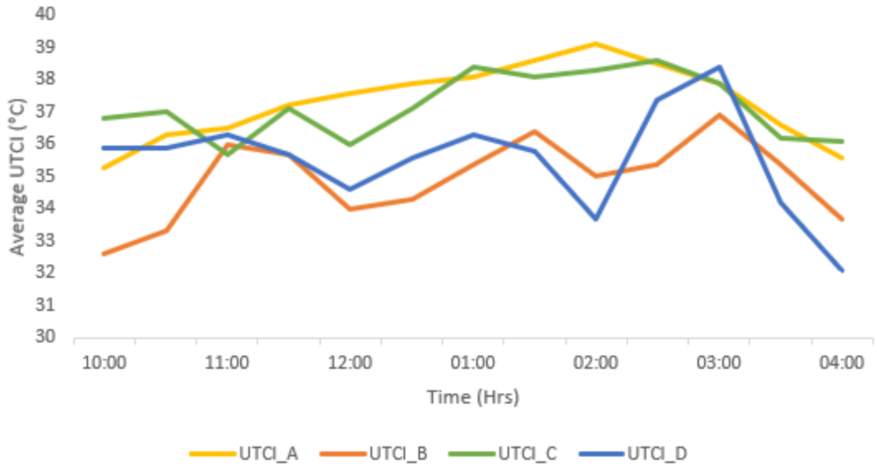

Figure 4. UTCI variations across sampled locations in Hampi

Questionnaire survey results

The questionnaire was distributed to the visitors in all the study areas. A total of 160 questionnaires were completed in four days. A total of 40 questionnaires were completed in each location from morning to afternoon.

In general, respondents consisted of 53.75% males and 46.25% females. The questionnaires were completed by 122 domestic visitors (76.25%) and 38 foreign visitors (23.75%). Most foreign visitors (84.2%) are from European countries, including Spain, France, Germany, the U.K., and Switzerland. Domestic visitors were 36% from Karnataka, 21% from Maharashtra, and 12% from West Bengal. Regarding age, 54.3% of visitors are aged 25-44 years, followed by those aged 45-64 years.

Thermal comfort sensation and satisfaction of tourists

Despite the questionnaire survey being completed in November (one of the cooler months), the thermal sensation vote (TSV) of the visitors is more inclined to the warmer range. The frequency distribution of thermal sensation is shown in Figure 5. Their preference for a cooler environment increased as the feeling of warmth intensified. However, about 43.1% of visitors were satisfied, 31.25% were slightly satisfied, and 3% were very satisfied with the thermal condition. Figure 5 shows the percentage of visitors' satisfaction.

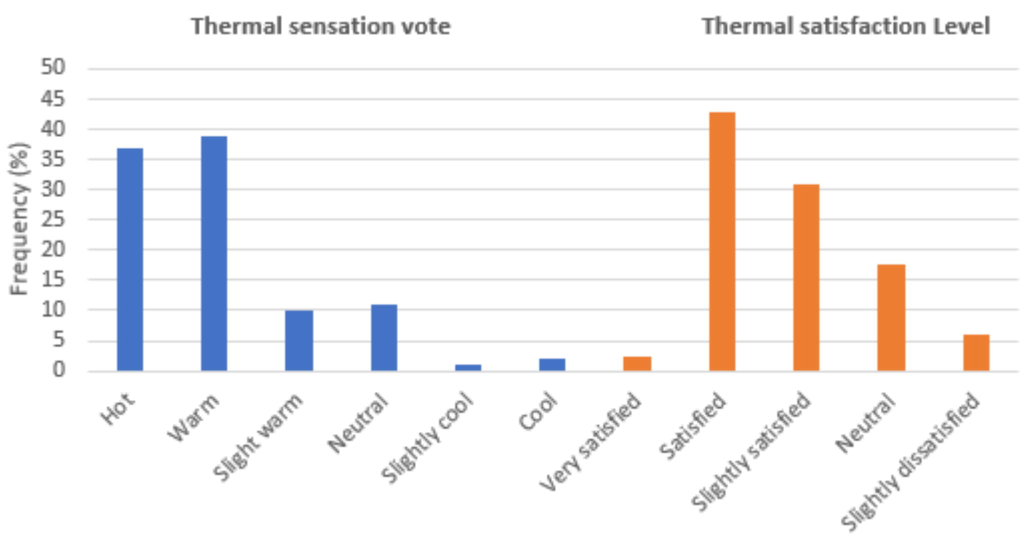

Figure 5. Frequency distribution of Thermal sensation vote and Thermal satisfaction level

Percentage distributions of satisfaction at each study area

The percentage distribution of satisfaction in each study area is shown in Figure 6. The study reveals that areas A, B, and D have the highest satisfaction percentages, while area C has the lowest percentage. The highest neutral percentage belongs to study areas A and C, with 20-22%. Study area C (Royal Centre) scored the lowest level of thermal satisfaction, despite having more trees and a larger grass surface. Trees present in study area C are in the periphery of the site, which does not provide suitable shade in the walkways.

Thermal comfort of visitors

60% of the visitors perceived this thermal condition as comfortable, while 40% voted neutral (Figure 7). In the present study, UTCI values ranged from 33.3°C to 39.1°C in winter. In hot and arid climates, UTCI values ranging from 35.6 to 43.2°C are considered to be under intense heat stress in Indian cities (Kumar & Sharma, 2022a). It is important to note that only 10% of the visitors voted for neutral sensation in winter. This lower percentage of neutral sensation can be due to visitors from different countries residing in different climates participating in this survey. Foreign visitors from various climate zones, such as Russia, Australia, and Norway, tend to prefer warmer environments.

In further questions, visitors were asked about their preferred adaptation strategies. 60% of the visitors prefer to "move to shade/tree," while 25% prefer to get more drinks. However, 80% of visitors also found that the study areas had significantly less greenery and vegetation. Overall comfort (OC) was correlated with the thermal sensation vote (Figure 8). The overall data sets were separated according to the TSV and its corresponding OC responses. The mean values of each data set of OC and TSV were calculated. Furthermore, a correlation was established and is observable in Figure 8.

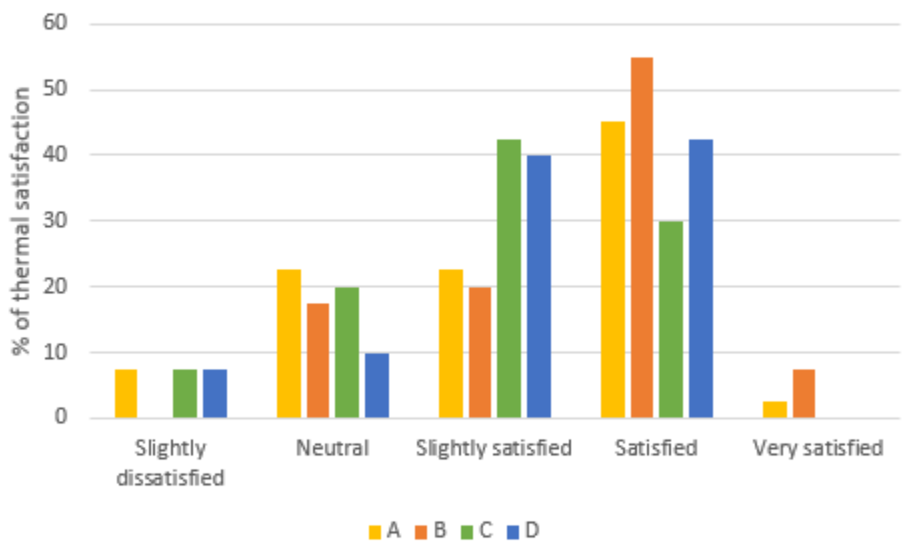

Figure 6. The percentage distributions of satisfaction at each study area

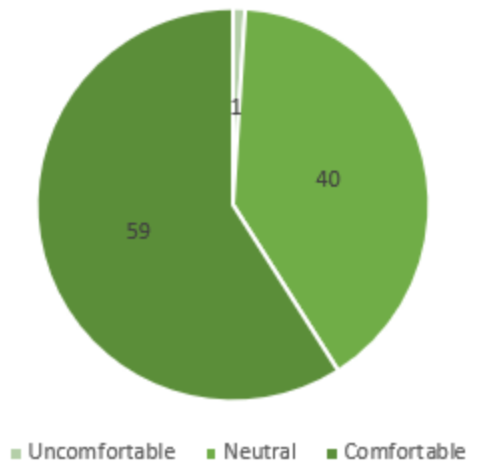

Figure 7. Frequency distribution of Overall comfort vote

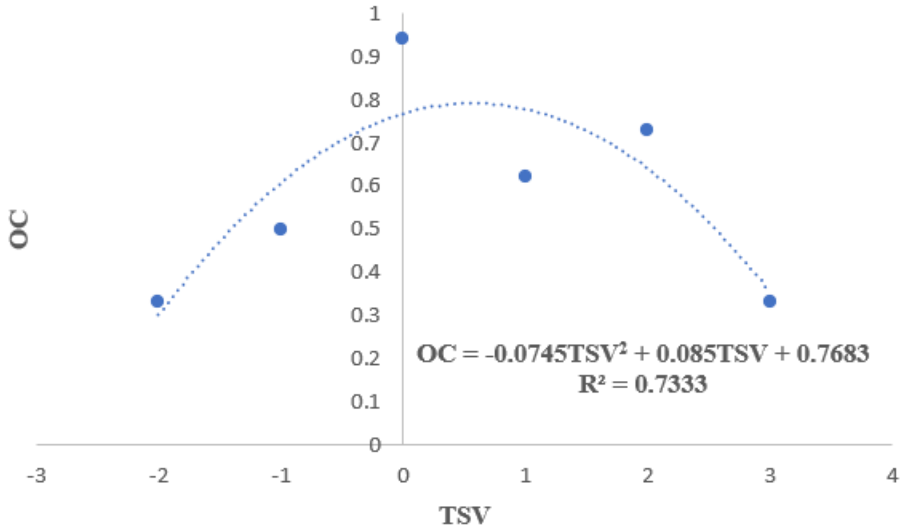

Figure 7. Correlation between the Overall comfort and Thermal sensation vote

Results of Photographic Analysis

In study area A (Figure 9, A1 and A2), a few deciduous trees provide shade where visitors seek shelter from intense solar radiation. Visitors are relaxed under the shade of trees, while those in exposed areas walk quickly. The use of caps, sunglasses, and scarves has also been noticed as an adaptation strategy. Study area B (Figure 9, B1 and B2) shows the walkway and entrance leading to the Vittala Temple. Very few deciduous trees can be seen along with dusty paving. This unshaded walkway is causing discomfort in the area. Visitors are observed in an active posture and walking quickly in the exposed area. Similar to the previous area, hats, caps, and sunglasses were used.

Figure 8. Photographs of study areas A and B
Source: Authors

Trees, lawns, and hedges are predominant in study area C (Figure 10, C1 and C2) in the Royal Centre. However, tree shade is not present on the walkways. Visitors are often seen walking under the exposed sun, employing adaptation strategies such as umbrellas and scarves. Visitors are seeking shelter near the shaded areas. Study area D (Figure 10, D1 and D2) is along the river, and boulders can be seen in the photographs. There is no shade from trees over the walkway. However, visitors are sheltering under the shade in a relaxed position. The use of caps, hats, and sunglasses is also seen in this photograph.

Figure 9. Photographs of study areas C and D
Source: Authors

Table 4 summarizes the key signs observed in the photographic analysis. Exposed trunk, glare, dusty paving, clear sky vault, fast walking, and squinting are signs of thermal discomfort in all the study areas.

Table 4. Summary of the key signs observed in the photographic analysis

Category	Subcategory	Photograph of Study Area A	Photograph of Study Area B	Photograph of Study Area C	Photograph of Study Area D
Spatial	Vegetation	Trees	Nominal trees	Trees on periphery, lawn and hedges	Trees and Bushes
	Light, shade and colour	Bright canopy, Cool colour	Dark boulders	Bright canopy, Cool colour	Bright canopy, Cool colour Dark boulders
	Water	-	-	-	Moving water
	Furniture	Stone benches	-	-	Stone benches
	Paving	Hard (Concrete)	Dusty	Dusty	Hard (Granite)

	Sky view factor	Clear sky vault	Clear sky vault	No sky vault	Clear sky vault
Behavioural	Posture and Expression	Active posture, Relaxed posture under tree shade	Active posture, Squinting	Active posture	Relaxed posture under tree shade
	Position	People walking under exposed sun, people sheltering under shade	People walking under exposed sun	People walking under exposed sun as well as people sheltering under shade	People sheltering under tree
	Motion	Fast walking, standing under shade	Fast walking	Both slow and fast walking	Slow walking
	Accessories	Cap, sunglasses, scarf	Hat, cap, sunglasses	Hat, cap, umbrella, scarf	Hat, sunglasses

Based on the visual signs of the photographs, 6 out of 12 signs convey thermal comfort, and the other six signs convey thermal discomfort in study areas A, C, and D. In photographs at study area B, all eight signs of thermal discomfort are conveyed. Most signs of thermal discomfort are related to direct, intense solar radiation and the absence of shade. This finding suggests that intense solar radiation in this climatic region is the leading cause of thermal discomfort. Furthermore, 62.5% of visitors also reported that solar radiation was intense during the survey, which made them uncomfortable. This argument aligns with existing studies that indicate exposure to direct solar radiation is the primary cause of thermal discomfort in outdoor spaces (Zhao et al., 2023; Ji et al., 2022).

Discussion

The study was conducted in Hampi, a World Heritage Site, which has a hot and semi-arid climate. This study analyses the outdoor thermal comfort conditions in the peak season through microclimate measurements, questionnaire survey, and photographic analysis, as a pilot study conducted during the winter of 2023. The results show that, despite being in the winter season, the thermal condition of the heritage is not significantly comfortable. The UTCI across the study areas in Hampi ranged from 33.3°C to 39.1°C during the field survey, similar to other studies in Bsh cities in India (Kumar & Sharma, 2022a, 2022b, 2022c). There is variation in UTCI values between the study areas, which can be attributed to the overcast, windy conditions during the survey period. Hence, the thermal conditions of the study areas can be considered the same. Visitors feel warmer during the high tourism season in November and prefer to be cooler despite winter. The calculated UTCI range during the survey is higher than the conventional UTCI neutral range in the Bsh climate, which typically ranges from 28.03 to 35.6°C. Notably, the neutral UTCI was 31.8°C in the summer season (Kumar & Sharma, 2022a).

This research also reports that, despite the heat stress in Hampi, 77% of the visitors are satisfied with the existing thermal conditions. Various authors report similar findings for tourism context studies where 78.57% and 50-60% of tourists were satisfied with the thermal conditions in Isfahan and Sevilla, Madrid, respectively (Karimi & Mohammad, 2022; Nasrollahi et al., 2017). This shows that the tourists are psychologically compatible with the thermal conditions of the tourist sites.

Photographic analysis reveals the signs of thermal comfort and discomfort in the spatial and behavioural categories. Exposed trunk, glare, dusty paving, clear sky vault, fast walking, and squinting are signs of thermal discomfort in all the study areas. However, few signs of thermal comfort are observed in all study areas, except for study area B, which includes relaxing in a posture under tree shade and slow walking on shaded pathways. These signs of thermal comfort and discomfort are under study (Cortesão et al., 2020). Visitors are often found seeking shade under trees in study areas A and D. This is in line with other studies in India, where visitors also seek shade under trees and overhead canopies; however, the availability of shade depends on the specific location (Manavvi & Rajasekar, 2020).

It is essential to note that visitors are generally satisfied with the existing thermal conditions; however, the spatial and behavioral patterns of the visitors are inconsistent with the results of the questionnaire survey and microclimatic measurements. This indicates the psychological compatibility and adaptation behaviour of the visitors. This finding aligns with the results of various studies in the tourism context (Karimi & Mohammad, 2022; Nasrollahi et al., 2017).

Simulation, microclimatic measurements, and questionnaire surveys can predict thermal comfort conditions. However, photographic analysis can complement conventional methods. Results from the questionnaire survey can be biased due to the visitors' mental adaptability and adaptation measures. Hence, this qualitative approach through photographic analysis can further validate or complement the findings from the questionnaire survey.

Photographic analysis can help researchers communicate the findings as visual guidelines to designers and planners. These visuals can help designers consider more climate-responsive designs. Photographic analysis can further help them to represent the thermal environment and improve the microclimate of a site. Visual signs in the photographs can help the researcher understand the relationship between spatial and behavioural patterns of visitors and thermal comfort or discomfort. These visual signs work together to assess the microclimatic condition. These visual signs are subjective. However, the researchers cannot control the behaviour-related signs. Thus, the thermal message is more realistic in photographic analysis, where the respondents are not directly involved.

The research has several limitations and offers some future perspectives for further investigation. Firstly, the present study was conducted only during the winter season; however, research work should also be carried out during the summer season. Secondly, a neutral UTCI could not be calculated since the variability in T_a was not large enough to determine a neutral temperature for the samples. Furthermore, intangible cultural aspects of the study have not been taken into consideration.

Conclusion

This research presents a preliminary approach to using photographic analysis as a qualitative method to assess the existing thermal environment in the World Heritage Site of Hampi, India. Outdoor thermal comfort was explored using microclimate measurements and questionnaire surveys. The proposed methodology enabled the exploration of existing thermal conditions in a heritage site using a qualitative approach in addition to conventional methods. This research is the first study to assess outdoor thermal comfort for visitors to the heritage site of Hampi. In the tourism context, the responses on the judgmental scales can be biased due to the visitors' psychological compatibility and adaptation measures. Therefore, the main focus of the study is to assess the outdoor thermal environment of the heritage site using the theory of semiotic analysis. The conclusions from this research are as follows:

[1] The average UTCI calculated for the study areas varied between 32°C and 39°C, with an average of 36.24°C, which corresponds to "strong heat stress."

[2] The majority of visitors experienced thermal sensations ranging from "warm" to "hot" during the winter season in a hot and semi-arid climate. It suggests that the existing thermal conditions of the heritage site are not very comfortable for visitors.

[3] Despite the study area experiencing strong heat stress and visitors feeling hot and warm, the majority of the visitors are satisfied with the thermal conditions of the heritage site. However, the overall comfort of the visitors correlates well with the thermal sensation votes.

[4] The most common signs of thermal discomfort are mostly related to intense solar radiation and the absence of shade. Thus, indicating the need for more shaded areas.

[5] We report an inconsistency in results between photographic analysis and the overall comfort vote of the visitors. Thus, photographic analysis can further validate the findings from the questionnaire survey. However, photographic analysis can be complemented by conventional approaches.

This approach can help researchers identify hotspots, determine suitable locations for the weather station, and identify feasible locations for the questionnaire survey. We can use this approach in other contextual studies to assess the thermal environment as a preliminary survey. This study's findings can help enhance the outdoor environment during peak tourist season. However, we can also utilise this framework during the low tourist season to further increase tourist footfall and enhance the visitors' experience. Results will help formulate heat stress mitigation strategies for visitors to World Heritage Sites, aiming to increase visitor numbers. The results can further guide the designers and decision-makers in World Heritage Sites in identifying the key signs of thermal comfort and discomfort for future preservation and management of heritage sites.

List of abbreviations

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers, ISO – International Organization for Standardization, ICOMOS – The International Council on Monuments and Sites, PET – Physiologically Equivalent Temperature, RH – Relative Humidity, T_a – Air Temperature, T_g – Globe Temperature, T_{mrt} – Mean Radiant Temperature, UTCI – Universal Thermal Climate Index , V_a – Wind Speed, WHS – World Heritage Site

Acknowledgements

The authors would like to thank the Archaeological Survey of India (Hampi Circle) for allowing us to conduct field surveys. The authors are grateful to the visitors at the heritage site who gave their consent to record their thermal perceptions.

Reference

Abdollahzadeh, N., & Biloria, N. (2021). Outdoor thermal comfort: Analyzing the impact of urban configurations on the thermal performance of street canyons in the humid subtropical climate of Sydney. *Frontiers of Architectural Research*, *10*(2), 394–409. https://doi.org/10.1016/j.foar.2020.11.006

Aiello, G. (2006). Theoretical Advances in Critical Visual Analysis: Perception, Ideology, Mythologies, and Social Semiotics. *Journal of Visual Literacy*, *26*(2), 89–102. https://doi.org/10.1080/23796529.2006.11674635

Ali, S. B., & Patnaik, S. (2018). Thermal comfort in urban open spaces: Objective assessment and subjective perception study in tropical city of Bhopal, India. *Urban Climate*, *24*, 954–967. https://doi.org/10.1016/j.uclim.2017.11.006

Aram, F., Solgi, E., Garcia, E. H., & Mosavi, A. (2020). Urban heat resilience at the time of global warming: evaluating the impact of the urban parks on outdoor thermal comfort. *Environmental Sciences Europe*, *32*(1), 117. https://doi.org/10.1186/s12302-020-00393-8

Banerjee, S., Middel, A., & Chattopadhyay, S. (2020). Outdoor thermal comfort in various microentrepreneurial settings in hot humid tropical Kolkata: Human biometeorological assessment of objective and subjective parameters. *Science of the Total Environment*, *721*. https://doi.org/10.1016/j.scitotenv.2020.137741

Banerjee, S., Middel, A., & Chattopadhyay, S. (2022). A regression-based three-phase approach to assess outdoor thermal comfort in informal micro-entrepreneurial settings in tropical Mumbai. *International Journal of Biometeorology*, *66*(2), 313–329. https://doi.org/10.1007/s00484-021-02136-7

Binarti, F., Triyadi, S., Koerniawan, M. D., Pranowo, P., & Matzarakis, A. (2021). Climate characteristics and the adaptation level to formulate mitigation strategies for a climate-resilient archaeological park. *Urban Climate*, *36*(February), 100811. https://doi.org/10.1016/j.uclim.2021.100811

Błazejczyk, K., Jendritzky, G., Bröde, P., Fiala, D., Havenith, G., Epstein, Y., Psikuta, A., & Kampmann, B. (2013). An introduction to the Universal thermal climate index (UTCI). *Geographia Polonica*, *86*(1), 5–10. https://doi.org/10.7163/GPol.2013.1

Bröde, P., Fiala, D., Błażejczyk, K., Holmér, I., Jendritzky, G., Kampmann, B., Tinz, B., & Havenith, G. (2012). Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology*, *56*(3), 481–494. https://doi.org/10.1007/s00484-011-0454-1

Colter, K. R., Middel, A. C., & Martin, C. A. (2019). Effects of natural and artificial shade on human thermal comfort in residential neighborhood parks of Phoenix, Arizona, USA. *Urban Forestry & Urban Greening*, *44*, 126429. https://doi.org/10.1016/j.ufug.2019.126429

Cortesão, J., Brandão Alves, F., & Raaphorst, K. (2020). Photographic comparison: a method for qualitative outdoor thermal perception surveys. *International Journal of Biometeorology*, *64*(2), 173–185. https://doi.org/10.1007/s00484-018-1575-6

Deng, J.-Y., & Wong, N. H. (2020). Impact of urban canyon geometries on outdoor thermal comfort in central business districts. *Sustainable Cities and Society*, *53*, 101966. https://doi.org/10.1016/j.scs.2019.101966

Dhariwal, J., Manandhar, P., Bande, L., Marpu, P., Armstrong, P., & Reinhart, C. F. (2019). Evaluating the effectiveness of outdoor evaporative cooling in a hot, arid climate. *Building and Environment*, *150*, 281–288.https://doi.org/10.1016/j.buildenv.2019.01.016

Ergonomics of the thermal environment — Instruments for measuring physical quantities. (1998). https://standards.iteh.ai/catalog/standards/sist/99f92eea-d1b3-48b4-8a3c-aj

Eslamirad, N., Sepúlveda, A., De Luca, F., & Sakari Lylykangas, K. (2022). Evaluating Outdoor Thermal Comfort Using a Mixed-Method to Improve the Environmental

Quality of a University Campus. *Energies*, *15*(4), 1577. https://doi.org/10.3390/en15041577

Fabbri, K., Ugolini, A., Iacovella, A., & Bianchi, A. P. (2020). The effect of vegetation in outdoor thermal comfort in archaeological area in urban context. *Building and Environment*, *175*, 106816. https://doi.org/10.1016/J.BUILDENV.2020.106816

Ghaffarianhoseini, A., Berardi, U., Ghaffarianhoseini, A., & Al-Obaidi, K. (2019). Analyzing the thermal comfort conditions of outdoor spaces in a university campus in Kuala Lumpur, Malaysia. *Science of The Total Environment*, *666*, 1327–1345.https://doi.org/10.1016/j.scitotenv.2019.01.284

Hirashima, S. Q. da S., Assis, E. S. de, & Nikolopoulou, M. (2016). Daytime thermal comfort in urban spaces: A field study in Brazil. *Building and Environment*, *107*, 245–253. https://doi.org/10.1016/j.buildenv.2016.08.006

Hondula, D. M., Balling, R. C., Andrade, R., Scott Krayenhoff, E., Middel, A., Urban, A., Georgescu, M., & Sailor, D. J. (2017). Biometeorology for cities. *International Journal of Biometeorology*, *61*(S1), 59–69. https://doi.org/10.1007/s00484-017-1412-3

Huang, K.-T., Yang, S.-R., Matzarakis, A., & Lin, T.-P. (2018). Identifying outdoor thermal risk areas and evaluation of future thermal comfort concerning shading orientation in a traditional settlement. *Science of The Total Environment*, *626*, 567–580. https://doi.org/10.1016/j.scitotenv.2018.01.031

ISO. (2005). *ISO 7730:2005(E) Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria* (3rd ed.). International Organization for Standardization.

ISO. (2005). *ISO 7730:2005(E) — Ergonomics of the thermal environment* (3rd ed.). International Organization for Standardization.

Ji, Y., Song, J., & Shen, P. (2022). A review of studies and modelling of solar radiation on human thermal comfort in outdoor environment. *Building and Environment*, *214*, 108891. https://doi.org/10.1016/J.BUILDENV.2022.108891

Jing, W., Qin, Z., Mu, T., Ge, Z., & Dong, Y. (2024). Evaluating thermal comfort indices for outdoor spaces on a university campus. *Scientific Reports*, *14*(1). https://doi.org/10.1038/s41598-024-71805-5

Johansson, E., Yahia, M. W., Arroyo, I., & Bengs, C. (2018). Outdoor thermal comfort in public space in warm-humid Guayaquil, Ecuador. *International Journal of Biometeorology*, *62*(3), 387–399. https://doi.org/10.1007/s00484-017-1329-x

Karimi, A., & Mohammad, P. (2022). Effect of outdoor thermal comfort condition on visit of tourists in historical urban plazas of Sevilla and Madrid. *Environmental Science and Pollution Research*, *29*(40), 60641–60661. https://doi.org/10.1007/s11356-022-20058-8

Kleerekoper, L., Van Esch, M., & Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling*, *64*, 30–38. https://doi.org/10.1016/j.resconrec.2011.06.004

Kumar, P., & Sharma, A. (2021). Assessing The Thermal Comfort Conditions In Open Spaces: A Transversal Field Survey On The University Campus In India. *International*

Journal of Built Environment and Sustainability, *8*(3), 77–92. https://doi.org/10.11113/ijbes.v8.n3.786

Kumar, P., & Sharma, A. (2022a). Assessing outdoor thermal comfort conditions at an urban park during summer in the hot semi-arid region of India. *Materials Today: Proceedings*, *61*, 356–369. https://doi.org/10.1016/j.matpr.2021.10.085

Kumar, P., & Sharma, A. (2022b). Assessing the monthly heat stress risk to society using thermal comfort indices in the hot semi-arid climate of India. *Materials Today: Proceedings*, *61*, 132–137. https://doi.org/10.1016/j.matpr.2021.06.292

Kumar, P., & Sharma, A. (2022c). Assessing the outdoor thermal comfort conditions of exercising people in the semi-arid region of India. *Sustainable Cities and Society*, *76*. https://doi.org/10.1016/j.scs.2021.103366

Langmann, S., & Pick, D. (2017). *Photography as a social science method.* Springer Nature.

Manavvi, S., & Rajasekar, E. (2020). Semantics of outdoor thermal comfort in religious squares of composite climate: New Delhi, India. *International Journal of Biometeorology*, *64*(2), 253–264. https://doi.org/10.1007/s00484-019-01708-y

Manteghi, G., & Mostofa, T. (2022). A Seasonal Field Investigation to Perceive Outdoor Thermal Comfort and Thermal Adaption at Malacca Tourist Area-A Pilot Test. *AIP Conference Proceedings*, *2644*(March). https://doi.org/10.1063/5.0104077

Manteghi, G., Mostofa, T., & Lamit, H. Bin. (2020). A Pilot Test to Analyze the Differences of Pedestrian Thermal Comfort Between Locals and Internationals in Malacca Heritage Site. *Environment and Urbanization ASIA*, *11*(2), 326–341. https://doi.org/10.1177/0975425320946311

Matzarakis, A., Rutz, F., & Mayer, H. (2007). Modelling radiation fluxes in simple and complex environments - Application of the RayMan model. *International Journal of Biometeorology*, *51*(4), 323–334. https://doi.org/10.1007/s00484-006-0061-8

Matzarakis, A., Rutz, F., & Mayer, H. (2010). Modelling radiation fluxes in simple and complex environments: basics of the RayMan model. *International Journal of Biometeorology*, *54*(2), 131–139. https://doi.org/10.1007/s00484-009-0261-0

Miao, C., He, X., Gao, Z., Chen, W., & He, B.-J. (2023). Assessing the vertical synergies between outdoor thermal comfort and air quality in an urban street canyon based on field measurements. *Building and Environment*, *227*, 109810. https://doi.org/10.1016/j.buildenv.2022.109810

Mohite, S., & Surawar, M. (2024). Assessing Pedestrian Thermal Comfort to Improve Walkability in the Urban Tropical Environment of Nagpur City. *Geographica Pannonica*, *28*(1), 71–84. https://doi.org/10.5937/gp28-48166

Nasrollahi, N., Hatami, Z., & Taleghani, M. (2017). Development of outdoor thermal comfort model for tourists in urban historical areas; A case study in Isfahan. *Building and Environment*, *125*, 356–372. https://doi.org/10.1016/j.buildenv.2017.09.006

Nikolopoulou, M., Baker, N., & Steemers, K. (2001). Thermal comfort in outdoor urban spaces: Understanding the Human parameter. *Solar Energy*, *70*(3), 227–235. https://doi.org/10.1016/S0038-092X(00)00093-1

Nikolopoulou, M., & Lykoudis, S. (2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and Environment*, *41*(11), 1455–1470. https://doi.org/10.1016/j.buildenv.2005.05.031

Nikolopoulou, M., & Steemers, K. (2003). Thermal comfort and psychological adaptation as a guide for designing urban spaces. *Energy and Buildings*, *35*(1), 95–101. https://doi.org/10.1016/S0378-7788(02)00084-1

Niu, J., Xiong, J., Qin, H., Hu, J., Deng, J., Han, G., & Yan, J. (2022). Influence of thermal comfort of green spaces on physical activity: Empirical study in an urban park in Chongqing, China. *Building and Environment*, *219*, 109168. https://doi.org/10.1016/j.buildenv.2022.109168

Othman, N. E., Zaki, S. A., Rijal, H. B., Ahmad, N. H., & Razak, A. A. (2021). Field study of pedestrians' comfort temperatures under outdoor and semi-outdoor conditions in Malaysian university campuses. *International Journal of Biometeorology*, *65*(4), 453–477. https://doi.org/10.1007/s00484-020-02035-3

Penn G. (2000). *Semiotic analysis of still images, Qualitative researching with text, image and sound: A practical handbook* (G. G. Bauer M. W., Ed.). Sage.

Pennington, D. (2017). Coding of non-text data. In *The Sage handbook of social media research methods*. Sage.

Pink, S. (2015). Going Forward Through the World: Thinking Theoretically About First Person Perspective Digital Ethnography. *Integrative Psychological and Behavioral Science*, *49*(2), 239–252. https://doi.org/10.1007/s12124-014-9292-0

Rutty, M., & Scott, D. (2014). Thermal range of coastal tourism resort microclimates. *Tourism Geographies*, *16*(3), 346–363. https://doi.org/10.1080/14616688.2014.932833

Rutty, M., & Scott, D. (2015). Bioclimatic comfort and the thermal perceptions and preferences of beach tourists. *International Journal of Biometeorology*, *59*(1), 37–45. https://doi.org/10.1007/s00484-014-0820-x

Shooshtarian, S. (2019). Theoretical dimension of outdoor thermal comfort research. *Sustainable Cities and Society*, *47*(November 2018), 101495. https://doi.org/10.1016/j.scs.2019.101495

Singh, A., Chandra, T., Mathur, S., & Mathur, J. (2024). Determination of outdoor thermal comfort thresholds for hot and semi-arid climates: A field study of residential neighbourhoods in Jaipur city. *Sustainable Cities and Society*, *115*, 105817. https://doi.org/10.1016/j.scs.2024.105817

Sözen, İ., & Koçlar Oral, G. (2019). Outdoor thermal comfort in urban canyon and courtyard in hot arid climate: A parametric study based on the vernacular settlement of Mardin. *Sustainable Cities and Society*, *48*, 101398. https://doi.org/10.1016/j.scs.2018.12.026

Su, Y., Wu, Z., Gao, W., Wang, C., Zhao, Q., Wang, D., & Li, J. (2024). Summer outdoor thermal comfort evaluation of urban open spaces in arid-hot climates. *Energy and Buildings*, *321*, 114679. https://doi.org/10.1016/j.enbuild.2024.114679

Thorsson, S., Lindberg, F., Eliasson, I., & Holmer, B. (2007). Different methods for estimating the mean radiant temperature in an outdoor urban setting. *International Journal of Climatology*, *27*(14), 1983–1993. https://doi.org/10.1002/joc.1537

Wei, D., Yang, L., Bao, Z., Lu, Y., & Yang, H. (2022). Variations in outdoor thermal comfort in an urban park in the hot-summer and cold-winter region of China. *Sustainable Cities and Society, 77*, 103535. https://doi.org/10.1016/j.scs.2021.103535

Yuan, T., Hong, B., Qu, H., Liu, A., & Zheng, Y. (2023). Outdoor thermal comfort in urban and rural open spaces: A comparative study in China's cold region. *Urban Climate*, *49*, 101501. https://doi.org/10.1016/j.uclim.2023.101501

Zhang, C., Zhou, Z., Wang, X., Liu, J., Sun, J., Wang, L., Ye, W., Pan, C., Medical, A., & Zhang, C. (2023). *Factors influencing outdoor thermal comfort in coastal spaces during the transition season in cold regions of China*. 1–25.

Zhang, Y., & Liu, C. (2021). Digital Simulation for Buildings' Outdoor Thermal Comfort in Urban Neighborhoods. *Buildings*, *11*(11), 541. https://doi.org/10.3390/buildings11110541

Zhao, H., Wang, S., Zhang, Y., Zhao, L., Zhai, Y., Brown, R. D., Jin, L., & Wu, R. (2023). The effect of solar radiation on pedestrian thermal comfort: A climate chamber experiment. *Building and Environment*, *245*, 110869. https://doi.org/10.1016/J.BUILDENV.2023.110869