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ROLE OF INFORMAL SECTOR IN CAUSING URBAN HEAT ISLAND: CASE OF COMMERCIAL MARKETS OF LUCKNOW

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ABSTRACT
With rapid urbanization, street vending emerged as the important element of informal economy worldwide. Vendors on the street offer essential services to urban people while surviving on their own business, limited resources, and labor. Street vendors' populace on the street is on the rise in contrary to the perception that with the improvised economy the vendors will subside significantly. Research has been done on informal sector focusing on the quality of life of vendors, economic and social engagements, impact on street and road environment, impact on buildings and overall urban quality of the place. However, the impact of informal sector in altering the urban environment through engagement of public spaces such as streets, pedestrian walkways and open spaces is still missing. The presence of informal activities on one hand economically supports urban areas but on the other it leads to traffic congestion, crowded streets and pedestrian walkways and untidy urban spaces which degrades the overall ambience of the place for which it was designed. Subsequently, the accommodation of street vendors on the available public spaces in commercial markets leads to capture of available green spaces thereby leading to reduction in vegetation and loss of natural environment in a densely populated area. The loss of natural environment accompanied by inflating urban population and increased activities in the market due to presence of street vendors contributes to manmade environment thereby increasing the temperature of the area as an impact of Urban Heat Island. Therefore, the aim of this paper is to examine the impact of informal sector in increasing the temperature of the commercial streets due to creation of manmade environment.

Keywords: Informal Sector, Street Vendors, Temperature, Urban Heat Island, Vegetation

1. INTRODUCTION

1.1 Defining Street Vendors

A street Vendor sells good to the general public without having a fixed structure or facility from which he could sell the commodity. Street Vendors can be either stationary vendors one who occupies space on pavement and public space or can be mobile vendors with their commodities on push carts or in baskets on their heads, moving from place to place. The street vendors count has increased substantially around the globe especially in developing countries including India. The factors responsible for increase of street vending have been identified and validated by the researchers. The first factor is the migration from rural to urban areas in search of better employment opportunities and good quality of life. These

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migrants are mostly uneducated which leads them to become part of informal sector. Secondly, there are workers who were working in formal sector but lost their job due to closure of company or any other reason. For the survival of their family, these workers are forced to join informal sector to earn livelihood. Consequently, Informal Street vending has become one of the essential parts of the informal economy which provides livelihood to a large number of urban populaces, while providing everyday requirements to the urban dwellers.

1.2 Street Vendors in Markets and the Urban Heat Island

Vending has been a vocation since the dawn of time, and street sellers are an important component of our urban culture. In the traditional Indian sense, shopping and marketing have been essentially informal. In contrast to the automated and sterile image of shopping favored by modern market and supermarket structures, social interaction is a fundamental part of Indian markets. The space allocation for street vendors is still missing in Indian cities which lead to encroachment of the available urban public spaces such as streets, sidewalks and available open spaces. The encroachment of public spaces degrades the overall quality of the space by altering the available vegetation and destruction of green covers thereby visually and physically altering the land use of the place. The alteration of land use for accommodation of street vendor alters the overall character of the place by decreasing the environmental quality and the thermal comfort level of the mass visiting the place irrespective of the fact that the vendors attract a large group of urban population from economically weaker group. The streets which were designed for a particular commercial capacity and expected populace is now being used by a large population and the public spaces accommodates various temporary and mobile street vendors. The overall built environment of the place is perturbed by the encroachment of public spaces, the overall burst in the holding capacity of a place leading to chaotic situation leading to discomfort concerning psychological, visual and thermal distress. The absence of natural environment accompanied by increase in manmade environment had resulted in increase of ambient air temperature of the places for which research in various cities is being conducted worldwide. Urban Climate has been defined by T. R. Oke as the variation in the atmospheric conditions of urban areas with peri urban areas and is caused by the differences in the pattern of the built environment [1]. Urban Heat Island effect is defined as accumulation of heat in urban areas caused by urbanization and anthropogenic activities by Li Yang [2]. According to Bek et al the phenomenon of informal areas has been associated with the rapid growth of urban areas in cities [3].

1.3 INFERENCES FROM LITERATURE REVIEW

The phenomenon of informal growth is associated with urbanization which leads to increase in anthropogenic activities for which the area was not planned leading to unplanned anthropogenic emissions causing rise in temperature, an attribute of Urban Heat Island as evident from the studies analyzed. Consequently, informal growth represents a defect in urban development in cities which is very significant in old cores of a city as unplanned growth has led to increased population area when compared to a newly planned area. Major studies referred for literature analysis included the study on Hyderabad [4]; Ludhiana [5]; Lucknow [6]; Bhatinda [7]; Bangalore [8]; Pune [9]; Kolkata [10]; West Bengal [11]; Jaipur [12]; Ahmedabad [13]; [14]; Mumbai [15]; Delhi [16]; Chennai [17]; and Murthal [18]. The literature review summarizes the nature of the studies conducted in India along with the description of data collection methodology which shows a shift from manual (Mobile Observation) approach to computer aided (Remote Sensing) approach. Further ENVI-met software has been used for conducting simulations. ENVI-met is considered as a holistic microclimate model which incorporates many urban complexities such as vegetation of different varieties, building materials and roads [19]. Also, through various studies it has been established that developing metropolitan cities such as

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Lucknow is experiencing multiple UHI effect on account of rapid urbanization, unplanned/ informal growth, and increase in population density in the central core of the city accompanied with reduction in vegetation and open area [20]. Accordingly, future research should be conducted in developing cities which will definitely contribute in confronting the issue of UHI in India. Thus, it can be concluded that developing country like India should focus on conducting research for analyzing the gravity of UHI phenomenon as the available research done in the country is not at par with the research conducted worldwide.

2. STUDY AREA

The study is conducted in the three prominent locations of Lucknow, the capital city of Uttar Pradesh. Lucknow city serves as the administrative and educational hub for state of Uttar Pradesh. It is also known for its splendid architecture, arts, culture and Ganga Jamuni tehzeeb accredited globally. The study area is carefully selected so that it consists of three areas with different characteristics and has their own identity. The study areas can be seen in the Figure 1 and are described below:

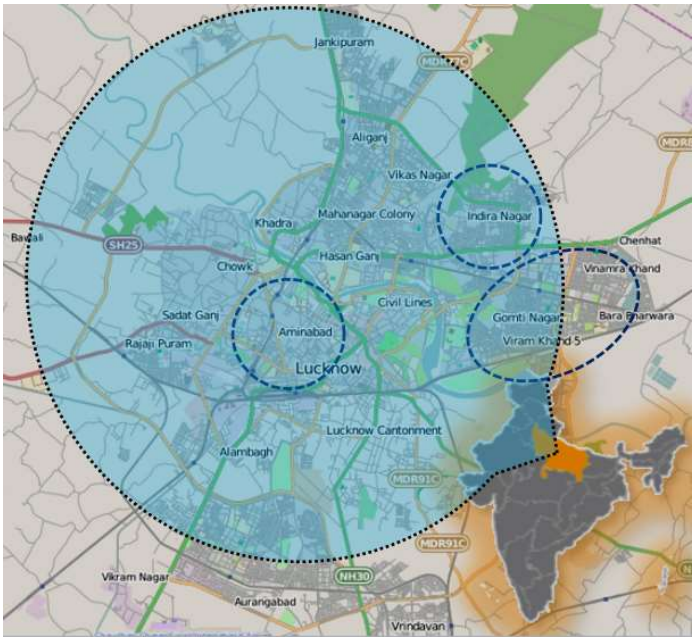

Figure 1 Study Area on Lucknow map

1. *Patrakarpuram Market, Gomtinagar, Lucknow*

Patrakarpuram is Gomti Nagar's busiest market. It houses restaurants, cafes, stores, and food places and is a major retail and leisure area. Street vendors have evolved as an activity support to the activities performed in the Patrakarpuram market, and they are clearly visible and distinctive. They sell a variety of items in informal stalls, including food, literature, clothing, coconut water, and other beverages, as well as mats and pottery on the sidewalk, cobblers, and other services related to daily needs.

2. Bhootnath Market, Indira Nagar, Lucknow

Located in Indira Nagar, Bhootnath provides a blend of Hazratganj and Aminabad markets. Bhootnath due to its location and catchment area becomes home for informal commercial spaces covering areas in front of permanent shops, side streets, open spaces etc.

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3. Aminabad Market, Indira Nagar, Lucknow

Aminabad is a major commercial area of Lucknow, built under the reign of Amjad Ali Shah between 1842 and 1847. It was conceived as a grain and vegetable market. Long rows of shops and warehouses were built with a rose garden in the rear. In later years, however the grain market moved out to other locations and it is now the largest clothes and general merchandise shopping area for the city. It is linked to other smaller markets around it - the hardware market on Sri Ram Road, guns and bullets on Latouche Road, small knick-knacks in GarbarJhala and vegetable markets in Nazirabad and Qaiserbagh. All these together form a major destination for the people of the city. It is the central part of Old Lucknow City which caters the maximum flow of visitors compared to the other markets of the city. But, from the last few years the market which meant to be an attractive public space has lost its charm and purpose due to heavy traffic congestion, illegal encroachment of hawkers and vendors, on street parking etc causing discomfort to the visitors.

3. RESEARCH METHODOLOGY

This study employs a mixed-methods approach, combining qualitative and quantitative research techniques to investigate the role of the informal sector in causing urban heat island effects in the commercial markets of Lucknow. Three commercial markets in Lucknow were systematically selected based on shopper density and geographical location within the city. The study focuses on two predominant vending practices:

- ***Traditional Vending:*** This practice is prevalent in the core area of Lucknow. Aminabad Market, characterized by substantial unplanned informal settlement sprawl due to urbanization and population expansion, serves as the representative study site for traditional vending practices.
- ***Contemporary Vending:*** This practice is observed in the newly developed colonies of Transgomti in Lucknow, specifically Indiranagar and Gomtinagar. For this study, Bhootnath Market and Patrakarpuram Market have been selected to evaluate the impact of vending activities on urban temperature variations.

Figure 2 TESTO 905-T2 Thermometer

The methodology involves real-time mapping of street vendors and recording temperature measurements at selected points through comprehensive field surveys and meteorological stations. This dual approach ensures accuracy and reliability in capturing the spatial distribution and temperature data. The collected data will undergo rigorous statistical analysis to assess spatial distribution patterns and their correlation with urban heat island effects. This analytical framework facilitates a detailed examination of how informal vending practices contribute to urban heat island phenomena in the

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commercial markets of Lucknow. The study aims to provide insights into the environmental impacts of the informal sector and inform urban planning and policy-making.

4. EXPERIMENT DESCRIPTION AND WEATHER CONDITIONS

Handheld data loggers were employed to measure ambient air temperatures across the designated study areas. Two coordinates were identified within each market area: one within zones of high informal sector activity and the other within zones of low informal activity. In Aminabad, an additional coordinate was selected within the heritage zone to record temperatures in an area free from informal activities, thereby providing a control for the temperature study.

The temperature measurements were carried out in two distinct periods due to the pandemic.

- The first temperature survey was conducted from 02 June 2020 (morning) to 10 June 2020 (night) in Patrakarpuram and Bhootnath Markets. This period experienced intermittent rainfall on 4 and 5 June 2020, resulting in lower ambient temperatures. During this survey, minimum temperatures ranged from 23°C to 25°C, while maximum temperatures varied between 34°C and 39°C. Daytime solar radiation peaked at 936 W/m². The predominant wind directions were North-West, West, and South-West, with wind speeds ranging from 4 to 11 km/hr, generally exhibiting calm conditions.
- The second temperature survey took place from 16 August 2020 (morning) to 22 August 2020 (night) in Aminabad Market. During this period, minimum temperatures ranged from 27°C to 29°C, with maximum temperatures spanning from 31°C to 35°C. Daytime solar radiation also peaked at 936 W/m². The predominant wind directions were North-East, East, and North, with wind speeds ranging from 3 to 15 km/hr, generally exhibiting calm conditions.

Temperature data were recorded using the TESTO 905-T2 thermometer (Figure 2). This instrument was selected for its high accuracy and reliability in capturing real-time ambient air temperatures across varying environmental conditions. The use of such precise equipment ensures the validity and robustness of the temperature data collected for this study. The experimental setup and data collection methodology were designed to provide a comprehensive understanding of the thermal impact of informal sector activities in the commercial markets of Lucknow. The comparative analysis of temperature variations across different zones within the study areas will contribute to a deeper understanding of the urban heat island effect in relation to informal sector activities.

5. FINDINGS OF SURVEY

5.1 Patrakarpuram Market, Gomtinagar, Lucknow

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Figure 3 Patrakarpuram Market Base Map with study area

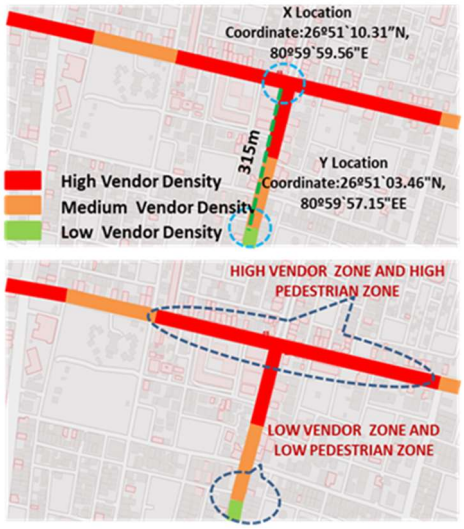

Figure 4 Street X and Street Y Location with vendor intensity

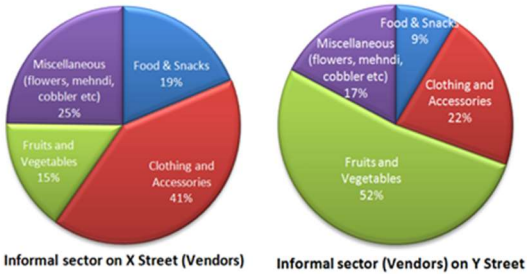

Figure 3 Vendor type mapping based on survey

While conducting the survey of the area the following things have been recorded:
1. No. of Vendors on X Location 137
2. No. of Vendors on Y Location 23

The vendors on X Street mainly comprised of: clothing stalls, food stalls, shoe stalls, coconut water carts, fruit and vegetable carts, Artifacts (metal art, local art, potteries etc.) on pavement, cobblers etc. The vendors on Y Street mainly comprised of fruit and vegetable carts, food stall etc. as shown in figure 5. The pilot survey was conducted just after the end of lockdown therefore the number of vendors and population density was comparatively low due to pandemic.

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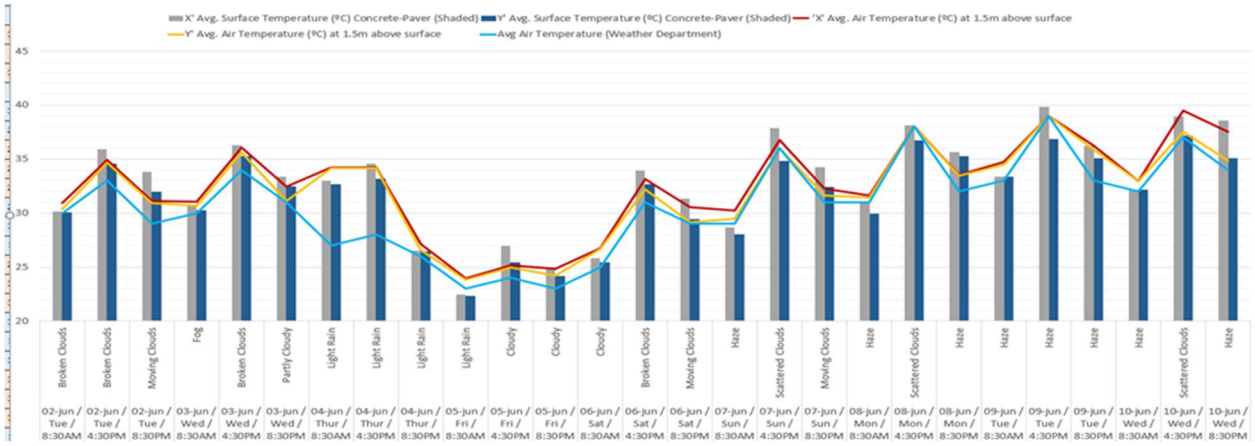

Figure 6 Temperature recorded on X and Y location in Patrakarpuram Market

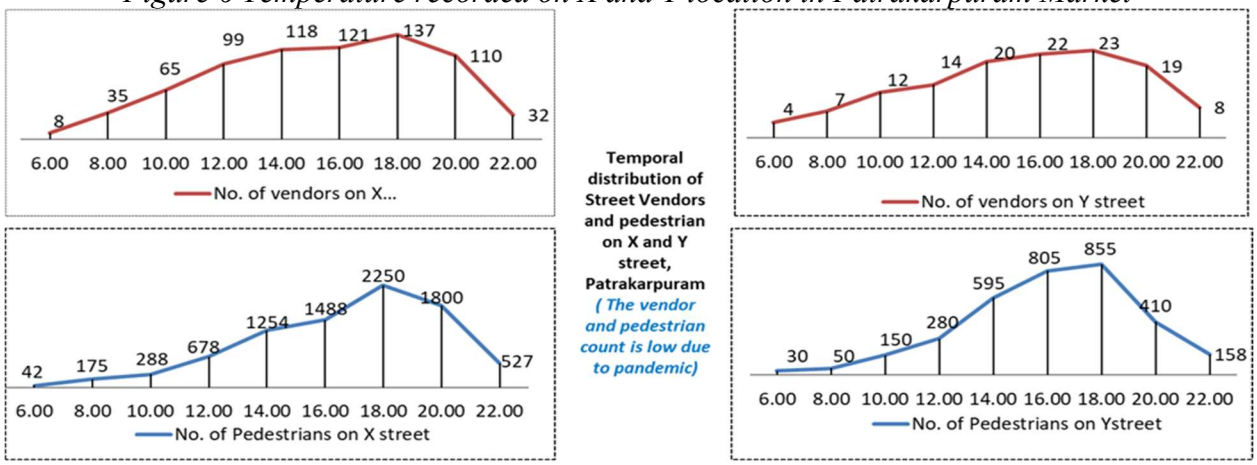

Figure 7 Temporal distribution of vendors and pedestrians on X and Y street, Patrakarpuram market

Based on the recorded and tabulated data, a temperature difference existed between the two selected locations (X and Y). The temperature at Location X was consistently higher in comparison to Location Y. The temperature difference ranged from 0.75°C in the morning to 2.7°C at night during the observation period of nine days. Additionally, the temperature increased progressively from June 6 to June 10, 2020, which can be attributed to the rainfall on June 4-5, 2020. This rainfall temporarily lowered the overall temperature, which resumed rising from June 6, 2020.

Location X had large urban canopies compared to Location Y on all days. Factors such as increased vendor density, population density, surrounding traffic intersections, and reduced green covers due to vendors contributed to the development of an Urban Heat Island (UHI) in this area. The evening hours consistently represented conditions of maximum temperature, with differences between the lowest and highest temperatures ranging from 0.97°C to 2°C at the selected points X and Y.

Furthermore, it was observed that the recorded temperatures were higher than those provided by the local weather station. The maximum difference observed was 2.55°C at Location X and 1.95°C at Location Y during the evening. The surface temperature was also measured along with air temperature, and it was noted that the surface temperature was higher than the recorded air temperature, with a difference of 1-3°C between the two locations.

5.2 Bhootnath Market, Indira Nagar, Lucknow

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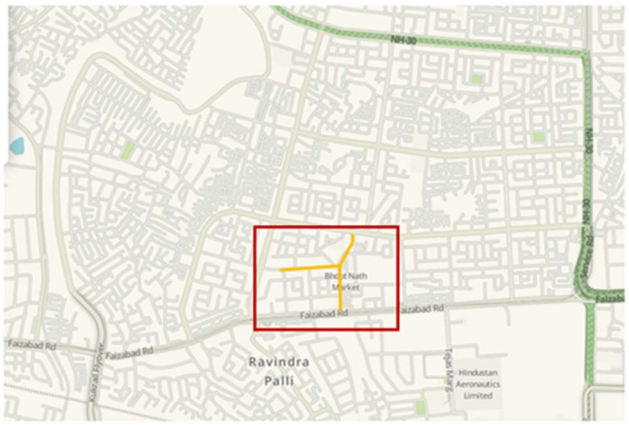

Figure 8 Bhootnath Market as study area

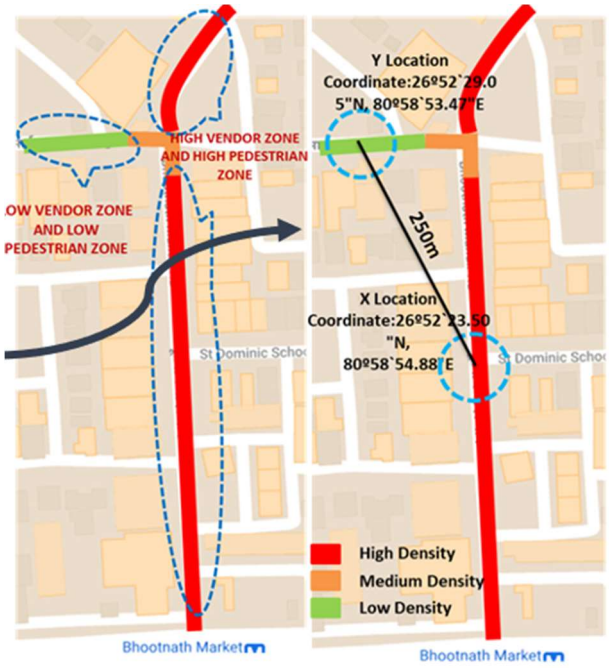

Figure 9 Street X and Street Y Location with vendor intensity

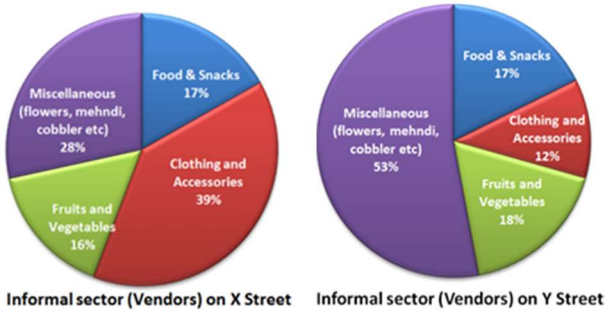

Figure 10 Vendor type mapping based on survey

The Bhootnath market area in Indira Nagar exemplifies how unplanned urban development can create significant temperature disparities, contributing to the formation of localized Urban Heat Islands

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(UHIs). Bhootnath serves as a confluence of the commercial characteristics found in the Hazratganj and Aminabad markets. This study investigated temperature variations between two specific locations within the market—Location X (Coordinates: 26º52'23.50"N, 80º58'54.88"E) and Location Y (Coordinates: 26º52'29.05"N, 80º58'53.47"E)—to understand the effects of unregulated growth on local microclimates. Due to its strategic location and the surrounding catchment area s visible in figure 8, Bhootnath has become a hub for informal commercial activities, with vendors occupying spaces in front of permanent shops, side streets, and open areas. During a pilot survey of the area, the following observations were recorded:

1. Number of vendors on X Street: 119
2. Number of vendors on Y Street: 17

The vendors on X Street predominantly consisted of those operating clothing stalls, food stalls, shoe stalls, coconut water carts, fruit and vegetable carts, and artifact vendors (including metal art, local art, and pottery) positioned on the pavement, as well as cobblers. In contrast, the vendors on Y Street primarily consisted of fruit and vegetable carts and food stalls, as illustrated in Figure 9 and 10.
The observations from the findings as shown in figure 11 and 12are as per below:

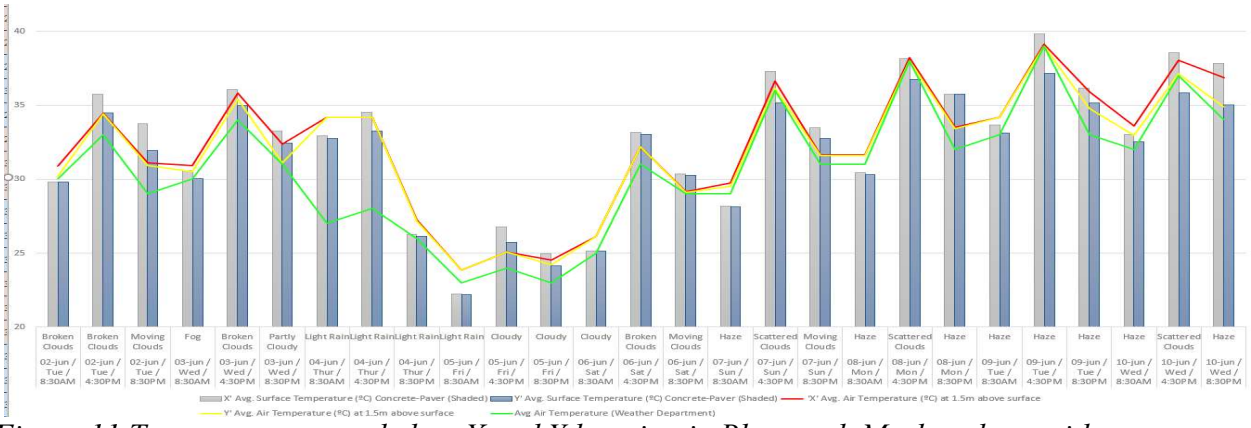

Figure 11 Temperature recorded on X and Y location in Bhootnath Market along with temperature from weather department

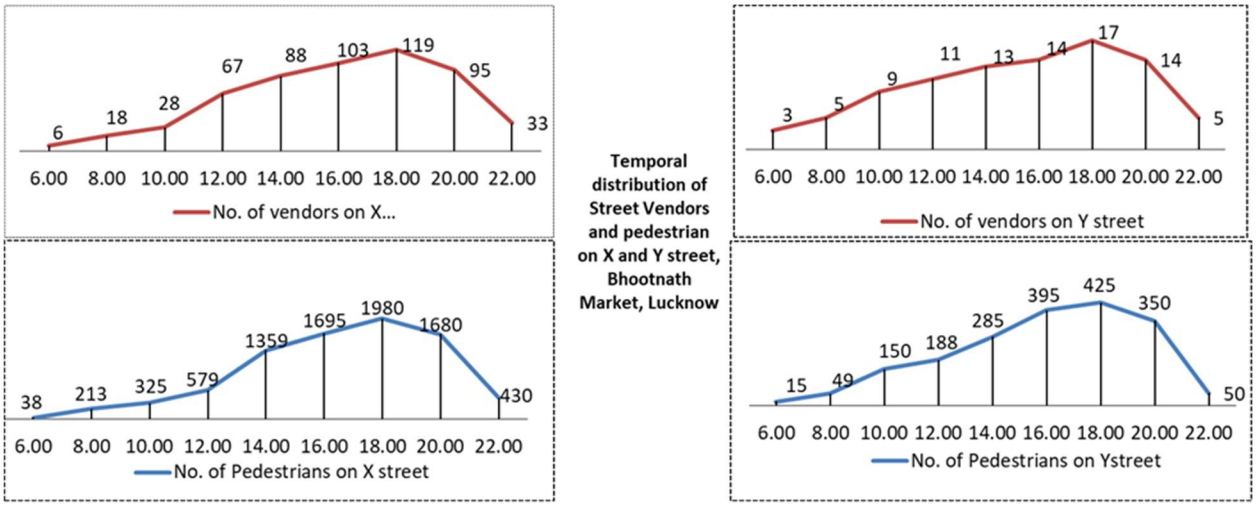

Figure 12 Temporal distribution of vendors and pedestrians on X and Y street, Bhootnath market

Location X, characterized by a higher density of vendors, extensive urban canopies, and significant

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commercial activity, consistently recorded temperatures that were 0.69°C to 2°C higher than those at Location Y. The presence of numerous vendors, coupled with heat-absorbing surfaces like concrete and pavement, contributed to a pronounced UHI effect in this area. Surface temperatures at Location X exceeded air temperatures by 1°C to 1.7°C, underscoring the impact of unplanned infrastructure on heat retention.

Location Y, although less densely developed than Location X, also exhibited elevated temperatures, though to a lesser extent. Despite having fewer vendors and commercial activities, Location Y still experienced a localized warming effect, likely due to heat-retaining surfaces and nearby traffic intersections. The temperature differences between air and surface measurements at Location Y also ranged from 1°C to 1.7°C, indicating that even less densely developed areas are affected by unplanned urbanization.

The temperature trends observed in both locations reflected broader environmental influences, such as weather conditions and the presence of urban structures. For example, following a period of light rainfall on June 4th and 5th, 2020, temperatures at both locations rose progressively, with Location X showing a more pronounced increase. This rise in temperature suggests that the cooling effect of the rain was temporary, with temperatures rebounding and intensifying due to reduced humidity and clearer skies.

Moreover, the recorded temperatures at both locations were consistently higher than those reported by the local weather station, with discrepancies reaching up to 2.5°C at Location X and 1.91°C at Location Y. These differences highlight the limitations of regional temperature measurements in capturing the localized impacts of unplanned urban growth, which can create intense heat pockets within a city.

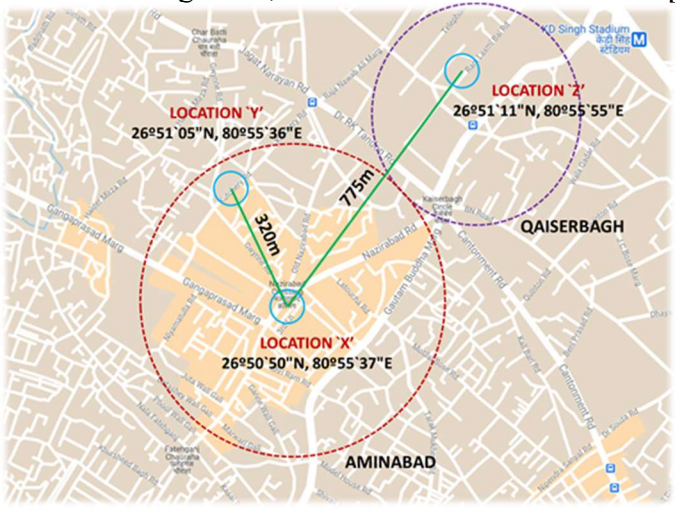

Figure 13 Aminabad Market map with study area

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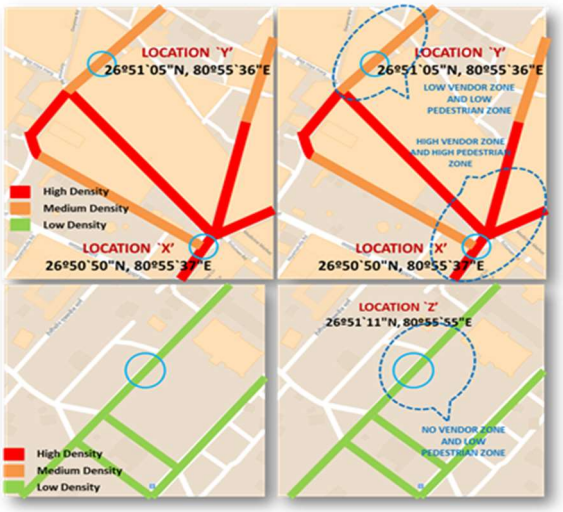

Figure 14 Street X, Y and Z Location with vendor density.

5.3 Aminabad Market, Indira Nagar, Lucknow

In the survey conducted in Aminabad, it was observed that Location X (26º50`50"N, 80º55`37"E) had a higher density of vendors compared to Location Y (26º51`05"N, 80º55`36"E), while Location Z (26º51`11"N, 80º55`55"E) remained free of vendors, as shown in Figure 14. The following key observations were derived from the survey, as depicted in Figures 15 and 16, with a particular emphasis on the impact of unplanned urban growth:

Analysis of the collected data revealed significant temperature differences among the three surveyed locations (X, Y, and Z). Location X consistently recorded higher temperatures than both Locations Y and Z. Over the nine-day observation period, Location X exhibited temperature increases ranging from 0.97°C in the morning to 3.19°C at night relative to Location Y.

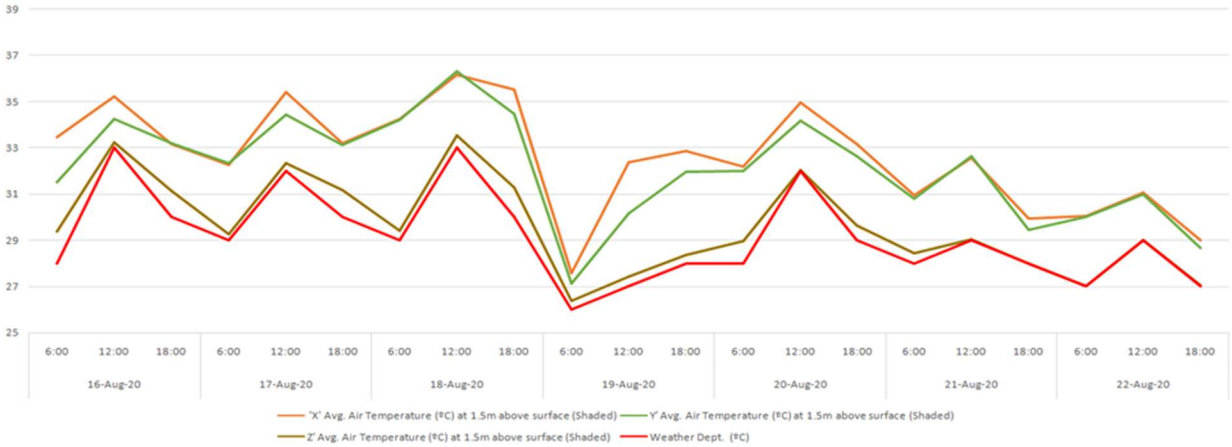

Figure 15 Temperature recorded on X, Y and Z location in Aminabad Market along with temperature from weather department

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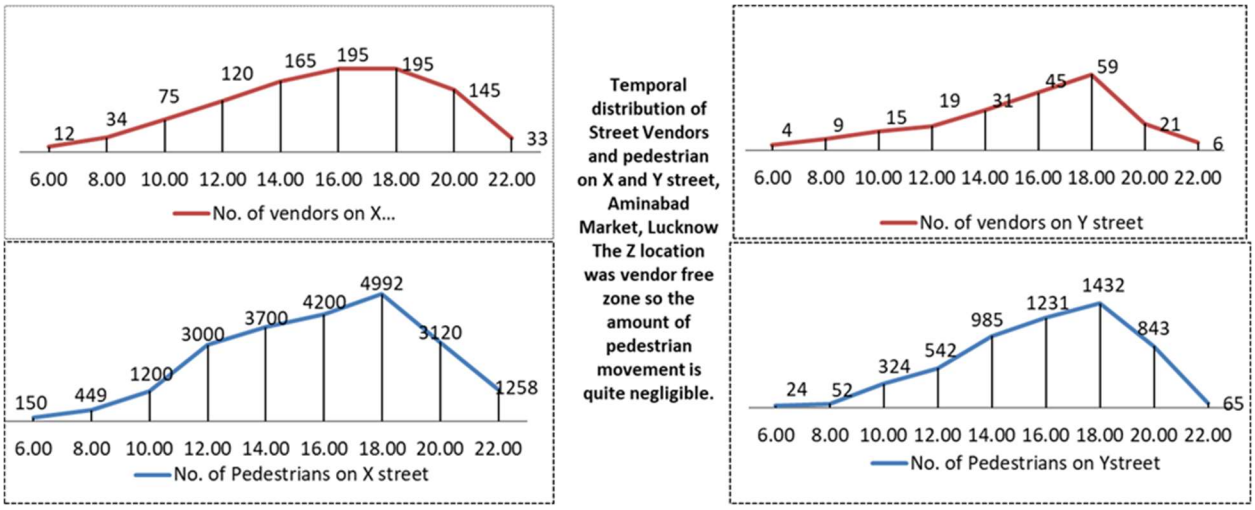

Figure 14 Temporal distribution of vendors and pedestrians on X and Y street, Aminabad market

The survey identified a pronounced Urban Heat Island (UHI) effect at Location X, which is strongly correlated with unplanned urban growth. This area has seen a rapid increase in vendor density, population density, and traffic congestion due to the lack of effective urban planning and infrastructure development. The proliferation of unregulated urban canopies, coupled with the high concentration of vendors and surrounding traffic intersections, has exacerbated the UHI effect in this area.

The survey data indicated that the evening hours were characterized by the highest temperature readings across the locations. The temperature differential between the lowest and highest recorded temperatures at Locations X and Y ranged from 0.85°C to 3.19°C, with unplanned growth contributing to the elevated evening temperatures.

The average air temperature at Location Z was consistently lower than at Location Y, with differences of 1.38°C in the morning and 6.50°C at night. Location Z, which has experienced more controlled development and lower population density, showed a reduction in average air temperatures compared to Location Y, with differences ranging from 0.56°C in the morning to 3.60°C at night.

The survey further revealed that recorded temperatures at the three locations were consistently higher than those reported by the local weather station. The maximum observed temperature deviations were 6.55°C at Location X, 5.22°C at Location Y, and 1.62°C at Location Z during the afternoon hours. These discrepancies highlight the local microclimatic effects induced by unplanned urban growth.

To check the spread of data the following statistical analysis was conducted for the case of Aminabad market as shown in figure 17.

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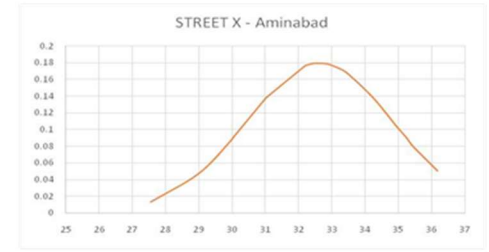

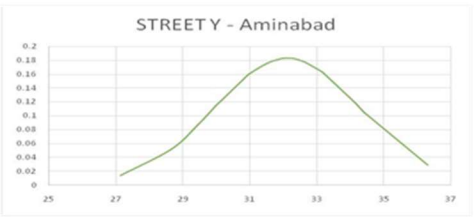

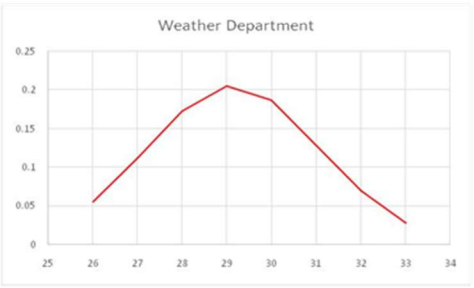

	'X' Avg. Air Temperature (°C) at 1.5m above surface (Shaded)	Y' Avg. Air Temperature (°C) at 1.5m above surface (Shaded)	Z' Avg. Air Temperature (°C) at 1.5m above surface (Shaded)	Weather Dept. (°C)
MEAN	32.63	32.12	29.63	29.14
MEDIAN	32.87	32.32	29.28	29.00
MODE	33.15	32.65	No Value	28.00
COUNT	21.00	21.00	21.00	21.00
VARIANCE	4.94	4.76	4.05	3.74
Standard Dev.	2.22	2.18	2.01	1.93

Norm. Dist.=				
27.56	0.013260703	0.013547732	0.054024764	0.05509582
29	0.047184585	0.051693849	0.084651791	0.11165765
29.95	0.086621255	0.086555991	0.087411897	0.11165765
30.05	0.091364708	0.114115707	0.108732377	0.11165765
30.95	0.134769112	0.123209098	0.143028937	0.17321411
31.05	0.13929968	0.152306541	0.162118844	0.17321411
32.17	0.175669772	0.160303441	0.167096762	0.17321411
32.25	0.176877261	0.176057789	0.187622841	0.17321411
32.37	0.178270363	0.182261827	0.188822373	0.17321411
32.55	0.179397099	0.182536758	0.190226941	0.20568516
32.87	0.178502578	0.182029349	0.195266153	0.20568516
33.15	0.174726093	0.17746577	0.196574478	0.20568516
33.15	0.174726093	0.17746577	0.197134791	0.20568516
33.2	0.173769638	0.163840547	0.198152272	0.20568516
33.45	0.16778638	0.162050435	0.150450768	0.18695951
34.24	0.138211316	0.117519886	0.147657058	0.18695951
34.95	0.104238711	0.114985716	0.14138482	0.18695951
35.24	0.090206163	0.112955082	0.095970462	0.06928059
35.42	0.081760095	0.104832096	0.079853648	0.06928059
35.54	0.076294847	0.102807934	0.039196302	0.02824431
36.18	0.050218218	0.028651602	0.029642264	0.02824431

Figure 17 Statistical Analysis

6. Conclusion

The monitored results substantiate the presence of the Urban Heat Island (UHI) effect across various commercial areas in Lucknow, with varying intensities. This study was conducted to evaluate temperature variations in three commercial markets—Aminabad, Bhootnath, and Patrakarpuram—to analyze spatial temperature distribution and understand the impact of urban characteristics on temperature variations. The findings reveal a heterogeneous pattern of temperature distribution among the markets studied. Aminabad, situated in the dense core of Lucknow, exhibited the highest temperatures compared to Bhootnath and Patrakarpuram. This elevation in temperature in Aminabad can be attributed to several factors: increased daytime population density, loss of vegetation due to encroachments, high street vendor density leading to higher shopper counts, and substantial vehicular emissions. Specifically, the temperature difference between Points X and Z in Aminabad was approximately 4 to 5°C. This significant variation indicates that Location X, located along the heavily trafficked Aminabad Road with extensive informal activities, including vendor encroachments and increased population density, experienced the highest temperature increases. Conversely, Location Y, situated on Kutchery Road with fewer informal activities, showed a smaller temperature increase relative to Location X. Location Z, with minimal informal activities, recorded the lowest temperature

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increases compared to Points X and Y.
In the Bhootnath and Patrakarpuram markets, the temperature increases ranged from 1.90 to 2.5°C between Points X and Y, which were notably lower than those observed in Aminabad. However, even in these markets, streets with higher vendor densities recorded higher temperatures due to increased shopper counts, loss of vegetation from encroachments, and vehicular emissions.
These findings emphasize the broader issue of how unplanned growth, whether moderate or severe, can significantly impact local microclimates and contribute to the development of UHIs. Addressing these issues through better urban planning, increased green spaces, and regulated commercial activity is essential to mitigating the UHI effect and improving thermal comfort in urban environments. The study highlights the importance of considering localized factors in urban planning to manage temperature variations effectively and enhance the livability of rapidly urbanizing areas.

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