A Parametric Analysis of Thermal Comfort of Street Vendors in the Traditional Settlements of Patna, India

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Abstract

High population and fewer opportunities in rural areas, coupled with migration has resulted in an increase of population in urban areas of developing countries like India. Unskilled labour and a low level of education have forced people to resort to street vending for their livelihood. Moreover, street vending does not need high levels of skills and there is also no rental burden. In fact, it has a very low capital requirement. They now make up about 2% of the population of the metropolis, an enormous growth in recent years. Therefore, street vendors involved in selling goods and services to people on the streets play a crucial role in urban economies. However, they have to frequently deal with difficult working conditions, such as exposure to thermal discomfort and poor air quality.

This paper examines how thermal comfort affects street vendors on different road geometries and settlements. It is assumed that the built environment along the street is an important parameter that governs thermal comfort of the hawkers and vendors. In order to achieve the intended outcome of thermal comfort, the research uses the empirical data collection of weather parameters and uses it in established software (Rayman). It is verified by means of a systematic questionnaire survey conducted among the intended target group (vendors). As research methodologies, PET (°C)/PMV were calculated by gathering all the data (Physiological & Weather) for two different street geometries at the same time. The readings were taken for statistically significant sample for a large period of time during summer. In doing so, it compares, Physiological Equivalent Temperature (PET)/ Predicted Mean Vote (PMV) for traditional and modern streets.

The findings show that traditional streets are thermally more compatible for street vendors in a composite climate where hot days are more, for most part of the year.

Keywords: Street Vending, Traditional Settlements, Modern Settlements, Thermal Comfort

1.0 Introduction

Street vendors are those who sell goods or services in public places like sidewalks, parks and markets without owning or renting a permanent commercial establishment. They provide a diverse choice of low-cost goods and services in public settings (NCEUS, 2006). Indeed, they sell everything: food, fresh vegetables, clothing, gadgets, jewelry, crafts, building materials, and secondhand goods. They rely primarily on spontaneous purchases to generate sales and may employ inventive marketing methods to entice customers. Their primary expenditure involves providing meals to their families and paying school fees for their children. These vendors have strong ties to the regular economy because they purchase commodities from formal businesses.

Street vending is a common means of self-employment and a source of income for millions of people around the world, especially in developing nations where formal work alternatives are scarce. Street vending, however, is almost always associated with poverty, informality, and social isolation. They generate employment not only for themselves, but also for security guards, transportation operators, storage providers, and others (Bhowmik, 2003). Many cities earn revenues from them through licensing and permit payments, fees and fines, and some types of taxes. Street vending is a form of informal economy, which implies it works outside the government's formal laws and regulations and without legal protection and recognition.

Despite these negative connotations, street trade adds vibrancy to urban life and is regarded as an integral component of historical, cultural, and tangible heritage in many cities. Although street merchants are a major and visible workforce in cities, it is impossible to exactly determine their numbers. According to WIEGO's Ghana (2015) (Linares, 2017) street vendors and market traders account for 29% of the total urban employment. In eight major African metropolises, street sellers account for 3% of women and 2% of males employed. In India from 2018-2019, 4% of women and 2% of men working in cities are street vendors. In Mexico in 2019, this number rises up to 4% of women and 3% of males work as street vendors. In Peru in 2015, four percent of men are street vendors.

Street vendors sell items and provide services at generally defined public locations such as open spaces, transportation interchanges, and construction sites. Often working under the sky, street vendors and their wares are subjected to direct sunlight, heavy rain, extreme heat or cold, and air pollution. Unless they work inside a market, they do not have access to shelter, running water, or restrooms near their workplaces. Changes in weather and air pollution seriously affect the health and survival of the street vendors.

1.1 Street Vending in India

Economic liberalization in India initiated in 1992 has opened international trade, boosting the economy of the nation. Urban areas are the hub of economic activities. In the pre-liberalization phase, the priority sector was rural areas, and the emphasis was on agriculture. Post-liberalization, a series of programs have been initiated for Urban development to attain a higher percentage of the urban population. It is believed that cities can lead to higher economic growth (Shaban et al., 2022). The Census of India reports a level of urbanization to be 31.16% in the year 2011 (Census of India, 2011). As per the IMF Report, India is the third largest economy in terms of Purchasing Power Parity (PPP) GDP (IMF, 2023) after USA and China. However, in emerging and developing economies, a higher share of 'informal job' opportunities exists as compared to the developed nations. These informal jobs lack social security and are often deprived of basic infrastructure for survival.

According to the Periodic Labour Force Survey 2017-18, informal jobs include street vending which comprises 2.0 % of the total urban population in India. Street vending is a low-capital enterprise with several members of the family engaged in one business. It is opted often by those who are unskilled, have limited education, and have minimal capital to start any better enterprise (Chakraborty, 2021). Non-obligatory requirement for street vending makes it an attractive opportunity for those struggling to find employment and who have migrated to the city from the rural areas.

Vending activities are performed mostly on the street either at a stationary location with a makeshift arrangement, or on a mobile arrangement carrying the goods on head, bicycle, or a cart. A second type of vending activity performed once a week is at a weekly market. Vendors find their locations mostly in dense commercial zones that have heavy footfall, like transit locations or dense residential zones selling the merchandise of daily needs and services. Since vending is an outdoor activity, vendors are constantly exposed to harsh weather conditions and inferior quality of air to breathe. Small vendors who have limited items like vegetables, fish, or other merchandise on baskets carried over their heads or bicycles often visit traditional settlements for vending.

This research paper does a parametric analysis of thermal comfort for hawkers moving in traditional settlements on narrow lanes vis-a-vis those street vendors on a wider commercial street. Its aim is to record the variations of thermal comfort for street vendors in two different street morphologies.

Its objectives are:

1. To evaluate the thermal comfort perceived by street vendors/hawkers.
2. To differentiate the thermal comfort experienced by street vendors in arterial road vis-a-vis the neighboring traditional street.

1.2 Constitutional Provisions for Street Vendors in India:

Right to Trade: as per Article 19 (1) (g), Indian citizens have the right to practice any profession, trade, or business (Bhowmik, 2003) .

A few Government initiatives for street vendors are SVANidhi Scheme for the benefit of over 50 street vendors, NASVI (National Association of Street Vendors of India) for the protection of livelihood rights of street vendors, The Street Vendor (Protection of Livelihood and Regulation of Street Vending) Act, 2014 enacted to regulate street vendors in public areas and protect their rights is also in operation.

Street Vendors Act- 2014 regulates vending activities by conducting a survey once every five years. 2.5% of the population must be accommodated in a vending zone as per the holding capacity in a ward or area. A certificate of vending is to be issued to each vendor who has completed the age of fourteen and above. A registered vendor who has been assigned a place in a vending zone cannot be evicted. The vendor has to maintain hygiene and cleanliness of the place occupied.

1.3 Traditional Settlements

It is well known that vernacular architecture has developed in response to the climate, culture, and availability of local materials at a place carried over time from generations. As Srivastava & Das (2023) point out, such habitable precincts form communities that respond well to climate. Over the years, the advent of newer building materials and the people's income have transformed these structures into neo-vernacular, architectural forms. The precincts of such settlements in urban areas express form that are not organic in nature, but straight, narrow streets with buildings built to edges. Side and rear setbacks of buildings required by laws are ignored, and the lanes are fit only for the pedestrians and the two-wheeler movements. Cars cannot be accommodated in such narrow lanes. Contrary to modern urban design principles of “enclosure” which articulate the ratio of the height of a building and width of it the abutting the street are absent such that they often produce claustrophobic effects. That is usually the perception of a modern urban designer influenced by the Baroque style of urban planning with wider streets accommodating monumental buildings for the climate which have more of cooler days. However, the warmer days and bright sunshine need different approaches to planning which the traditional settlements have exhibited.

Indeed, traditional settlements exhibit a greater degree of outdoor thermal comfort as compared to such modern settlements, having wider roads along with vehicular pollution, and buildings although also have front, rear, and side setbacks.

1.4 Typical Life of Street Vendors

Early in the morning, a street vendor sets up their cart or stand at their chosen spot. They must upload equipment, cook food, and present their product in an appealing manner. Once the vendor has been established, they can begin selling their products to clients. They may have both regular clients who return daily or weekly and new consumers who happen to pass by. To attract more consumers, the vendor may employ numerous marketing methods, such as calling out to passers-by, offering free samples, or promoting their brand on social media. The merchant may need to refresh their supplies and ingredients throughout the day. They may need to rush to a neighbouring store or supplier to obtain additional supplies. Street vendors frequently work long days, sometimes up to 12 hours or more. They may take brief rests, eat, or use the loo throughout the day. The vendor packs up their equipment and products, cleans their cart or stand, and collects their winnings at the end of the day. They might have to get rid of any remaining food or rubbish. Finally, the vendor may use the end of the day to plan for the next day, such as ordering supplies or brainstorming new marketing ideas. They may also analyse how their day went and any improvements they may make to their firm (Saha, 2011).

2.3 Thermal Comfort as Per the Season, Type, and Work of the Street Vendors

Other than ambient temperature, relative humidity, wind velocity, solar radiation, metabolic rate, and Clo Value, thermal comfort for each sort of vendor depends on many other elements, such as seasonal change, type of street vendor, and their work. There are many different kinds of street vendors, each with their own distinct set of products, services, and qualities. Here are a couple of such examples:

Food Sellers: These street vendors serve everything from vegetables and fruit to snacks like hot dogs and pretzels to whole meals like tacos and kebabs. Vendors of fruits and vegetables merely need to keep their products fresh and dust-free. As a result, they regularly sprinkled water. As a result, they feel more at ease contacting water throughout the summer, though; they experience thermal discomfort in winter. Food vendors such as kabab and snack vendors such as Momo and hot dogs used to heat and fry their products before serving it. In that situation, they were completely unpleasant in the summer, but extremely comfortable in the winter.

Flower Vendors: flower vendors and fruit vendors are in the same category; they can only keep their goods fresh and dust-free. They will be more comfortable in summer than the winter.

Craft Vendors, **Second-Hand Goods Vendors, and Service Vendors**: These street vendors sell handmade items like jewellery, pottery, textiles, books, electronics, and clothing, or provide services to customers shoe polishing, haircut, bike repair, etc. In such cases, only metabolic rate affects thermal comfort keeping all parameters the same, i.e., keeping the ambience of thermal comfort.

2.4 Locations and Thermal Comfort

Vendors often set up carts or stalls in busy public areas like parks, River Side, street corners, Chowks, and near railway stations. They may set up their carts near cemeteries, parks, and other areas where people go to pay their respects or enjoy nature. They may operate in busy areas where people need quick and convenient services.

The Parkside area is generally full of greeneries and trees, so in the summer season thermal comfort could be achieved in tree shades, and building shades although they became less comfortable during winter and rain. Most of the time vendors on street corners, *chowks*,

and near railway stations feel heat stress due to the micro-heat island effect localized to those areas only. Direct solar radiation, heat due to reflection, back radiation of streets, and vehicular warm smoke in densely populated areas make the situation worse for pedestrians and street vendors.

2.0 Theoretical Basis of Thermal Comfort

2.1 Climatic Characteristics: Composite Climate

Patna has a humid subtropical climate, according to the Koppen climatic classification system devised by German-Russian meteorologist Wladimir Köppen (1846-1940). Patna has a humid subtropical climate. According to the National Building Code of India (NBC, 2016), it can be divided into five major climate zones, as shown in the Table 2: hot-dry, warm-humid, moderate, cold, and composite. A composite zone is a climatic zone with no seasons for at least six months. The city selected for this study has three seasons: summer, winter, and mild autumn and spring. The meteorological conditions in this climatic zone change greatly over the summer and winter seasons. Summer starts in April and lasts until September. The maximum daily temperature ranges from 32°C to 43°C, while the maximum overnight temperature ranges from 27°C to 32°C.

Table 1: Climatic Zone Classification Criteria
Source: (NBC-2016)

SI No.	Climatic Zone	Mean Monthly Max. Temperature(°C)	Mean Monthly Relative Humidity (%)
1.	Hot-dry	Above 30	Below 55
2.	Warm-humid	Above 30 Above 25	Above 55 Above 75
3.	Temperate	25 – 30	Below 75
4.	Cold	Below 25	All Values
5.	Composite	Any of the season does not fall for more than six months	

Up to 12 hours or more, they may take brief rests, eat, or use the loo throughout the day. The vendor packs up their equipment and products, cleans their cart or stand, and collects their winnings at the end of the day. They might have to get rid of any remaining food or rubbish. Finally, the vendor may use the end of the day to plan for the next day, such as ordering supplies or brainstorming new marketing ideas. They may also analyse how their day went and any improvements they may make to their firm (Saha, 2011).

3.0 Review of Literature

Quite a good number of studies of external thermal comfort analysis for a pedestrian are available, but only a few works reflect the thermal comfort analysis of vendors. Pedestrians are momentarily street visitors for commuting to their workplace, leisure trips, shopping, or some specific purpose. Vendors are full-time street merchandisers accepting the vagaries of nature in the form of thermal comfort or discomfort.

Banerjee et al. (2020) point out that outdoor thermal comfort (OTC) is essential in the city of Kolkata, India because the micro-entrepreneurial activities are carried out on the streets and the health of the entrepreneurs (vendors) are of prime importance for the wellness of the city. She found that Annual Neutral PET was 23.58 °C with a range between 19.48 °C–27.59 °C. $T_{neutral}$ range was 22.10 °C to 27.56 °C. Similarly, Banerjee et al. (2022) examine the issue in Mumbai, the financial capital of India, have discovered varied results in calculating the neutral PET for summer (28.0° C for Kumbhadwada and 35.5°C for Fashion Street) and for winter (23.2°C for Flower market 23.2°C for Fashion Street), although Mumbai has no such clear distinction between summer and winter, because of maritime climate.

In contrast, Mangan et al. (2020) look at Turkey and conclude that the Height/ Width (H/W) ratio of 2:1 for Urban Canyon is the best ratio during summer for optimum thermal comfort. In fact, the Height and Width ratio also controls the Sky View Factor (SVF) which controls the global radiation reaching the street (Miao et al., 2023). For tropical countries,

thermal radiation from the sky is undesirable in the Summer, while it is highly required during the winters. However, the construction of fly-overs has created a lot of shades on the streets making them more compatible for the pedestrians (Das et al., 2023) reducing the SVF and thereby reducing the global radiation.

Wind velocity is a complex phenomenon in urban canyons when there is a mix of buildings with unequal-heights. According to the findings of a research by Givoni,

> "An urban profile of variable heights, where buildings of different heights are placed next to each other, and when the long facades of the building are oblique to the wind, actually enhances urban ventilation."
>
> Givoni, 1998:231

This phenomenon is quite interesting in traditional settlements where we have pockets of high wind velocity as compared to general wind velocity enhancing the PET (°C). However, Bhat (2022) points out that "to create comfortable microclimates for social uses in urban environments, sufficient shading facilities are a primary strategy." This can be achieved through increasing the green index for the city. Similarly, Mukhopadhyay & Das, (2023) show that the blue spaces or the water bodies in the city of Bangalore have significantly decreased due to urban pressure on land thereby affecting the micro-climate of the city. However, according to Kumar & Das (2022) this situation of blue and green spaces at the regional level are decreasing in the case of Bihar, India. According to them, planting greeneries in balconies gives a cooler sensation to interior rooms. It also cools the surrounding areas. Therefore, quite a good number of households are greening their balconies for visual delight and thermal comfort.

Adding to these arguments, Eskandar et al. (2022) point out that street alignment in traditional settlements influences outdoor thermal comfort. In an extensive study of the historical core of Iran, they found that thermal comfort is higher in Radial- Tributary (RT) than in Grid-Tributary (GT) and Tributary-Tributary (TT) street arrangements. In NE-SW, NW-SE, N-S, and E-W directions, thermal comfort has better conditions, respectively. The thermal status of the streets next to the old plots was better than the streets next to the mixed plots and mixed plots had better thermal status than plots with new patterns.

Overall, these studies highlight the importance of having a thorough grasp of outdoor thermal comfort that takes into account the various requirements and experiences of both street sellers and pedestrians.

Research Methods

This paper examines thermal comfort for street vendors in informal regions of cities. It employs a case study approach as a research method. The selection of the case study is based on street morphology typical to an old settlement. Having lived in Patna for over a decade, the author draws on personal experiences when picking Mahendru residential area for this study. Notably, while street hawkers have been concentrated in many regions of the cities, a significant number of street vendors and hawkers continue to frequent this area (Mahendru).

Two essential aspects in this case study are explored: first, the variation in PET (Physiological Equivalent Temperature) and PMV (Predicted Mean Vote) values for street hawkers as one proceeds from the main road (Ashok Rajpath) to internal linked streets. Second, it examines street hawkers' perceptions of thermal comfort in these places, determining whether or not they experience variations in thermal comfort. Weather data were collected across different alleys of the traditional settlement to fully appreciate the thermal comfort of street hawkers operating in confined streets.

Keeping in mind the seasonal variations of the composite climate, the research was conducted throughout two seasons: summer and winter, to explore the perceptions and preferences of street vendors in each season.

Fig. 1: Patna Monthly Average Temp. (°C) and RH (%)
Source: Indian Meteorological Department

The study is based on empirical data collection of meteorological parameters and using it in established software (Rayman) to get the desired result of thermal comfort. It is validated through a structured questionnaire survey among the target groups.

Empirical Data Collection

A settlement (Ward No 50) was chosen for the parametric study which exhibited the character of a traditional setting like narrow lanes (up to 2 m), buildings of low rise (2-3 story high), absence of building bye-laws and culture exhibited in coherence to traditional lifestyles. Meteorological parameters like Temperature, Relative Humidity, Globe Temperature, and wind velocity were recorded at a height of 1.1 m above the ground (Mayer & Höppe, 1987) (Thorsson et al., 2007) (Fang et al., 2018). Air Temperature and Relative Humidity (RH) were recorded using handheld equipment, Metravi Data Logger for Temperature and Humidity DL-TH-01 (Relative Humidity Range: 0 to 100%; RH Accuracy: ±3.0%; Temperature: -40 to 70°C; Accuracy: ±1°C). Globe temperature was measured using a 15 cm dia. globe thermometer. For recording wind velocity, Meco 961p Air Flow Anemometer (INS-Meco 961P) was used.

The investigation was conducted in Ward No. 50 of the city, which has evolved during the medieval era. The primary route connecting the residential areas is Ashok Rajpath. The streets linked to the Main Road are relatively smaller in length and width. The geometry of a few streets allows vendors with hand carts. Hawkers carry their goods in baskets on their heads in order to pass through them.To analyze the thermal comfort in the narrow streets of Mahendru traditional settings, nine locations were selected as per road width. These locations are marked L1, L2……L9 in Figure

Fig. 2: Study area Residential Settlement Map
Source: Author

The Case Study: The Site

Site (part of Mahendru Residential Area, Ward No -50, Ashok Rajpath, Patna)

Patna is the capital and the largest city of the Indian state of Bihar. It is located on the Ganga's bank. Patna (formerly Pataliputra), a historic city that was formerly the capital of the Magadh Empire in the 4th century BCE, has a rich past as the capital of the entire Indian subcontinent. The city's expansion is linear, about 25 kilometers long from the East to West along the Ganga River, which is 9-10 kilometres broad. According to the 2011 Indian census, the Patna Municipal Corporation has a land area of 109.218 km^2 and a population of 16.84 lakh people (Census of India). In 2011, the average population density per square kilometer was 16845, and the predicted population growth was 20.84 lakh in 2021 to 24.51 lakh in 2031 (India).

Fig. 3: Location of site of Patna
Source: Author

The city exhibits a layer of historic settlements which can be identified from the pattern of the streets. The whole city has been divided into three parts as per the settlement pattern. The old city has traditionally narrow streets and dense settlements.

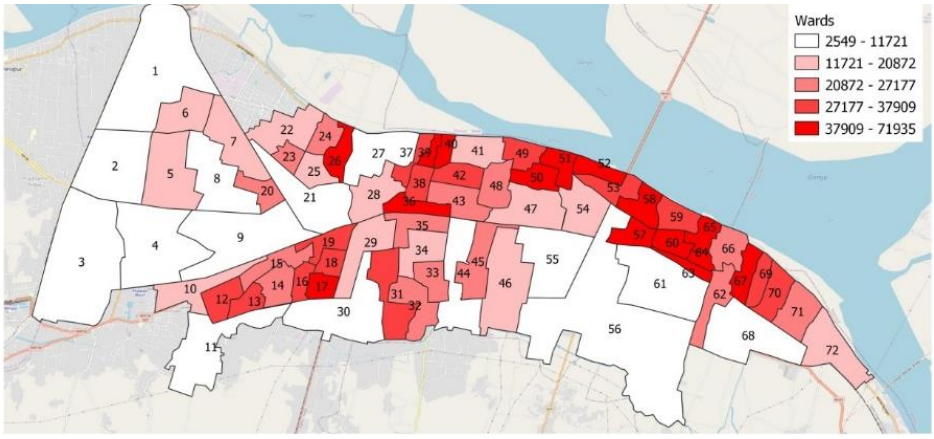

Fig. 4: Map of Patna showing ward population density
Source: Author

Ashok Rajpath, an ancient and bustling road that connects the old city to the developing urban landscape, is significant in the city's history. This road, which dates back to the Sher Shah Suri reign was designed originally for horse carts, horses, and bullock carts. However, it has evolved to handle a wide range of modern vehicles, including automobiles, motorcycles, and cycles, as well as motorbikes, tractors, auto-rickshaws, buses, and, of course, pedestrians. The 11-kilometer route from the old city to Mahendru maintains a width of approximately 7.5 metres, providing a unique blend of antiquity and modern transit needs.

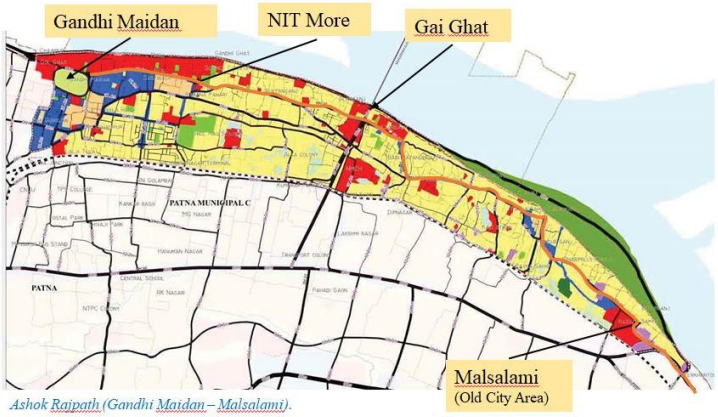

Fig. 5: Land Use map of Eastern Patna
Source: Author

The route from Malsalami to Gai Ghat is approximately 8 km long and serves as an important link in the city's transport network. This route has a maximum road width of 10.20 metres, providing plenty of room for vehicles and commuters. The minimum road width, however, narrows to 7.62 metres, reflecting the road's varied size along its route. The metalled width of this road portion is 4.27 metres, with no pavements on either side, emphasising the difficulties that pedestrians may confront. Auto-rickshaws and cycle-rickshaws are the principal modes of public transportation in this densely populated area, which has 37,000 to 71,000 people per square kilometre, making it a lively and frenetic corridor of urban life.

From Gai Ghat to NIT More, densely populated district has a dynamic mix of residential and commercial development, with G+3 or G+4 buildings lining the road, resulting in a vibrant urban setting. Access to this area is made possible through short pathways ranging in width from 1 to 3 metres. The road itself is around 3 kilometres long and has varied proportions, with a maximum road width of 13.56 metres and a minimum road width of 7.62 metres. The metalled portion of road measures 6.34 metres but lacks walkways on either side, making it difficult for pedestrians.

Auto-rickshaws, cycle-rickshaws and mini busses use the route as a key method of public transit, adding to the high traffic volume that frequently leads to congestion due to the road's narrow width. This road is one-way for all cars, and the lack of city bus services increases reliance on local transit choices. Notably, auto-rickshaws account for a major component of the traffic composition, accounting for 29% of total vehicles in this busy region, emphasizing the importance of effective traffic management.

Findings

A recent study Eskandar et al. (2022) found that the settlement of this specific site follows a grid tributary pattern. The width of the internal streets, which connect to the Ashok Raj route, varies between 4.6 and 2.4 metres. Buildings in this neighbourhood often range in height from G+2 to G+3 stories and have balconies projected towards the street, ensuring consistency in this aspect. The drainage system is partially covered and runs parallel to the roadway lines. During the day, the sun only shines directly on the land surface for a few hours. Street vendors with their movable carts, or "thelas," may easily access these streets. According to Tandon & Sehgal (2017) Streets define a city's spatial qualities and are its most essential feature. The most internal streets are created in a unique way, with one end smoothly connected to another internal street and the other ending in a dead end.

Most interior streets also include buildings with balconies protruding onto the street; the drainage system is partially covered and runs along the streets; and the land surface receives direct sunlight for 1-2 hours daily. However, the road width fluctuates, with some streets as short as 1.5 metres, making them primarily accessible to hawkers carrying their products on their heads.

Fig. 6: A narrow street leading to main road
Source: Author

Fig. 7: View of the traditional settlement
Source: Author

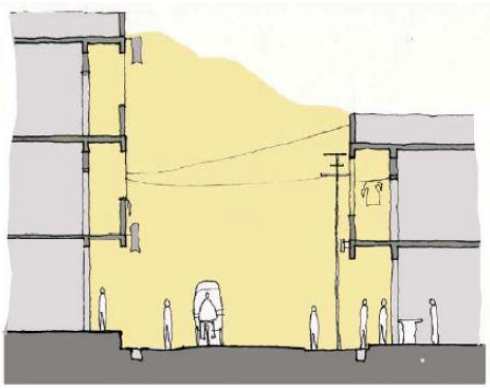

Fig. 8: Residential access through a 1 m -4 m wide pathway. This type of pathway connects to Ashok Rajpath (City Main Road) at every 15- 20 m. on linear stretch.
Source: Sankalp, 2007

Table 2: Instrument Details
Source: Manufacturer Catalog

Variables	Instruments	Range	Resolution	Accuracy
T_a	Metravi Data Logger (DL-TH-01)	-40 to 70 °C	0.1 °C	±1°C
RH	Metravi Data Logger (DL-TH-01)	0 to 100%	0.1 %	±3.0%
T_G	15 cm dia standard Globe Thermometer.	0 to 50°C	0.5 °C	-
Wind Velocity	INS-Meco 961P	1 to 25 M/s	0.01 M/s	± (3% Rdg ±0.2 M/s)
Surface Temp.	Metravi HT-3004CT Digital Temperature and Humidity Meter	-50 to 500°C	1 °C	±2.0%

Rayman Pro was used to analyse the Physiological Effective Temperature (PET) which considers the microclimate parameters (air temperature, relative humidity, surface temperature, wind speed, Mean Radiant Temperature, and solar radiation), and personal factors (gender, height, weight, clothing, and metabolism) (Matzarakis et al., 1999). Radiation from the sky was incorporated by using the Sky View Model (Figure 9). Fish eye image was captured using 'Fish Eye Lens 180°' over a smart mobile phone. The Sky View Factor (SVF) is an important attribute that controls the thermal radiation coming from the open sky and it is a dimensioned UCP that captures three-dimensional form using horizon limiting fractions (Middel et al., 2018). Based on the activity of vendors metabolic rate has been taken an average of 350 watts (Table 2), assuming that the vendor is always used to walking and moderate lifting.

Table 3: Metabolism as per activity
Source: Koenigsberger,

Activity	Watts
Sleeping	Min. 70
Sitting, Moderate movement, e.g. typing	130-160
Standing, Light work at machine or bench	160-190
Sitting, Heavy arm and leg movements	190-230
Standing, moderate work, some walking	220-290
Walking, moderate lifting or pushing	290-410
Intermittent heavy lifting, digging	440-580
Hardest sustained work	580-700
Maximum heavy work for 30 min. duration	Max. 1100

With reference to the ASHRAE handbook of fundamentals, Clo Value 0.86 was taken for the vendor (Briefs: 0.05; Vest: 0.15; T-shirt: short sleeve: 0.25; Trouser: light material: 0.26; Scarf/Shawl: 0.1).

PET and PMV were calculated for a male hawker having a height of 152 cm, weight 65 kg, age 35 years, clothing of 0.83, with a metabolic activity of 350 Watt. Mean Radiant Temperature (MRT) is a critical physical parameter that describes how humans perceive radiation in their surroundings (Mechanics, 2010) is calculated by Equation 1 given below according to ISO 7726. (AC08013621, 1998).

$$\left[\text{MRT}= (GT + 273.15)^4 + \frac{1.1\times10^8\times v_a{}^{0.6}}{\varepsilon D^{0.4}}\right]^{1/4} - 273.15$$

Equation-1

MRT= Mean Radiant Temperature (°C)
GT = Globe Temperature (°C)
v_a = air velocity at the level of the globe (m/s)
ε = emissivity of the globe (no dimension)
D = Diameter of the globe (m)
T_a = air temperature (°C)
And for the standard globe (D = 0.150 m, ε = 0.95)

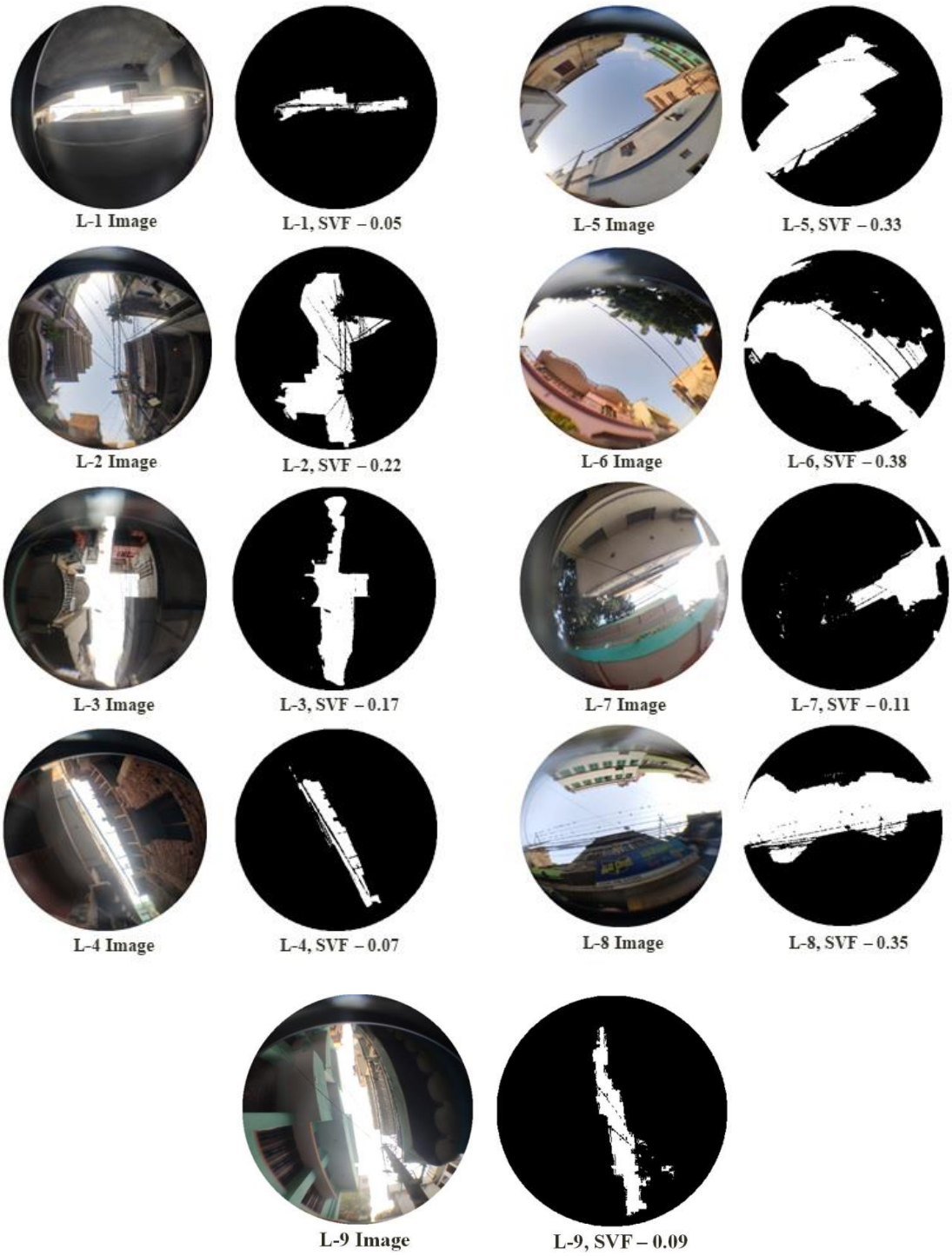

Fig. 92: Fish eye view and Sky View Factor of selected locations
Source: Author

The road width for each location was measured initially, followed by environmental data such as ambient temperature, relative humidity, wind velocity, surface temperature, globe temperature, fish eye view, and cloud cover. We calculated the mean radiant temperature using temperature, wind velocity, globe temperature, and sky view factor from the fisheye view.

Then, using Rayman Software, PET and PMV values for vendors- were discovered as shown in Table 3.

Table 4: Calculation of PET and PMV for street vendors using Rayman software
Source: Author

Location	Road Width (m)	T_a (°C)	RH (%)	Wind Velocity (m/s)	Globe Temp. (°C)	Cloud (octas)	Surf. Temp. (°C)	MRT (°C)	SVF (%)	PET (°C)	PMV
L_1	1.2	31	51	0.6	29.0	0	28	26	5.5	**28.5**	4.4
L_2	3.6	32	45	0.2	31.0	0	27	30	22.4	**31.2**	4.6
L_3	2.4	29	42	0.4	29.0	0	27	29	16.8	**28.5**	4.2
L_4	1.5	29	56	1.0	29.0	0	27	29	6.7	**28.0**	4.2
L_5	4.6	33	37	0	32.0	0	33	31	32.5	**33.0**	4.6
L_6	3.7	32	45	0.2	32.0	0	32	32	38.3	**32.2**	4.7
L_7	3.0	32	50	0.5	31.5	0	33	31	10.5	**31.4**	4.8
L_8	6.4	32	43	0.2	31.0	0	33	30	34.5	**31.2**	4.6
L_9	2.75	29	54.5	1.2	28.5	0	28	27	8.5	**27.0**	4.3

T_a = Air Temperature (°C), RH= Relative Humidity (%), MRT= Mean Radiant Temperature (°C), SVF= Sky View Factor (%), PET= Physiological Equivalent Temperature, PMV= Predicted Mean Vote. L_1, L_2....L_9 are site locations.

Table 5: Ranges of the physiological equivalent temperature (PET) for different grades of thermal perception by human beings and physiological stress on human beings; internal heat production: 80 W, heat transfer resistance of the clothing: 0.9 clo.
Source: (Matzarakis & Amelung, 2008)

PET	Thermal Perception	Grade of Physiological Stress
<4°C	Very cold	Extreme cold stress
4.1- 8°C	cold	Strong cold stress
8.1- 13°C	Cool	Moderate cold stress
13.1 - 18°C	Slightly cool	Slight cold stress
18.1- 23°C	Comfortable	No thermal stress
23.1- 29°C	Slightly warm	Slight heat stress
29.1- 35°C	Warm	Moderate heat stress
35.1- 41°C	Hot	Strong heat stress
>41.1°C	Very hot	Extreme heat stress

5.1 Validation through Structured Questionnaire Survey

Simultaneously all the parameters were recorded for a specific site on a wider street which is an arterial road and vending is performed. The respondents are vendors and are in the age group of 12-68 years. The survey was conducted during business hours 8:30 am to 10:30 pm. The independent variables chosen for the field survey are environment and personal variables, Vendors' response was collected through a questionnaire, and a thermal perception survey was used to collect thermal sensation (*tsv*) for the outdoor thermal environment on the ASHRAE seven-point thermal sensation scale. During the study, 50 samples were collected from nine vending locations in Ashok Rajpath and Mahendru residential areas respectively. Table 3 shows the statistics of vendor Demographic composition of Street Vendors at Ashok Rajpath and Mahendru Residential Area.

According to the sample survey, the bulk of the sample street sellers (48%) are from the scheduled caste community, 11% are from the scheduled tribe community, 29% are from other backward castes, and only 12% are from the general society. Hinduism is practiced by 88% of them, Islam by 10%, and Christianity by barely 2%.

Table 6: Demographic composition
Source: Author

Age Group (years) % Total						Marital Status % Total				
Less than 20	20-29	30-39	40-49	50-59	Above 60	Married	UM	Widow	Widower	Separated
8	22	44	20	4	2	85	15	12	4	2

Demographic composition shows that most of the vendors are in the age range of 30-39, and one study (Mishra & Ramgopal, 2013) says that thermal discomfort is different for different age groups of people. Less than 20 years old and people over 60 are more affected than others.

Urban poverty in many Indian cities is caused by a lack of work possibilities and poverty in rural areas and smaller towns. The majority of the urban poor lack the skills and education required for formal occupations, which are becoming increasingly scarce. As a result, the informal sector has grown fast in major cities. Due to its minimal skill and financial requirements, vending is a frequent option for the urban poor to make a living.

Table 6: Reason behind the Vending Business in Patna
Source: Author

Reason	Poverty	Unemployment	Family Business	Start-up
% of Total	44	32	14	12

According to Table 5, 44% of vending business owners are poor, 32% are unemployed, 14% have taken over the family business, and 12% started their vending business as a start-up.

Table 7: Level of Education of Street Vendors in Patna
Source: Author

Education	Illiterate	Class-4	Upper Primary	Secondary Level	Higher secondary	Graduate
% of Total	12	28	22	12	14	12

Education is very important for growth; however, this survey (table 5) says that 12% of vendors are illiterate, 28% of vendors can write their name and address, and 26% of vendors are well-educated and sensible; they have started their vending business purposefully. Female vendors had the highest levels of illiteracy; they were also less communicative and hesitant to respond. A few of the vendor's children were also helping them either full-time or after school.

There are many different kinds of vendors; some sell ready-to-eat food, half-ready food, electronic goods and plastic goods. Few vendors sell their goods by hoisting them on their heads or arms, while some use carts to transport their goods. Thus, their level of thermal comfort is likewise influenced by their work. According to Table 6, 22% of vendors reported feeling comfortable due to the natural temperature conditions, 48% thought it was only slightly warm, 24% thought it was warm, and only 6% thought it was scorching.

Table 8: ASHRAE Thermal Sensation Scale (TSV)
Source: Author

(TSV)	Cold (-3)	Cool (-2)	Slightly Cool (-1)	Neutral (0)	Slightly Warm (1)	Warm (2)	Hot (3)
% of Total	0	0	0	22	48	24	6

Conclusions

It is found that air Temperature is lower to the extent of 4° C in narrow traditional streets (avg. 29° C) as compared to the arterial streets (avg. 33°C) in the same locality but at different location. Physiological Equivalent Temperatures (PET) for hawkers are lower in

traditional streets (avg. 27°C) as compared to arterial modern streets (avg. 33°C). Although PET varies from person to person and on the activity along with age and gender, the findings revealed that at PET of 29 °C the TSV was 48% towards 'Slightly warm' and 22% and 24% respectively for 'Neutral' and 'Warm Conditions respectively. We observe that the difference in PET is 6°C. Traditional streets ensure a better thermal environment for street vendors/hawkers in summer as compared to modern streets. Similarly in winter, the traditional streets are colder as compared to the modern streets. Traditional streets of Patna being in a composite climate zone with eight months of summer, offer a thermally compatible workspace as compared to the modern streets.

Narrow streets serve an important role in reducing the impacts of solar radiation and enabling cross-sectional wind movement, resulting in large temperature variation, although as per interaction with the vendors, the objective was the sale of merchandise, and thermal comfort was not an issue with them except under extreme weather conditions of heat waves, rain, and extreme cold.

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