PrepareCenter.org
Prepare. Innovate. Learn. Together.

American Red Cross

Climate Centre

GLOBAL HEAT HEALTH INFORMATION NETWORK

Evaluating of extreme heat risk among informal sector workers

based on perception and micrometeorological field study.

Dr. Rajashree Kotharkar, Sagar Rajopadhye and Sanyukta Shaw

Department of Architecture and Planning,
VNIT Nagpur

This page intentionally left blank

PrepareCenter.org
Prepare. Innovate. Learn. Together.

American Red Cross

Climate Centre

GLOBAL HEAT HEALTH INFORMATION NETWORK

Evaluating of extreme heat risk among informal sector workers

based on perception and micrometeorological field study.

Dr. Rajashree Kotharkar
VNIT, Nagpur

Sagar Rajopadhye
VNIT, Nagpur

Sanyukta Shaw
VNIT, Nagpur

Department of Architecture and Planning,
VNIT Nagpur

This page intentionally left blank

AUTHORS

DR. RAJASHREE KOTHARKAR*

She is an architect-urban planner, working as a Professor at the VNIT, Nagpur, India. She is a member of the expert committee for the review of National Disaster Management Authority guidelines on heat wave preparedness. She has worked extensively in the field of urban heat islands and extreme heat, and has multiple international publications in the same area. Her current work focuses on developing and implementing intervention policies, effective risk management and adaptation practices for urban heat risk mitigation at the urban level.

SAGAR RAJOPADHYE*

He is an undergraduate student in the bachelor of architecture program at VNIT, Nagpur, India. His design interests dive into the larger spectrum of sustainability, including issues of heat and energy vulnerability and how they relate to the built environments.

AR. SANYUKTA SHAW*

She is an Urban Designer. She has graduated from VNIT, Nagpur, India. She has completed her master's in Urban Design. She has worked for smart and sustainable initiatives under pan-city and area-based development of Nagpur City, abiding by the guidelines of the Ministry of Housing and Urban Affairs, Government of India. Her current work focuses on energy-efficient infrastructure and real estate.

**Department of Architecture and Planning, Visvesvaraya National Institute of Technology, Nagpur, India*

This page intentionally left blank

AKNOWLEDGEMENTS

This project has been carried out by VNIT over the span of 6 months. The authors of the report that encompasses the project, express gratitude to the American Red Cross and the Global Disaster Preparedness Center (GDPC) for providing a platform to put forth the study on public perceptions towards heat. They also acknowledge the technical assistance offered by the GDPC, the Red Cross Red Crescent Climate Center, and the Global Heat Health Information Network (GHHIN) throughout the research.

The authors would like to thank VNIT, for the assistance in the administrative process for the research project. The authors would like to appreciate Nagpur Municipal Corporation and the Town Vending Committee for guiding them through the procurement of crucial information regarding the market areas.

They express special thanks to Dr Ravindra Keskar, for guidance and training in generating statistics required to carry out the study. The authors also wish to acknowledge Ar. Aveek Ghosh, senior research fellow, VNIT; Ar. Anchal Vidyasagar, research scholar, VNIT; Ar. Sakshi Joshi, research associate, VNIT; and Ar. Pariskshit Dongersane, project associate, VNIT for their assistance in the preparation of the questionnaire, execution of surveys and reviewing of the report. Special mention to Anjali Vardani, Isha Londhekar, Hansika Raipure and Urvi Deshmukh for assistance in carrying out the surveys.

Most importantly, the authors would like to acknowledge the informal workers- sellers, labourers, drivers, and employees- for seeking a portion of their valuable working time to comply with the survey questions. They went out of their way to give crucial objective and subjective information, thereby facilitating this report with indispensable insights.

This page intentionally left blank

ABSTRACT

The global climate is changing, with extreme heat phenomena like heatwaves leading to disproportionate effects on vulnerable groups. It is a growing concern and presents multifarious challenges, especially to street vendors and outdoor workers working in high-exposure city environments. A large portion of India's unorganized informal sector is exposed to high ambient working temperatures, which puts them at increased risk for mortality and morbidity. These populations can mitigate the negative consequences if they perceive the risk, understand coping mechanisms, and take appropriate adaptive measures. Despite the fact that extreme heat is a pressing issue in India, there has been a lack of studies assessing heat risk perception, resulting in a significant knowledge gap about heat risk perception and effective communication about it.

The purpose of the study is to fill this gap and assess the heat risk perception of street vendors and outdoor workers in a land-locked tropical city, Nagpur. The city experiences extreme temperatures with recurring heat waves in the summer season. Yet, certain populations, such as poor urban workers, continue to work under the scorching sun even during heat wave days, putting their lives at risk. The study intends to investigate this behaviour by creating a construct for heat risk perception and measuring it on a scale, the HRP Index (Cronbach's Alpha=0.761). The study adopts a mixed-method approach (qualitative and quantitative surveys), i.e., using in-situ micrometeorological data to evaluate the outdoor thermal comfort, an on-site subjective survey to assess human thermal sensation, and a self-reported heat risk assessment for assessing the heat risk perception. Using a statistical analysis, the study examines how socio-demographic factors and knowledge influences heat risk perception, but also how risk perception affects adaptation. Additionally, it documents the beliefs of street vendors regarding heat adaptation, their lifestyle changes, and coping mechanisms along with the physical interventions they apply.

There was a high-risk perception of extreme heat among most street vendors based on the mean heat risk perception index of 0.72. They exhibit high sensitivity to heat, as well as a high level of heat tolerance. It was found that the perception of risk was shaped by local knowledge and previous experience with heat. The vendor knowledge was not completely in line with scientific knowledge due to limited access to training and awareness programmes, resulting in low awareness regarding new and elevated heat risks. There was a statistically significant association between heat risk perception and adaptive measures, suggesting that risk perception is a necessary antecedent for protective behaviours and coping mechanisms. No significant associations were found between age, occupation, education, migrant status, and heat risk perception. A vendor's perceived vulnerability was an important predictor of heat risk perception, as demonstrated by the case of vendors who had pre-existing illnesses and suffered from heat-related illnesses in the past.

It has been possible to identify what additional work needs to be done based on the findings and carefully develop policy options for urban poor populations who have few resources to adapt to such extremes on their own. ULBs were given a few recommendations, among which is the need to include heat risk perception studies of different vulnerable groups when formulating heat action plans. The study also establishes a framework for future research on other vulnerable groups by investigating climatic variables in relation to the informal workforce.

This page intentionally left blank

TABLE OF CONTENTS

FIGURES

Chapter 1:

Chapter 2:

Chapter 3:

Chapter 4:

TABLES

Chapter 2:

Chapter 4:

CHAPTER 01

Introduction

Contents

1.1 INTRODUCTION

There has been a noticeable increase in weather-related events, which has led to an increase in the seasonal hazards of heat waves, droughts, flooding, and cold snaps. More focus has been placed on the heat wave study in the modern era of rapid reporting of such conditions and its accessibility to the majority of people. The current and expected rise in these occurrences show the relative magnitude and scope of weather change. It is now well recognised that there is an association between climate change and the frequency and severity of extreme heat occurrences. In major urban regions that are not well suited to them, heatwaves are expected to grow more frequent and strong, especially in the higher latitudes. This is predicted by general circulation models of climate change.

A significant public health issue around the globe is extreme heat events, which are characterized by stagnant, warm air masses and a string of nights with high minimum temperatures. These events will be made worse by the cumulative impact of a warming climate, urbanisation, and an ageing population. In fact, extreme heat events (EHE), or heatwaves, account for serious fatalities each year right alongside calamities such as hurricanes, lightning, tornadoes, floods and earthquakes (G and M, 2016).

Despite the high mortality rate linked with extreme heat events and climate change predictions, the risk of severe heat exposure is not universally perceived, and metropolitan areas often lack preparatory measures like heatwave response plans. The fact that heatwaves are silent killers—natural calamities that do not leave a path of devastation in their wake—represents a portion of the issue. They occur sporadically, like other natural catastrophes, but unlike hurricanes, which leave behind permanent reminders of the destruction, memories of the heatwave vanish once cooler weather arrives.

A similar shift in climate impact research has also occurred as a result of the climate science community's pivot from mean change to extreme heat projections: it is now widely recognised that many systems are more vulnerable and affected nonlinearly during extreme heat occurrences, such as agriculture, ecosystems, and human health. However, impacts also affect other sectors (including infrastructure) and these three are not autonomous. For instance, hot weather increases the demand for energy while taxing generating and transmission facilities, increasing the likelihood of power outages just when they could have the most negative effects on human mortality. Another recurring issue is how high heat affects various societal and economic sectors. For instance, extreme heat can raise power prices, reduce labour productivity, and have an impact on social stability and violent crime rates (Horton et al., 2016).

Extreme heat can result in hospitalizations and fatality both directly from hyperthermia and associated acute illnesses as well as indirectly, for instance by escalating preexisting ailments like cardiovascular and pulmonary diseases. All-cause, all-age mortality increases globally by 1-3% each 1 °C above the regional "unusually hot" threshold (which depends on the type of climate and the capacity to adapt). This mortality risk varies greatly throughout cities, for example, along socioeconomic gradients (such as income and access to air conditioning) and based on physical neighbourhood characteristics like impermeable land cover, which can further increase local surface air temperatures. It should be highlighted that a large portion of all heat-related deaths occur during moderate summer warmth, distinct from extreme heat events per se, particularly when it lasts for abnormally long periods of time.

Extreme heat has a heterogeneous impact on public health. There is a wide variation between the traditional history, lifestyle-related to the working environment-daily schedule-diet, migration history, health history, level of education, prominence in the community, etc., that makes meteorological phenomena affect the public with different intensities, who are equipped differently.

1.2 AIM AND OBJECTIVE

Urban areas go through many stages of development. Infrastructure investments have improved residential, institutional, industrial, commercial, and other urban regions, and they have also sped up the growth of existing and the creation of new public centres. As a result, the public spaces draw informal workers who establish semi-permanent markets, sell labour hours to new construction projects, and use their expertise in a variety of supplementary enterprises.

The resultant population group, who stem from the same city or migrate from other regions, owing to the make-shift nature of work, becomes a participant of the most visible public activity in any city. This visibility depicts factors such as spontaneity, saleability, ability to assemble and dismantle the individual business set-up, willingness to migrate, insecurity, instability, etc. The group faces the most unfiltered effects of weather conditions. This interaction gives the crudest responses. Studying the unforgiving effects of long exposure to extreme heat upon the vulnerable population gives an honest perception of heat, risks related to heat and the most readily available/feasible adaptive measures taken by them voluntarily/involuntarily. The study also aims to point to the exigency desired at authoritative and institutional levels to implement adaptive measures which the affected are unable to invent, procure or invest in. Moreover, it compels the urban local bodies to draw inspiration from the grass root level committee or community on a range of sustainable and self-implemented modifications that can be implemented by the uninformed to prevent themselves from suffering the adversities. The overall outcome of such improvements is intended to curb the risk of medical extremities.

The following study aims to identify heat-risk-related frameworks accessible at various scales and investigate the level of perception along with the factors affecting the said perception.

This is an attempt to find the interrelation between the heat perceived at the institutional level, the risk of heat perceived at the grass root level and some adaptive measures formulated by global or local authorities and others ingrained in the citizens through tradition and community.

Due to the larger availability of informal workers in public locations, the study aims to identify the market areas of an urban region. The informal workers in these parts of the city are involved in a diverse range of labour and selling activities. Informal workers in their individual market units in primarily residential regions are also investigated for a large data pool since they can offer intricate variety in their method of monitoring heat and heat-related dangers. It seeks to compile responses from typical market settings and market clusters in central and outlying urbanised locations.

The study seeks to explore establishing neutral PET and neutral thermal range that, in the end, will help in developing a correlation between the replies to the heat-related queries of the informal workers and the micro-climate/location-based meteorological factors. The study also attempts to assess the workers' perception of heat-related danger under the effect of various socio-economic and geographic elements by using a heat perception index.
The process is intended to formulate the range of modifications and customizations an individual makes at their workplace and dwelling to count in as adaptive measures against seasonal and extreme heat. The study ultimately aims to identify the gap between awareness and adaptive measures for combatting extreme heat, perceived and implemented at institutional, community and individual levels.

1.3 METHODOLOGY

In an attempt to understand the influence of extreme heat, other meteorological parameters and socio-economic factors on the heat risk perception of informal workers of a selected urban region, the methodology of the study has been formulated (Figure 1.1). It revolves around aspects such as:

1. **Understanding the events of extreme heat, heat waves, heat stress and vulnerability in their generic forms through the works of various scholars and agencies to bolster self-awareness about such occurrences.**
   There are numerous case studies on the effect of heat-related phenomena that affects various population groups all over the world. The agencies put in efforts to create awareness through their guidelines at their corresponding scales. The first phase of the study was to understand the weather conditions associated with heat and to assess the level of awareness possessed at institutional levels.

2. **Identifying the aspects of vulnerability and learning about where the informal workers are established in the vulnerable group.**
   As vulnerability is an umbrella term, the second phase of the study involves the identification of the factors which make informal workers vulnerable, with the help of existing policies for informal workers and case studies throwing light on the effect of heat on informal workers.

3. **Design of survey questionnaire and experimental setup**
   It becomes necessary to evaluate objective parameters that can be assessed through subjective thermal stress and objective thermal comfort using the PET index. This phase includes the designing of a questionnaire for evaluating the same. Another evaluation is based on a subjective approach to heat-related risks that includes the designing of a questionnaire for self-reported heat risk assessment.

4. **Selection of study area**
   For gaining data through the maximum number of informal workers and the wider range of their immediate environment, the next phase incorporates documentation and mapping of marketplaces and public places of different scales, at different locations amidst various land use and urban contexts.

5. **Survey and data collection**
   As the study’s underlying concept is based on heat, following the phase of questionnaire design, the next phase scheduled in the month of May includes

direct interaction spanning over 10 minutes with the informal workers at finalised locations during the peak afternoon hours of the day encouraging genuine responses to the questionnaires regarding live extreme heat conditions.

6. **Synthesis and analysis of the procured data**
   Detecting the relations between all the aspects covered in the questionnaire and measured through equipment formed this phase of the study, which focused on the heat risk perception and the factors that regulate the said perception.
7. **Conclusions and applications of the study**
   The resultant conclusion of the heat risk perception gives way to the concluding phase of the study, which enumerates the suggestions to be incorporated at the individual, community and authoritative levels for curbing the dangerous effects of exposure to extreme heat. The phase also elaborates on the potential applications of the study and the scope it holds for the future.

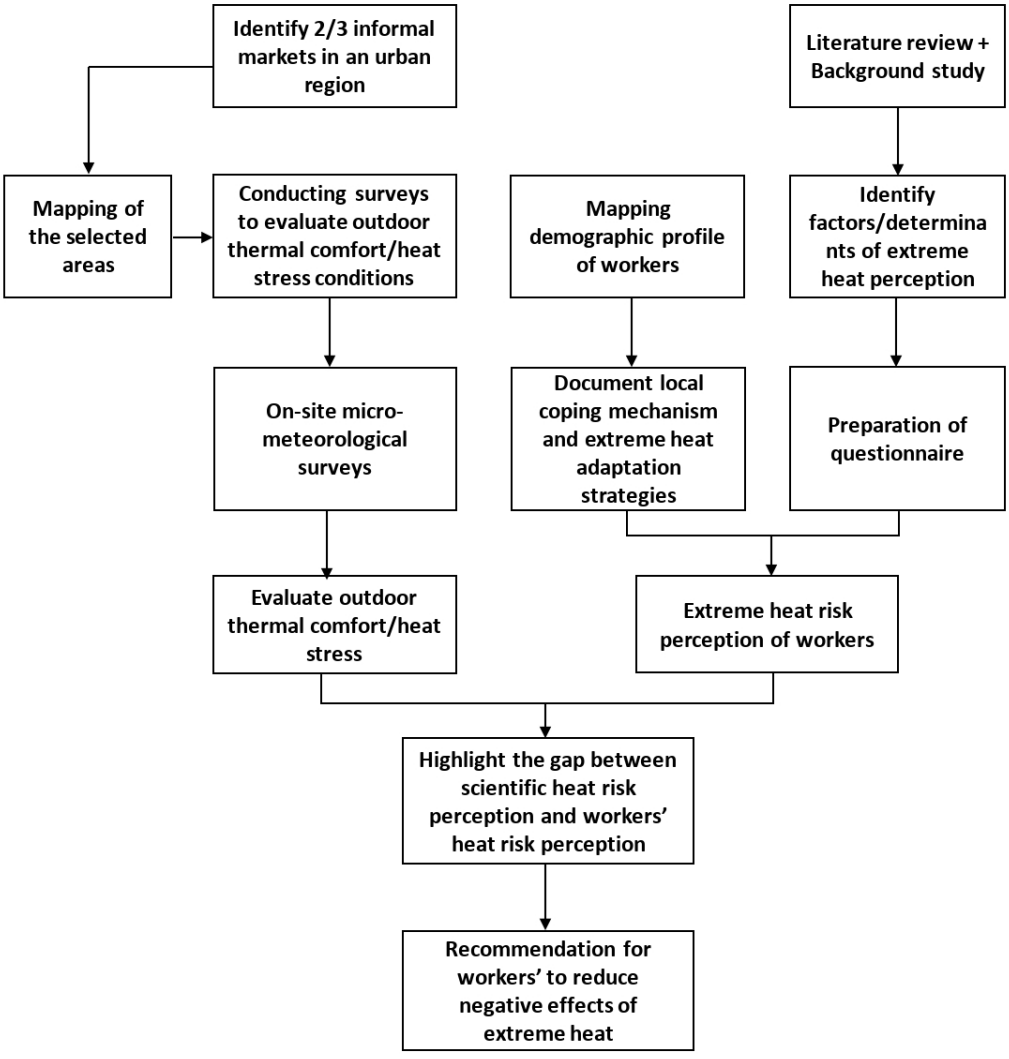


Figure 1.1: Methodology

1.4 SCOPE AND LIMITATION

It takes into account factors including demographics, general knowledge, perception of heat-related risks, coping mechanisms, and the financial effects of heat.

The spectrum of respondents includes informal labour in markets that serve and operate at the city, sub-city, and neighbourhood levels. The research is condensed to evaluate only the variables connected to heat. In order to record individual/customized responses under a homogeneous climatic condition, just one city has been documented regionally for the purpose of clarity in the assessment of risk perception. The review will take place in Nagpur, which is a city in central India. In order to prevent any macro-meteorological variance, other locations are not documented.

The source of respondents is focused particularly on the section of informal workers whose occupations are carried out from an informal set-up, benefitting from minimal administrative services, who are either registered or not registered as an informal vendor in the Town Vending Committee of Nagpur Municipal Corporation, seeking for negligible investment into their immediate environment.

The respondents approached for the survey hail from a background of limited means, with low capital investment into their business set-up. The respondents' group has not been expanded to workers under controlled indoor conditions and formal employees or businessmen as the effect of heat and extreme heat under such an environment is adulterated.

The assessment is limited to data procured through the survey carried out in the selected region. There is no prior presence of documented/compiled subjective responses against heat-related inquiry that focuses on informal workers. Owing to the evaluation being one of the initial attempts of its kind, the data related to heat risk perception in the study is entirely based on the questionnaire, with no availability of secondary data.

To conduct the survey, it was difficult to approach all the respondents with the term "heatwave", as not all of them were familiar with it. The respondents were provided with many explanations about heat waves to help them fill out the survey. The questionnaire was piloted, and it was realized that many vendors were unable to comprehend the concept of a 5-point Likert scale. As a result, the questionnaire was simplified by limiting the number of questions using it as a measurement. Also, there is a possibility that different interpretations of the same question might have resulted from the translations since all the surveys were conducted in Marathi or Hindi.

1.5 CHAPTER OUTLINE

Chapter 01: Introduction
The development of the study's goal, objective, scope, and limitations is the subject of this chapter. It specifies the study methods required at different levels and elaborates on the entire work methodology.

Chapter 02: Literature Review
This chapter aids in establishing a fundamental understanding of how people perceive heat risk and the protective measures they take. It goes on to review academics' research on the numerous facets of heat waves, heat stress, and vulnerability.

Chapter 03: Study Area
The impact of extreme heat events on various categories of people at various intensities. Its impact on the vulnerable population sheds light on its genuine nature. Since they are a vulnerable group of people, informal workers are subject

to weather extremes.

The policies, identification, and categorization of informal workers are the topics of this chapter. Additionally, it sheds light on the city that was chosen for the examination of heat risk perception, the significance of informal labourers to urban regions, and the areas where respondents were sought out. The chapter lists the spatial characteristics, microclimate, scale, and general description of the chosen locales in addition to identifying them.

Chapter 04: Results and Analysis
The physiological equivalent temperature, PET index is used to assess both objective thermal comfort and subjective thermal stress in this chapter's discussion of heat stress evaluation; study on heat risk perception using a Heat Risk Perception Index based on self-reported health and economic risk features as likelihood, severity, concern, worry, fear, etc. for street sellers in Nagpur. It then describes how sociodemographic traits, knowledge of and sensitivity to heat, historical exposure to heat waves and heat-related illnesses, adaptive measures and protective behaviours, and the impact of heat risk perception on them affect these perceptions.

Chapter 05: Conclusion
The chapter bookends the investigation by summarising all the data obtained during the research, which leads to talks on the recommendations that should be made for institutions and agencies to review their frameworks. It also covers the subsequent substantiation of the study by exploration of its projected applications and its scope for the future.

CHAPTER 02

Literature Review

Contents

This page intentionally left blank

2.1 INTRODUCTION

This chapter aids in establishing a fundamental understanding of how people perceive heat risk and the protective measures they take. It goes on to review academics' research on the numerous facets of heat waves, heat stress, and vulnerability.

2.2 HEATWAVE

The intense weather phenomenon that caused the 2022 heat wave in India and Pakistan made March 2022 the warmest month in India since 1901. The following chapter deals with understanding the term through different perspectives of global and national agencies, apex bodies, researchers and other stakeholders.

2.2.1 Heating up of cities and its impact

Since last few decades, the temperature has significantly risen around the globe. While this increase varies within nations, urban or metropolitan regions that are much warmer than the nearby rural areas are referred to as urban heat islands (UHI) because of human activity as well as the buildings and roads' ability to absorb solar heat (IPCC, 2007).

Differences in land use, surface features, and urban area geometry are primarily responsible for this human-caused modification of the local climate (Coutts, Beringer and Tapper, 2007). Urban building materials, such as concrete and asphalt, for instance, can absorb heat during the day and reflect it back at night, in contrast to vegetation (Bhargava, Lakmini and Bhargava, 2017). In addition, the heating and cooling systems of buildings and automobiles add to the ambient heat in urban areas.

There is a noticeable rise in frequency of the weather-related events that produce corresponding seasonal risks of flooding, drought, heatwaves and cold spells. In the era of rapid reporting of such conditions and their access to most people, more attention has been given to the heat wave study. The heating of cities has an impact on energy consumption, air quality, objective thermal comfort, health and the economy. The existing and prospective increase in such incidences demonstrates the relative scale and magnitude of change in weather.

Such is the magnitude of the gap between the vernacular sustainability with the ecosystem and the highly advanced disconnected technology, that climate, belonging particularly to those regions where the population is high, greatly affects the group of people least responsible for the unnatural rise in temperature. This particular group, which is present in a large scale and is the most visible in the public domain, modify their dwellings, daily routine, clothing, diet and economic choices to survive the phenomenon.

2.2.2 Defining heatwave

An extended stretch of exceptionally hot weather, usually lasting two or more days, is known as a heat wave. A region's historical average temperature must be exceeded for the temperatures to qualify as a heat wave. In addition to the customary naming of hurricanes by humans, the United States began nicknaming winter storms in 2012.

Recently, for a soaring temperature of 112 degree Farenheit between July 24 and July 27 in Seville, Spanish scientists named the resultant heatwave ‘Zoe’. Thus,

Zoe is the name given to the first heat wave. According to Jose Mara Martn Olalla, an associate professor in the department of condensed matter physics at Sevilla University, this campaign is a fresh initiative to create awareness amongst the public about severe temperatures and its associated hazards (Osborne, 2022).

2.2.3 Heat management at the international level

Various international organisations identify heatwave as a major calamity, with their respective parameters to detect rising temperature above the average for the months of summer and guidelines to combat with the rising heat, discomfort, health issues, and other indirect issues due to heatwaves.

2.2.3.1 WHO on heat wave

The United Nations has a dedicated agency for worldwide public health called the World Health Organization (WHO), which in its framework, has stated that, due to the urban heat island (UHI) effect, although the consequences of heat may be worse in cities, non-urban people's livelihoods and general well-being can also be severely disturbed during and following periods of unusually hot weather.

According to the Intergovernmental Panel on Climate Change (IPCC), the global temperature rise must be kept to 1.5°C in order to avoid catastrophic health effects and millions of fatalities brought on by climate change. A certain amount of global temperature rises and other climatic impacts are already unavoidable due to past emissions. Even 1.5°C of global warming is not seen to be safe, and every additional tenth of a degree of warming will have a significant negative impact on individual lives and health.

The severity and length of the heatwave, population adaptability and acclimatisation, infrastructure and readiness, all affect how a heatwave affects health. Due to the body's inability to regulate high temperatures, exposure to heat can produce severe symptoms including heat exhaustion and heat stroke, which can lead to fainting and dry, heated skin. Other signs and symptoms include weakness, heat rash on the neck, cramping, headache, irritation, and swelling in the lower limbs. Heat can contribute to thrombogenesis, acute cerebrovascular events, and severe dehydration (blood clots). A heatwave increases the risk of complications and death for elderly persons, children, and those with chronic conditions who use daily prescriptions.

If proper disaster prevention, preparedness, response, and recovery measures are implemented in a sustainable and timely manner, the scale of human costs associated with heatwaves can be decreased. By creating contingency plans that identify the risks, sensitive populations, available capacities, and resources, WHO collaborates with the health sector for better governance, preparation, and response to heatwaves. These plans also incorporate early warning systems and guarantee that sensitive populations, including those in hospitals, nursing homes, and schools, have access to enough cooling equipment.

As the leader of the health cluster for international emergencies, WHO collaborates with allies to address:

- Assembly of mobile health teams and outreach;
- Guarantee of sufficient dietary supplements;
- Re-establishment of primary care services, such as immunization, child and maternal health, and mental health;
- Performance of surveillance, early warning, and response for epidemics;
- Demand of urgent financing for health-related activity.

Climate change is making people more susceptible to heat, and this trend will continue. Extreme temperature occurrences are seen to be becoming more often, longer, and larger on a global scale. Around 125 million more people were exposed to heat waves between 2000 and 2016 than there were in 2000. Compared to ordinary years, 175 million more individuals were exposed to heat waves in 2015. Week-long, consecutive single occurrences might cause a large amount of excess mortality. In 2010, a 44-day heatwave in the Russian Federation resulted in 56,000 extra deaths, compared to 70,000 deaths in Europe in 2003 due to the June-August catastrophe.

All humans are physiologically affected in different ways by prolonged exposure to heat, which frequently exacerbates pre-existing illnesses and causes early mortality and disability. With proper public health measures, the harmful effects of heat are foreseeable and largely avoidable. WHO has published public health recommendations on how to deal with high heat for both the general public and medical professionals.

WHO insists to Aim to maintain a cool living environment by checking the room temperature between 8:00 and 10:00, at 13:00, and at midnight, where ideally, the room should be kept at or below 24 °C at night and below 32 °C during the day. For babies, individuals over 60, and those with chronic health concerns, this is especially crucial. The utilisation of the cool air that occurs in nighttime, by opening shutters is widely encouraged. Electrical saving by using only cooling appliances is looked forward to prevent outages and to schedule the strenuous activities between 4 to 7 in the morning. WHO identifies that increased neglect on appropriate response to heat related precautions and consequences on individual level also increases the load on public health infrastructure (World Health Organization, 2022).

2.2.3.2 WMO on heat wave

With 193 Member States and Territories, the World Meteorological Organisation, WMO is a specialised organisation of the United Nations (UN). It is the UN system's foremost authority on the condition and behaviour of the Earth's atmosphere, as well as on how it interacts with the land and oceans, causes weather and climate, and affects how water resources are distributed.

Heat waves are not yet officially defined by WMO in a way that is both consistent and mathematically sound. These are uncommon occurrences that, even in the same place, differ in personality and influence. When extremely high temperatures are registered over an extended period of time, the area experiences a heat wave. These high temperatures don't just apply to maximum values, which are normally recorded during the day, but also to values that persist high enough overnight to create a very uncomfortable environment. If present, high humidity and weak winds make people more susceptible to heat stress. Consequently, even if a heat wave is a meteorological occurrence, its effects on people must be considered while evaluating it (Robinson, 2001).

A heat wave can be defined in a variety of ways. Although the impact of a heat wave is correlated with its length, there is no clear cut threshold for defining especially long heat waves in terms of duration (Robinson, 2001). Since brief but extremely acute heat episodes can have a negative impact on human health, the scientific community generally agrees that the time gap between high temperatures should not be less than 2 or 3 days. In fact, there is evidence that, during a heat wave, the second warm night—when homes are expected to reflect the heat from the outside—is when illness and mortality are most likely to occur (Dellasala and Goldstein, 2018).

In a similar manner, there is no universally accepted cutoff point for maximum and minimum temperatures at which a heat wave is considered to exist. The effects of heat waves vary widely because local populations make physiologic, behavioural, cultural, and technological adjustments to fit the local environment. As a result, there are several factors to consider when assessing how heat waves affect human health. A variety of variables, including age, sex, health, fitness, past conditioning from living in a certain area, and/or recent exposure to extremely heated temperatures, affect physiological components of the body's overall thermoregulation. The remaining elements rely on regional sociocultural climate adjustments.

Heat waves have been defined using a number of metrics based on temperature thresholds, synoptic patterns, and thermal stress indices. Temperature or thermal indices-based definitions are based on relative or absolute thresholds (Baccini et al., 2008; Russo et al., 2015; Alexander et al., 2006; Fischer and Schär, 2010; Ballester et al., 2011; Nairn and Fawcett, 2014); or even a combination of both (Baccini et al., 2006; Fischer and Schär; (Beniston et al., 2007). Instead of using relative thresholds that assess severe episodes of a fixed rarity, the adoption of absolute parametric thresholds ensures the rigorous investigation of extreme events of a fixed intensity.

2.2.4 Heatwave definition in India

The Government of India's Ministry of Earth Sciences oversees the India Meteorological Department (IMD), which is in charge of seismology, weather forecasting, and meteorological measurements. According to IMD, in terms of air temperature, a heat wave is a condition when the human body becomes fatally vulnerable. It is quantified based on the temperature thresholds that apply to a location in terms of the actual temperature or the deviation/departure from the norm.

The National Disaster Management Authority (NDMA), the apex body under Government of India, defines heat wave as a period of unusually high temperatures that lasts longer than the summer season's average high temperature in North-Western India. Heat Waves normally occur from March to June, and in a few unusual instances, they might even last into July. People who live in these areas are negatively impacted by the excessive temperatures and accompanying climatic conditions because they produce physiological stress, which can occasionally result in death.

2.2.5 Heatwave management in India

National agencies, particularly IMD along with the apex bodies like NDMA have attentively taken action on the rising effects of heatwaves on all socio-economic categories.

2.2.5.1 IMD on heatwave

In some instances, countries define it in terms of the heat index based on temperature and humidity or based on the temperature's extreme percentile. According to IMD, When a station's maximum temperature hits at least 40°C or higher for plains regions and at least 30°C or more for hilly regions, it is deemed to be a heat wave.

- Based on Departure from Normal Heat Wave: Departure from normal- 4.5°C to 6.4°C Severe Heat Wave: Departure from normal- >6.4°C

- Based on Actual Maximum Temperature Heat Wave: actual maximum temperature ≥ 45°C Severe Heat Wave: actual maximum temperature ≥47°C

If the conditions meeting the above criteria is observed for at least 2 consecutive days at at least 2 meteorological subdivisions, then a heatwave is declared on second day. It most often occurs from March till June, with a few uncommon instances even occurring in July. May is when the heat wave in India reaches its peak.

From March to June, heat waves frequently affect the plains of northwest India, Central, East, and north Peninsular India. It includes portions of Maharashtra, Karnataka, Andhra Pradesh, and Telengana as well as Punjab, Haryana, Delhi, Uttar Pradesh, Bihar, Jharkhand, West Bengal, Odisha, Madhya Pradesh, Rajasthan, and Gujarat. Occasionally, it also affects Kerala and Tamilnadu.

Climate (temperature, relative humidity, wind, direct sunlight), social/cultural (clothes, occupation, accommodations), and physiological (health, fitness, age, level of acclimatisation) elements all have a role in how uncomfortable the heat is for an individual. A colour code impact based heat warning is issued jointly by India Meteorological Department and National Disaster Management Authority

- Green (No action) Colour denotes no warning, indicates a normal day.
- Yellow Alert (Be updated) indicates Heat Alert and warns about heat wave conditions at isolated pockets that can persist for 2 days. Moderate temperature; Heat is tolerable for general public but moderate health concern for vulnerable people e.g. infants, elderly, people with chronic diseases are listed as impact under this category of alert. Actions like avoidance of heat exposure, coverage of head by cloth or umbrella and preference of light-coloured loose clothes are suggested.
- Orange Alert (Be prepared) indicates Severe Heat Alert for the day and warns about (i) Severe heat wave conditions persisting for 2 days (ii) Though not severe, but heat wave can persist for 4 days or more. Heat illness, high health risk for vulnerable population and high temperature are enlisted as impacts under this category. Avoidance of heat exposure, dehydration and insistence on hydration (even if not thirsty) by drinking Oral Rehydration Solutions (ORS), homemade drinks like lassi, torani (rice water), lemon water, buttermilk, etc. are suggested actions.
- Red Alert (Take Action) indicates Extreme Heat Alert for the day. The alert warns about (i) Severe heat wave that can persist for more than 2 days. (ii) Total number of heat/severe heat wave days can exceed 6 days. Its impact is as severe as affecting everyone with heat related illness irrespective if their vulnerability. Taking extreme caution with respect to dehydration and sun exposure are the suggested measures to combat the harmful effects.

2.2.5.2 NDMA on heatwave

Even though heat waves do not garner as much media attention as more dramatic disasters like earthquakes and floods, they used to kill a lot of people in India. They were responsible for 24,223 deaths nationwide between 1992 and 2015. Despite these figures, there was no strategy or vision at the national level to deal with the heat wave as a crisis. Up until 2015, the illnesses and fatalities that heat waves caused did not have the proper national acknowledgment as dangers.

The government's goal is to reduce the number of heat-related deaths in India to zero. Since 2015, this goal has been pursued. Prior to 2015, state governments had the main duty for disaster risk management. Heat waves have been classified as a local catastrophe in Chhattisgarh, Odisha, Kerala, Rajasthan, Andhra Pradesh, Maharashtra, and Karnataka. According to the current disaster relief procedures, heat waves were not declared a disaster at the national level.

“Two- three years ago, thousands of people would lose their lives every year due to heat-wave. After that, NDMA organized workshops on heat wave management as part of a campaign to raise awareness among people. Mass participation led to good results.” - Shri Narendra Modi, Prime Minister, Mann Ki Baat, Telecasted on 28 Feb 2018

2.2.6 Heat action plan (HAP)

Heat waves, as discussed earlier, are sporadic in nature. But with increase in its severity and lack of awareness in the consequent years, its short-term effects and long-term effects may also significantly increase. However, the data related to these are yet to create awareness amidst the masses. With the recent onset of COVID 19 and its subsequent variants, government bodies and civilians, through mass media and word of mouth, have observed the pandemic situation where effectiveness of basic amenities, namely, food, water, appropriate shelter, awareness and updates for media are tolled under the crippling rise of the sufferers. Which is why, the authorities factor in all the calamities, including extreme heat and heat wave, that can topple the basic amenity ecosystem leading to unprecedented death or illness. Various guidelines and frameworks are prepared to curb the quantitative and qualitative effect from the beginning.

2.2.6.1 Rationale for heat action plan by NDMA

As an example, during the heat wave season, numerous States are affected, including Andhra Pradesh, Telangana, Odisha, Gujarat, Rajasthan, Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Maharashtra, Karnataka, Tamil Nadu, Bihar, Jharkhand, West Bengal, Haryana, Punjab, and Delhi. Second, the true number of deaths brought on by the heat wave is more than what has been reported. Most of the time, heat wave-related deaths in rural areas go unreported. Thirdly, the burgeoning service industry is particularly susceptible to the effects of heat waves due to the large number of vegetable vendors, auto technicians, cab drivers, construction workers, and other roadside kiosk operators. Fourthly, while the wealthier parts of India are equipped with air conditioners and coolers to withstand greater temperatures, the lower population is still susceptible to them.

Therefore, it is not unexpected that the majority of heat wave fatalities in India are caused by these labourers, the homeless, and the elderly. Fifthly, with an evidence-based plan, good implementation, and regular updating in line with current scientific advancement, these heat wave related deaths can be avoided.

Thus, it is important to build a national strategy and plan to combat heat waves. Government agencies, non-governmental groups, and civil society must all be involved in a comprehensive heat readiness and response.

2.2.6.2 Objective of HAP

The goal of the Heat Wave Action Plan is to offer a framework for creating implementation plans, interagency coordination, and impact evaluations for heat wave response initiatives in cities and towns that lessen the adverse effects of

excessive heat. The main goal of the Plan is to warn those who are at a high risk of heat-related disease in areas where extremely hot conditions already exist or are about to. Since excessive heat also puts a great deal of stress on livestock and other animals, the plan also calls for protection measures.

The heat wave action plan aims to organise departments and communities to assist in defending communities, neighbours, friends, and family members against avoidable health issues during periods of extremely hot weather. The Plan also aims to assist early warning organisations and the media in taking proactive measures to lessen the effects of waves. All States, Districts, Cities, and Towns can design an effective heat wave response strategy by learning from the experiences of others and from their own.

2.2.6.3 Managing heat wave

The prevention, preparedness and mitigation measures in NDMA HAP guidelines include cool roofs. Cool roofs are a cost-effective alternative. The definition of a cool roof is a white reflective roof that reduces heat absorption while reflecting thermal radiation to assist reduce solar heat gain. According to studies, cool roofs can reduce indoor temperatures by 3-5° C and can be up to 30°C colder than standard roofs. Cool roofs can lessen a city's urban heat island effect when used extensively. In order to enhance thermal comfort, cool roofs can be coated with materials including white tarp, white china mosaic tiles, white acrylic resin coating, and lime-based whitewash.

The daily Maximum Temperature (T.Max) has been selected by the cities of Ahmedabad, Nagpur, and Bhubaneswar to serve as the threshold. The dry and arid climate in Ahmedabad is a key factor in the decision to use T.Max for threshold determination. In a similar vein, Nagpur has arid summers. The threshold is based mainly on mortality rates in the specific time and presumed under the influence of Climatic and Weather-based variables of the specific time and day. (National Disaster Management Plan National Disaster Management Authority Ministry of Home Affairs Government of India, 2019)

2.2.7 Vulnerability

People who belong to vulnerable communities are more likely to have poor physical and social health. Due to differences in their physical, economic, and social health status when compared to the dominant group, they are regarded as vulnerable. The likelihood of getting a sickness or illness is referred to as vulnerability. Vulnerable groups may be less equipped to prepare for, deal with, resist, or recover from a hazard's effects. Population vulnerability to disasters is not largely influenced by distance from the disaster's cause. For instance, several socially vulnerable populations' well-being may be affected by a single mild hazard incident.

In the context of research, there are numerous methods to characterise someone is vulnerable. People who are unwell and dependent on a clinician for care, members of racial or ethnic minorities, people who do not understand English, children, people from low-income families, and people with decreased mental capacity are a few examples. Nearly everyone will be eligible if all of these groupings are taken into account. Vulnerable people are those who are comparatively (or completely) unable to protect their own interests. More specifically, they can lack the strength, finances, power, intelligence, education, or other qualities necessary to safeguard their own interests (World Health Organization and Council for International Organizations of Medical Sciences, 2017).

Everyone faces hazards, but those in low-income and underdeveloped nations and communities are those whose health is being impacted by the climate crisis earliest and worst. They also contribute the least to its causes and are least able to defend themselves and their families from it.

The current health inequalities between and among communities could be made even worse by the climate issue, which poses a danger to the last fifty years of advancement in development, global health, and poverty reduction. It seriously jeopardises the attainment of universal health coverage (UHC) in a number of ways, including by increasing the disease burden already present and escalating current barriers to obtaining health services, frequently at the most critical times. Around 12% of the world's population, or more than 930 million individuals, spend at least 10% of their family income on health care. Around 100 million people are presently pushed into poverty each year due to health shocks and pressures, with the effects of climate change making this trend worse because the poorest people are mainly uninsured.

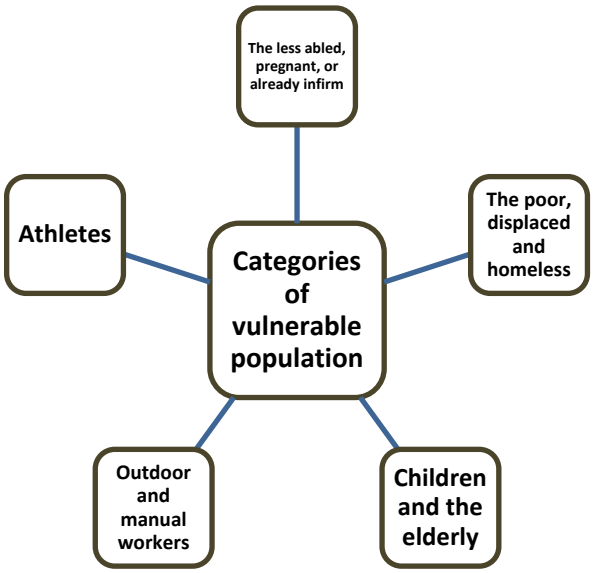


Figure 2.1: Identification of vulnerable population

The disruption of food systems, rise in zoonoses and food-, water-, and vector-borne diseases, as well as mental health problems are all significant effects of climate change on health. Extreme weather events like heatwaves, storms, and floods are also becoming more often. In addition, many of the social factors that influence health, such as access to healthcare, equality, and livelihoods, are being weakened by climate change. The most vulnerable and disadvantaged people, such as women, children, ethnic minorities, poor communities, migrants or displaced people, elderly populations, outdoor and manual workers and those with underlying health issues, are disproportionately affected by these climate-sensitive health concerns (World Health Organization, 2021) (Figure: 2.1). Vulnerability factors are:

- Demographic factors
- Geographic factors
- Biological factors & health status
- Socio-political conditions
- Socioeconomic factors Exposure pathways
- Extreme weather events Heat stress
- Air quality

- Water quality and quantity
- Food security and safety
- Vector distribution & ecology

2.2.7.1 Vulnerability and heatwave

Since the late seventeenth century, urbanisation processes have been recognised as one of the primary geographical expressions. However, this fact did not become obvious outside of major cities and metropolitan areas in Latin America and the Caribbean until the second half of the 20th century. In this macro-region, where cities account for 79.5% of the global population, the majority of people reside in large and medium-sized cities that may experience a variety of tropical, desert, or temperate temperatures (World Health Organization, 2021).

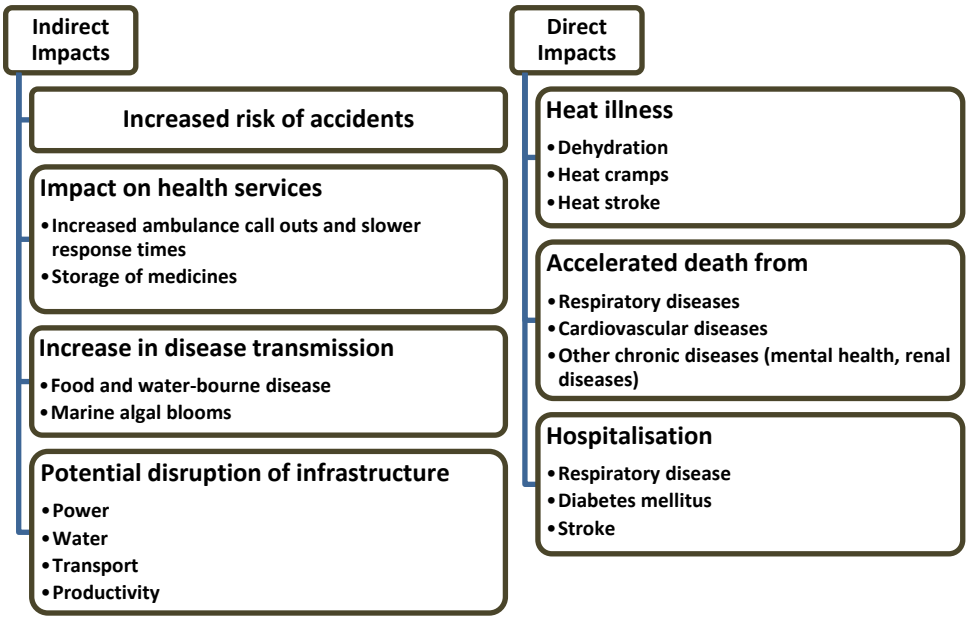


Figure 2.2: Indirect and Direct impact of extreme heat

All people are impacted by increasing global temperatures (Figure: 2.2). However, some people are more susceptible to physiological stress, aggravated sickness, and a higher risk of passing away from exposure to excessive heat, either due to exposure or because they are more physiologically or socioeconomically fragile. These people include the young and old, pregnant women, those who work outdoors or in manual labour, athletes, and the underprivileged. When considering heat exposure, gender can be crucial.

2.2.7.2 Statistics for heat-related vulnerability

Heat affects vulnerable populations from many directions and have an impact on all scales. The effect on physical activity, labour capacity, sentimental outbursts or expressions, mortality, food and shelter availability, etc., are documented numerically to create the awareness of the impact (Lancet Countdown, 2022).

- **Exposure of Vulnerable Populations to Heatwaves**: In 2020, compared to the average for the years 1986–2005, children under the age of one were exposed to heatwaves for 626 million more person-days, while people over 65 were exposed to heatwaves for 3.1 billion more person-days.

- **Heat and Physical Activity**: People in the country groups with low Human Development Index have seen an average loss of 3–7 hours of safe exercise per day in 2020. Over the past four decades, the number of hours when temperatures were too high for outdoor exercise has increased.
- **Change in Labour Capacity**: In 2020, excessive heat exposure resulted in the loss of 295 billion hours of potential employment, with the agriculture sector accounting for 79% of all losses in nations with low Human Development Indexes.
- **Heat and Sentiment**: With a 155% rise in unfavourable expressions on Twitter during heatwaves in 2020 compared to the average for the years 2015 to 19, exposure to heatwave occurrences increases stated mood.
- **Heat-Related Mortality**: With the exception of Europe, all WHO regions had an increase in heat-related mortality in this susceptible age group between 2018 and 2019, with an estimated 345000 deaths in this age range.
- **Health and Extreme Weather Events**: In comparison to 2001–2004, there was a nearly 60% rise in the number of days in which people were exposed to very high or extremely high fire hazard, and 72% of nations had an increase in the number of days during which people were exposed to wildfires. Up to 19% of the world's land surface experienced extreme drought in any one month in 2020.
- **Food Security and Under Nutrition**: In comparison to the average crop yield potential between 1981 and 2010, the crop yield potential for maize has decreased by 60%, for winter wheat by 30%, for soybeans by 54%, and for rice by 18%.
- **Migration, Displacement and Sea Level Rise**: There are approximately 569.6 million people living below the sea level, and both direct and indirect concerns from rising sea levels could put them at risk.

2.3 HEAT STRESS

With the previous chapter’s description of how the Heatwave is perceived and alerted about at an individual, local, national and global level, this chapter deals with its aftermath, that is the effect of heat on the body and the different approaches taken to measure the heat stress. This chapter also describes the vulnerability of informal vendors and the effect of heat stress on them.

Heat received over what the body can bear without experiencing physiological impairment is referred to as "heat stress" (Kjellstrom et al., 2016). For continuous regular body function, a core body temperature of about 37°C is required. achieving this balance of body temperature demands a continuous transfer of heat from the body to the surroundings. The heat output depending on the overall heat generated by the body via muscular and physical activity activities and any heat that was gained from the environment, if any (NIOSH, 2016). (4) Environmental elements contributing factors that raise a worker's stress level in a hot environment at work include: temperature, humidity, wind speed, and radiant heat sources like the sun or a furnace (EHS, 2018).

The body's natural cooling processes can no longer keep body temperature at a level necessary for normal operation once heat stress levels beyond a certain threshold. As a result, there is a higher chance of pain, restrictions on physical abilities and functions, and eventually, injuries and illnesses brought on by the heat.

The latter disorders range in severity from potentially lethal heatstroke to milder conditions including heat rash, heat cramps, and exhaustion. Physical and mental abilities are compromised if the body temperature rises beyond 38 degrees Celsius (heat exhaustion), and the danger of organ damage, loss of consciousness, and ultimately death rapidly increases if it climbs above 40.6 degrees Celsius (heatstroke) (IPCC, 2014a).

Only up to a certain point can physiological heat acclimatization1 provide protection, and it takes a specific amount of time (usually one to two weeks of heat exposure) for it to occur. The acclimatisation threshold of workers is far too frequently exceeded during peak heat times in several hot nations, and the dangers of working in high temperatures continue.
The effects of heat stress vary across various industries and geographical areas. Because the physical activity itself generates a lot of internal heat that needs to be expelled to prevent the beginning of heat exhaustion, jobs that require a lot of physical exertion, for example, are particularly affected by rising temperatures. Heat stress is also more likely to disrupt work environments when employees are required to wear heavy garments and personal protective equipment. Therefore, among those who are most exposed are those in agriculture and construction (IPCC, 2014a). However, if the temperature within factories and workshops is not properly controlled, heat stress can also become a concern for industrial workers in indoor settings.
Jobs in the transportation, tourism, sports, emergency repairs, and waste collection are just a few of the occupations in the service sector that are impacted by rising temperatures. At high temperatures, even routine office and desk chores become challenging as mental fatigue sets in (Hancock, Ross and Szalma, 2007; Costa et al., 2016).
The fact that migrant workers in the construction industry or self-employed farmers in developing and rising nations are the most severely affected by heat stress highlights issues of social fairness. In some tropical places, the problems of heat exposure to social fairness are already apparent (Kjellstrom et al., 2018).

2.3.1 Measuring heat stress

When the body loses more heat than it gains, heat stress results. If the imbalance is not corrected, the body temperature increases, leading to symptoms like heat exhaustion, heat stroke, cramping, and swelling of the feet and ankles. Additionally, conditions like dermatitis and fungus infections can get worse due to heat stress.
Many businesses, including glassmaking, metal refining, baking, and commercial catering, can experience heat stress. There are thermal indices* that can be used to quantify the risk, such as Wet Bulb Globe Temperature (WBGT) and Predicted Heat Strain (PHS), however they frequently overstate it, putting unnecessary restrictions on operations. When utilising these indices, it is also challenging to determine the impact of protective clothing and other types of PPE.

It cannot be presumed that risk management strategies like work-rest schedules are successful. As a result, taking physiological measurements, especially of body temperature, is frequently considered either as a "add-on" or as a substitute for these indicators.

Rectal temperature was regarded as the "gold standard" for determining core body temperature for a long time. Rectal temperature used to be the primary indicator of core body temperature, but in recent years, intragastric temperature—measured with a temperature-sensitive radio pill—has taken over. However, logistical and financial constraints prevent its adoption as a regular monitoring technique.

2.3.1.1 Physiological Equivalent Temperature (PET)

There has been a trend in recent years for media weather reports to provide more helpful information. For instance, estimates of pollen counts, measures of UV radiation strength, or data on the likelihood of experiencing symptoms like headaches or cardiocirculatory issues due to the weather are all examples of this.

The most helpful information for those who listen to these weather forecasts might be some tips on what to wear before heading outside, especially what is most likely to keep them warm.

Urban and regional planners looking to create comfortable microclimates are also calling for simply accessible methodologies for the assessment of the thermal component of climate, in addition to the growing demand for biometeorological information in daily weather reports.

Weather and climate have long had an impact on human health and wellbeing. Hippocrates discussed regional climatic variations and their connection to health statuses over 2,500 years ago. Seasonal variations in fevers, people's moods, and different psychological disorders are all common. Winter brings on joint agony, while heat waves in the summer render people unwell and can kill them. World Meteorological Organization, 1999.

Extreme heat-related situations can also lead to health issues, such as heat stress, UV radiation, air pollution, and heat stroke. An analysis of cause-and-effect relationships between the atmospheric environment and human comfort can be done using a human-biometeorological classification that takes into account:

- The thermal complex, which consists of climatic components that affect human thermophysiology.
- The actinic complex (which includes the visible and ultraviolet spectrum of solar radiation that has a direct biological effect) and
- The air pollution complex (which includes solid, liquid, and gaseous natural and anthropogenic air pollutants that have an influence on human health)

More broadly applicable models incorporate all fundamental thermoregulatory functions, including physiological sweating and the constriction or dilation of peripheral blood arteries (Höppe 1993, 1999). They give the user the ability to forecast "actual values" of the body's thermal parameters, such as skin temperature, core temperature, perspiration rate, or skin wetness.

A thermo-physiological heat balance model of this kind is the Munich energy balance model for individuals (MEMI) (Höppe 1993). It serves as the foundation for determining the physiologically equivalent temperature (PET). In detail the MEMI model is based on the energy balance equation for the human body:

$$M + W + R + C + E_D + E_{Re} + E_{Sw} + S = 0$$

In this equation, M stands for metabolic rate (internal energy production), W for physical work output, R for net body radiation, C for convective heat flow, ED for latent heat flow to evaporate water diffusing through the skin (imperceptible perspiration), ERe for the sum of heat flows to heat and humidify the inspired air, ESw for heat flow resulting from sweat evaporation, and S for storage heat flow to heat or cool the body mass. Each term in this equation has a positive sign if it gives the body more energy and a negative sign if it gives the body less energy (M is always positive; W, ED, and Esw are always negative).

Watt is the measurement unit for all heat flows (Höppe 1999).

The following meteorological factors regulate each heat flow individually (Verein Deutscher Ingenieure 1998; Höppe 1999):

- C, ERe for air temperature
- Air moisture: ED, ERe, and ESw
- C, ESw wind speed
- Radiant heat average: R

In addition, the following thermophysiological parameters are needed:

- Clothes that are heat-resistant (clo units)
- The presence of humans (in Watt)

According to Verein Deutscher Ingenieure (Verein Deutscher Ingenieure, 1998; Höppe, 1999), PET is defined as being equivalent to the air temperature needed to reproduce in a standardised indoor setting as well as the core and skin temperatures observed in the conditions being assessed for a standard person. The standardised person is characterised by a work metabolism of 80 W of light activity, in addition to basic metabolism; and by 0.9 clo of heat resistance as a result of clothing.

The following assumptions are made for the indoor reference climate:

- Mean radiant temperature equals air temperature (Tmrt = Ta).
- Air velocity (wind speed) is fixed at v = 0.1 m/s.
- Water vapour pressure is set to 12 hPa (approximately equivalent to a relative humidity of 50% at Ta = 20°C).

The calculation of PET includes the following steps:

- Calculation of the thermal conditions of the body with MEMI for a given combination of meteorological parameters.
- Insertion of the calculated values for mean skin temperature and core temperature into the model MEMI and solving the energy balance equation system for the air temperature Ta (with v = 0.1 m/s, VP = 12 hPa and Tmrt = Ta).
- Examples of physiological equivalent temperature (PET) values for different climate scenarios. Ta air temperature, Tmrt mean radiant tempertaure, v air velocity, VP water vapour pressure are shown below (Table 2.1).

Scenario	**T_a (°C)**	**T_{mrt} (°C)**	**v (m/s)**	**VP (hPa)**	**PET (°C)**
Typical room	21	21	0.1	12	21
Winter, sunny	-5	40	0.5	2	10
Winter, shade	-5	-5	5.0	2	-13
Summer, sunny	30	60	1.0	21	43
Summer, shade	30	30	1.0	21	29

Table 2.1: physiological equivalent temperature (PET) values for different climate scenarios

2.3.2 Heat stress on informal workers

When exposed to excessive heat, a worker's natural defence strategy is to slow down, take more frequent and prolonged breaks, and/or limit the number of hours they work. As a result, productivity, economic production, and family income are all reduced. For both acclimatised and non-acclimatized personnel, there are now international regulations that outline the maximum recommended heat exposure levels and call for frequent rest times at the workplace (ISO, 1989; Parsons, 2003).

One of the most severe economic effects of climate change is anticipated to be how

heat stress affects labour productivity. At different scales, economic losses are anticipated to impact individual individuals, their families, businesses, and entire communities. The repercussions could be so severe in heavily exposed economies that they would weaken national economic output, which would then have an impact on the prognosis for the entire world. The effects of heat stress on the economy, society, and health would make it more difficult to combat poverty, advance human development.

As a result, achieve most of the Sustainable Development Goals (SDGs) of the United Nations, including those pertaining to poverty, food security, health, decent work and economic growth, inequality, and cities.

An ongoing structural revolution in Asia and the Pacific is significantly changing the composition of employment over time. Around 760 million people, or up to half of all employed people in 1995, were employed in the agriculture industry, which is characterised by precarious employment and informal working conditions. This agricultural dominance was most obvious in Southern Asia (59%) and South-East Asia (51%); it was less apparent in Eastern Asia (45%), and even less so in the Pacific Islands (17 per cent). These shares are expected to fall throughout all subregions, with the exception of the Pacific Islands. On the other side, the construction sector's contribution is anticipated to grow significantly, from 4% in 1995 to over 10% in 2030. With approximately 1 billion workers employed and 50% of all employment in the region in 2030, the service industry is expected to overtake all other sectors as the dominating one. In the table below, International Labour Organisation has listed the projections in loss of working hours due to heat stress (Working on a WARMER planet, 2019) (Table: 2.2).

Country	1995						2030					
	Agriculture (in shade) %	Industry %	Construction (in shade) %	Services %	Total %	Total (thousand Full-tie jobs)	Agriculture (in shade) %	Industry %	Construction (in shade) %	Services %	Total %	Total (thousand Full-tie jobs)
Afghanistan	0.16	0.06	0.16	0.01	0.12	7	0.38	0.17	0.38	0.03	0.25	36
Bangladesh	6.28	2.59	6.28	0.30	4.24	2274	9.58	4.96	9.58	0.72	4.84	3833
Bhutan	0.14	0.04	0.14	0	0.09	0	0.70	0.22	0.70	0.01	0.38	1
India	**5.87**	**2.95**	**5.87**	**0.63**	**4.31**	**15519**	**9.04**	**5.29**	**9.04**	**1.48**	**5.80**	**34056**
Iran	0.42	0.22	0.42	0.07	0.22	34	0.87	0.48	0.87	0.16	0.42	108
Maldives	0.16	0	0.16	0	0.04	0	0.85	0.04	0.85	0	0.15	0
Nepal	1.38	0.56	1.38	0.08	1.17	106	2.62	1.26	2.62	0.23	2.05	391
Pakistan	6.19	3.68	6.19	1.12	4.19	1439	8.83	5.83	8.83	2.22	5.54	4603
Sri Lanka	3.58	0.98	3.58	0.04	1.83	119	6.98	2.49	6.98	0.16	2.67	221
Southern Asia	5.64	2.75	5.64	0.58	4.02	19498	8.43	5.00	8.43	1.36	5.29	43251

Table 2.2: Working hours lost to heat stress, Southern Asia, (projections)

2.3.2.1 Occupational heat stress and brickmaking workers in India

Millions of people work in the brick industry in India, the most of whom have moved from impoverished areas to the outskirts of cities. These labourers, who sometimes include young children, have poor socioeconomic standing, endure difficult working circumstances, and are paid meagrely or not at all.

High temperatures and radiant heat levels, a demanding physical workload, and a lack of awareness of occupational safety and health (OSH) issues are just a few of the serious concerns these employees must contend with. They are indeed exposed to tremendous radiant heat from the kilns where the bricks are burnt as well as extremely high ambient temperatures, which can reach 40 to 45 °C during the hot summer months. Due to the lack of or restricted availability of on-site cooling methods, this heat exposure is made worse (Lundgren-Kownacki et al., 2018).

It is determined that a 1°C rise in temperature results in a 2 percent decrease in productivity when assessing the effects of heat stress on the productivity and health of female brickmakers in West Bengal. When they were completely worn out, the study's participants had just brief (10–15 minute) rest breaks in the shade before going back to work. In high temperatures, their physiological stress parameters—peak heart rate and cardiac strain, for example—were significantly higher. Although most workers were aware of their heat stress symptoms, they lacked the information and resources necessary to put preventative measures into place (Sett and Sahu, 2014).

The Factories Act 1948 and the Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act 1996 are two Indian statutes that are pertinent to unorganised industries like brickmaking. However, these rules do not explicitly state how brickmaking workers' occupational safety and health is to be safeguarded.

Additionally, the majority of these individuals are unaware of their legal rights at work and have few other options for employment, which drives them to continue working in such inhumane conditions (Chandran, 2016).

2.3.2.2 Case studies by OSHA reinforcement

A group of case study was done on outdoor stationery worker, outdoor mobile worker and indoor worker to assess the effect of heat stress (www.osha.gov).

Case 1: Roofing worker

A 42-year-old guy began working as a roofer in July. Despite the fact that there was an abundance of water, ice, and Gatorade on site, his business did not have a clear plan in place to safeguard new employees from heat-related illnesses. The first two days at work went without any issues for the employee. The weather on his third day of work was a little bit warmer, with a high of roughly 86°F and a relative humidity of 57%, giving it a heat index of 90°F. The employee informed his coworkers that he felt hot and ill in the afternoon. He descended from the roof and went to a solitary bench in the sunshine. A few minutes later, when his coworkers went to check on him, he was showing signs of heat stroke. After being brought to a hospital, he passed away. The radiant temperature may have been somewhat lowered by a few scattered clouds, but a reconstruction using data from a nearby airport showed a wet-bulb globe temperature of 82°F.

Key learnings:

- Protect new hires throughout their first two weeks on the job, according to the case study. Make sure they get adequate rest and drink enough water.
- When employees report experiencing problems connected to the heat, never leave them alone. Their situation could rapidly deteriorate! Take them somewhere cool and give them first aid. First aid can save a life or put it at risk with even a momentary delay.
- It need not be exceedingly hot for workers to suffer from heat stroke. Remember that environmental heat and workload together make up total heat stress. A Heat Index value of 90°F is produced by air temperatures in the 80s (°F). They are also high enough to cause the death of some employees.

Case 2: Delivery worker

A 50-year-old man has six years of experience working for a delivery service. He had to deliver mail and packages through residential areas while operating a vehicle. The temperature abruptly increased in late May. This worker experienced heat fatigue and heat cramps on the second hot day. As a result of dehydration, he spent two days in the hospital with acute kidney failure. After receiving intravenous fluid replacement, his condition got better.

Key learnings:

- Even seasoned workers can get heat-related illnesses when the weather warms up. Treat every employee as if they must acclimate to working in the heat during the first week of warmer weather. Extra care should be taken to safeguard them from heat-related ailments.
- Make sure employees are adequately hydrated whether it's warm or hot outside.

Case 3: Foundry worker

A 35-year-old worker had spent six years at the foundry. Ovens and molten metal produced a lot of heat in the enclosed workspace. In a cooler part of the building, he performed his regular job duties. He was asked to work in a hotter area near an oven on the day of the event. To protect his skin from burns, he wore thick protective clothes. After working for several hours, the man passed away from heat stroke.

Key learnings:

- Indoors, heat-related sickness is possible. Outside employees are not the only ones at risk.
- Some types of work attire inhibit the body from releasing heat. The risk of heat-related sickness in these circumstances is understated by environmental heat measures.
- When they are reassigned to warmer job responsibilities, employees run the risk of contracting a heat-related sickness.

2.4 HEAT RISK PERCEPTION

As heatwave is understood and discussed widely by agencies, heatstress is observed widely in association to workers and vendors under direct exposure of heat, the concept of risk and its perception also holds varying amount of significance. This chapter describes the types of risk, the different lenses through which the risk can be perceived. The chapter also gives insight on how changes in socio-economic backgrounds and level of institutional awareness can change the intensity at which the risk of heat is perceived.

2.4.1 Concept of risk

Risk has been defined as a measure of the likelihood (i.e., frequency or probability) of an incident occurring and the potential severity of the consequences (Coppola, 2020). The likelihood of the risk can be understood by asking “how soon it can occur” or “how often does it occur”. There are three common ways to evaluate the consequence: damages (costs reported in currency), injuries (to humans) and deaths/fatalities (human losses). Risk is essentially reduced when the likelihood of a hazard or its potential consequence is reduced.

In addition to this, another factor involved in working out the risk is the vulnerability of the individual or the community. Whenever a highly vulnerable population faces a highly probable disaster, it is subject to very high risk or danger.

Disaster risk is expressed as the likelihood of loss of life, injury or destruction and damage from a disaster in a given period. Globally, disaster risk is increasing, with more people dying or being affected by disasters in the last five years than before. (United Nations Office for Disaster Risk Reduction, 2022). As population growth and settlements expand, more people and infrastructure will be exposed to existing hazards, and climate change will exacerbate disaster risks in many ways.

For the study, the urban region of Nagpur was selected. Along with many other Tier 2 cities of India, has been experiencing expansion from last three decades, giving rise to formerly suburban areas, now recognised as parts of the main city. This expansion has increased the population from 17 lakhs to 29 lakhs in the last thirty years, with the annual growth rate ranging from 1.5% to 2.5%. This also indicates that the city has an increased workforce areas and workplace areas that have attracted individuals from all socio-economic backgrounds to sustain a livelihood in the city, thereby increasing the vulnerable population hailing from older age groups, younger age groups, strenuous labour workers, informal vendors and self-employed workers. According to the 2022 Global Assessment Report on Disaster Risk Reduction, the annual number of global disasters could increase from around 400 in 2015 to 560 by 2030.

2.4.2 Concept of risk perception

Despite the data showing an increase in global disaster risk, these risks are not necessarily interpreted equally by everyone. This is due to people’s judgements and evaluations of the hazards they or their environments are or might be exposed to, called Risk Perception. When asked what risk means, a person might give an example of what they consider to be "risky behaviour" themselves.

The concept of risk means different things to different people, according to Slovic's (1978- 2015) research on perceived risk. It incorporates the wider social and cultural values, as well as the outlook, people adopt toward hazards. (Encyclopaedia of Environmental Health, p.573). There are several factors and many theories related to risk perception, and they often have overlapping ideas and concepts.

Decisions about risks are driven by risk perceptions, which in turn influence behaviour before, during, and after disasters. This is given by Protection Motivation Theory (PMT), one of the most cited. It suggests when people anticipate negative consequences, want to avoid them, and feel they can take preventive measures, they are more likely to protect themselves. People are unlikely to prepare for or mitigate a hazard if they do not perceive it to affect them personally. People's perceptions and responses, coupled with their socioeconomic circumstances, result in an array of vulnerabilities in any community.

Habituated Action Theory argues to explain the lowered perception due to acclimatization. An individual's perception of risk is reduced when he engages in high-risk behaviour repeatedly and without negative outcomes. Social Action Theory states that people tend to take risks more when the general community perception about a given risk is low. This leads to people engaging in potentially dangerous behaviours just because “everyone else is doing it”.

As people become more informed and have more details about a specific risk, they're less likely to fear it (Damon P. Coppola, 2020). Thus, having better knowledge about a risk, its severity and its consequences might influence the perception and behaviour. However, it is important to recognize the difference between an individual's subjective assessment of his or her knowledge about a risk, compared to the actual level of correct knowledge.

Another facet is the traditional ecological knowledge that local people possess, as a result of which risk perception can be effectively decreased, as it can be used effectively to deal with situations that outsiders perceive to be dangerous.

There is a tendency for people to perceive events as likely or frequent if they are easily able to imagine or recall instances. However, this perception bias can be accurate only when considering events that really occur frequently and not because they receive constant media attention. (Damon P. Coppola, 2020). The ability to cope with hazards might also influence perception. For instance, the ability to cope with adversity better is demonstrated by people who are able to cope through technology, financial attributes, education, and political power (Young, 1998).

In general, risk perception strongly influences societal acceptance or tolerance of various hazards, providing valuable insights into protective behaviours people use when confronted with threats.

2.4.3 Heat risk

Heat extremes are becoming more frequent, intense, and prolonged due to climate change, putting more individuals, communities, and health systems at risk (Stocker TF, Qin D, Plattner G-K, et al., 2013). Extreme heat poses a risk to infrastructure and services as well as to human health and well-being. Heat cramps, weariness, and potentially fatal heat strokes can all be brought on by excessive heat, which can have a detrimental impact on human health. Heat stress raises cardiovascular strain during heat extremes, with more old adults dying from cardiovascular events than from nearly any other cause related to heat (Bunker et al., 2016). Heatwaves not only negatively affect people's health directly but also put a strain on the current healthcare system by increasing the frequency of emergency hospital admissions.

Additionally, heat waves affect the city's economy and the delivery of important services by limiting the number of hours that outdoor workers can work safely, decreasing productivity in buildings with inadequate cooling, and affecting industries like tourism. (Heatwave Guide for Cities. 2019. Red Cross Red Crescent Climate Centre).

More than one billion workers worldwide are exposed to high heat episodes, and roughly a third of them suffer negative health effects. This makes them highly vulnerable to the negative impacts of extreme heat. In outdoor work environments, high metabolic heat production, coupled with low airflow, high ambient and radiant heat, and sometimes high humidity, increase human heat strain (Ebi et al., 2021). Extreme heat can also affect their productivity, economic output, and family income by slowing them down, making them take frequent longer breaks, or limiting their

working hours. Thus, globally, outdoor workers are urgently in need of solutions, especially in tropical regions, where increased warming means physiological limits could be reached more often. The figure below describes how occupational heat stress typically leads to workers taking more unplanned breaks or working at a slower pace to adjust their output.

2.4.4 Heat risk perception

Heat risk perception can be explained as a subjective assessment of the probability of high temperatures occurring and the level of concern about the consequences (Slovic, 2015).

It is possible to reduce the chances of mortality and morbidity related to heat exposure if people perceive the risk, are provided with appropriate resources, and take appropriate precautions before exposure occurs. (George Luber, Michael McGeehin, 2008).

A number of studies have examined public perception and attitudes towards extreme heat. However, though heat waves are a common phenomenon in India, there are no existing studies in which heat risk perception has been specifically evaluated. Hass, Runkle and Sugg (2021) conducted a scoping review of several studies published within the last decade and identified drivers for heat risk perception which can be categorised into 4 domains – Environmental, Social, Personal and Structural.
Geography is one environmental factor that influences perception. For example, those who live near tropical regions tend to think that since it's hot for a large part of the year, they won't be affected by heat. (Heatwave Guide for Cities. 2019. Red Cross Red Crescent Climate Centre). This is a function of perceived acclimatization due to high exposure and can lower the perception. However, Howe et al. found that populations located in warmer climates within the US have the highest risk perceptions. A study by Cutler et al. (2018) provides evidence that changing climate phenomena, such as recurring heatwaves, increase the public's concern of a higher risk for heat exposure and higher heat health risk (Ban et al., 2017; Akompab et al., 2013).

Social factors such as age, income, education and living conditions also contribute to heat risk perception levels. The risk of exposure is often better understood by young people who have access to education (Williams et al., 2019). High-risk perceptions of heat are more common among those with higher education (Ban et al., 2017; Rauf et al., 2017; Liu et al., 2013). The pre-existing knowledge and information people receive from a variety of sources and their everyday interactions within society may shape their attitudes and beliefs about climate-related risks such as heat waves (Carvalho, 2007). The findings of a study by Rauf et al. (2017) show that respondents with low- and middle-income levels have more knowledge and, consequently, a higher perception of danger than those with high incomes. This is due, in part, to the fact that those with a high income do not consider themselves at risk for heat exposure or negative health outcomes, most likely because they have a wider range of adaptive resources available to them (Akompab et al., 2013; Cutler et al., 2018; Rauf et al., 2017; Williams et al., 2019). Figure below shows how cart vendor perceives heat as a risk at a level enough to prevent him from standing exposed to direct heat, as opposed to standing out and attract customers through peddling calls (Figure: 2.3).

Figure 2.3: Informal vendors resting in their market units

Women often experience high heat risks due to their caretaking responsibilities (Akompab et al., 2013; Howe et al., 2019; Liu et al., 2013; Rauf et al., 2017; Williams et al., 2019) Living conditions such as living alone or with people vulnerable to the effects of heat can influence risk perception. For example, when an individual is worried about someone living with them, they may perceive heat risk as higher (Akompab et al., 2013). In addition, a person's perception of risk is amplified and intensified by the extent to which influential social referents, such as friends and family, deem climate change events, such as heatwaves, as a serious risk (van der Linden, 2015). Some studies have found a negative correlation between vulnerability and heat risk perception. For instance, older persons perceive heat risks less and employ coping mechanisms less frequently, despite having a diminished capacity to thermoregulate (Howe et al., 2019; Lane et al., 2014; Liu et al., 2013; Williams et al., 2019).

Studies have also identified personal drivers such as greater occupational exposure to heat, and pre-existing chronic illnesses contribute to greater heat risk perception. (Hass and Ellis, 2019b; Liu et al.,2013; Zander et al., 2017). According to a study conducted in Australia by Singh et al. (2015), workers' lack of autonomy and sense of helplessness makes heat safety in the workplace less of a priority. The main concern they have is losing pay if their productivity decreases. Migration status also influences perception, such as in a study by Messeri et al. (2019) which reported that migrants perceive less heat, and their productivity drops less than native workers.

Structural drivers can be identified on a city level, such as lack of green spaces, lower vegetation cover, paved and impervious surfaces, and low albedo materials which can significantly increase the exposure to ambient heat. The importance of this aspect must, however, be considered by the decision-makers, as mitigation measures may otherwise be viewed as less important. Both personal and structural drivers play an important role in determining the level of adaptive behaviour taken. Socio-demographic characteristics may have an impact on adaptive behaviour in some cases (Wilhelmi and Hayden, 2010), but may not have a heavy influence in others (Esplin et al., 2019). Research has shown that the likelihood of adaptive behaviours increases when someone has experienced heat and heat health effects in the past or knows someone who has (Akompab et al., 2013a; Ban et al., 2017; Esplin et al., 2019; Hass and Ellis, 2019b; Rauf et al., 2017; Zander et al., 2017). In contrast, taking precautions is less likely when people think they are used to the heat or already know what to do (Hass and Ellis, 2019b; Lane et al., 2014; Williams et al., 2019). When it is common knowledge that it is a heatwave, adaptive measures are more likely and can reduce mortality and morbidity (Hass and Ellis, 2019).

Effective risk communication and adaptive strategies are possible when public perceptions and knowledge are addressed (Toloo et al., 2013).

Post industrialisation, globally, there has been a visible increase in urbanisation, contributed by the rural population who migrate to the urban areas in search of wider range of employment or business ideas, higher income and well-articulated infrastructure. Among the growth in any city, the gap between the infrastructure supply and demand, and the formal and informal trade is inevitably high. This, just like the categorisation of some individuals into Rural Poor, gives categorisation of some city dwellers into Urban Poor. A Rural Poor person is still tethered strongly to their family and community, which contribute to their intellectual and moral assets in the form of heirloom, whereas, an Urban Poor, who migrates with few family members, is disconnected from their extended family or community, making themselves more vulnerable to the relatively foreign and new conditions and being exposed to the same with relatively less knowledge to aide in combatting or sustaining in it. An Urban Poor is more reliable on immediate foster community and institutional framework to survive any calamity. Heat has been present on this planet from a long time and its knowledge has been passed through generations by evolving media.

But, the coverage of the rise in global temperature is at a higher rate than the rapidness of the spreading of its knowledge, making it difficult for the population to keep up with the knowledge of rising temperature. A rural poor grandfather must have passed down his knowledge to his rural poor grandson, keeping the latter under the impression of the same survivable heat. This prevents the younger generation to draw the differences that accompanied the heat, for example, the older generation, who lived in the village faced shorter duration of extreme temperature, cooler nights. They also benefitted from cooler microclimate and closer knit social circles resulting in humbler aspirations and more comfortable working hours. On the contrary, the younger counterpart faces longer duration of extreme heat and warmer nights in the city, amidst wider social circle that perceives survival as a race. Under such weather conditions and increased demands, the city-based informal worker is compelled to priortise income over health. As health, being ingrained as invincible by heat in the mind of a migrated worker through their preceding generations makes them perceive extreme temperature a passable phase and not a long-term risk.

Risk is perceived more seriously when there is a higher visibility of symptoms and aftermath of a phenomenon. The significance in the number of people getting affected makes a difference too. The rapidness with which the phenomenon can change the world also has a potential to rattle a population. COVID and its variants are a good example. It required a gruesome display of symptoms and aftermath of affectedness for people to perceive it as a risk. The steep rise in fatalities drove people to take actions for their protection from the disease, irrespective of their socio economic background. People are unlikely to take action to mitigate or prepare for a hazard if they do not perceive it as personally affecting them or lack the necessary resources to take adaptive measures, as shown below (Figure: 2.4).

Figure 2.4: Different responses to heat exposure by informal workers

2.5 ADAPTATION TO EXTREME HEAT

In the cycle of survival. Knowing weather conditions falls first, followed by its effect and perceiving it as risk. This cycle is bookended by the steps which are willingly taken or avoided to answer the condition with available means. This chapter deals with a voluntary or involuntary adaptive capacity that an individual or a community possesses or develops.

2.5.1 Concept of adaptation

The term "adaptation" describes how ecological, social, and economic systems are adjusted in response to actual or anticipated climate change and its implications.
One aspect of climate change adaptation relates to assessing impacts and vulnerabilities, and the other to developing and evaluating response options. By reducing vulnerability and exposure to extreme events, events that are currently considered extreme in some regions might be adapted. (IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability)

A system, region, or community's adaptive capacity is its ability to adjust its characteristics or behaviour, in order to expand its coping range to climate change impacts. It is the ability to design and implement effective adaptation strategies, as well as respond to evolving hazards and stresses, to reduce the likelihood and/or magnitude of climate-related hazards that lead to negative outcomes (Brooks, Nick & Adger, W. & Khan S., 2004). Learning from previous climate experiences and applying them to cope with future climates, including unexpected events, is an essential part of the adaptation process.

The refusal to accept the risks associated with climate change, or the refusal of key actors to accept responsibility for adaptation, can undermine adaptive capacity. It is possible for refusals to be ideological or to be a result of vested interests that deny climate change risks.

Resources are needed for the implementation of adaptation strategies, including financial capital, social capital (such as strong institutions), human resources (such as labour, skills, knowledge, and expertise), and natural resources (e.g., land, water, raw materials).

An adaptive strategy won't be successful unless those affected are willing to adapt, and if there is a level of consensus as to what actions are appropriate. The adaptation gap reflects the difference between actual actions and societal goals, which is primarily influenced by preferences, resource constraints, and competing priorities (UNEP et al., 2021). Adaptation deficits refer to insufficient or inadequate adaptation to present conditions.

Also, it is important to note that there are also some limits to adaptation, meaning that no amount of adaptation will suffice to achieve society's goals. The larger and more effective adaptation efforts within the constraints can reduce adaptation gaps. It is only through mitigation that adaptation gaps beyond constraints may be closed (Dow et al., 2013) (Figure: 2.5).

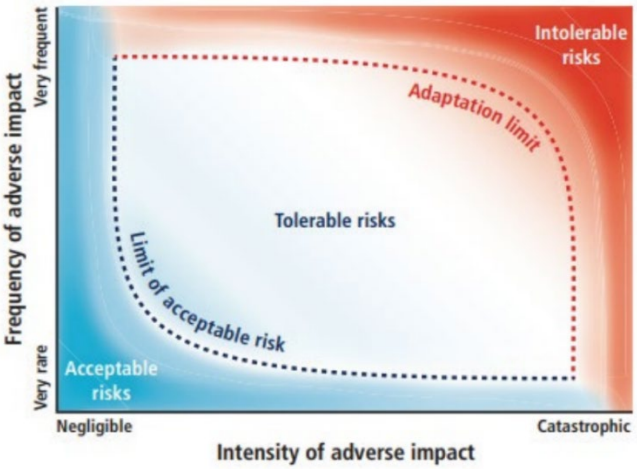


Figure 2.5: Intensity of adverse impact (Drawn by Yuka Estrada, IPCC, based on Dow et al., 2013, Klinke and Renn, 2002; Renn and Klinke, 2013)

These barriers and limits can be natural, technological, economic, social or formal institutional (Islam M. et al, 2014). Natural barriers relate to geographical limitations, technological to lack of tools and techniques which constrain adaptation. Social barriers have also been identified as important by many studies (Adger W. et al., 2009; Jones L et al., 2011; Lof A., 2006). Among key aspects of social barriers, Adger et al. point to ethics (what people value), knowledge (what they know), risk (what they perceive) and culture (how they live). Risks are perceived, interpreted, and adapted by people according to their worldviews, values, and beliefs (Moser and Ekstrom, 2010). Thus, risk perception plays an important role in motivation for adaptation. In terms of institutional barriers, these are the regulatory rules and processes that may prevent, delay, or divert adaptation to climate variability and change.

It is impossible to apply a single strategy to all communities. Rather, a variety of adaptation responses are deployed at different levels. Governments and institutions will integrate lessons learned from past hazards into forward-looking adaptation strategies through a combination of planned and reactive adaptation. It is important to acknowledge, however, that adaptation is ultimately a local phenomenon, a response to the local manifestations and impacts of climate change (Adger W. et al., 2009). Locally, adaptation occurs as social systems reorganize themselves in response to external stress, in an unplanned manner. Thus, the approach by the governments, NGOs and other agencies must acknowledge that people pursue adaptation strategies according to their individual circumstances.

Indigenous knowledge (IK) is the knowledge developed by societies and cultures with long histories of interactivity with nature and Local knowledge (LK) refers to the

understandings and skills that individuals and populations have developed specifically for their local environment (IPCC, 2019). The experience-based and practical knowledge of local and indigenous people might also shape perceptions of climate risk, which is essential for managing climate risk both in day-to-day activities and over longer periods of time.

As a result of migration, migrant populations may bring their knowledge across regions, providing global relevance to knowledge that is embedded in institutions or oral traditions. Migrants who lack local adaptation knowledge, on the other hand, may struggle to adapt to the local environment.

Studies like Ignatowski and Rosales (2013) have confirmed findings of IK and LK with scientific insights. Nonetheless, IK and LK provide specific, alternative viewpoints on environmental change (Mellegård and Boonstra, 2020), since they can capture aspects of tacit and embodied knowledge, which is generally not captured by scientific models. In the formulation of adaptation governance and related strategies, Indigenous Knowledge and Local Knowledge (IKLK), combined with scientific knowledge, play an important role (IPCC, 2007), and it can contribute to addressing the serious lack of education on climate change and uncertainties regarding the quality, importance, credibility, and legitimacy of knowledge bases available on the subject (IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability).

2.5.2 Adaptation to extreme heat

All over the world, heat waves result in an increase in mortality and morbidity, as well as losses in economic output, employment, and productivity. In order to reduce the impacts of heat waves on human health, adapting to them is a strategy which reduces the vulnerability to their severity. Adaptation is the most effective means of avoiding or reducing the health effects of heat waves.

According to IPCC (2012), strategies to reduce the risk of natural hazards such as heat waves are an important part of climate change adaptation. Moreover, analysing the impact of adaptation to heat waves on morbidity is also crucial since it provides valuable insight into designing and formulating strategies to reduce the adverse impacts of heat waves.

Adaptations to extreme heat can be broadly classified into four - behavioural or cultural, institutional, infrastructural or technological, and ecosystem-based adaptations (TurekHankins et al., 2021). Behavioural adaptations include the most common spontaneous behaviours such as drinking more water, wearing a sunhat, bathing more frequently etc. Institutional adaptations are employed by agencies on a larger scale which includes communication about heat risks and outreach or education to the public, collaboration with other organizations, and opening cooling centres among others. Actions taken in Nigerian savannas such as the installation of air-conditioning, the installation of solar panels to offset electricity costs during periods of high air-conditioning use, insulation, and passive cooling structural design can be classified as Infrastructural or technological adaptations (Tambo and Abdoulaye, 2012). Planting more trees or retaining existing trees around homes, farms and urban areas to provide shade can be examples of ecosystem-based adaptations. Figure below shows pedestrians and informal workers covering forehead and ears is a readily available adaptive measure that enables the vendors to carry about the trade without interruptions (Figure: 2.6).

Figure 2.6: Vendors protecting head from direct sun with scarves

In a city, different adaptation capacities exist based on how people adjust to and manage extreme urban temperatures and the resources needed to prevent adverse effects on their health. A study conducted by Deressa et al. (2011) found that education level, household size, gender and temperature as the important determinants of adaptation. Among other factors are age, occupation, and heat waves-related knowledge (Zhi-hui et al., 2013), heat wave warning systems like television broadcasts, newspapers, and radio (Das, 2016), Access to finance improved advisory services, and electricity availability (Di Falco, Veronesi and Yesuf, 2011). Seeking different expanses of shade is desirable for every exposed vendor, as shown in the figure below.

A study in Pakistan (Bakhsh, K., Rauf, S. and Zulfiqar, F.,2018) found that the most commonly used adaptation strategies during heat waves included using plenty of water, and juices, increasing the number of baths, using an umbrella, cloth/cap, wearing sunglasses, and using green sheets/chicks in the house. One other common adaptive measure is to stay indoors, under the fan or in the air-conditioning. While air conditioning is an effective cooling method, it is not an option for millions of people who work on the streets (Mastrucci et al., 2019). Street vendors, waste pickers, cart-pullers, and rickshaw drivers are among many types of self-employed workers. In addition to behavioural adaptations, physiological heat mitigation strategies include improving aerobic fitness, acclimatizing to heat, and pre-cooling (Alhadad, Tan and Lee, 2019). Other ‘common-sense’ measures were to wear light-coloured, loose, cotton clothes and cover their heads when going out in the daytime.

Lao et al. (2016) interviewed 32 men working outdoors in Australia about the impact of heat on their work lives and found they exhibited high levels of heat adaptability. For Chinese construction workers, keeping hydrated, wearing light-coloured breathable clothes, resting in the shade, and stopping work seemed to be common-sense methods for preventing heat stress at the workplace (Han et al., 2021). Observations from a study on outdoor workers in Zimbabwe reflected that some street vendors implement heat-avoidance strategies such as the construction of illegal shelters made from cardboard boxes, canvas and plastic sheeting (Ngwenya, 2018).

Liu et al. (2013) found that the higher the perception of potential risk in general, the higher an individual's willingness to adapt will be. It was found that almost all of the participants employed at least one spontaneous adaptation behaviour during heat waves, with drinking more water, opening windows, and resting in shade being the most common.

By studying nuanced coping strategies, risk perceptions, and attitudes towards heat, we may enhance the understanding of adaptive capacity as well as add to and contribute to quantitative findings (Wilhelmi and Hayden, 2010). In addition to understanding the problem and causes of urban heat, narratives contribute to defining solution options for different populations. It is possible to use people's experiences with heat, especially their experiences with increasingly intense urban heat, how they adopt adaptive behaviour, and how they perceive the changing climate to inform mitigation and adaptation efforts. (O'Neill et al., 2017; Krauss and Bremer, 2020)

On an urban level, adaptation programmes such as Heat Action Plans (HAP) have been formulated by governmental agencies in cities like Ahmedabad, Nagpur, Surat, Gorakhpur etc. To reduce the health impacts of extreme heat on vulnerable populations, the Ahmedabad HAP stipulated a series of actions to increase preparedness, information sharing, and response coordination. It is estimated that less than 20 people died in Ahmedabad from heat-related causes during the 2015 heatwave (Ahmedabad Heat Action Plan 2016). With the 'cool roofs' initiative launched in 2017, AMC aims to reduce heat risks in vulnerable slum communities.

It was mandated by the Odisha labour department in 2019 that construction work be avoided between 11 a.m. and 3:30 p.m. Recently, in 2022, the Karnataka State Disaster Management Authority rolled out a plan to deal with heat waves. In addition to non-working hours from 11 a.m. to 3 p.m., cooling centres in public places and temples are also being incorporated, as well as the use of "cool-roofs" to provide thermal comfort. In spite of these guidelines, they have been openly violated because of the lack of stringent penal laws.

2.6 CHAPTER SUMMARY

As a result of climate change, global temperatures as well as the frequency and severity of heatwaves will increase in the twenty-first century. Extended periods of high daytime and nocturnal temperatures put the body under cumulative physiological stress, which makes the world's leading causes of death, such as diabetes mellitus, cardiovascular disease, and kidney illness, worse. Heatwaves often result in public health emergencies, have a significant negative influence on public health, and have a domino effect on other aspects of society (e.g. lost work capacity and labour productivity). As a result of the disruption caused by the power outages that frequently accompany heatwaves, they can also result in a reduction in the capacity for providing health services.
The threats to one's health caused by heatwaves and extended exposure to high temperatures are still not sufficiently known. Planning and interventions by health experts must be modified to account for rising temperatures and heatwaves. Interventions that are realistic, doable, and frequently inexpensive can save lives at the individual, group, community, organisational, governmental, and societal levels. For such realistic measures, heatwave is now being looked at holistically, with close mapping of its direct and indirect effect on every entity.

Heat stress has been measured in varied ways- environmentally, physiologically (internal and external) and psychologically. The most effective and feasible procurement of data is through environmental and physiological indicators.

However, subjective measurement of physiological changes increases accuracy and determines a deeper understanding of causes of heat-related ailments, thereby attracting a comprehensive framework of guidelines. Heat stress is an outcome of climatic and microclimatic conditions.

Heat Stress is the most visible on vulnerable population who are comprised of old, too young or strenuous workers. Among strenuous workers, the informal vendors and self-employed workers face outdoor temperature and sun radiation for the longest duration of time, making them the most susceptible to heat related illness, which, during a heatwave, cannot be properly tended to, if not properly addressed in the first place, leading to aggravated symptoms of heat related illness or chronic disease.

Risk from disaster is increasing globally. Risk is not assessed by an individual unless it directly affects them. Risk is feared less when the knowledge about it is covered by the affected or potentially affected. Heat risk percolates to many levels and affects all activities on a global level. Geographical locations, socio-economic factors, structural drivers and evolved familiarity or cluelessness affects heat risk perception greatly.

Adaptation is governed by resource availability, compelling priorities and the effectiveness with which it can be carried out by an individual, community or authority. Adaptation gains feasibility when applied through customisation catering to variety, which succeeds more due to shared indigenous and local knowledge. Most adaptive measures against heat are developed through readily available resources.

CHAPTER 03

Study Area

Contents

3.1 INTRODUCTION

The impact of extreme heat events on various categories of people at various intensities. Its impact on the vulnerable population sheds light on its genuine nature. Since they are a vulnerable group of people, informal workers are subject to weather extremes.

The policies, identification, and categorization of informal workers are the topics of this chapter. Additionally, it sheds light on the city that was chosen for the examination of heat risk perception, the significance of informal labourers to urban regions, and the areas where respondents were sought out. The chapter lists the spatial characteristics, microclimate, scale, and general description of the chosen locales in addition to identifying them.

3.2 POLICY, ACT AND IDENTIFYING STREET VENDORS

In a country recognised as a developing nation worldwide, a vast portion of trading still falls under unorganised trade, where according to the Central Statistical Organisation [CSO], 2004, 3.95 crore individuals are employed, which accounts to 98% of the total trade employment, as opposed to roughly 5 lakh people being employed in the organised trade i.e., 2% of the same. unorganised sector is where almost all the retail trade takes place in small, privately owned shops and hawkers dominate the Traditional food and grocery retailing in India (which accounts for 70% of retailing). They are largely community based.

Most of the urban dwellers and migrants find appropriate job, accommodation and other ancillary amenities. But for those who do not, a creation of place in the urban economy is still essential, which is achieved by them through entry-level employment or business, that requires less capital and minimal skills, thus establishing themselves as a part of unorganised sector- where they are self-employed in unregistered enterprises or employed as a wage-earner in unprotected jobs. ((Seepana, 2022))

Though street vendors can represent all the socio-economic categories nowadays- individuals with formal education using a street-vending setup, for their entrepreneurship as a start-up; individuals with substantial liquid cash or loan, hailing from well-to-do families, venturing into new business ideas; retired individuals wishing to invest time and skills- a large part of the street vendors is still represented by the urban poor, who can only risk a small amount of capital. This is the reason why street vending can be categorised as an informal enterprise which is run by petty trade. The individual needs or does not need paid workers' or family members' assistance. They are answerable to no higher authorities for their profits or losses. It is highly flexible and directly caters to the goal of getting goods and services to be purchased by the ultimate consumer for their usage and disposal at an affordable price and satisfactory convenience. The occupation of street vending since hundreds of years has led to the formation of a crucial identity- socially and economically- and has been the cornerstone for almost all urban centres throughout the civilisations (Bromley, 2000).

The street is defined as that part of the Urban Texture which has integral functions- provide access to the built structures or spaces for the living beings, the motorised or non-motorised vehicles and the commodities; conceal the underground services; facilitate social functions such as recreation, communication, entertainment and processions. Street vending represents an important share in the above exchange. International Labour Office, 2002, defines street vendors as

mobile or immobile vendors with fixed or semi-fixed stalls, kiosks, foldable table, crates, collapsible stands, wheeled pushcarts, plastic sheets, fabric, or bicycles that display their merchandise.

In 2004, Government of India, through National Policy for Urban Street Vendors defined them as the one who offers goods and services for sale to the public without having a permanent built-up structure but with a temporary static structure or mobile stand or head load, the said policy was revised in 2009. In India, policies or acts related to street vending are synonymous with Ministry of Housing and Urban Poverty Alleviation, which states that there are 10 million street vendors in India, from which 250000 are in Mumbai, 450000 in Delhi, and 150000 and 100000 in Kolkata and Ahmedabad respectively.

With more streamlined interventions, the Parliament of India enacted on Street Vendors (Protection of Livelihood and Regulation of Street Vending) Act in 2014, which was formed on the basis of prevention of harassment by police or civic authorities, demarcation of vending zones as a resultant and as a form of traditional natural markets and their representation in decision making bodies to facilitate an establishment of grievance redressal and improvement mechanism. The role and responsibilities of the act are as following:

- Formation of a Town Vending Committee in each local authority constituted of Municipal Commissioner or Chief Executive Officer and other members representing the planning authority; medical officer of the local authority; traffic police and police; and members from association of street vendors, market associations, trader's associations, non-governmental organisations, community based organisations, resident welfare associations, banks and such other interests. These members are to be nominated by appropriate local government. Percentage of members from Non-Government organisation and members representing street vendors must be not be less than 10% and 40% respectively.
- The Committee is responsible for holding regular meetings, wherein, complying with the measures of regulations i.e., survey of street vendors, issue/renewal of certificate of vending and identity card under stipulated categories such as stationery vendor, mobile vendor, etc., after verification of their mentioned criteria- mainly that the occupation is their only means of livelihood, procurement of vending fees, etc.
- The committee is also responsible for acknowledging and educating the vendors of their rights and civic duties
- The act also consists of a provision of street vending plan, to be designed by the planning authority that adheres to its principles- ensuring the vendors to constitute 2.5% of the ward population, facilitating free movement to commuters along with the planned vending area coinciding with the existing natural markets to fair degree that leads to efficient distribution of goods, taking into account the civic facilities such as-
    - solid waste disposal facility,
    - public toilets to maintain cleanliness,
    - aesthetic design of mobile stalls/ push carts,
    - electricity,
    - drinking water facility,
    - protective covers to protect their wares as well as themselves from heat, rain and dust and,
    - storage facilities including cold storage
- The plan must have determination of spatial planning norms; determination of vending zones as restriction-free vending zones, restricted vending zones and no-vending zones.

- Above all, the subsequent plan must be incorporated in revisions of the existing master plan, development plan, zonal plan, layout plan, etc.

3.3 ECONOMIC PROFILE OF NAGPUR

In the 9892 sq.km of Nagpur District, 6440 sq.km of the area is identified as cultivable, making the region's predominant economy agrarian. Most of the trade perpetrators are mineral resources and fisheries apart from agricultural produce. The secondary sector being the industrial estates sprawled over 3887 Ha, marks the foundation of the economy for the city- Butibori being the largest, followed closely by Maharashtra Industrial Development Corporation (MIDC), among the 9 others. The IT sector also shares a major part in the estate.

Nagpur has numerous Medium, Small and Micro Enterprises/Industries (MSME), where 3.5 lakh citizens are engaged in fabrication workshops, rolling mills, foundries and manufacturers of automobiles in public and private sector enterprises. The ratio being 41:59.

The tertiary sector of economic activities is comprised of markets, the activities of which are also the most visible and accessible to the common people irrespective of age or socio-economic status. The case of Nagpur is not different. These markets are a combination of the formal and informal setups. The most identifiable classification to the buyer, is based on the types of good the market sells, at wholesale or retail prices. The responsibility of regularisation and maintenance of such markets lies with the Market Department at Nagpur Municipal Corporation (NMC), as follows:

- Construction of market places
- Operation and maintenance of Market Places through in-house personnel or through outsourcing by auctioning
- Allotment of stalls or land parcels to vendors
- Collection of revenue from vendors or Operation and Maintenance Contractors.

Although the Market Department at NMC has complied with most of the above duties, the usher of New Town Vending committee has led to the convergence of various responsibilities (City Development Plan for Nagpur-2041, 2015).

3.3.1 Informal markets in Nagpur

Unlike formal markets, which necessarily do not need a populous area or an abutment to a connecting road or busy street- for e.g., DMart, car showrooms, etc.- informal markets spring up synonymously with the inhabited areas- for e.g., Sita Buldi, Itwari, Gokulpeth, Khamla, etc. These markets are given purpose and meaning by the users who are seeking goods that are useful in their day-to-day lives, at a negotiable price and ensures direct contact with the material and the seller.

The pattern of increase in informal market coincides with the pattern of increase of Nagpur's developing regions; for e.g., at its oldest, today's centremost area, Mahal was among the first of the market places as Nagpur's settlement limits were in its vicinity, but with evolution and expansion, an area like Jaitala, which was merely a semi-agricultural forest has now transformed into an active residential area in the last twenty years, resulting in the area becoming a commercial magnet for the socio-economic category who is willing to invest the least capital and reap a sufficient income i.e., the informal vendors. Thus Jaitala Market, which is a combination of weekly and daily market, is an outcome of the settlement near it.

Much like any other city in India, the informal market of Nagpur is run mostly by the urban poor, who reside mostly in the informal settlements after migration, mainly from neighbouring regions, either near to their corresponding market places, if their

place of business is in predominantly residential area or in the urban fringes, if their place of business is in predominantly commercial area. Although the majority of the age groups involved are aged 20-50, all age groups are expected to contribute since it does not go through a formal scrutiny. According to the report on Conditions of Work and Promotion of Livelihoods in the unorganized sector, 2007, male vendors earn Rs. 70 on an average. Whereas, women earn Rs. 40. In Nagpur, few markets of the older parts of the city have vendors working since the inception of the market place through generations. As for the developing and contemporary parts of Nagpur, the number of vendors with their units increase with passage of time. These vendors usually hail from homes with a typical family unit with an average of 4 members dwelling together (City Development Plan for Nagpur-2041, 2015).

The city is a hinterland, that gathers goods from major trading cities of India- Kolkata, Delhi, Mumbai, etc. This makes markets like Cotton Market and Kalamna Market the originating points of all the saleable items, as most of the goods are docked at their corresponding railway stations. Most of the items being related to food and other household goods. The vendors set up their units comparatively late as compared to major cities, i.e., around 10 in the morning and wrap up around 9 at night; food item sellers are an exception. The informal markets in Nagpur belong to mainly three categories- weekly market, daily market- catering on a city or partial-city level- and neighbourhood cluster markets.

3.3.2 Daily markets

Nagpur, with its central location possesses potential of becoming the logistic hub in the near future, exercising a strong foothold over formal and informal sector. Additionally, the city has an added benefit of having equal access to produced and manufactured goods all over India. This has result in establishment of vital daily markets in the city. Located particularly in Central Business District (CBD) zones, Mahatma Fuley Bazaar, Dahi Bazaar, Itwari, etc. are the most sought after market places in the city. In expanded parts of the city, namely Pardi and adjoining villages absorbed in the city, Kalamna market, an afterthought of Kalamna railway station, proves to be the primary source of goods that circulate in other market places of Nagpur.

The specific characteristics of such market places lie in their quality to dispose goods to other markets of smaller scale as compared to them. Markets and shops all over the city receive material from these places on daily and mostly weekly basis.
Most popular daily markets:

- Mahatma Phuley Market, widely known as Cotton market
- Kalamna market
- Itwari Phul Bazaar
- Dahi Bazaar
- Kamal Talkies Bazaar

3.3.3 Weekly markets

Like most cities, weekly markets are generally identified by names dedicated to days of the week. For example, Itwari is named after Sunday and traditionally remained close on the said day; some other markets like Jaitala operate in full force on Sundays. In the evolution of Nagpur, daily markets, on one side, were catering on a city level.

Weekly markets were established by specific communities of vendors, who either migrated in search of business opportunity or fanned out of saturated daily markets to attract more direct customers from newly formed areas.However, these markets have slowly transformed into daily markets owing to the prospects of larger consumer pool and increasing demand of goods. Little difference remains between the daily and weekly markets of Nagpur.
The large scale weekly markets outnumber the large scale daily markets. As their established names draw customers to these areas, most vendors stick throughout the week to ensure continuous trade with consumers from various areas in the vicinity. Therefore, these markets operate on a sub-city level. The major difference between normal days and an officially assigned weekly day for either working or non-working business day is the magnitude of active shops. The prime names for such markets being:

- Gokulpeth Bazaar
- Somewaripeth Bazaar (Budhwari Bazaar)
- Netaji Market, Supermarket Sitabuldi, Mahatma Phuley Bazaar
- Mahal Bazaar
- Itwari Bazaar
- Kadbi Bazaar
- Kamal Talkies Bazaar
- Mangalwari Sadar Bazaar

3.3.4 Overview of existing authorised and unauthorised markets

The authorisation of the markets was mainly done by the NMC according to the zonal divisions of the city, where the urban local body strives to establish at least one market in each zone (City Development Plan for Nagpur-2041, 2015).

Out of the 10 zones, 8 possess active weekly markets which are authorised by the NMC. NMC took the responsibility of development of almost 4,500 market units. The recorded segregation regarding the set-up of these units are shops establishment, benches/platform and seats which amount to 2400, 612 and 1419 numbers respectively. Further, according to the report by Crisil on City Development Plan of Nagpur, 2015, Mahatma Phuley Market in Dhantoli zone contains the most number of developed units by the NMC, with precisely 769 shops, 217 platforms and 373 seats. Somewaripeth (Budhwari Bazaar) of Hanuman Nagar zone has the least number of market units developed by the NMC. Along with providing the authorisation of these market units in the markets- that ensures their identification as rightful vendors- NMC is responsible for providing uninterrupted services related to water supply, sanitation, electric supply, etc. For the same purpose, NMC collects Rs. 10 per market units, especially from daily markets. If the proposal for authorising and collecting tax from all the daily market units is approved, the revenue generation for safeguarding the prospect of amenities will amount to Rs. 20 lakh annually (City Development Plan for Nagpur-2041, 2015).

The stark difference which sets the unauthorised markets apart from the authorised markets is the absence of tax collection. As with the duty of tax, the vendors to whom the market units are allotted are entitled to basic infrastructure. This also ensures the regulation of the services, an arrangement which the unauthorised markets lack. According to the survey taken by the market department in the year 2015, there are 24 weekly markets and 17 daily markets that are unauthorised. Upon there authorisation, an annual revenue collection of 30 lakhs will be possible. In addition to the authorisation of natural market places, NMC has also addressed

to the demand of commercial space that has better infrastructure, by proposing these at 6 locations- Danaganj, Goklupeth Market, Panch Paoli Market, Jaripatka Bus Stop, Water Works Office near Sitabuldi, Netaji Market, to be built on Public Private Partnership-Built Operate Transfer basis.

Street vendors, being indispensable means of affordable trade, are also to be identified by the NMC and TVC as a part of vendor zones in Gokulpeth market, Near Medical Chowk, Somewaripeth Bazar (Budhwari Bazar), Mahatama Phuley market (platforms), Shukrawari (platforms), Panch Paoli near flyover, Near Maskasath PWD office, Near Deputy signal, Mini-Matta nagar, Bhandewadi (Pardi), Dhobighat (Teenkhaba), Kamall Chowk, Near Jaripatka bus stand, Gittikhadan opp. police station on Katol road, Mangalwari market, along the sides of Anjuman engineering college, Dhantoli flyover (near Kumbhartoli). Along with Vendor Zones, certain hawking zones are to be designated by the authority, where the hawkers are ready to shift, as per the discussions held among the hawkers' association and market department.

3.4 SELECTION CRITERIA

Nagpur is a tier 2 city with combinations of densities; highrise-high density, lowrise-low density, highrise-low density, lowrise-high density, mediumrise-medium density, and so on. These are the resultant of both saturation and scattering of population, as the typical citizen buys land far off of the heart of city at considerably lesser prices, waits for the area to get developed and then shifts subsequently. And owing to the prevailing economic centres since Nagpur's identification as a settlement, Nagpur has major division of characteristics of area as work force area (majorly residential) and work place area (majorly commercial). The intensity of such characteristics has given rise to market places of different scale, intensities and different types of saleable goods.

The study aims at integrating all typologies of markets to attain a holistic data pool. Since different scales and types of markets are magnets to different types and amounts of people with varying intents for commercial exchange; their set-up, infrastructural development, spatial organisation; revenue generation and identity as a part of the city differ from each other. The variation results in different reactions to the natural environment- which blankets the whole city in the same manner. The market with a range of market units' amount, scale, establishment year can be categorised into city level market places, sub-city level market places and neighbourhood level street vendor clusters (Figure 3.1).

In case of city level market places, the markets are relatively centrally located; prominent among the citizens from all over Nagpur. They are the originating point for various goods that are transferred to the market units all of the city, thereby ingrained in the vocabulary of city-wide sellers and consumers, ultimately establishing the presence of strong intent of buyers- coming from farthest parts of the city and strong intent of the sellers- continuing being at their disposal amidst almost any natural or man-made conditions. Moreover, they have major commercial complexes and medium to small range formally appointed shops in close vicinity and their saleable items cover all types of goods attracting both buyers and sellers.

In case of sub-city level market places, the markets cater to more than one neighbourhood and have medium to small range formally appointed shops in close vicinity with a strong vocabulary with the informal vendor. In case of neighbourhood level street vendor clusters, the presiding landuse are residential. The vendor units are in proximity to each other to form a dense or scattered cluster and the saleable

items are mostly comprised of items disposable to the end-of chain buyers. In all the cases the active hours of the markets include the ones in afternoon. The informal set-up in this markets is temporary, i.e, kiosk, table, mat, umbrella, vehicle, podium, stand, hand held display unit, cart, etc. In addition to these, the circulation spaces in these markets also bear a certain movement pattern and a hierarchy in exposure to sky, basic infrastructure and ancillary facilities. The market places or clusters of vendors, in the presence of their large-scale, medium-scale and small-scale complexes/shops/showrooms exist with a strong vocabulary with the informal vendors.

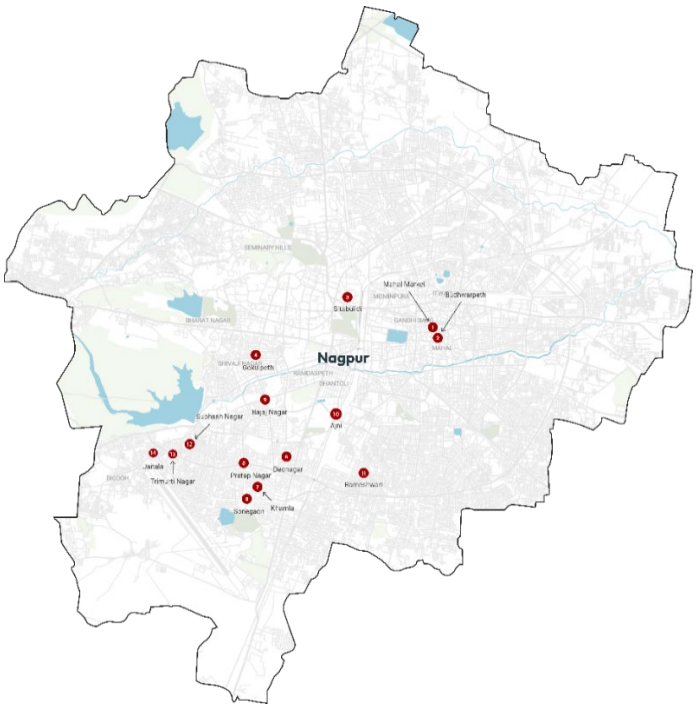


Figure 3.1: Heat Risk Perception survey locations

3.5 ZONAL MARKETS

These set of markets are categorised by the NMC as daily or weekly markets falling under the municipal zones of the city. They serve the city on a city, sub-city or zonal level depending on their prominence and variation and competition in the saleable items. The footfall in such markets are considerably lot more than the footfall in neighbourhood vendors' cluster.

3.5.1 Mahal market

In the Eighteenth Century, the Gonds first settled in Nagpur which is the present day Mahal. Over the centuries, upon its articulation, Mahal developed as a predominantly residential area and Itwari, a predominantly commercial area. But over the years, Mahal witnessed its transformation into a combination of residential and commercial area. As of today, all of the buildings that flank the main road have been absorbed into shops- starting first as purely residential quarters for the servers of the royal; to being a shop on ground floor and a residence on the first and/or second floors in the pre and post-independence era; to finally being a combination of shops-storage-office in the present day. This has led to it becoming a major commercial centre that attracted various informal vendors who abut most of the central street. (Figure 3.2)

The Kalyaneshwar Mandir is now a major commercial square, from which, two heavily commercialised streets emanate in both the directions.

Simultaneously, Gol Bazaar was also developed in the Pre-Independence in the name of Tukaram Sakhre that houses a number of informal and formal shops. The interiors of Mahal that branches out of the main streets are residential- low rise high density.

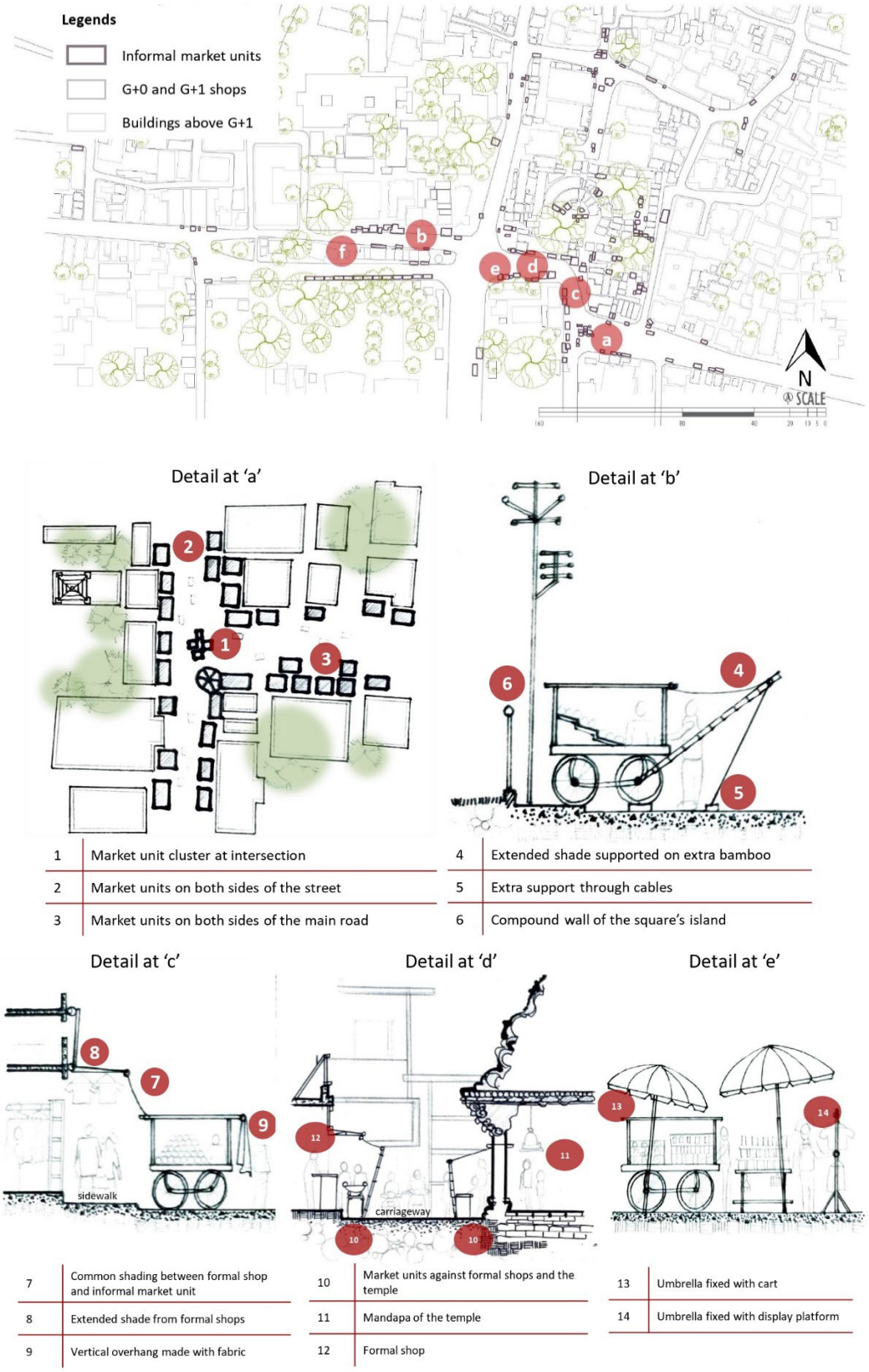


Figure 3.2: Details of Mahal Market

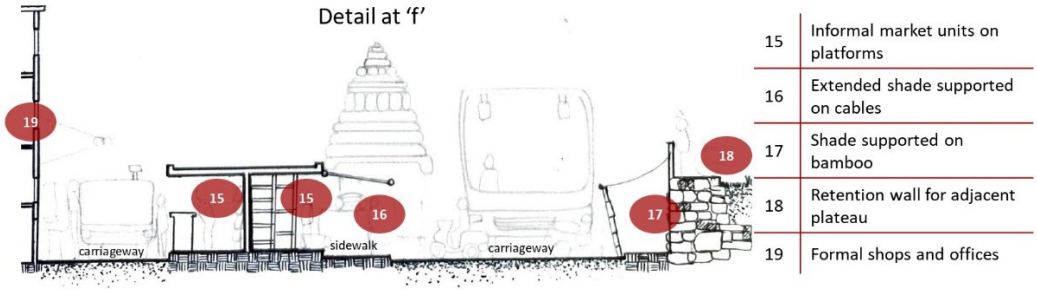


Figure 3.3: Detailed section of Mahal street

Mahal Market stretches uptil 500 m in 3 directions, i.e., Tillak Road, Killa Road, Kelibagh Road with respect to Kalyaneshwar Mandir (Figure 3.2). Gol Bazaar, a substantial part of Mahal Bazaar, is established on an area of 0.3 Ha. The market is linear in terms of its occupation on the main streets and concentric in terms of Gol Bazaar, literally translated to Circle Bazaar. The market is typically accessed by people on vehicle for the streets. A part of the visitor group does park at the area provided by the authority, i.e., at the square or near NMC, Mahal.

Predominant setup of informal shops comprise of stone/concrete/brick plinth-steel sections-profile sheets-spillouts supported by poles and fabric (Figure 3.2), bamboo (Figure 3.2) and umbrellas (Figure 3.2), carts (Figure 3.2), open tents, mats, compound walls (Figure 3.3) used as a backdrop for displaying items.

3.5.2 Budhwarpeth

The market falls in the Gandhibagh Zone. It serves most of the East Nagpur. But due to its early prominence, the market serves as a go-to shopping place, where almost every grocery and daily needs item is available. As the market is falls in the route of various commuters throughout the day who scale various ends of the city, the informal set-up of Budhwarpeth is one of the errands stop for many citizens. (Figure 3.4)

The market, for remaining close on Wednesdays, in earlier days, is known as Budhwarpeth. However, with the increased prospect of vendors to gain more income, almost all the market units remain open on Wednesday too.

Demographically, the female and male vendors contribute to 23 % and 77 % of the total, respectively. The market is typically known for selling food items, Pooja Samagri (sacred offerings) and other kitchen related accessories in the Gol Bazaar area; and for selling clothing items along the main streets, mostly set up by vendors aged 36-50, 21-35 and 51-65 in decreasing prominence. These vendors basically reside in Nagpur, due to which, their dwelling unit is composed of a set if typical family members of all ages. Those who have migrated, generally belong to Madhya Pradesh or Chhattisgarh.

Predominant setup of informal shops comprise of carts (Figure 3.4), open tents (Figure 3.4), mats, compound walls (Figure 3.4) used as a backdrop for displaying items. The frontage of formal shops is used as a backdrop space to increase access to each unit from all sides (Figure 3.4).

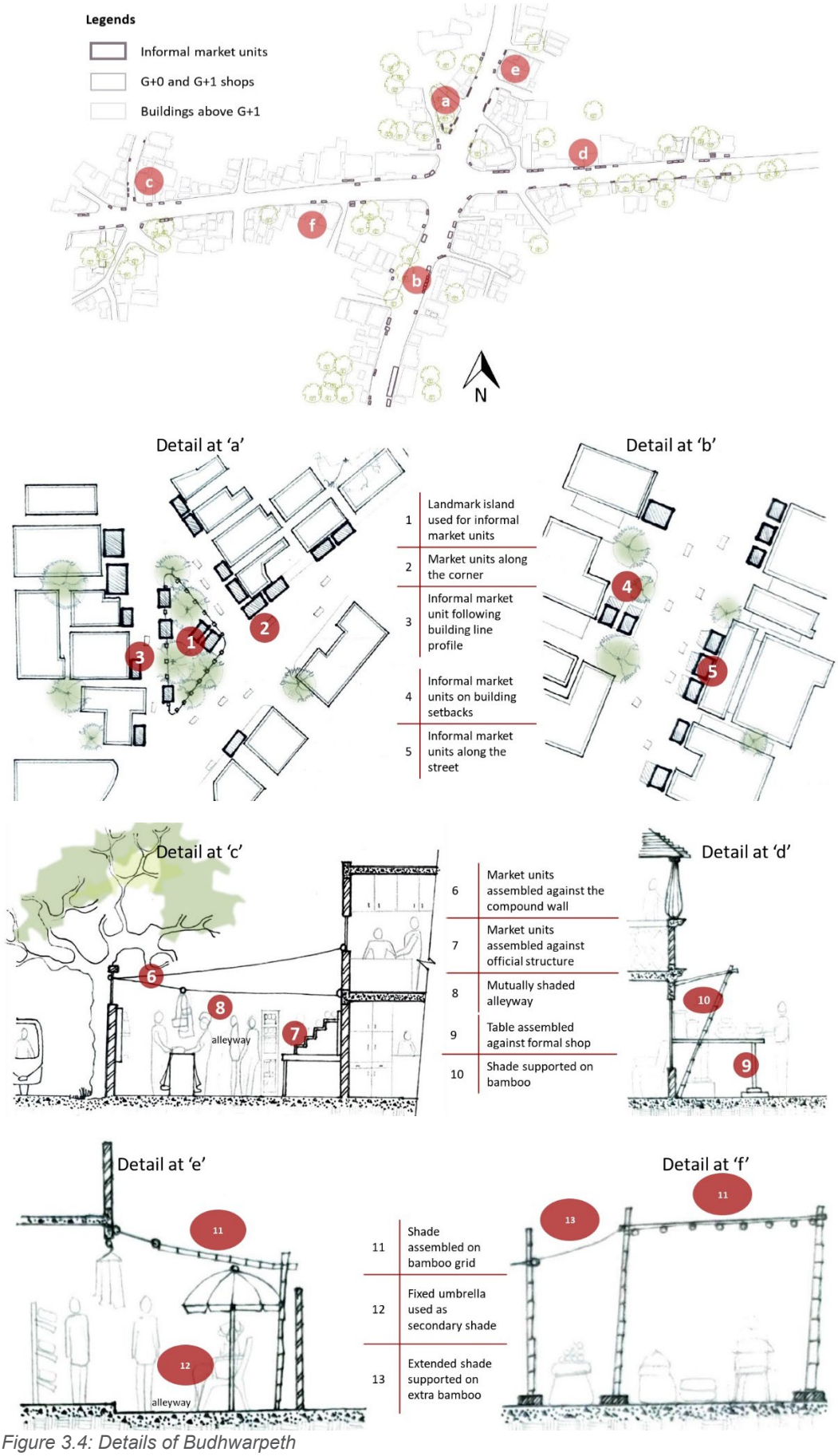


Figure 3.4: Details of Budhwarpeth

3.5.3 Sitabuldi

In the Eighteenth Century, Sita Buldi Fort, built by Raja Bakht Buland Shah, atop the Plateau, trickled down to settlements at sea level in the vicinity. Mahadwar was one of the gates that fortressed the precinct. But even in those days, the settlement scattered from this gates, resulting in residential occupancy transforming into commercial one, just like the transforming case of Mahal.

Sita Buldi is now the hub of shops of clothing, accessories and other domestic items. The informal vending scenario is synonymous with this category of shops- everything except daily needs or groceries. The market falls in Dharampeth zone. Low rise High density residential structures along with other public buildings like bank merge with the market area.

The market is registered in Dhantoli zone. Since the location of market is on a road that connects major satellite towns of Nagpur i.e., Amravati and Wardha, the most premium offices, business centres, institutions and other shops incident on the same route, making the shops adjacent to these mammoths, a familiar name among the citizens, as they pass this market area almost every day on their way to workplace or home (Figure 3.5).

The resultant sprawl of the informal street vendors is the go-to shops for most of the goods needed. College students, women from all socio-economic background visit the place on a daily, weekly, mostly monthly basis, hailing from areas as far as suburban Hingna.

The market is set on a main road that spans upto 750 m and is an expansion towards Amravati Road for another 100 m (Figure 3.5). The market mainly spreads in the form of branches on both sides from the said Main Street.

The market is provided with set of grounds, complex premises and stretches of streets for parking vehicles. These provisions are mainly used by the visitors, who park their vehicle or arrive on public means of transport to the precinct.

Female vendors constitute upto 2-5% of the total number of vendors. The vendors mostly belong to their early 20s to their late 30s. The dominant commodity is related to clothing and accessories, with eateries becoming the ancillary business for a few vendors owing to Sitabuldi’s recreational nature.

Vendors have generally migrated from Madhya Pradesh and Northern states like Uttar Pradesh and Bihar, some living with family, others living in groups; yet most of the vendors belong basically to Maharashtra.

Predominant Setup of Informal shops includes carts (Figure 3.5), open tents, mats, kiosks (Figure 3.5), shared tents (Figure 3.5), mobile display, tables/platforms. The main street branches out to both sides giving a narrow alleyway for setting up market units (Figure 3.5).

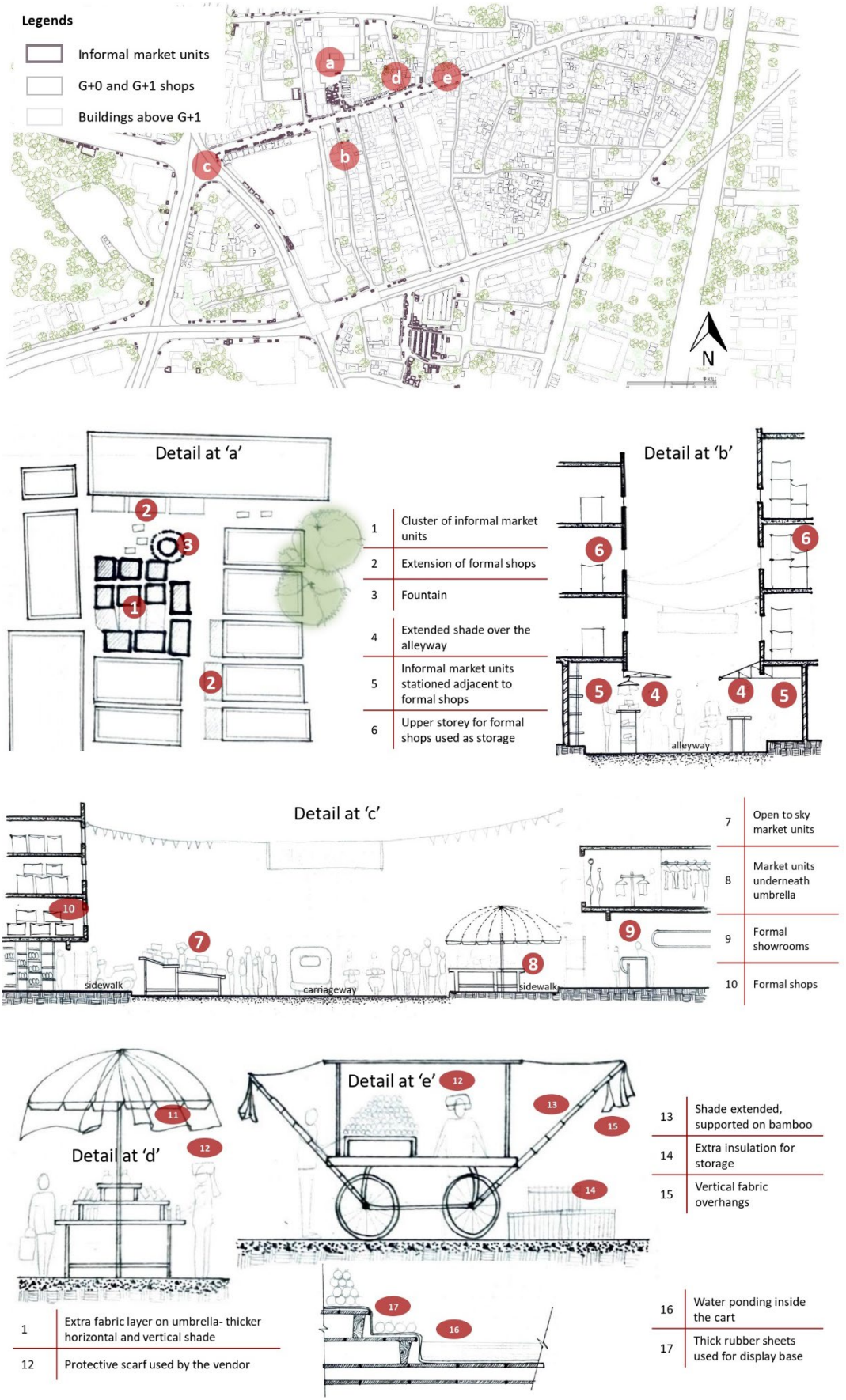


Figure 3.5: Details of Sitabuldi

3.5.4 Gokulpeth

Originating in the Pre-Independence era, the area surrounding the market flourished immensely in the contemporary times. For its distinguished residents, the market is developed on an open land that seeps through the lanes surrounding it. Major Commercial Shops and Complexes were developed in the region. It boasts of prominent clothing shops, recreation centres, jewellers, eateries, showrooms, etc., that were built in the past few decades.

Unlike Mahal, Dharampeth possesses originally dedicated commercial buildings and complexes (Figure 3.6). The surrounding residential settlement is articulated with medium rise and medium density residential and commercial buildings. The market falls in Dharampeth zone. It serves majority of the central Nagpur residents and commuters who passed through it. For Wednesdays and Festivals, vast number of citizens from West and South Nagpur come for grocery shopping. The open to sky ground measures 1.9 Ha.

Amidst fair amount of trees, the market units have either established semi-permanent roof or fabric tents (Figure 3.7). The natural sprawl is comparatively less than Buldi and Budhwar Bazaar. The market is rectangular in settlement form. With its cart-vending and mat unit spillout to the lanes in all directions upto 50 m. Visitors usually throng to the area on foot by parking the vehicles on the periphery (Figure 3.7).

Female market vendors constitute upto 27% of the total vendors. All vendors majorly sell food, fruit and meat items. The market, in its zone and vicinity neighbourhood is famous for selling items needed on festivals, i.e., flowers, sacred offerings, etc. Apart from this, the market also has few repairing shops. Above 80 % of the seller belong to 21-50 years of age group. Fair ratio of vendors hail from outside Maharashtra, leading to almost half of them living amidst family or fellow vendors. Predominant setup of market units includes stone/concrete/brick plinth-steel sections-profile sheets-spillouts supported by poles and fabric in the interiors of the area (Figure 3.7) with mutually shared shading materials (Figure 3.7), carts in the frontage of the formal shops (Figure 3.7), open tents, mats, kiosks, etc.

Figure 3.6: Gokulpeth market

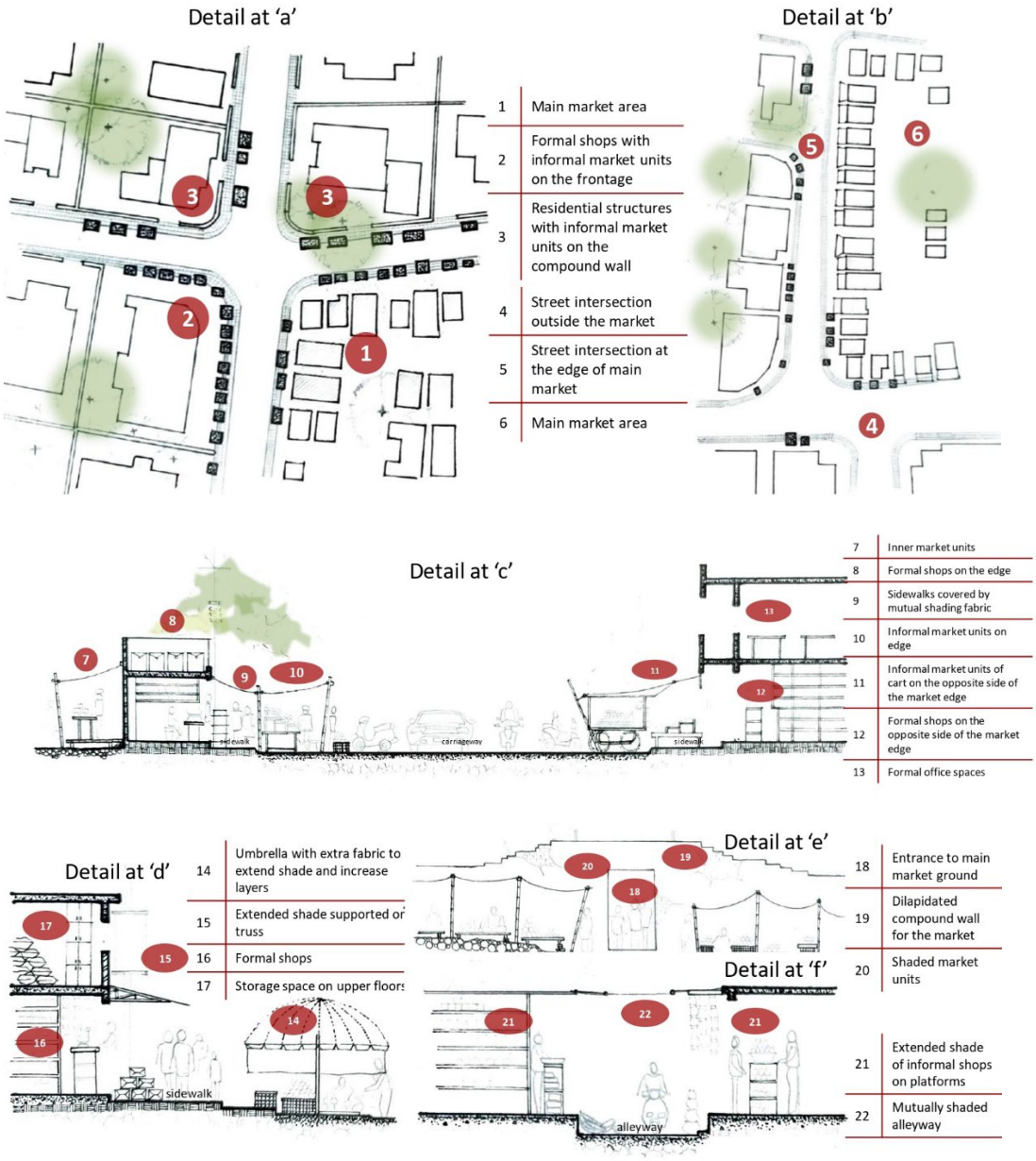


Figure 3.7: Details of Gokulpeth market

3.6 NEIGHBOURHOOD MARKET UNIT CLUSTERS

Majority of the Tier-2 city Nagpur is comprised of residential zones. For workplaces that belong mostly to large market places like Fule market, Mahal, Itwari, Sitabuldi, Jaripatka, Sadar, etc.; industrial places like MIDC, Butibori, etc. and official places like IT-Park, Civil Lines, Ramdaspeth, etc., there are work-force places that generally are located in the vicinity or in the intermediate areas. These residential zones are identified as neighbourhoods where people who work in the Work Place area reside.

The nature of such zones with respect to street activity, density and footfall is distinct from the market places. The structures in these areas are mostly comprised of residential buildings with only 15% of their carpet area dedicated to shops, offices, etc. with few neighbourhood level diners, supermarkets, offices, early schools, places of worship, gardens, etc. Such locality attracts different set of vendors who focus mainly on daily needs like fruits, vegetables and granary.

Generally, such vendors witness a steep surge in their footfall during the morning hours and evening hours- when residents are returning from a morning or evening health routine, or on the way to or returning from the office respectively and ought to run errands. The other contributors of their footfall are the home makers and children, who seek items for daily needs, mostly in the late morning hours or during the afternoon hours. These market units procure their material on a weekly or bi-weekly basis from the zonal markets like Fuley market, Itwari or Mahal.

3.6.1 Ajni

The market is set in between two crucial squares, Ajni Railway station square and Ajni Square. Ajni square connects two logistical route- Wardha Road and Food Corporation of India godown road, both pivotal in connecting city to city and storage supply to city respectively. Ajni Railway Station is the secondary railway station for Nagpur City that caters mainly to the passengers boarding or descending from and to the Southern Nagpur respectively. This makes these two crucial squares a hub for many goods exchanges. Moreover, the route connects many workplaces to workforce places. For example, the route leads to Sitabuldi, Dhantoli, FCI godown. Ajni square is also a host to a major school, a research centre and central jail. The customers are from city-wide and immediate workplaces; passengers; transporters; residents from the neighbourhoods in the vicinity.

The logistical and utilitarian nature of the stretch make sit the most suitable to have multiple business units focusing on vehicle repair and maintenance. The other ancillary market units, that help residents and travellers are the ones who sell earthen pots, fruits, vegetable, juice, helmets, eatables, etc. Since its close proxemics to residential area, there are also few scrap mongers. The group of market units are laid out in linear pattern on a span of 1.2 km main road, starting from Ajni Square to Ajni Railway station square on the FCI godown road. This road is flanked by trees that poartially belong to the Central Jail campus and the railway tracks. The reason for this linear arrangement is mainly the presence of the central jail premises on one side and FCI godown, residential units and railway tracks on the other. Almost all the customers access the market unit on a vehicle (Figure 3.8).

The market is set in between two crucial squares, Ajni Railway station square and Ajni Square. Ajni square connects two logistical route- Wardha Road and Food Corporation of India godown road, both pivotal in connecting city to city and storage supply to city respectively. Ajni Railway Station is the secondary railway station for Nagpur City that caters mainly to the passengers boarding or descending from and to the Southern Nagpur respectively. This makes these two crucial squares a hub for many goods exchanges. Moreover, the route connects many workplaces to workforce places. For example, the route leads to Sitabuldi, Dhantoli, FCI godown. Ajni square is also a host to a major school, a research centre and central jail.

The customers are from city-wide and immediate workplaces; passengers; transporters; residents from the neighbourhoods in the vicinity. The logistical and utilitarian nature of the stretch make sit the most suitable to have multiple business units focusing on vehicle repair and maintenance (Figure 3.8). The other ancillary market units, that help residents and travellers are the ones who sell earthen pots, fruits, vegetable, juice, helmets, eatables, etc.

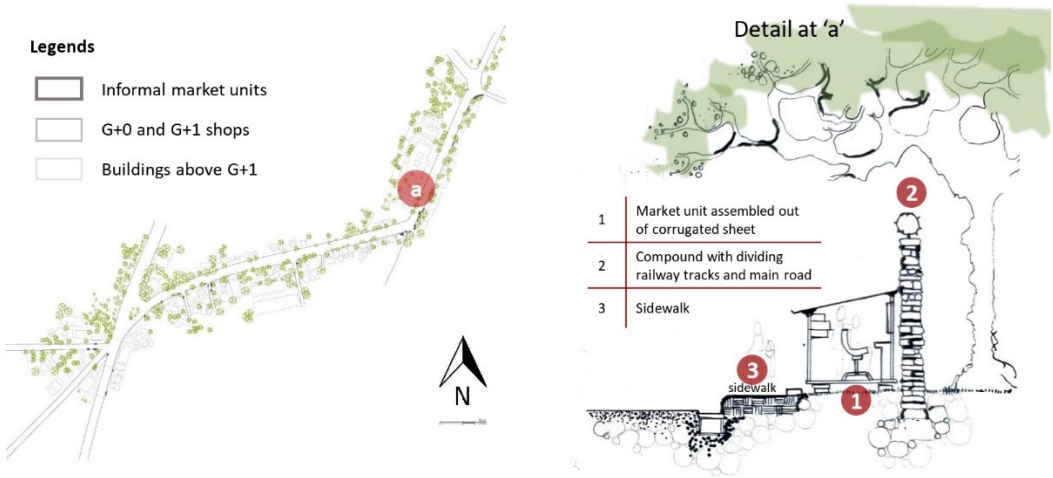


Figure 3.8: Details of Ajni

Since its close proxemics to residential area, there are also few scrap mongers. The group of market units are laid out in linear pattern on a span of 1.2 km main road, starting from Ajni Square to Ajni Railway station square on the FCI godown road. This road is flanked by trees that partially belong to the Central Jail campus and the railway tracks. The reason for this linear arrangement is mainly the presence of the central jail premises on one side and FCI godown, residential units and railway tracks on the other. Almost all the customers access the market unit on a vehicle.

3.6.2 Jaitala

Compared to other neighbourhoods, Jaitala is relatively new. Real estate developers through the last 8 years have invested in residential complexes owing to rapid urbanisation. As of now, Jaitala is a purely residential zone as it is adjacent to Hingna, which is a combination of commercial, educational and residential development- in that order. Thus, Jaitala is still a developing neighbourhood with many plots to spare for future residential development. Some land parcels are also dedicated for agricultural activities. It garners buyers from Subhas Nagar, Trimurti Nagar, Nelco Society and Jaitala.

The main road that starts from Mangalmurti Square and leads to the innards of the area is where most of the market activities are carried out. Jaitala Market is mainly an outcome of the original market that occupies approximately 0.27 Ha open ground (Figure 3.9). Jaitala Market, also known as the Sunday Market, assembles every Sunday, and carries out trade throughout the day. The market is an intermediate selling place between Hingna, Khamla and Pratap Nagar.

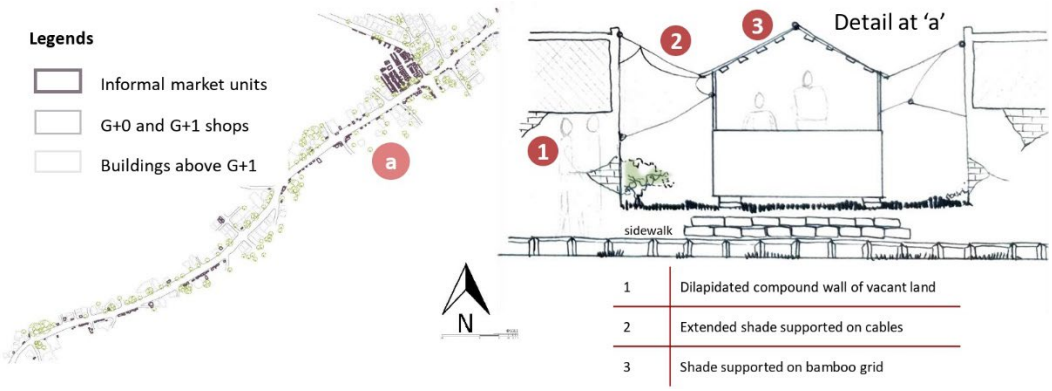


Figure 3.9: Details of Jaitala

Like every weekly market, this market too, is an example of temporary urbanism. Which means that each market unit is set up in the early hours of Sunday like a tent with the help of materials like tarpaulin, green shade net with a layer of gunny bags or cotton fabric. The commodities are displayed on raised platforms, tables and mats made from salvageable materials. The whole set-up gains footfall as the day passes, with maximum customers coming at night, post-dinner time, in the prospect of buying goods like fruit, vegetables, spices and even few clothing items and accessories at a good deal. By Monday morning, none of the market units are seen, even with a trace of the materials used in building the set-up.

3.6.2.1 Jaitala daily market

Apart from the weekly market, which abuts the Jaitala Main Road, the other market units are arranged in a linear pattern along the road itself, for upto 1.2 km. These market units remain present throughout the week. These are built with material like bamboo, steel sections and have roofs made out of tarpaulin, sun shade net and fabric along with timber platform or mats to display the commodities (Figure 3.9). The assembly is easy to dismantle. Some units are also mobile- on mini-trucks. The main road is sparsely dotted with trees along it. Making most of the market units exposed to the open sky.

Women constitute to less than 10% of the total vendors. These vendors belong mostly to the age-group of 25-35 and live with their families in nearby areas like Hingna or Jaitala, irrespective of their original state.

3.6.3 Subhash Nagar and Nelco Society

Subhash Nagar and Nelco Society are heavily residential with few variations like Temples, Playschools and a hospital. For the vendors in this locality, the type of customers is mainly focused to the immediate residents. The other type of customer is the students or employees who work in the institution that is adjacent to the neighbourhood. The footfall in neighbourhoods increase in the morning and evening hours.

Unlike Jaitala or Ajni, the neighbourhood market cluster of Subhash Nagar and Nelco Society are mostly scattered in nature. The main reason for this is the absence of a major landmark- like Ajni Station in Ajni and the absence of an allotment of a land parcel; specifically, to carry out informal trade- like Sunday Market ground for Jaitala. Thus, the vendors in this area are stationed near neighbourhood level landmarks like a temple or a street corner. Characteristically, these neighbourhoods have trees around such corners, where the vendors would naturally prefer to set up market units (Figure 3.10).

These market units are mostly easy to dismantle, as they are built with materials like sun shade net, tarpaulin, timber, gunny bags and fabric, but as the residential buildings' streets are less busy as compared to workplace areas', the vendors usually leave the set-up sans the commodities for the next day (Figure 3.10). The main items and services for selling are vegetable, fruits, sacred offerings, eatables or repairing centres for vehicles, bags, shoes, etc.

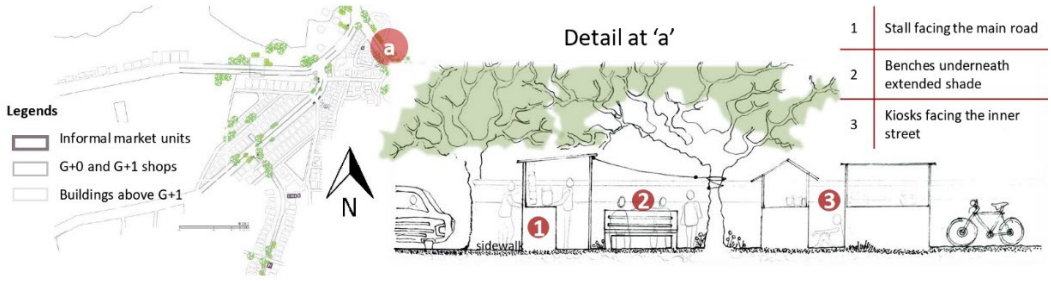


Figure 3.10: Details of Subhash Nagar

3.6.4 Trimurti Nagar

Compared to the its neighbouring settlements, Trimurti Nagar is older by 3 decades. The neighbourhood abuts the Ring Road, which is a highway, and most of its market units are set up in the close proximity to this road.

Their business depends on the active hours of the garden, as it attracts visitors from vicinity stretching upto 3 km, due to it being the only happening open space. The other node is dependent on the residents and the commuters en-route. Their grand frontage makes the square a vibrant stop for buyers throughout the year, but especially during festivals.

There are two nodes at which the market units are the most densely placed- one is near the Trimurti Nagar square, where all the buildings are residential on the upper floor and commercial on the ground floor, with provision of godown; the other is outside NIT garden (Rajiv Gandhi Udyan), where the buildings are a mixture of purely residential and residential and commercial use. At both the nodes, the shops, like the shops in other neighbourhoods, are in sync with the temporary set-up by the vendors outside (Figure 3.11).

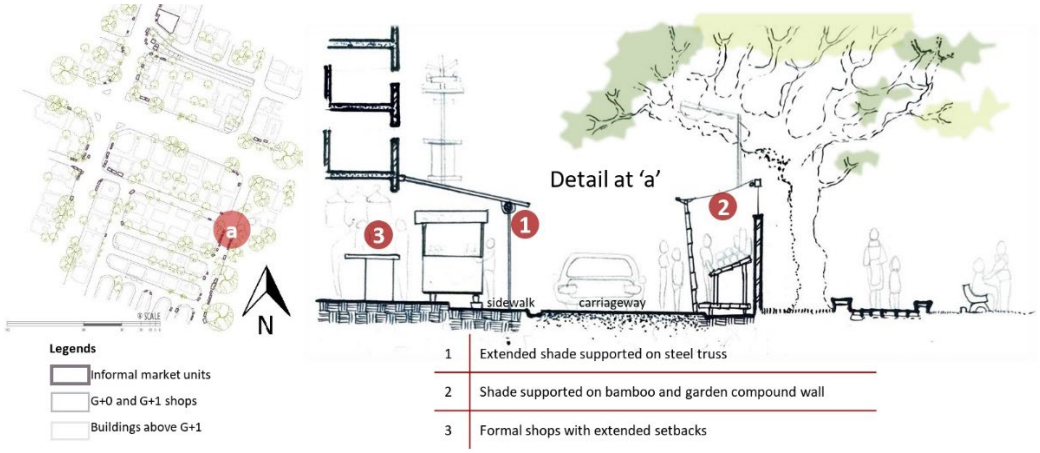


Figure 3.11: Details of Trimurti Nagar

Very few vendors in this area display their commodities at ground level. Most of the set-up is made of temporary materials that are left in the same throughout the hours of the day and night. The node near the garden is shaded with trees and the streets that are adjacent to the garden area form a perfect edge for the vendors to set up fruits', vegetables' and eatables' kiosks, as it gives them two sides for access for the buyers, who, mainly visit the market units in the morning hours and evening hours, when the garden is used the most (Figure 3.11).

A particular habit of the shop owners in this area- of keeping the shops closed during the late afternoon hours- has led to some of the street vendors to take short breaks too. Approximately 20 % of the vendors are women. Mostly middle-aged individuals run the business, who reside in the inner parts of Trimurti Nagar, Khamla and Survey Nagar.

3.6.5 Khamla, Deonagar and Sonegaon

Set in between parallel running Ring Road and London Street, Khamla consists combined building usage- mostly residential, followed by healthcare related and educational buildings. Khamla is also adjacent to a 200 m wide and 5 km long land parcel that was earlier intended to be a railway track (Figure 3.12).

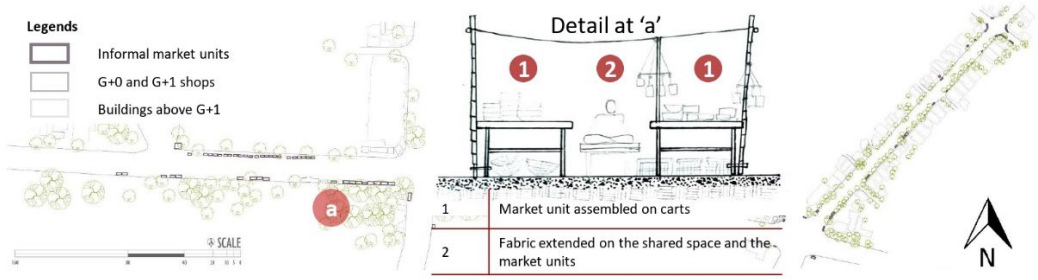


Figure 3.12: Details of Khamla

The Khamla market starts at the Bhajimandi Square, where most of the kiosks are set up. It is from this square, that the markets spread in linear form along the street for upto 1 km towards Jaiprakash Nagar. Every day, a cluster of various fruit and vegetable selling kiosks, tents and platforms are set up. The market is mostly visited in the evening hours. As the market directly abuts a heavily vegetated Government Land Parcel, the one side of the street on which the market is set, receives partial shade from the trees, with the other side exposed to sky having some kiosks periodically shaded by a couple of tall buildings (Figure 3.12).

The Khamla Market is usually accessed by people living in the same area and by commuters to the areas in vicinity such as Chhatrapati Square, bhende Layout, Sonegaon, etc. This market proves to be useful for many entrepreneurs who have set up small shops, mess and other eateries that serve students and hospital visitors in the nearby localities.

Deonagar area is the closest to highly commercial and prominent squares that incident on the logistic Ring Road and Wardha Road respectively. The square possesses landmark buildings such as Orange City Hospital, Plaza containing showrooms, offices and clinics, eateries and central jail. Sonegaon comprises of an aerodrome, adjacent naval land, Indian Air Force base and few residential settlements (Figure 3.12).

The main street of Deonagar is mainly used as a connecting street between Orange City Square and Ajni Square, making it a decently sought commercial strip with formal shops flanking on both the sides, and informal market spilling over to the street and dotted around the secondary squares that fall on intersections of narrower streets. Deonagar neighbourhood market unit cluster consists of kiosks that are closely associated with commercial frontage of the respective street that measures 1.3 kilomentre. The kiosks are set up at the street intersection nodes and few are scattered along the street, mostly under the shade of the tree. Being a small cluster of informal market units, the Sonegaon cluster is mainly stationed beneath the trees at the respective square.

Timber platforms covered with sun shade net and tarpaulin sheets are seen the most. As most of the market units sell fruits, vegetables and sacred offerings, the commodities are typically covered with gunny bags. Few of the market units are also set up under an umbrella or inside an immobile Mini-Truck.

On an average, more than thirty percent of the total vendors are women. These vendors mostly sell vegetables and fruits for the neighbourhood residents. And as most of the attention is paid to the residential customers, the seasonal and festive items are also sold. A significant number of vendors have migrated to the city, mostly from Madhya Pradesh, Bihar and Uttar Pradesh.

3.6.6 Bajaj Nagar

With its innards comprising of buildings of residential use, the periphery of Bajaj Nagar is lined with residential buildings having prominent commercial shops. Its peripheral streets abut major educational institutes' campuses, which makes these streets happening (Figure 3.13). As a result, many diners are established in the surrounding area, ultimately giving rise to informal eateries, fruit and vegetable vendors and flower sellers.

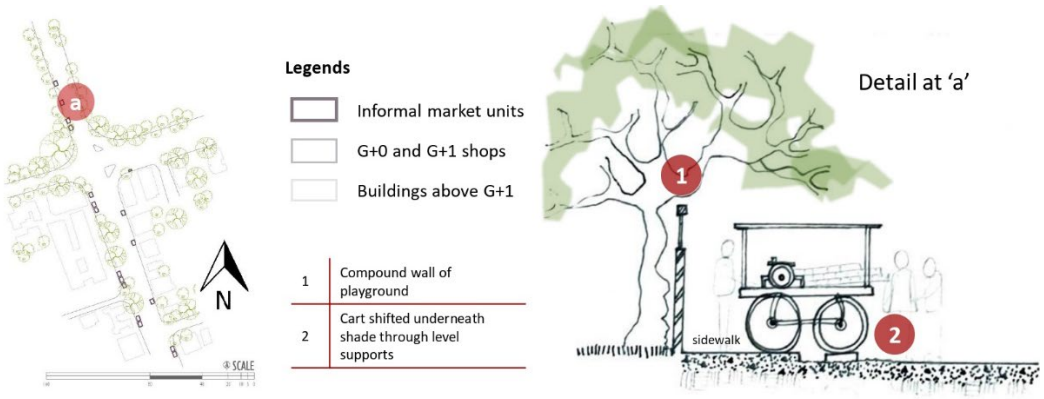


Figure 3.13: Details of Bajaj Nagar

The usual crowd is mostly made of students, immediate residents and a subsequent gathering of other user-groups through word of mouth and social media. The residents and students primarily rely on fruit and vegetable vendors selling their commodities through the day, but the major crowd is attracted in the evening due to vendors selling eatables.

With the help of adjoining institutional campuses and formal agricultural spaces, most of the vendors set up their units beneath the trees at a fair visibility from the intersection nodes of the streets. Both consolidated cluster and scattered vendors can be seen in this area.

Most of these vendors set up carts, followed by tents (Figure 3.13). These are shaded by gunny bags, cotton fabric and sun shade nets. Almost all the units are run by male vendors. Most of them have migrated from Madhya Pradesh.

3.6.7 Pratap Nagar

The area is spread across significant commute routes of the city, i.e., the Ring Road and South Ambazari Road. Like Bajaj Nagar, Pratap Nagar too, gets highly residential as it moves away from these roads, but remain heavily commercial through the street joining the above two routes.

These commodities are sought by the residents of the adjoining areas and the commuters who use this connecting street. The area is vibrant throughout the day as it is situated in between the heavy traffic lanes. This street has two characteristics along its 1.2 kilometre span- the stretch near the South Ambazari Road and in the middle is laden with informal shops selling eatables of all types, mainly due to the vicinity to the institute and due to the prominent Temple located on the street.

The other end of the span is already flanked by well-established formal diners, thus the remaining informal set-up is mainly due to the vegetable and fruit vendors, with seasonal and festive vendors displaying an even vibrant frontage. Amidst a fair amount of trees, the street provides shade to these informal vendors. The remaining vendors extend their shading material from the formal shop establishment (Figure 3.14).

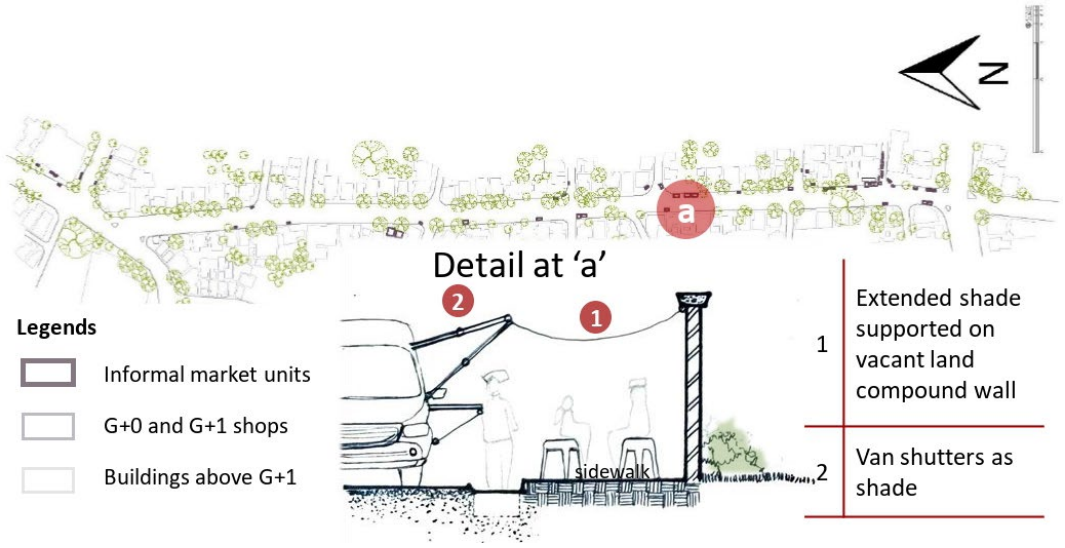


Figure 3.14: Details of Pratap Nagar

Pratap Nagar's vendors mostly sell items related to food, either raw or prepared. Most vendors who sell fruits and vegetables use spacious timber platforms or concise carts. The vendors outside the Temple selling sacred offerings use platforms yearly. With some festivals, a tent with elaborate platforms are set up in the setback patch of the shops. Vendors selling eatables use carts or mini trucks and mini vans (Figure 3.14). Almost 40 percent of the vendors are female. Some of the vendors have migrated from Madhya Pradesh, Uttar Pradesh and Bihar.

3.7 CHAPTER SUMMARY

The market places of Mahal, Sitabuldi and Gokulpeth are more sought after for availability of goods as compared to the neighbourhood market unit clusters. These market places not only provide a wider range of products, but also give a wider time window for buyers to shop. This significance has led to the market place becoming a stakeholder in the informal market activity of people, resulting in them ensuring their availability irrespective of the weather for gaining more customers. The market places of every scale face the same heat conditions owing to their presence in the same climate, however, due to their stronger visibility and dependency, the zonal markets are generally more adaptive to every subjected weather condition as compared to neighbourhood market unit cluster. The resultant microclimate- from adjacent shops, close-knit market units, etc. aide in the vendors' adaptability too.

The vendors in these areas arrive at their place of business around 10 in the morning and stay as late as possible, up to 11 at night in summers, as coming at earlier hours prevents them from losing their selling spot and leaving late enables shoppers to shop till late- as customers too, prefer to leave house in cooler temperature.

Unlike neighbourhood market unit clusters, the shoppers seeking market places come from places other than the adjacent neighbourhood. The higher availability and adaptability is also dependent on factors like footfall. When the market place is busy, the mind of the vendor is preoccupied in conducting business, making heat a secondary problem. The heat becomes the primary problem regarding the most essential activity of a vendor, i.e., protection of their goods. Most of the measures taken by them, which are, sun-protective nets, cotton fabrics, umbrella, tarpaulin sheets and gunny bags with different customisations and combinations, are intended to serve towards the maintenance of their commodities.

The neighbourhood market unit clusters of Ajni, Jaitala, Subhash Nagar, Trimurti Nagar, Khamla, Deonagar, Sonegaon, Mangalwari, Pratap Nagar, Bajaj Nagar, etc. have emerged as a result of expansion of the city as a part of an intricate neighbourhood, where the dominant building use is residential. These clusters, unlike the zonal markets, provide two to three category of goods that are at the disposal of the residents on a daily basis.

The time spent by the buyers in these markets is not more than 30 minutes. Being the goods provider of a very focused range of products, few vendors somehow can afford to miss a day or two. As these clusters on most occasions do not possess a ground, most of them depend on the microclimate created by a tree or an extended shade from a building, which makes a small group of 3-4 vendors set-up mutually. And such groups are scattered throughout their respective streets, nodes where shade is present.

Unlike zonal markets, these clusters have lesser competition, making almost all the vendors leave their stands/kiosks at the spot for the night sans the commodity. This cannot be seen in the zonal markets, as only few groups can afford leaving the set-up on trust. With more residential crowd, these vendors wrap up their business by 9 pm at night irrespective of the weather. However, due to the availability of dairy products, fruits that are essentially helpful for walkers, their business commences early too- some of them as early as 5 in th morning. As the footfall is lesser in such clusters, the vendors keep their health before the business, taking out time in the afternoon or taking a few days off if exhaustion from the heat is felt.

Many vendors attribute the noticing of rise in temperature to people staying generally indoors in the past two years, thereby creating a sense of obliviousness to the outdoor conditions.

This page intentionally left blank

CHAPTER 04
Results and Analysis

Contents

4.1 INTRODUCTION

This chapter deals with the study of the extreme heat risk perception of street vendors and outdoor workers in Nagpur. The study has been conducted in three parts - Heat Stress study, Heat Risk Perception (HRP) assessment and Adaptive Measures study - in order to determine how street vendors across different marketplaces perceive and cope with the danger of extreme heat in the city. The first part evaluates outdoor thermal comfort and heat stress and assesses heat tolerance and sensitivity. The second part establishes heat risk perception as a multidimensional construct and attempts to quantify and measure it using an index. It primarily aims to find out whether street vendors, who face increased exposure and rising incidences of heat stress due to climate change, recognize that they are at risk. The third part examines the adaptive measures, both physical and lifestyle changes, and documents the coping mechanisms of the city vendors. The study also examines the interrelationships between outdoor thermal comfort, heat risk perception and protective behaviours along with identifying their potential predictors, drivers, and inhibitors. Finally, it presents key conclusions, which may be useful for future policymaking for street vendors, and if considered while formulating Nagpur's next Heat Action Plan, may aid in reducing morbidity and mortality.

4.2 METHODOLOGY

Heat Stress, as discussed previously, poses a threat to workers globally, especially those working in tropical climates with strenuous workloads. Their physical capabilities are compromised by extreme heat during working hours, which lowers their productivity and puts them at risk of being dehydrated, and ill, losing their jobs and business, and incurring high medical expenses.

Studies around the world have measured thermal comfort and heat stress using different scales such as the temperature-humidity index (THI), the wet bulb-globe temperature index (WBGT) and more recently physiological effective temperature (PET) and the universal thermal climatic index (UTCI). The current study uses PET, a thermal index, to estimate the thermal sensation of street vendors and the corresponding heat stress level. To take into account the summertime human tolerance/preference in various outdoor environments, it measures "neutral" thermal comfort - neutral PET as well as neutral thermal range. Along with the objective thermal comfort, the study evaluates subjective thermal stress based on onsite questionnaires.

The negative impacts of heat stress can be prevented if the street vendors perceive the risk and take proper adaptive measures, as indicated by several studies (ref. literature review). Heat risk perception (HRP) entails the awareness, beliefs, and attitudes concerning the likelihood, severity, threat intrusiveness, and attitudes that may reflect on the manner in which one perceives and responds to the risk of extreme heat. This study calculates a Heat Risk Perception Index [0,1] for the street vendors of Nagpur based on questionnaires containing self-reported health and economic risk characteristics such as likelihood, severity, concern, worry, fear etc. It, then, also identifies, using statistical analysis, how socio-demographic characteristics, awareness and sensitivity to heat, and past experience with heat waves and heat-illnesses shape these perceptions.

The questionnaires for both parts of the study were filled during parallelly conducted surveys in the already identified (ref. Chapter 03 Study Area) markets and vendor clusters during May 2022.

The study also documented the physical adaptations (such as shading devices) and coping mechanisms (protective behaviours, lifestyle changes) that the street vendors engage in during heatwave-like temperatures in the city for further analysis.

4.3 HEAT STRESS STUDY

4.3.1 Introduction

Human outdoor thermal comfort is a vast area of research and is continuously being explored. Outdoor thermal comfort (OTC) has now been acknowledged as a complex phenomenon by the research community. OTC is closely related to individual perception and sensitivity (Zaninović and Matzarakis, 2009). Moreover, human perception of microclimate also relies upon physical characteristics, urban morphology, and geometry. (Sharmin and Steemers, 2018; Lemonsu et al., 2019). Various studies have investigated the association of urban morphological parameters (aspect ratio, SVF, building height, etc.) and thermal comfort perception using thermal comfort index such as physiological equivalent temperature (PET) (Emmanuel and Johansson, 2006; Matzarakis et al., 2007; Lin et al., 2010; Chen et al., 2021). It has been also confirmed that the inclusion of vegetation can also alleviate thermal stress in outdoor environments (Bourbia and Awbi 2004). Emmanuel et al., (2007) reported a significant reduction in PET from shade enhancement and increased aspect ratio. Charalampopoulos et al., (2013) investigated OTC at six different locations in Greece and found significant relationships of SVF with PET and heat index (HI). Perini and Magliocco (2014) confirmed the significant influence of tall buildings in increasing thermal comfort in outdoor environments. Othman and Alshboul (2020) concluded that different geometries and morphologies present within the same city have a huge impact on thermal comfort and PET. Additionally, multiple studies have also assessed pedestrian thermal comfort using a questionnaire survey and micro-meteorological parameters measured at the real urban canyons (Priyadarshini et al., 2008; Yahia and Johansson, 2012b; Jamei et al., 2016; Elnabawi and Hamza, 2020; Nasrollahi et al., 2021; Sun et al.,2022).

Empirical data of climatic variables from field surveys in urban contexts is critical in the evaluation of human thermal comfort in outdoor spaces (Nikolopoulou and Lykoudis, 2006). Globally, geographers and urban climatologists across disciplines have considered field surveys critical to evaluate thermal comfort to account for the greater complexity and spatio-temporal variability of outdoor environments. Field measurement helps researchers obtain empirical micro-meteorological datasets and is fundamental to urban microclimate studies (Sun et al., 2022). They offer 'real-world' microclimatic conditions (Oke et al., 2017) while portraying reliable results with high spatio-temporal resolution (Nunez and Oke, 1977). Numerous bio-meteorological and thermal comfort studies have extensively applied field measurements globally. Although, numerical modelling and simulation-based approach is another widely used research approach (Peng and Jim; 2013; Brown et al., 2015). But they must be validated by field measurement data as a reference for evaluation (Liu et al., 2021). Many studies have assessed OTC using both simulation and field surveys in different climatic zones (Kántor et al., 2012; Rajan and Amirtham, 2021). Multiple studies have applied simulations based on PET to analyse urban form, shading and wind speed to assess OTC (Abreu-Harbich et al., 2013; Rodríguez Algeciras and Matzarakis, 2015). Past research efforts have applied microclimatic simulations (Rodríguez Algeciras and Matzarakis, 2015; De and Mukherjee, 2017; Ndetto and Matzarakis, 2017) and machine learning algorithms (Kariminia et al., 2015; Liu et al., 2021) in thermal comfort studies.

Hence, it is important to evaluate the thermal sensation of pedestrians using an optimal thermal index and correlating the predicted sensations against micrometeorological parameters.

In developing countries like India, very few studies have been conducted with objective and subjective assessments of thermal comfort in outdoor spaces. Das et al., (2020) assessed summertime OTC across different local climate zones and reported that the highest PET was recorded in densely built-up areas. The research concluded that respondents living in compact low-rises and open low-rises were more sensitive to the thermal sensation as compared to those living in other zones. Deevi and Chundeli (2020) applied user-perception surveys and empirical measurements to investigate factors influencing a street canyon's OTC. It noted that SVF showed a strong correlation with PET and observed that respondents' comfort sensitivity is higher in range than that of comfort standards. Kumar and Sharma (2021b) applied three indices (WBGT, PET and UTCI) to screen the monthly heat stress during summertime. The study found the highest average WBGT in July (33.4 ± 0.77°C), the highest mean PET in June (42.47 ± 2.34°C) and the highest mean UTCI in June (38.58 ± 1.82°C). In another study, (Kumar and Sharma, 2022) assessed OTC in an urban park in a hot-dry climate in India. The results indicated that the neutral PET, UTCI, and WBGT were found to be 30.8°C, 31.8°C, and 24.8°C respectively. Rajan and Amirtham (2021) correlated OTC with changing built form using the PET index and noted a maximum PET difference of 22°C between the locations.

Moreover, the application of micro-meteorological measurements to evaluate OTC remains limited in Indian cities due to the complexity and heterogeneity of the built environment (Mills, 2014; Middel et al., 2022). A holistic understanding of OTC in the context of hot-dry and tropical climates is crucial to comprehend the quality of space, usage, vitality, and urban image. In recent years, scholars and researchers have developed an interest to investigate OTC in the tropics considering the growing discomfort and heat stress in urban areas. There remains a paucity of research efforts and a lack of information on thermal comfort conditions in outdoor spaces in Indian cities.

Additionally, the present study evaluates neutral PET to account for the summertime human tolerance/preference in different outdoor environments. This will ultimately help in a strong interdisciplinary collaboration between urban designers, planners, and climatologists to design thermally comfortable outdoor spaces. Therefore, this study aims to facilitate such integration in evaluating OTC through the use of in-situ micrometeorological data and subjective assessment in a tropical city.

The objective of this section of the study is to evaluate "neutral" thermal comfort i.e., neutral PET (NPET) and neutral thermal range (NPETR). It evaluated objective thermal comfort using the PET index and subjective thermal stress using an onsite questionnaire survey of informal workers/ vendors/ labours etc. to assess human thermal sensation. This will ultimately help to understand and enumerate thermal stress perceived by underprivileged communities. This study examines the correlation between the micro-meteorological parameters and the actual votes of thermal sensation collected during the survey to understand the way urban microclimate affects thermal comfort in the tropical city of Nagpur.

This study consists of a subjective outdoor thermal comfort survey at five different locations in the city of Nagpur with a parallel recording of micrometeorological parameters. This methodology section consists of the selection of study areas, framing and details of the survey questionnaire and specifications of calculation of mean radiant temperature (MRT).

4.3.2 Study Area

This study was conducted at five different locations (ref. Fig 4.1) from 2nd May to 23rd May 2022. All five site locations with area descriptions have been presented in Table 4.1. The table also presents weather conditions, distance from the central business district (CBD) and morphology within a 50m radius. As the study was conducted during the peak of summer, a day of this study was also accompanied by a heatwave and air temperature as high as 43.44 °C.

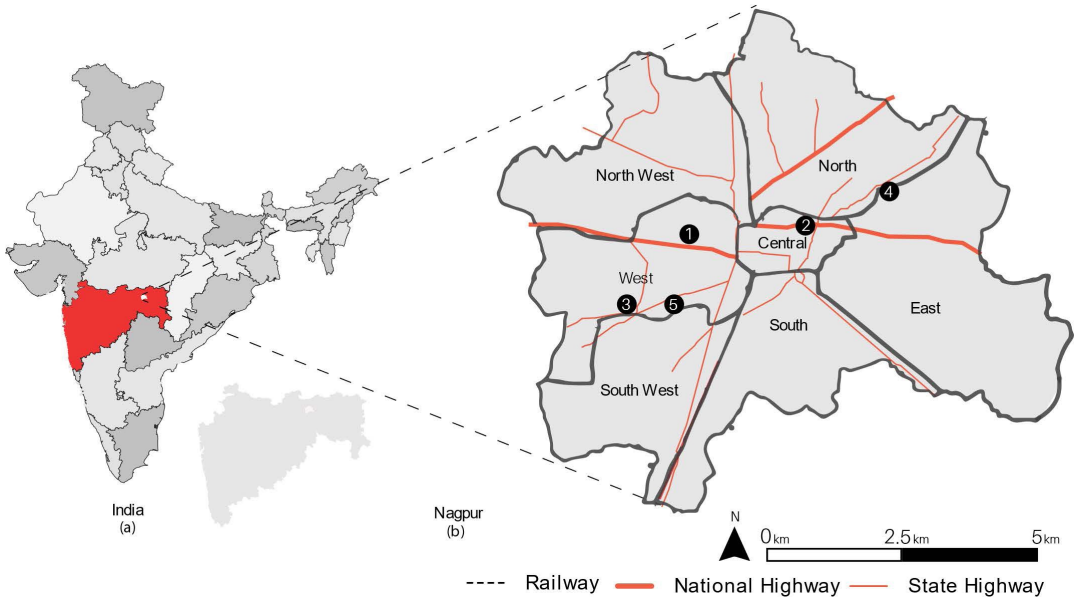
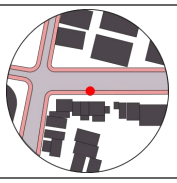
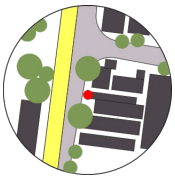
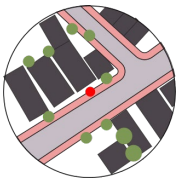
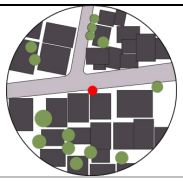


Figure 4.1: OTC survey locations across the city of Nagpur

Locations selected for this study were urban marketplaces to record the maximum number of labours and informal workers. These site locations include Jaitala (JYT), Gopal Nagar (GPL), Gokul Peth (GKP), Cotton Market (CMKT) and APMC. JYT is a low-rise residential area with a building height of up to G+3 with moderate vegetation. GPL is a highly dense urban morphology with a scarcity of vegetation, pervious surface and building height up to G+4. GKP and CMKT are urban marketplaces with an abundance of fruit, vegetable, and clothing vendors. APMC is a distant rural-urban marketplace with multiple fruits, vegetables, and grain vendors and labours. In all of these locations, the responses recorded were a good mix of people with various occupations, age groups, outdoor working hours etc.

This study assessed both objective and subjective assessments of human thermal comfort. Objective measurements consisted of air temperature (AT), relative humidity (RH), Grey Globe Temperature (GT), Winds Speed (Va) and wind direction. This data was recorded at one-second intervals with RTPL Weather Station. The weather station includes a 3D Sonic anemometer with an accuracy of 0.01 m/s, AT and RH probe of accuracy ±0.2℃ and ±2% respectively. In addition to these, the 150mm black globe and a 38mm grey globe was also installed. (ref. Fig 4.2). Large copper black globe of 150mm may require 20-30 min to reach equilibrium (ISO 7726, 1998; Spangolo and de Dear, 2003). Therefore, a 38mm grey globe with shade RAL 7001 was used to better align with the outer surface of a clothed person (Thorsson et al. 2007, ISO 7726,1998, ASHRAE 2001). This weather station was installed at each location from 08:30 hrs to 18:00 hrs.

Table 4.1: Survey locations within Nagpur City

Sr. No.	Area	Description	Day(s) of Survey	Weather Condition	Maximum Temperature	Area of Assessment
1	GKP 4851m from CBD	Urban market place	02 May & 04 May 2022	Heat Wave Partly Cloudy and Dry	43.44 43.00	
2	CMKT 1708m from CBD	Urban marketplace	10 May 2022	Clear and Dry	43.49	
3	JYT 8532m from CBD	Residential area + urban marketplace	22 May 2022	Partly Cloudy and Dry	42.17	
4	APMC 4251m from CBD	Rural Marketplace	23 May 2022	Partly Cloudy and Dry	42.42	
5	GPL 6881m from CBD	Densely built residential area.	12 May 2022	Partly Cloudy	42.41	

4.3.3 Survey Questionnaire

The questionnaire survey consisted of a total of 18 questions which were referred from Johansson et al., 2018 and ISO 10551. The questionnaire can be substituted into four parts. The first six questions were about respondents' personal information such as their occupation, age, gender, outdoor working hours and physical activity. The next six questions were regarding their thermal sensation, comfort, preference, acceptance, and personal tolerance. The rest of the questions were regarding their use of cooling systems at their workplace and home, clothing particulars and their colours. Along with this skin temperature of respondents was also recorded with IR Gun Testo 830-T1. A total of 346 responses were recorded from all five locations. (ref. Fig 4.3)

Clothing values were calculated as specified by Ng and Cheng (2012). The activity levels in responses were cycling, intense outdoor activity, standing, walking, and sitting. Their respective Metabolic rates were acquired from ASHRAE standard 55 (2004). 9-point thermal sensation scales were also used in this study for their better alignment with maximum thermal comfort indices. Thermal comfort votes (0 Comfortable, +1 Slightly Uncomfortable, +2 Uncomfortable, +3 Very Uncomfortable, +4 Extremely Uncomfortable) and tolerance (0 Perfectly Bearable, +1 Slightly Difficult to Bear, +2 Fairly Difficult to Bear, +3 Very Difficult to Bear, +4 Unbearable) were asked with a 5-point scale while the thermal preference of temperature, humidity, sun, and the wind was recorded with McIntyre Scale. (Cooler -1, No change 0, Warmer +1). A total of 419 responses were recorded. (ref. Appendix A.1)

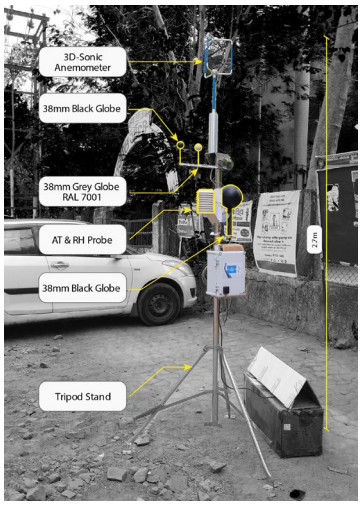


Figure 4.2: RTPL Weather Station Figure 4.3: On-site Survey

4.3.4 Calculation of Mean Radiant Temperature (Tmrt)

Mean radiant temperature (Tmrt) can be defined as the 'uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure' (ASHRAE, 2001). The significance of Tmrt returns to its influence on the energy balance and thermal comfort of the human body (Mayer & Höppe, 1987; Spagnolo & de-Dear, 2003). Tmrt in this study has been calculated based on the conversion of globe temperature data measured by the globe thermometer consisting of a thermocouple wire held at the middle of a 38 mm diameter grey table-tennis ball and attached to RTPL weather station using Eq(1) (Thorsson, Lindberg, Eliasson, & Holmer,2007).

$$T_{mrt} = [(T_g + 273.15)^4 + (1.335 \times 10^8 V_a^{0.71} / \varepsilon D^{0.4})(T_g - T_a)] - 273.15 \quad \text{...Eq.1}$$

4.3.5 Descriptive Statistics and Neutral PET

The survey questionnaire recorded a total of 349 responses. Among these 77.16% were recorded as male and 22.84% as female. The majority of the responses i.e., 46.13% belonged to the 36-50 age group, 27.79% belonged to 21-35 years and 18.91% of responses were recorded within the 51-65 years of age group. The rest 7.17% of people were found to be distributed in other age groups. Outliers in the recorded responses were removed using some arguments which were referred from PET thresholds derived by Lin and Matzarkis (2007). Table 4.2 presents these arguments. This argument filtered 92 responses identified as outliers.

Table 4.2: Arguments to Recognize Outliers

No.	Assumption Statements	Responses Filtered
1	Neutral (TSV = 0) > 45°C of PET	10
2	Slightly Warm (TSV = +1) > 45°C of PET	21
3	Warm (TSV = +2) > 45°C of PET	35
4	Hot (TSV = +3) < 40°C of PET	16
5	Very Hot (TSV = +4) < 40°C of PET	10
Total		**92**

The 'Neutral' temperature refers to the optimal temperature at which people perceive neither cool nor warm (Fanger, 1972). It is one of the key indicators to assess OTC preference which closely associates with a mean thermal sensation vote of zero (MTSV = 0) (Cheung and Jim 2017). PET index is based upon the physiological reaction of a "typical" Central European man. (Matzarkis and Mayer, 1996; Matzarkis et al., 1999). However, using these threshold values in a region like India, may not be suitable considering the local habitant's adaptation. Therefore, PET thresholds according to the respondents' adaption to the climate of Nagpur have been calculated in this study.

Neutral PET (NPET) have previously been calculated with multiple statistical approaches such as linear regression, displacement analysis, relative frequency etc. Among these, the linear regression method has been found to be widely accepted. This method requires the calculation of MTSV with specific data bins of PET like 0.5°C / 1°C / 2°C etc. (da Silveira Hirashima et al., 2016; Kántor et al., 2016). In this study for higher precision 0.5 (da Silveira Hirashima et al., 2016; Kántor et al., 2016 of PET bins were used to perform Linear regression against MTSV. Upon performing correlation, a strong relationship with R = 0.859 and R^2 = 0.737 was revealed. By substituting MTSV = 0 in Eq (2) the value of NPET was calculated as 30.99°C. The neutral PET range (NPTER) can also be calculated by substituting MTSV with ± 0.5 to understand the thermal comfort range. Substituting these values in Eq (2) the neutral range is 28.48°C to 33.50°C. Refer Figure 6.

$$MTSV = -6.1660 + PET \times 0.1989 \quad p<0.05 \qquad \text{(Eq.1)}$$

Further substituting the values in equation (1) thermal comfort thresholds were also calculated and presented in table 4.3.

Table 4.3: Thermal Comfort Thresholds

Very Cold (-4)	Cold (-3)	Cool (-2)	Slightly Cool (-1)	Neutral (0)	Slightly Warm (+1)	Warm (+2)	Hot (+3)	Very Hot (+4)
10.88	15.91	20.94	25.96	30.99	36.02	41.04	46.07	51.10

4.3.6 Analysis

NPET similar NPET ranges were found in studies. Heng and Chow (2019) estimated a neutral PET of 26.2°C in a large Singapore urban park. Another study conducted in India by Manavvi and Rajasekar (2020b) assessed OTC in open-air markets across New Delhi and found the neutral PET to be 24.7°C. In Chandigarh, the thermo-neutrality of respondents corresponded to a PET of 24.09°C (Manavvi and Rajasekar, 2021). Recently, Kumar and Sharma (2021a) also assessed thermal perceptions of people exercising outdoors with objective and subjective measurements in a hot-arid region of India. The neutral temperature range of people exercising was found to be 26-36.4°C for PET. Several studies have also noted seasonal variation in thermal comfort range across various climate zones (Hirashima et al., 2016; Salata et al., 2016).

This study was conducted during the summer among informal vendors and labours. The working hours of the respondents were found to be maximum outdoors. NPET values and NPET range of this study were found inclined towards higher PET with respect to other studies in similar climatic zones (ref. Fig 4.4). Acclimatization of the respondents might be one of the key factors resulting in higher thermal neutral values.

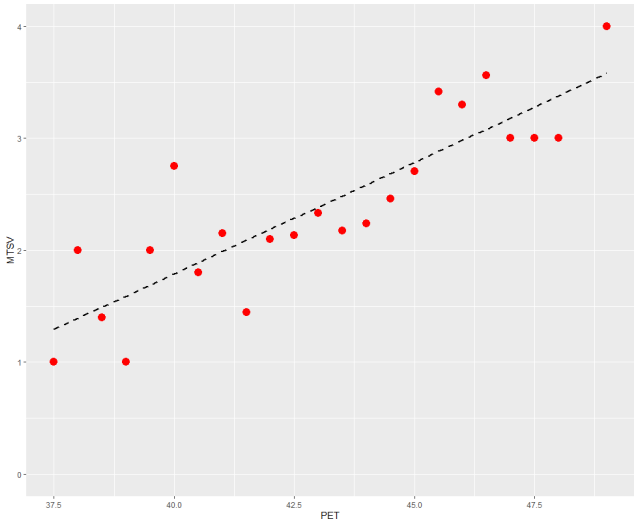


Figure 4.4: LR (MTSV ~ PET)

4.4 HEAT RISK PERCEPTION ASSESSMENT

4.4.1 Introduction

Occupational health risks are created by excessive heat, which limits a worker's ability to perform physically and work effectively and efficiently (ILO, 2019). Urban street vendors and outdoor workers are among the most vulnerable groups to extreme heat as there is an increased risk of heat-related illnesses, due to their labor-intensive jobs, restricted access to shaded areas, and irregular access to cooling techniques (ILO, 2019; Red Cross Climate Centre, 2019). Moreover, extreme temperatures may limit their productivity, economic output, and family income, if they remain too exhausted, unwell, or unhealthy. These adverse effects can be mitigated, but only if street vendors perceive heat as a risk, have access to necessary resources, and take appropriate precautionary action (Luber and McGeehin, 2008)

The purpose of the study is to measure and assess the heat risk perception of street vendors using a heat perception index. It also intends to determine how perceptions of heat risk are influenced by existing knowledge, awareness and, sociocultural and demographic factors and how this affects adaptation. In addition, it aims to document the changes made to lifestyles and physical interventions taken in response to the heat.

Thus, the study aims to fill a knowledge gap by investigating knowledge, perception, and adaptation to heat waves, as well as identifying factors that influence these variables. The findings would help shape future policy by offering helpful insights into how street vendors perceive and cope with heat waves.

4.4.2 Questionnaire Design

Using literature on extreme heat and its risk perception, a questionnaire was developed. The study conducted a self-reported heat risk assessment (i.e., heat risk perception) based on an individual questionnaire (Ban et al., 2017; Huang et al., 2018). It included four sections: sociodemographic information (including age, educational level, gender, family setup, migrant status and chronic diseases or health problems), awareness and sensitivity towards heat, heat risk perception, and adaptive measures (ref. Appendix A.2). Some constructs used in the survey

were based on a combination of previous research questionnaires (e.g.: Lohrey et al., 2021; Howe, Marlon, Wang and Leiserowitz, 2019; Ban et al., 2017) However, each question was tailored for a better understanding of street vendors and fitted to the setting of heat waves.

The questions regarding adaptive measures and protective behaviours were asked in terms of the physical interventions and lifestyle changes made during the period of extreme heat and their perceived effectiveness. The study attempted to include the recommendations given by Wilson, Zwickle and Walpole (2018) in developing a measure for risk perception and added components assessing the effect and severity of consequences.

4.4.3 Study Area

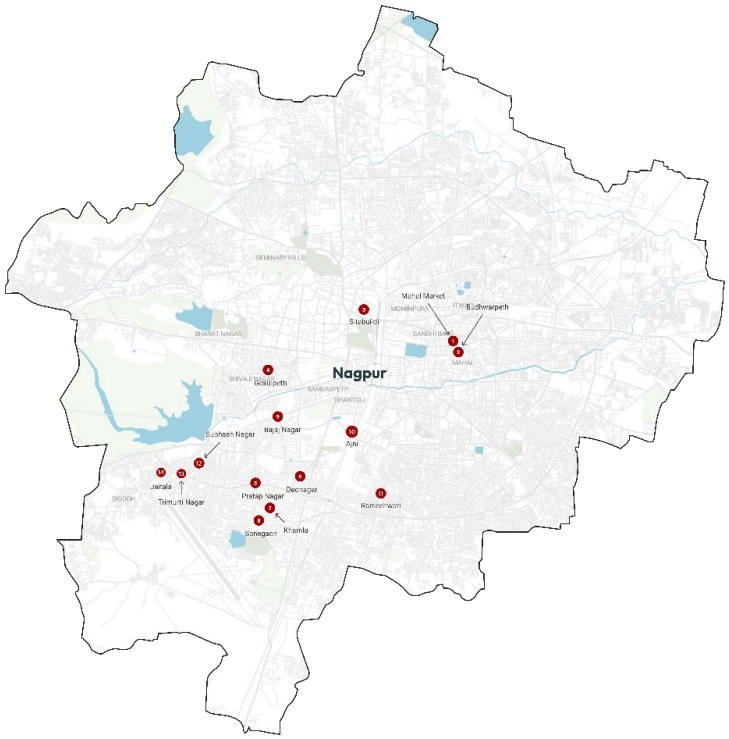


Figure 4.5: HRP survey market locations

The study conducted face-to-face questionnaires in May 2022, when most parts of India were experiencing a heatwave. The surveys were conducted in 13 locations (as identified in Chapter 03 Study Area) which included City Level Market Places, Sub-City Level Markets Places and Neighbourhood Level Street Vendor Clusters (ref. Fig 4.5). The aim was to integrate all typologies of markets with active street vendor presence to attain a holistic data pool.

At the city and sub-city levels, 4 markets – Budhwarpeth, Mahal Bazar, Sitabuildi and Gokulpeth were targeted. City Level Market Places are relatively centrally located (such as Budhwarpeth) and are prominent among the citizens from all over Nagpur, and saleable items from their street vendors must cover all types of goods attracting both buyers and sellers. In the case of Sub-City Level Market Places, they cater to more than one neighbourhood (such as Gokulpeth) and have a medium to small range of formally appointed shops in close vicinity with a strong vocabulary with the informal vendor.

Mahal Market stretches 500m in 3 directions, i.e., Tilak Road, Killa Road, and

Kelibagh Road with respect to Kalyaneshwar Mandir. Gol Bazaar, a substantial part of Mahal Bazaar, also called Budhwarpeth, is established on an area of 0.3 Ha. The informal vendors here mainly sell clothing items. The second prominent range of items is vegetables-fruits-granary, followed by pooja samagri (sacred offerings). Sitabuildi market is set on the main road that connects major satellite towns of Nagpur i.e., Amravati and Wardha. It spans up to 750 m and is an expansion towards Amravati Road for another 100 m. It primarily sells every item of clothing, accessories, home accessories, footwear, electronic items, etc. Some vendors also sell snacks and fruits.

In Gokulpeth, a vast number of citizens from West and South Nagpur come for grocery shopping on Wednesdays and during festivals. The open-to-sky ground measures 1.9 Ha. Amidst a fair number of trees, the market units have either established semi-permanent roofs or fabric tents. It sells grocery items, fruits, vegetables, cosmetics, pooja samagri, granaries, etc.

This study focused on seven neighbourhood markets: Ajni, Pratap Nagar, Khamla, Jaitala, Subhash and Trimurti Nagar. Each neighbourhood attracts a different set of vendors who focus mainly on daily needs like fruits, vegetables, and granaries. Generally, such vendors witness a steep surge in their footfall during the morning hours and evening hours- when residents are returning from a morning or evening health routine, or on the way to or returning from the office respectively and ought to run errands. The set-up of street vendors in these markets is temporary, i.e., kiosk, table, mat, umbrella, vehicle, podium, stand, handheld display unit, cart, etc.

The respondents were briefed about the objective of the study and verbal consent was obtained before the start of the survey. The respondents were also assured of the confidentiality of their personal data. This entire process was carried out in Hindi or Marathi, depending on the language understood by the respondent. It took about ten minutes to complete the questionnaire. 441 questionnaires were filled out and selected for the final analysis.

4.4.4 Survey Experience

The marketplaces of Mahal, Budhwarpeth, Sitabuildi and Gokulpeth are more sought after for the availability of goods as compared to the neighbourhood market unit clusters. These marketplaces not only provide a wider range of products but also give a wider time window for buyers to shop. This significance has led to the marketplace becoming a stakeholder in the informal market activity of people, resulting in them ensuring their availability irrespective of the weather for gaining more customers. The marketplaces of every scale face the same heat conditions owing to their presence in the same climate, however, due to their stronger visibility and dependency, the zonal markets are generally more adaptive to every subjected weather condition as compared to the neighbourhood market unit cluster. The resultant microclimate- from adjacent shops, close-knit market units, etc. aids in the vendors' adaptability too. The vendors in these areas arrive at their place of business around 10 in the morning and stay as late as possible, up to 11 at night in summer, as coming at earlier hours prevents them from losing their selling spot and leaving late enables shoppers to shop till late- as customers too, prefer to leave the house in cooler temperature. Unlike neighbourhood market unit clusters, the shoppers seeking marketplaces come from places other than the adjacent neighbourhood.

The higher availability and adaptability are also dependent on factors like foot fall. When the marketplace is busy, the mind of the vendor is preoccupied with conducting business, making heat a secondary problem. The heat becomes the primary problem regarding the most essential activity of a vendor, i.e., the protection of their goods. Most of the measures taken by them, which are, sun-protective nets, cotton fabrics, umbrellas, tarpaulin sheets and gunny bags with different customizations and combinations, are intended to serve the maintenance of their commodities.
Neighbourhood-level Clusters

The neighbourhood market unit clusters of Ajni, Jaitala, Subhash Nagar, Trimurti Nagar, Khamla, Deonagar, Sonegaon, Mangalwari, Pratap Nagar, Bajaj Nagar, etc. have emerged as a result of the expansion of the city as a part of an intricate neighbourhood, where the dominant building use is residential. These clusters, unlike the zonal markets, provide two to three categories of goods that are at the disposal of the residents on a daily basis. The time spent by the buyers in these markets is not more than 30 minutes. Being the goods provider of a very focused range of products, few vendors somehow can afford to miss a day or two.

As these clusters on most occasions do not possess a ground, most of them depend on the microclimate created by a tree or an extended shade from a building, which makes a small group of 3-4 vendors set up mutually. And such groups are scattered throughout their respective streets, nodes where shade is present. Unlike zonal markets, these clusters have lesser competition, making almost all the vendors leave their stands/kiosks on the spot for the night sans the commodity. This cannot be seen in the zonal markets, as only a few groups can afford to leave the set-up on trust.

With more residential crowds, these vendors wrap up their business by 9 pm at night irrespective of the weather. However, due to the availability of dairy products, and fruits that are essentially helpful for walkers, their business commences early too- some of them as early as 5 in the morning. As the footfall is lesser in such clusters, the vendors keep their health before the business, taking out time in the afternoon or taking a few days off if exhaustion from the heat is felt.

4.4.5 Measurement of Variables

Awareness and sensitivity towards heat were assessed by asking questions like, ‘Have you heard about “heatwaves” in the past?’,’ In the past several years, did you feel the weather was hotter than before?’, ‘Do you check the weather forecast daily before leaving your house?’, and ‘Did you ever have access to a training/ awareness program for heat-related risks?’. The respondents were also asked if they received heat warnings and identified their source. This section also included a component of past experience with extreme heat through questions like ‘Have you ever experienced a heatwave?’, ‘Have you ever experienced a heat illness at work?’. On getting a positive response to these questions subsequent questions, ‘If yes, which have you experienced?’ and ‘What measures did you take to combat your heat-related illness?’ were asked for documentation.

Since risk perception is a multidimensional construct (Slovic, Fischhoff, & Lichtenstein, 1982), a variety of risk characteristics have been used to measure it. Heat Risk Perception (Cronbach’s alpha = 0.761) was calculated as an aggregated index, using a survey instrument consisting of 10 questions posed with the intent of generating responses regarding the perceived negative impacts of extreme heat

such as likelihood, severity, concern and fear of health impacts, economic concern, and vulnerability.

Based on the probability and intensity of heat waves and their implications for Nagpur, the dimensions of perceived likelihood and severity were measured on a five-point Likert scale. The respondents were asked about their concerns about heat health impacts on themselves (personal risks), their family members (family risks) and their community (community risks). The personal risk was ranked on a five-point Likert scale ranging from “1 = Low” to “5 = Severe”, where a higher number signifies greater risk perception. The response options for questions about family and community risks were “Yes” and “No”. Similarly, the concern regarding the negative implications of heat on general expenses, household expenses, and employment and productivity had response options of “Yes”, “Maybe” and “No”. Respondents were also asked to rate their perceived fear of heat-related health effects as “Yes,” “Maybe,” or “No”. As a final question, respondents were asked if extreme heat was a risk in their lives, to determine their perceived vulnerability to extreme heat (ref. Appendix Figure A.2).

4.4.6 Data Processing and Normalization

The survey included questions with different response options, some evaluating on a five-point Likert scale (ordinal) and others on nominal scales such as “Yes”, “Maybe”, and “No” or “Yes” and “No”. Indicator values from different units were normalized into a standard scale. This study applied a rescaling method (minimum-maximum) of normalization. Here the transformation is based on a range of values. The indicator questions are normalized to have an identical range of [0,1]. Finally, each respondent’s mean of all ten indicators was calculated to obtain the Heat Risk Perception Index value (0.719 ±0.221).

4.4.7 Statistical Analysis

The data obtained were imported into Excel, which served as a database for descriptive and bivariate analysis performed using R and RStudio (R Core Team, 2020; RStudio Team, 2020). The mosaic plots to visualize the Pearson residuals were made using the ‘vcd’ plot package (Meyer D, Zeileis A, Hornik K ,2022). An overview of all sections of the questionnaire, including socio-demographic factors was obtained using descriptive analysis. Means and standard deviations were calculated for all continuous variables. In bivariate analysis, Chi-square (expected cell frequencies less than or equal to five) were used to test for the associations among categorical variables of socio-demographics, awareness and past experience, adaptive measures, and risk perception to identify the drivers. The associations with a p-value < 0.05 were considered to be statistically significant.

4.4.8 Results

4.4.8.1 Socio-demographic characteristics of respondents:

The survey had a total of 441 participants, 83.4% of whom were men and 16.6% of whom were women. The mean age of respondents was 39.56±12.41 years, and 42 per cent of them were between the ages of 36 and 50. Respondents’ occupations were grouped into 12 broad categories, and those who did not fit into any category were grouped as ‘Miscellaneous’. The most common occupations were Clothing

Accessories (17%) and Vegetable Vendors (12.2%). The majority of respondents had only completed high school (29.7%), and 13% had no formal education at all. 28% of those surveyed said they had migrated to Nagpur, with men making up the majority (87.1%). In response to the question of how their family was constituted, 72.3% of respondents said that their family either had someone younger than 15 or older than 65. In this case, it was considered that they were caregivers to family members who were at greater risk from extreme heat. (Stanberry, Thomson and James, 2018; Romanello et al., 2021) . 11.6% of the respondents reported that they had a pre-existing chronic illness, most belonging to the 36-50 age group (45%). About 70% of the vendors worked outdoors every day for more than 5 hours on average. In all, 62.8% of those surveyed considered their work to be physically demanding, 24.7% did so sometimes, and 12.5% did not.

4.4.8.2 Heat Risk Perception Evaluation:

The study calculated a heat-risk perception index of street vendors ranging from 0 to 1, with higher values indicating higher risk perceptions. The vendors with a high heat risk perception were more likely to - (i) Perceive a high likelihood of heatwaves occurring (ii) Recognise the high severity of heatwaves in Nagpur (iii) Be worried about the health consequences of extreme heat to themselves, their family and community (iv) Have a concern about the negative impacts of extreme heat on general and household expenses, employment and productivity (v) Be scared of heat-health illnesses (vi) Consider themselves vulnerable to extreme heat.
Across all markets in the city, the HRP Index averaged 0.72. However, there were variations in the mean HRP based on market location as shown in fig. 4.6

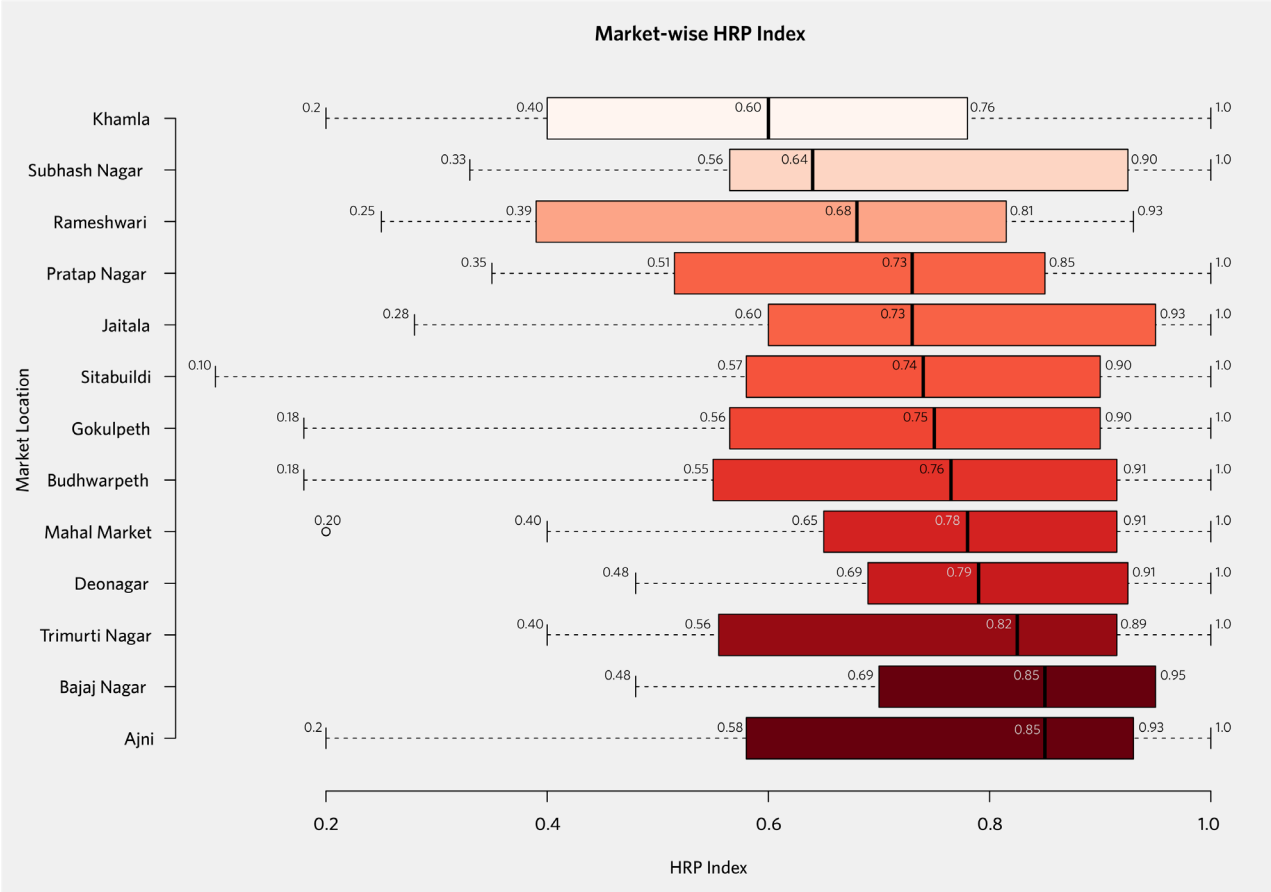


Figure 4.6: Market-wise HRP box plot

A closer inspection of the plot shows that vendors at the city and sub-city levels have a higher HRP index than those at neighbourhood-level markets such as Khamla and Subhash Nagar, but lower than those at Trimurti Nagar and Ajni. This may be the influence of the character of the market. Markets like Khamla are sundries and do not have a strong sense of community within the vendors. In fact, only half the vendors surveyed in Khamla perceived heat as a risk to their community. Additionally, vendors there perceived less likelihood, severity, and health dangers from heatwaves than their counterparts in the city. Vendors come to city-level markets such as Sitabuildi and Budhwarpeth because they attract a large number of customers. They recognize the possibility of economic risk but underestimate both the severity and likelihood of the situation. Having to compete for their place in the market makes it impossible for the vendors to rest or change their work schedules. The situation is different in neighbourhood-level markets like Trimurti Nagar and Ajni, where vendors are unlikely to operate in the afternoon. Since their homes are often nearby, it is natural for them to only operate when most customers are around.

On average, male vendors had a marginally greater HRP (0.721 ±0.216) than female vendors (0.708 ±0.027). Cart Pullers (0.800 ±0.211) had the highest HRP among the occupations and Tea/Coffee sellers had the lowest (0.671 ±0.198). This finding suggests that risk perception is related to the exposure an occupation has to the sun and how much the job is physically demanding. Almost all cart pullers or handymen surveyed described their work as physically demanding and involved more than five hours of exposure to the sun in a day. There was a greater HRP among respondents who migrated to Nagpur or whose families had someone younger than 15 or older than 65. No significant difference was found in the mean HRP of those who had access to cooling, such as desert coolers, at home and those who didn't (ref. Table 4.4).

Table 4.4: Mean HRP across socio-demographics

Socio-cultural Characteristics	Categories	Mean HRP Index	Socio-cultural Characteristics	Categories	Mean HRP
Gender	Male	0.720	Occupation	Tea / Coffee Stall	0.671
	Female	0.718		Flower Vendor	0.684
Age	≤ 20	0.788		Food Vendor	0.687
	21-35	0.719		Puncture Repairing	0.689
	36-50	0.723		Vegetable Vendor	0.702
	51-65	0.708		Clothing Accessories Vendor	0.734
	66-80	0.679		Books and Stationery Vendor	0.737
Highest Education	No Formal Education	0.699		Autorickshaw Driver	0.753
	Grade 4	0.678		Fruit Vendor	0.759
	Grade 7	0.737		Clothing Vendor	0.760
	Grade 10	0.723		Metal Articles Vendor	0.797
	Grade 12	0.721		Cart Puller	0.800
	Undergraduate	0.752			
	Postgraduate	0.566			
Migration Status	Migrant	0.733			
	Non-migrant	0.714			
Chronic Illness	Yes	0.722			
	No	0.719			

During the survey, 63.3% of the vendors surveyed thought Nagpur experienced heatwaves almost every year, and most considered them very severe (70.3%). It should be taken into account that, the surveys were conducted in summer of 2022, which was the vendors' first full year of work after the city's COVID-19 lockdown shut them down for two years. There were many vendors who admitted that they perceived the heat severity more intensely this year because they had lost acclimatization.

4.4.8.2.1 Health Risks:

The majority (47.2%) believed that heat waves were harmful to their health, while only 6.3% did not. A similar concern regarding heat health impacts also existed for families and communities. However, expectedly, more vendors were worried about their families (73.9%) than their communities (56.5%). Many vendors asked the other members of their households to stay at home out of heat-related health concerns. Even though they would have preferred to take heatwave days off but could not afford it, due to financial responsibilities. In contrast, based on some vendors' interpretation, they did not have a concern about their families they were safe at home and able to cool themselves using a desert cooler.
Many were hesitant to perceive fear of heat illness, with 46.9% denying, 37.4% accepting, and 15.6% uncertain. Occasionally, this question elicited strong responses, which was expected since fear is a sensitive subject, and it is instinctive to protect emotional security. It was also common for vendors to say they could not be afraid because they had to earn a living and face the realities of life. Drinking water and shading devices at work, as well as cooling methods at home, were reported to be the major drivers of increases in expenditures at work (64.9%) and at home (77.6%).

4.4.8.2.2 Economic and Productivity Risks:

To aggravate the situation, 73.7% of the vendors perceived a loss in employment and productivity, affecting their incomes. According to the survey, 33.3% of vendors switch occupations based on the season. A few said that they sold different things in both the morning and evening. As a result of a self-assessment made based on all the above factors, 68.9% of vendors believed they were vulnerable to the negative effects of heat and saw it as a risk.

4.4.8.3 Awareness, Sensitivity about Heat Waves and Past Experience:

First, the respondents were asked what they considered extreme heat. Most of the respondents felt it was associated with a temperature rise above a certain threshold (52.4%), followed by, the time when the discomfort is felt (30.7%), when changes are needed in normal behaviours or activities (8.8%), and when health effects are experienced (7.9%). 76.4% of the vendors had heard about heatwaves in the past or about 'Navatapa', the local term. 18.1% of the respondents had not heard about it at all, out of which 14.3% were males and 3.9% were females.

Following this, the source of their information and awareness was examined. In order to prevent and control heat-related illnesses and injuries, training and education are the most effective methods (El-Shafei et al., 2018). Almost none of the vendors had access to training or awareness programmes conducted for heat-related risks (95.9%). Close to half (47.6%) of the vendors received heat warnings, through Newspapers (15.2%), Word of mouth (13.8%), Internet (8.8%), TV/Radio (5.4%), and Mobile Broadcast (4.3%). According to 13.2% of respondents, since they have been experiencing extreme heat for many years, they were not concerned about

these warnings. In fact, more than two-thirds of the vendors (70.1%) do not check the weather forecast daily before leaving for work, primarily because not all of them own smartphones, and newspapers arrive after they've already left. There were many people who believed weather forecasts had no bearing on their daily lives since they had to continue working regardless of the forecast.

The results of many studies show that there is a clear relationship between experience and perception of the same kind of risk (Ohman, 2017) . It was found that 68% of vendors had experienced extreme heat in the past, 21.5% had not, and 10.4% were unsure. Irrespective of whether they had migrated to Nagpur, this was consistent. In India, heatwave days are increasing at a rapid rate every 10 years. During 1981-90, there were 413 days with extreme heat, but in 2001-10 there were 575 and in 2011-20 there were 600 days across 106 weather stations (IMD). Most of the respondents (85.3%) felt that the weather was hotter than before. Interestingly, none of the female vendors interviewed stated no to this question, with only 6.8% saying they did not know. Furthermore, vendors stated that the construction of concrete roads, which result in more impermeable surfaces, as well as reduced tree cover and pollution, contributed to higher temperatures.

47.8% of the vendors had experienced a heat illness such as heat rashes, heat exhaustion or heat stroke at work. While the percentages were relatively close in other age groups, contradictory to the hypothesis, 66.2% and 75% of the vendors aged 51-65 and 66-80 respectively reported that they did not experience an illness.

Table 4.5: Common illnesses and coping strategies across markets

Study Sites	Total Responses	People who reported illnesses	Top four perceived Heat-Related Symptoms	Number of times reported	Percentage of people who reported illnesses	Top Heat Coping Strategies
Budhwarpeth	80	34 (42.5%)	Tiredness or Weakness	24	18.90	Consulting doctor, resting in shade, Increasing fluid intakes like water, lemon sugar salt water, lime and mint water and buttermilk.
			Headache	19	14.96	
			Feeling Hot	17	13.39	
			Thirsty	16	12.60	
Mahal Market	80	46 (57.5%)	Feeling Hot	36	19.15	Increasing water intake, consulting doctor, taking timely breaks and rest, cooling off by moving to shaded areas and splashing water.
			Tiredness or Weakness	32	17.02	
			Thirsty	31	16.49	
			Heavy Sweating	22	11.70	
Gokulpeth	75	50 (66.6%)	Heavy Sweating	32	17.39	Drinking cool water and glucose-rich drinks, consulting the doctor.
			Tiredness or Weakness	22	11.96	
			Dizziness	21	11.41	
			Feeling Hot	20	10.87	
Sitabuildi	76	26 (34.2%)	Tiredness or Weakness	16	17.98	Taking timely rest and breaks, taking days off, and moving to shaded areas.
			Headache	12	13.48	
			Feeling Hot	10	11.24	
			Heavy Sweating	10	11.24	
Khamla	22	10 (45.4%)	Tiredness or Weakness	6	19.35	Carrying an onion bulb and chilli around every time while heading out in the sun, drinking mango drinks.
			Muscle Cramps	5	16.13	
			Heavy Sweating	5	16.13	
			Headache	3	9.68	

It is apparent from table 4.5 that tiredness or weakness, headache, feeling hot, dizziness, heavy sweating, and thirst were the most reported heat-related symptoms. The most common coping strategies after experiencing these symptoms were to increase the fluid intake (water, lemon salt sugar water, glucose drinks, mango drinks etc.), take timely rest in shaded areas and breaks in the afternoon, take days with extreme heat off, and cool off by splashing water. Most of the vendors consulted doctors and took medications only after experiencing serious symptoms of heat stress like fainting, dizziness, fever etc. A few vendors resorted to ancient beliefs, such as carrying onion whenever they went outside in the sun, despite the fact that none of these practices is scientifically proven. Despite not experiencing heat-related symptoms often, many vendors stock up on Oral rehydration salts and water all year round for their customers, who often feel faint and dizzy when shopping in extreme heat. The behaviour can be linked to concern for the community during a crisis and demonstrates a sense of coming together.

4.5 ADAPTIVE MEASURES STUDY

4.5.1 Introduction

Globally, across different impacts of heat, adaptation is being taken place on different scales of implementation. Varying regions, countries, and income levels exhibit different levels and types of adaptations, and varied individuals, communities, and governments have different ways of putting them into action. Turek-Hankins et al. (2021) found that individuals or communities autonomously adapt in 63% of the studies, illustrating how up to this point, responses have mainly consisted of coping mechanisms. Additionally, behavioural or cultural adaptations are more prevalent in low- and middle-income nations outside of Northern America, Europe, and Eastern Asia.

The purpose of the study is to document the beliefs of street vendors regarding heat adaptation, their lifestyle changes and coping mechanisms along with the physical interventions they apply.

4.5.2 Adaptive Measures and Protective Behaviors

When working during very hot weather, 42.9% of street vendors thought they should always adjust their work habits, 25.9% thought they should do it occasionally, and 31.3% did not think it was necessary at all. In addition, on receiving a heat wave warning, 42% made a difference to their daily routine.

55.1% took adaptive measures when stepping out of their homes always, 10.7% often, 19.7% sometimes, 8.8% rarely, and 5.7% never. Common among these were staying hydrated, wearing appropriate clothing (such as light-coloured, full-sleeved and cotton clothes), staying in the shade or near coolth, and modifying diet (less food and more fluids) to suit the summer. There were 12% of vendors who only drank water when they were thirsty, 1.6% who drank plenty of fluids before starting work, 30.8% who drank fluids regularly during work hours, and 55.6% who did all three. Some also scheduled their outdoor activities carefully, changed their work schedule (increasing night hours and reducing daytime hours) and took long lunch breaks to avoid the noon heat. A few also checked for updates in the weather forecast, took homemade immunity booster medicines and learned the signs and symptoms of heat impacts (ref. Fig 4.9).

Figure 4.7: Some vendors do not employ physical adaptive measures because erecting and removing them every day consumes a lot of time and energy.

Figure 4.8: As there is little business in the summer afternoons, vendors at neighbourhood markets take long lunch breaks.

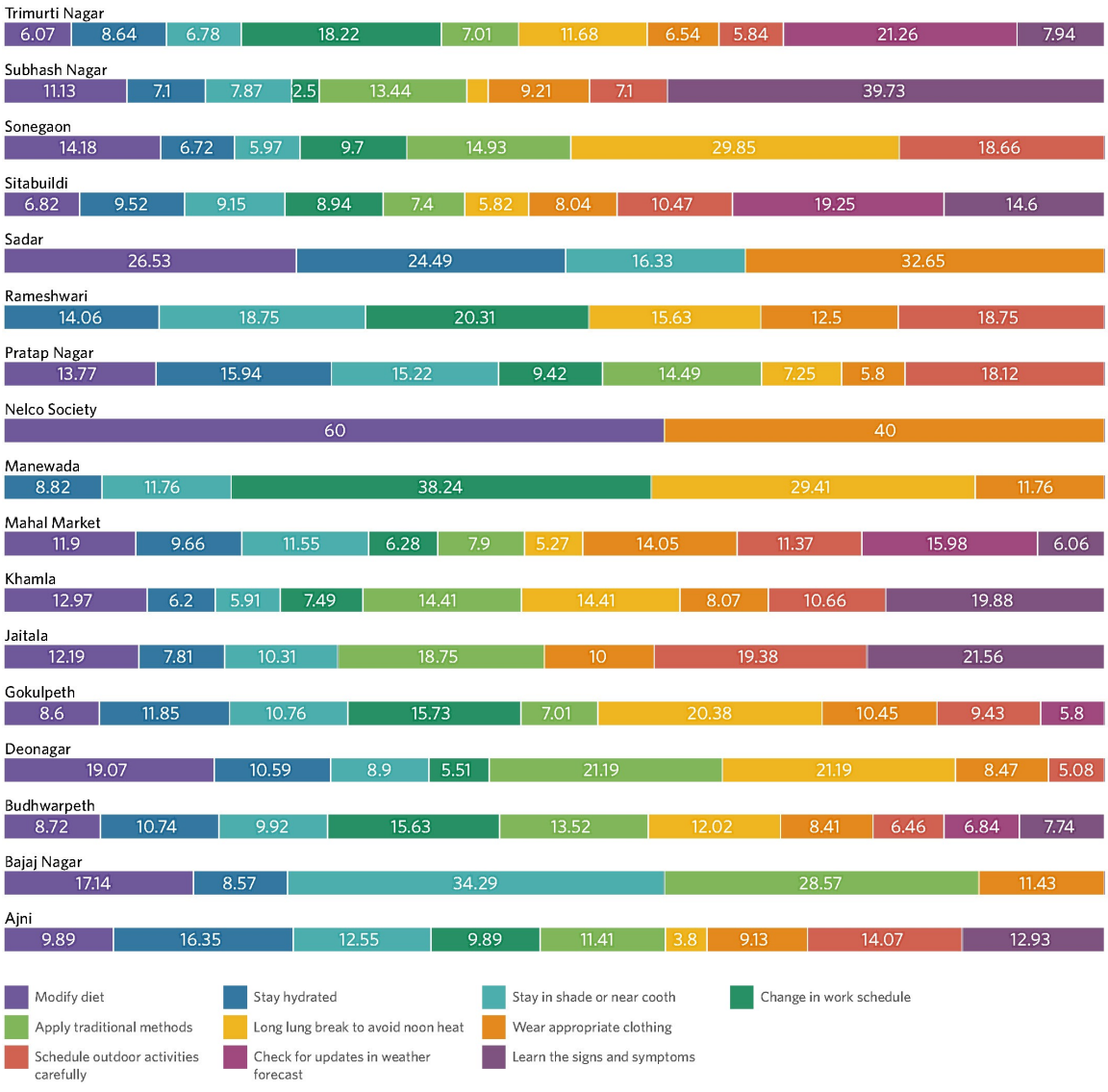


Figure 4.9: Market-wise lifestyle adaptative measure types

There were two main explanations for not taking any adaptive measures: they were used to the hot weather (63.9%), and they didn't have the capacity to change their behaviour (30%). Very few attributed this to heat waves not having any effect on them (5.3%) and the weather being not hot enough (2.4%) (ref. Fig 4.7, 4.8). In the sample population surveyed by the study, 49.2% of the vendors operated in areas completely shaded, 33.6% in partially shaded and 17.2% in unshaded areas. Vendors in shaded areas generally did not take any additional physical adaptations. There were, however, limited opportunities due to reduced tree cover, especially in markets like Sitabuildi, Mahal, and Budhwarpeth.

76.2% had taken measures to modify their workspace while 23.8% hadn't. Green-coloured sun shade HDPE net was the most frequently encountered measure (51.9%). Vendors were willing to invest in nets with more density as they offered better protection. Other employed garden or rain umbrellas (13.9%), and gunny bags (11.3%). Other measures included using cardboard, tin sheets, bamboo and cane nets, tarpaulin sheets, and cotton cloths such as sarees, curtains and bedsheets. The typical reasoning for using a tarpaulin sheet was that it offers protection from both sun and rain and thus was viewed as a better alternative. Those who could afford and had access to electricity at the workplace also used a table fan to cool off. 85% used a desert cooler at home (ref. Fig 4.10, Table 4.6).

Figure 4.10: Physical adaptive intervention types

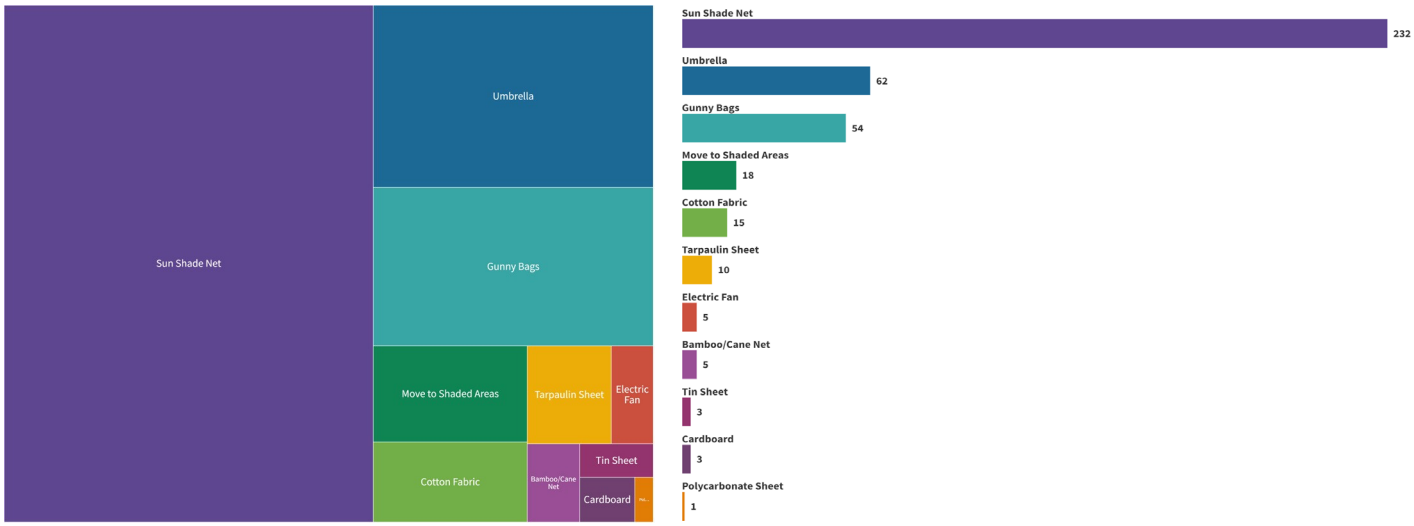


Figure 4.11: Tarpaulin sheet tied to a nearby tree

Figure 4.12: Garden umbrella with wet gunny bags

Figure 4.13: Cardboard sheets in between two carts

Figure 4.14: Cotton fabric sheets

Table 4.6: Market-wise percentages of physical adaptive intervention types

Physical Adaptations	Ajni	Budhwarpeth	Gokulpeth	Jaitala	Khamla	Mahal	Pratap Nagar	Sadar	Sitabuildi	Subhash Nagar	Trimurti Nagar
Sun Shade Net	52.9%	59.1%	59.1%	61.4%	90%	57.9%	48.8%	71.4%	20%	39.7%	64.3%
Umbrella	5.9%	24.2%	24.2%	6.8%	-	15.8%	20%	14.3%	20%	28.6%	-
Gunny Bags	29.4%	1.5%	1.5%	26.1%	10%	10.5%	7.5%	-	-	7.9%	28.6%
Move to Shaded Areas	5.9%	7.6%	7.6%	-	-	-	10%	-	-	6.3%	-
Cotton Fabric	5.9%	-	-	-	-	5.3%	3.8%	-	60%	9.5%	-
Tarpaulin Sheet	-	3.0%	3.0%	-	-	5.3%	2.5%	14.3%	-	4.8%	7.1%
Polycarbonate Sheet	-	1.5	1.5	-	-	-	-	-	-	-	-
Electric Fan	-	1.5%	1.5%	1.1%	-	-	2.5%	-	-	1.6%	-
Tin Sheet	-	1.5%	1.5%	1.1%	-	5.3%	-	-	-	-	-
Cardboard	-	-	-	3.4%	-	-	-	-	-	-	-
Bamboo/Cane Net	-	-	-	-	-	-	5.0%	-	-	1.6%	-

Furthermore, it was determined whether these adaptive measures were perceived as satisfactory, with the majority (51.9%) agreeing, 32.4% disagreeing, and 15.6% unsure. Many vendors combined types of shading when one was not viewed as satisfactory enough, such as wet gunny bags over an umbrella; cotton cloth and tarpaulin; two or three layers of sun shading net etc. The most popular solution was to add a waterproof layer to a porous fabric, creating a solution for all seasons (ref. Fig 4.11-4.18).

Another observation was regarding the durability of the physical adaptive measures. Markets and vendor clusters at the neighbourhood level tend to have more formwork, as well as appropriately anchored and shaded items and vendors. However, vendors in large markets, such as those in city-level markets, used interventions that were more temporary and makeshift since they had to be removed at the end of the day. According to vendors in Mahal Market, another reason is that they can be removed quickly when the anti-encroachment squads come to streamline them. Shading devices were viewed as attempts to establish unlicensed shops and vendors lived in fear of civic authorities. Some vendors forego physical interventions instead of causing unnecessary hassle. Sitabuildi vendors are unable to shade their products because it reduces the visibility of the stores behind them, which is not allowed by store owners.

Figure 4.15: Green sun shade net lined with tarpaulin sheet

Figure 4.16: Rain Umbrella (F), Cane Net (B).

Figure 4.17: PVC flex banner tied to steel bars

Figure 4.18: Combination of garden umbrella and cotton sheets

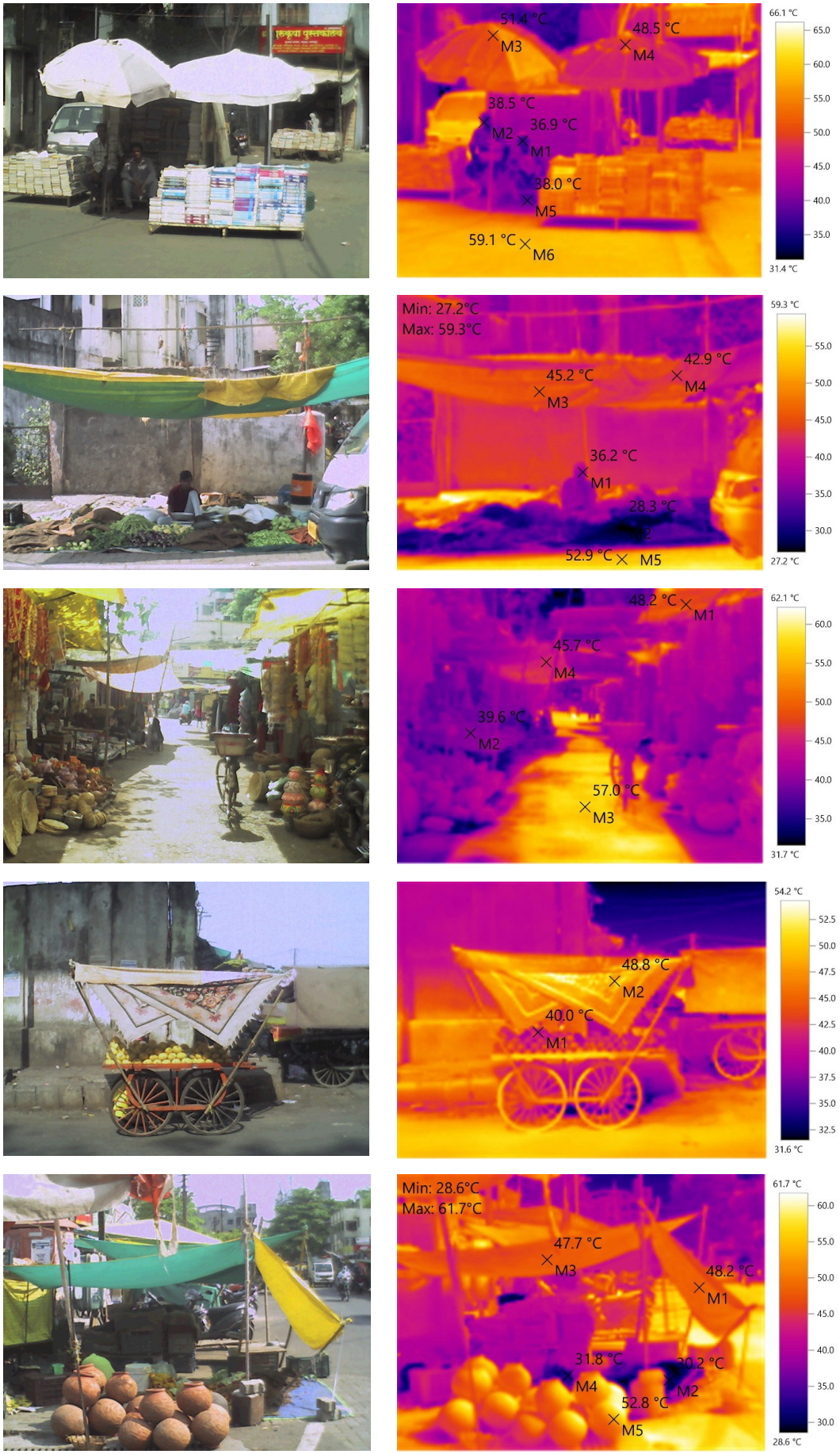


Figure 4.19: Thermal images of different adaptive measures

Some vendors, like those selling produce, are particularly vulnerable to the heat. Fruit and vegetables are prone to ripen and spoil, so each day is a race against time. Metal articles and clothing articles are prone to discolouration and damage due to heat. Thus, vendors usually need to cover their goods from noon until 4 p.m. As a result, the physical adaptations were primarily aimed at protecting their goods and not themselves. It was not uncommon for vendors to keep their merchandise shaded while standing in the scorching summer sun (ref. Fig 4.20).

Figure 4.20: Sometimes, adaptive measures are used to protect only goods from the effects of weather

4.6 ANALYSIS

The objectives of this study were to examine the perception of street vendors towards heat waves and identify and analyze the determining factors of perceived effect. By using Chi-squared tests, the study examined the factors that significantly influenced the perception of heat risk, and it also examined whether two qualitative variables were statistically significant.

4.6.1 Associations between socio-demographic characteristics and HRP

The study did not find statistically significant associations between the gender of respondents and the perceived likelihood, severity, and health concern (self, family, or community) of extreme heat. However, women were more likely to perceive themselves as vulnerable and at risk of extreme heat than men, $X2(1, N=441) = 12.321$, $p < 0.001$. They were also more likely to be concerned about general as well as household expenses than the men. Surprisingly, overall male vendors had a marginally greater HRP (0.721 ±0.216) than female vendors (0.708 ±0.027). This outcome is contrary to the studies by Akompab et al. (2013); Howe et al. (2019); Liu et al. (2013); Rauf et al. (2017); Williams et al. (2019) where women had a higher heat risk perception. This demonstrates that perceived vulnerability alone is insufficient to influence risk perception.

Furthermore, no significant associations were found between age, occupation, education, migrant status, and heat risk perception (ref. Table 4.7). Some of these findings were also reported by Ban et al. (2017) where none of the demographic factors had an impact on HRP except education level. Respondents whose families had members below the age of 15 and above the age of 65, were more likely to be concerned about the heat-related health risks that can affect their community, $X2 (1, N=441) = 5.461$, $p = .019$ and to fear heat-related illnesses, $X2(2, N=441) = 7.108$, $p = .029$. This might be directly linked to the heat-health concern due to the vulnerability of children and the elderly.

Table 4.7: Pearson chi-squared tests results for HRP characteristics and socio-demographics

Pearson Chi-Square Tests

Socio-demographic Factors	HRP Factors	Frequency	Severity	Self-Health Concern	Family Health Concern	Community Health Concern	Fear of Heat Illnesses	Worry about General Expenses	Worry about Household Expenses	Worry about Employment and Productivity	Perceived Vulnerability
Gender	Chi-square	5.096	7.277	9.010	3.103	3.072	5.299	6.763	8.310	1.499	12.321
	Sig.	0.278	0.122	0.061	0.078	0.080	0.071	**.034***	**.016***	0.473	**.000***
Age	Chi-square	17.466	49.402	30.516	18.161	7.234	11.380	14.979	7.661	8.178	8.231
	Sig.	0.356	-	-	-	0.124	0.181	-	-	-	-
Education	Chi-square	24.110	21.643	28.838	8.356	6.063	21.802	9.096	8.958	17.346	8.344
	Sig.	0.455	0.601	0.226	0.213	0.416	-	0.695	0.707	0.137	0.214
Chronic Illness	Chi-square	3.167	3.175	8.456	6.128	7.641	15.150	3.531	3.826	1.336	10.032
	Sig.	0.53	0.529	0.076	**.013***	**.006***	**.001***	0.171	0.148	0.513	**.002***
Migration Status	Chi-square	9.062	6.616	8.403	0.413	0.414	1.022	1.480	0.884	0.344	0.322
	Sig.	0.06	0.158	0.078	0.520	0.520	0.600	0.477	0.643	0.842	0.571

*. The Chi-square statistic is significant at the .05 level.

Pre-existing chronic illness was found to be an important determinant of HRP as respondents were more likely to worry about the heat impacts that could affect their families (p = .013) and community (p = .006). They were also significantly more likely to fear heat health illnesses than those without pre-existing conditions (p = .001) and to perceive themselves as vulnerable to heat risks (p = .002); (ref. Fig 4.21, 4.22). These results reflect those of Beckmann and Hiete (2020) who also found that people suffering from chronic diseases were more likely to perceive heat as a risk.

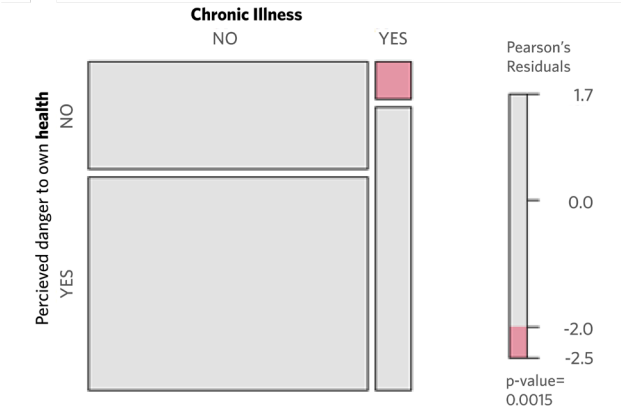


Figure 4.21: Mosaic plot showing association between having a pre-existing chronic illness and perceiving danger to health

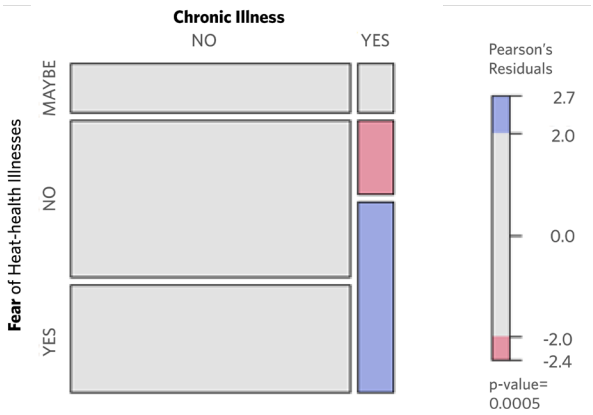


Figure 4.22: Mosaic plot showing association between having a pre-existing chronic illness and fearing heat-health illnesses

4.6.2 Associations between socio-demographic characteristics and awareness

The study revealed differences in the awareness and sensitivity of street vendors about extreme heat and who was at more risk of experiencing heat illness. In comparison to female respondents, who were considerably more likely to suffer from a heat illness at work (p=.005) than male respondents, male street vendors were more likely to get warnings about the heat (p =.025) and feel the weather has

gotten hotter than before. The figure shows that the likelihood of experiencing illness decreased with increasing age from 21 years old. Education had little effect on sensitivity, other than vendors with no formal education being least likely to receive heat warnings. This is likely to be related to their inability to read newspapers, their primary source of written information about heat, as expressed by many during the surveys. Heatwave knowledge was significantly lower among migrant workers (p=.002), owing to two main factors: first, they hadn't spent enough time in Nagpur to acquire local knowledge, and second, heatwaves were uncommon in their hometowns, particularly in villages, to build heat-related knowledge. There was a greater likelihood for vendors with chronic diseases to have experienced heat illness in the past (p=.004), which makes them more vulnerable to mortality and morbidity (ref. Fig 4.23, 4.24).

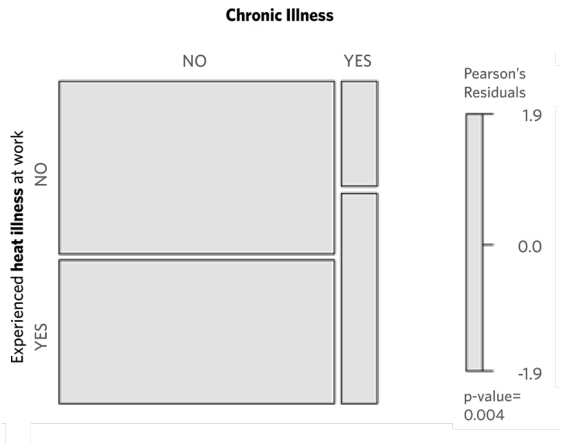


Figure 4.23: Mosaic plot showing association between having a pre-existing chronic illness and experiencing heat illness at work

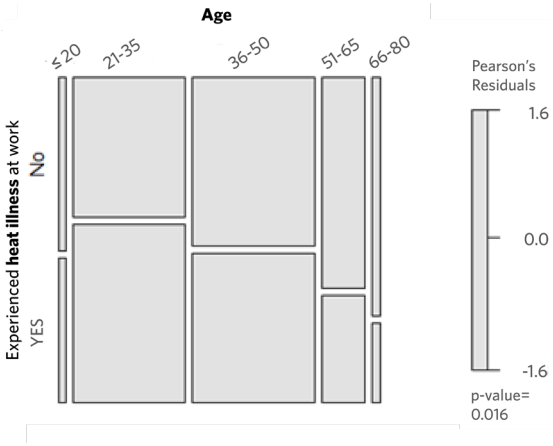


Figure 4.24: Mosaic plot showing association between age and experiencing heat illness at work

4.6.3 Associations between awareness and HRP

According to the findings, precautionary measures, such as checking weather forecasts, were associated with greater health concerns about family (p=.047), and community (p=.013) as well as fear of heat illnesses (p=.001). Heat warnings were associated with a higher perceived concern (p=.031) and fear (p=<.001) of heat waves to health. Since training and awareness programmes were not available in significant numbers, their significant impacts were not found aside from increased community health concerns. The likelihood (p<.001) and severity (p<.001) of heatwaves in Nagpur were significantly higher for those who had heard about heatwaves previously, and fear (p=.001) and concern (p<.001) about rising general expenses and health were more prevalent.

History of heat illness at work is one of the most important predictors of perception of heat risk since it affects almost all factors, including self-reported heat health concerns, family and community concerns, as well as a high sense of health fear and economic and employment concerns. (ref. Fig 4.25, 4.26).

Similarly, previous experience of heatwaves also had an influence on heat risk perception as it increased the perceptions of factors including likelihood and severity. The vendors who recognized that the weather had gotten hotter than before were more likely to have a higher heat risk perception. Meanwhile, respondents who did not feel the weather was hotter than before were significantly less inclined

to believe they are vulnerable to the negative effects of extreme heat, making it another predictor of perceived risk. This also accords with Slovic's observations, which showed that the perception of risks will be lower if they are not perceived as increasing in likelihood or frequency.

Overall, the findings show that risk communication systems motivate people to be more concerned and fearful and improve their perceptions of heat risk frequency and severity. However, as noted in the study earlier, a considerable number of street vendors do not have access to this knowledge, so their negative experiences with previous episodes of extreme heat, including illnesses, are largely responsible for their high perceptions of heat risk. Several vendors in Nagpur have grown accustomed to the hot weather and no longer regard it as a new risk, which is counterproductive in this study because it makes vendors less cognizant of the vastly elevated heat risk due to climate change and the urban heat island effect (Coleman, 2022; Reid et al., 2009).

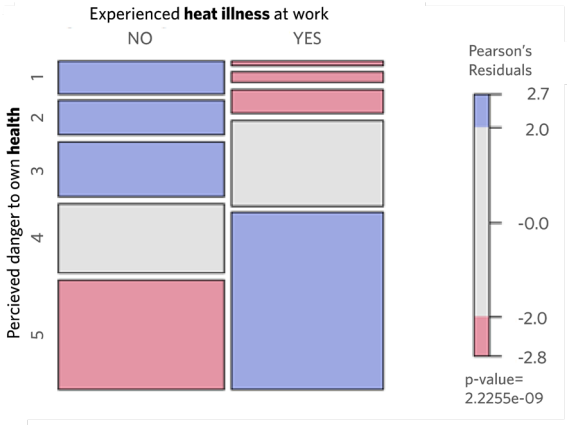


Figure 4.25: Mosaic plot showing association between experiencing heat illness at work and perceiving danger to own health

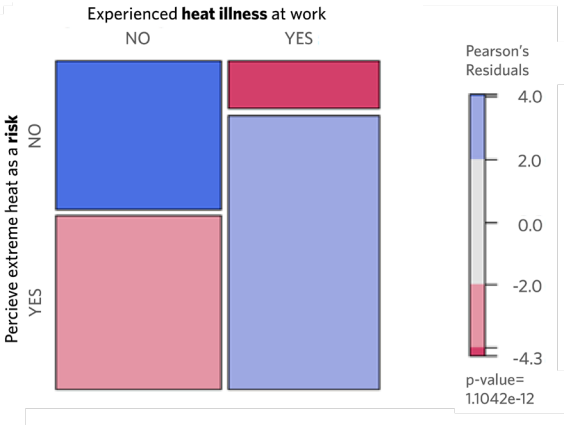


Figure 4.26: Mosaic plot showing association between experiencing heat illness at work and perceiving extreme heat as a risk

4.6.4 Variation in adaptive measures across socio-demographics of street vendors

Across age groups, genders and family setups, the Chi-squared test results found that there were no statistically significant differences in heat adaptive behaviour motivations. The respondents who had a chronic illness were significantly more likely to make a difference in their daily routines upon receiving a heat warning (p=.004). Perhaps as a result of the perceived vulnerability, some workers changed their work schedules, worked fewer hours, took afternoon breaks, or totally avoided working during the heatwave.

Vendors who had no formal education or had primary school as their highest education were less likely to modify their workplace than the vendors with a better formal education. In fact, they were also much more likely to carry out their activities in a completely unshaded location. Then again, these vendors were also the ones who were most dissatisfied with the adaptive measures they'd taken. There can be two possible explanations for these behaviours, the obvious one being the lack of capital and resources required. The other is the lack of access to correct advice or partial information on adaptive measures leading to adaptation deficits, such as using cardboard attached to the top of the cart (ref. Fig 4.27), and maladaptation, such as using tin sheets as shading devices (ref. Fig 4.28).

It was noted during the surveys, that most vendors adopt strategies at their workplace that either can be easily procured or generally adopted by everyone in the market they sell. It is important to note, as part of successful adaptation, it is not only essential for the vendors to identify adaptation options and weigh their costs and benefits, but also to exploit mechanisms that increase their adaptive capacity.

Figure 4.27: A fruit cart vendor attempts to use cantilevered cardboard sheets to shade himself.

Figure 4.28: A scrap metal and paper recycling vendor uses salvaged tin sheets to shade his workplace while he himself sits down under the shade of a tree.

Vendors who had migrated to Nagpur were significantly less likely to do business in a shaded location (p<.001) in addition to not taking adaptive measures while stepping out of their homes (p=.005) and not taking measures to modify their workplace (p=.009) even during extreme heat (ref. Fig 4.29, 4.30). The most likely reason for this is the financial constraint that probably drove the migration in the first place. But lack of local knowledge and awareness, such as the availability of drinking water and location of cooling centres and medical management and referral centres (Nagpur Heat Action Plan, 2022), coupled with concerns about job security and grappling with cultural and linguistic barriers also play an important role in suppressing adaptation. With a finite pool of worry, where they can only worry about so many things at the same time, heat risk takes a back seat.

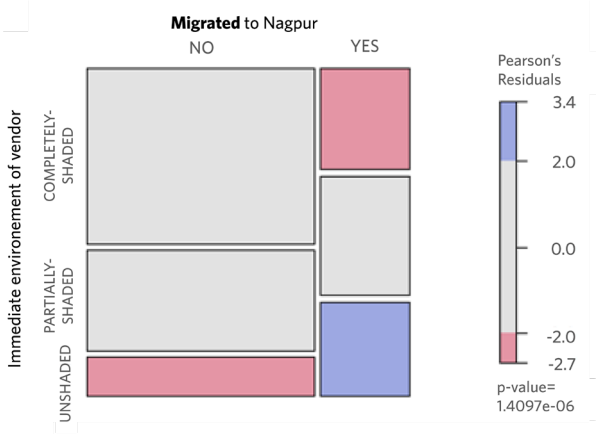


Figure 4.29: Mosaic plot showing association between migrating to Nagpur and the immediate environment of the vendor

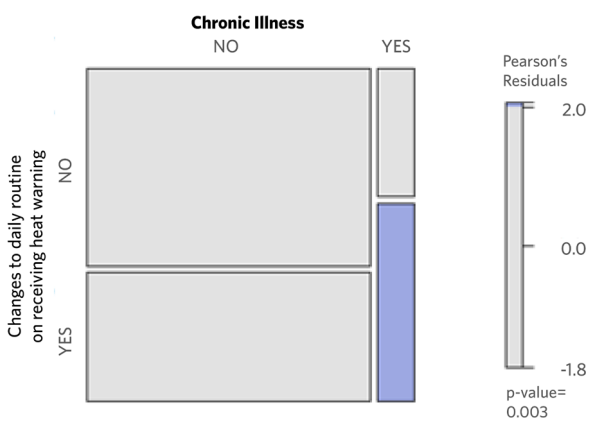


Figure 4.30: Mosaic plot showing association between having a chronic illness and changing daily routine on receiving heat warning

4.6.5 Impact of awareness, sensitivity to heatwaves and past experience on adaptive measures

It was observed that vendors who knew about heat waves were more likely to add just their work habits personally (p=.001) and make a difference in their daily routine after receiving a heat wave warning (p=.005). This implies, even if they receive a heat warning, the presence of basic knowledge about heat waves is a necessary condition for warnings to promote adaptive behaviours. Even in cases where people had a vague idea about the term “heatwave”, they were likely to change their work habits at least occasionally. The mean HRP index of those who knew about heatwaves (M=.732, SD=0.221) was more than those who said “Maybe” (M=.671, SD=0.254) or “No” (M=.681, SD=0.241).

Taking adaptive lifestyle measures while stepping out of home, though was a widespread practice but, was more significantly associated with vendors receiving heat warnings (p=.004). The ability to access training/awareness programs and altering one’s daily routine were found to be related in a similar manner (p=.030). The risk perception as a result of past experience of heatwaves in turn was identified as a predictor of adaptive measures including working in a shaded immediate environment (p=.044), adjusting work habits (p<.001), and making a difference to the daily routine (p=.001). Likewise, these adaptive measures were as significantly associated with vendors having a previous experience of heat illness.

The weather forecast had no impact on adaptive measures, as those who took measures did so based on their greater character of the season, regardless of daily weather changes. Many vendors said they knew they would have to take measures since it was summer, and the weather would be hot every day for three months. The vendors who were satisfied with their adaptive measures did not particularly feel an increase in summer temperatures over the years (p=.001).

4.6.6 Impact of heat risk perception on adaptive measures

Heat risk perception was positively related to changes in work habits when working during hot weather, particularly in terms of perceived danger to the health of one’s own (p=.007), family (p<0.001), and community (p=.001) and perceived vulnerability (p=.014). Interestingly, the vendors who thought they should adjust their work habits were less likely to be afraid of heat health illnesses. These vendors were also more likely to adopt other adaptive behaviours, such as altering their daily routine in response to a heat warning (p<0.001) and taking lifestyle adaptive measures while stepping out of their homes (p<0.001).

In addition to the risk perception factors mentioned above, vendors who were threatened with losing their jobs or productivity were more likely to act in response to a heat wave warning (p=.016). Additionally, the respondents who made a difference in their daily lives upon receiving a heat warning were significantly less likely to step outside their homes without taking adaptive measures.

Adaptive measures such as covering the face and ears using a cap or a headgear (locally called ‘gamcha’), wearing light-coloured, loose-fitting cotton clothes, and carrying sufficient drinking water are significantly more likely to be taken if the vendors are concerned about the heat illnesses that can affect their family (p<.001) and also the overall community (p=.001). The reason for these relationships might be explained in part by the reason that if their family members fall ill, they themselves should be healthy enough to take care of them and handle any financial

strain. For many street vendors, there's an elevated sense of fear of heat illnesses (p=.019) that they themselves might suffer from, being the primary breadwinner of their family, in turn, promoting these lifestyle changes during summers.

Conversely, respondents who had a concern about heat risks neither to family (p=.007) nor to the community (p=.006) were significantly less likely to take physical adaptive measures to modify their workplace. The same group was more likely to feel dissatisfaction with their environment (p=.001). It was found that vendors who used coolers at home were more likely to consider extreme heat as a risk to their household expenses. This finding suggests that there is an interplay between heat health and heat economic risk. As indicated by other studies like Madrigano et al., (2018), any statistically significant differences in the perceived vulnerability (or viewing extreme heat as a risk) of vendors with and without cooling capacity, could not be found. It was interesting to note, many vendors said that they can bear the heat because they're out in the sun and are used to the heat, while was a bigger issue for people who use air conditioners or desert coolers in summer, to survive the heat. So, though they have cooling capacity at home, they try not to use it as much as possible.

Other than drinking more water, which was done regardless, the study found significant associations between heat risk perception and adaptive measures and protective behaviours.

Figure 4.31: A market alley in the afternoon in Gokulpeth wears a deserted look.

Figure 4.32: A vendor uses multiple layers of fabric and a pool of water to protect fruits from spoiling.

Figure 4.33: A vendor adjusts a shading device to protect himself from the afternoon sun.

Figure 4.34: Different degrees of adaptations by people on a hot morning, Sitabuildi

Figure 4.35: A vendor adjusts a shading device to protect himself from the afternoon sun.

4.7 CHAPTER CONCLUSIONS

The study assessed the heat risk perception of 441 street vendors and outdoor workers in Nagpur and measured it using an index [0,1]. It also identified the factors that influence the perception and how HRP in turn affects adaptive measures and protective behaviours.

In Nagpur, vendors exhibit high sensitivity to heat, as well as a high level of heat tolerance. The neutral physiologically equivalent temperature (PET) was found to be higher than in other studies in similar climatic zones. This is likely because of the high levels of acclimatization due to constant exposure to extreme heat for many years in the city. The ability to tolerate heat appears to improve with a gradual increase in intensity or duration of work in a hot environment. However, the NPET found corresponds with the morning summer temperature, which increases as the day progresses and the thermal sensation remains in the 'warm' and 'hot' range. During peak heat periods, such as during heatwave days in May, workers' acclimatization threshold is too often exceeded, increasing the risks associated with working in high temperatures. Additionally, as a result of climate change and global warming, physiological limits are more likely to be often met in Nagpur.

The findings indicate that extreme heat poses a high risk to street vendors in the city. This is also echoed by the vast majority (70%) of vendors in Nagpur, who perceive extreme heat as a risk. No significant associations were found between age, occupation, education, migrant status, and heat risk perception. Other sociodemographic factors had statistically significant associations between one or more constructs of HRP, such as pre-existing chronic illnesses associated with health concerns and fear of heat illnesses, along with high perceived vulnerability. For occupations with a higher workload intensity or physical demands and direct exposure to the sun, like cart pullers, HRP is higher than for occupations like tea sellers. This suggests that thermal comfort plays an important role in risk perception. Health risks were perceived more through the lens of negative consequences for one's family than through the lens of one's own health. In addition to increased expenses and decreased earnings, the perception of self-health risks drops due to increased economic and productivity risks.

Heat is not a new phenomenon in Nagpur, so most vendors are aware of heat waves or at least the local terminology. A majority of knowledge about severity, frequency, and coping mechanisms comes from past experiences and information passed down from generation to generation. The perception of heat risk is heavily influenced by previous interactions with heat, which are unique to each individual. In the absence of training & capacity-building programmes or heat wave warnings, scientific and institutional knowledge has little impact on risk perception. The study identified past negative experiences with heatwaves including illnesses, recognition that the weather has gotten hotter than before, and fear of heat-related illnesses, to be important predictors of high heat risk perception. The vendors considered a health risk to be the most important factor when evaluating overall heat risk.

The study found significant associations between heat risk perception and adaptive measures and protective behaviours. The vendors who perceived heat as a risk were more likely to take lifestyle and physical adaptive measures. However, lifestyle changes were more likely than physical adaptations, most possibly due to the perceived locus of control and financial constraints. Protecting goods and produce was the primary focus of physical measures. Moreover, the measures are taken by vendors based on the information and observations they have gathered.

However, these measures are also sometimes not adequate and coupled with financial constraints, they lead to adaptation deficits. Several similar measures were documented by the study, indicating their widespread use, affordability and easy availability is what motivates their adoption. Acclimatization to heat though helps in preventing illnesses but lowers perception with “being used to the high temperatures” being the main reason why street vendors do not take adaptations.

This page intentionally left blank

CHAPTER 05

Conclusions and Applications

Contents

5.1 SUMMARY OF CHAPTERS

5.1.1 Literature Review:

As a result of climate change, global temperatures as well as the frequency and severity of heatwaves will increase in the twenty-first century. Extended periods of high daytime and nocturnal temperatures put the body under cumulative physiological stress, which makes the world's leading causes of death, such as diabetes mellitus, cardiovascular disease, and kidney illness, worse. Heatwaves often result in public health emergencies, have a significant negative influence on public health, and have a domino effect on other aspects of society (e.g. lost work capacity and labour productivity). As a result of the disruption caused by the power outages that frequently accompany heatwaves, they can also result in a reduction in the capacity for providing health services.

The threats to one's health caused by heatwaves and extended exposure to high temperatures are still not sufficiently known. Planning and interventions by health experts must be modified to account for rising temperatures and heatwaves. Interventions that are realistic, doable, and frequently inexpensive can save lives at the individual, group, community, organizational, governmental, and societal levels. For such realistic measures, heatwave is now being looked at holistically, with close mapping of its direct and indirect effect on every entity.
Heat stress has been measured in varied ways- environmentally, physiologically (internal and external) and psychologically. The most effective and feasible procurement of data is through environmental and physiological indicators.
However, subjective measurement of physiological changes increases accuracy and determines a deeper understanding of the causes of heat-related ailments, thereby attracting a comprehensive framework of guidelines. Heat stress is an outcome of climatic and microclimatic conditions.

Heat Stress is most visible in vulnerable populations who are comprised of old, too-young or strenuous workers. Among strenuous workers, the informal vendors and self-employed workers face outdoor temperature and sun radiation for the longest duration of time, making them the most susceptible to heat-related illness, which, during a heatwave, cannot be properly tended to, if not properly addressed in the first place, leading to aggravated symptoms of heat-related illness or chronic disease.

The risk from disaster is increasing globally. Risk is not assessed by an individual unless it directly affects them. Risk is feared less when the knowledge about it is covered by the affected or potentially affected. Heat risk percolates to many levels and affects all activities on a global level. Geographical locations, socio-economic factors, structural drivers and evolved familiarity or cluelessness affect heat risk perception greatly.
Adaptation is governed by resource availability, compelling priorities and the effectiveness with which it can be carried out by an individual, community or authority. Adaptation gains feasibility when applied through customization catering to variety, which succeeds more due to shared indigenous and local knowledge. Most adaptive measures against heat are developed through readily available resources.

5.2.2 Study Area

The marketplaces of Mahal, Sitabuldi and Gokulpeth are more sought after for availability of goods as compared to the neighbourhood market unit clusters. These marketplaces not only provide a wider range of products, but also give a wider time window for buyers to shop. This significance has led to the marketplace becoming a stakeholder in the informal market activity of people, resulting in them ensuring their availability irrespective of the weather for gaining more customers. The market places of every scale face the same heat conditions owing to their presence in the same climate, however, due to their stronger visibility and dependency, the zonal markets are generally more adaptive to every subjected weather condition as compared to neighbourhood market unit cluster. The resultant microclimate- from adjacent shops, close-knit market units, etc. aide in the vendors' adaptability too.

The vendors in these areas arrive at their place of business around 10 in the morning and stay as late as possible, up to 11 at night in summers, as coming at earlier hours prevents them from losing their selling spot and leaving late enables shoppers to shop till late- as customers too, prefer to leave house in cooler temperature. Unlike neighbourhood market unit clusters, the shoppers seeking marketplaces come from places other than the adjacent neighbourhood. The higher availability and adaptability is also dependent on factors like footfall. When the marketplace is busy, the mind of the vendor is preoccupied with conducting business, making heat a secondary problem. The heat becomes the primary problem regarding the most essential activity of a vendor, i.e., the protection of their goods. Most of the measures taken by them, which are, sun-protective nets, cotton fabrics, umbrellas, tarpaulin sheets and gunny bags with different customizations and combinations, are intended to serve towards the maintenance of their commodities.

The neighbourhood market unit clusters of Ajni, Jaitala, Subhash Nagar, Trimurti Nagar, Khamla, Deonagar, Sonegaon, Mangalwari, Pratap Nagar, Bajaj Nagar, etc. have emerged as a result of expansion of the city as a part of an intricate neighbourhood, where the dominant building use is residential. These clusters, unlike the zonal markets, provide two to three categories of goods that are at the disposal of the residents on a daily basis. The time spent by the buyers in these markets is not more than 30 minutes. Being the goods provider of a very focused range of products, few vendors somehow can afford to miss a day or two. As these clusters on most occasions do not possess a ground, most of them depend on the microclimate created by a tree or an extended shade from a building, which makes a small group of 3-4 vendors set-up mutually. And such groups are scattered throughout their respective streets, nodes where shade is present.

Unlike zonal markets, these clusters have lesser competition, making almost all the vendors leave their stands/kiosks on the spot for the night sans the commodity. This cannot be seen in the zonal markets, as only a few groups can afford to leave the set- up on trust. With more residential crowds, these vendors wrap up their business by 9 pm at night irrespective of the weather. However, due to the availability of dairy products, and fruits that are essentially helpful for walkers, their business commences early too- some of them as early as 5 in the morning. As the footfall is lesser in such clusters, the vendors keep their health before the business, taking out time in the afternoon or taking a few days off if exhaustion from the heat is felt.

Many vendors attribute the noticing of rise in temperature to people staying generally indoors in the past two years, thereby creating a sense of obliviousness to the outdoor conditions.

5.1.3 Results and Analysis

The study assessed the heat risk perception of 441 street vendors and outdoor workers in Nagpur and measured it using an index [0,1]. It also identified the factors that influence the perception and how HRP in turn affects adaptive measures and protective behaviours.

In Nagpur, vendors exhibit high sensitivity to heat, as well as a high level of heat tolerance. The neutral physiologically equivalent temperature (PET) was found to be higher than in other studies in similar climatic zones. This is likely because of the high levels of acclimatization due to constant exposure to extreme heat for many years in the city. The ability to tolerate heat appears to improve with a gradual increase in intensity or duration of work in a hot environment. However, the NPET found corresponds with the morning summer temperature, which increases as the day progresses and the thermal sensation remains in the 'warm' and 'hot' range. During peak heat periods, such as during heatwave days in May, workers' acclimatization threshold is too often exceeded, increasing the risks associated with working in high temperatures. Additionally, as a result of climate change and global warming, physiological limits are more likely to be often met in Nagpur.

The findings indicate that extreme heat poses a high risk to street vendors in the city. This is also echoed by the vast majority (70%) of vendors in Nagpur, who perceive extreme heat as a risk. No significant associations were found between age, occupation, education, migrant status, and heat risk perception. Other sociodemographic factors had statistically significant associations between one or more constructs of HRP, such as pre-existing chronic illnesses associated with health concerns and fear of heat illnesses, along with high perceived vulnerability. For occupations with a higher workload intensity or physical demands and direct exposure to the sun, like cart pullers, HRP is higher than for occupations like tea sellers. This suggests that thermal comfort plays an important role in risk perception. Health risks were perceived more through the lens of negative consequences for one's family than through the lens of one's own health. In addition to increased expenses and decreased earnings, the perception of self-health risks drops due to increased economic and productivity risks.

Heat is not a new phenomenon in Nagpur, so most vendors are aware of heat waves or at least the local terminology. A majority of knowledge about severity, frequency, and coping mechanisms comes from past experiences and information passed down from generation to generation. The perception of heat risk is heavily influenced by previous interactions with heat, which are unique to each individual. In the absence of training & capacity-building programmes or heat wave warnings, scientific and institutional knowledge has little impact on risk perception. The study identified past negative experiences with heatwaves including illnesses, recognition that the weather has gotten hotter than before, and fear of heat-related illnesses, to be important predictors of high heat risk perception. The vendors considered health risk to be the most important factor when evaluating overall heat risk.

The study found significant associations between heat risk perception and adaptive measures and protective behaviours. The vendors who perceived heat as a risk

were more likely to take lifestyle and physical adaptive measures. However, lifestyle changes were more likely than physical adaptations, most possibly due to the perceived locus of control and financial constraints. Protecting goods and produce was the primary focus of physical measures. Moreover, the measures are taken by vendors based on the information and observations they have gathered. However, these measures are also sometimes not adequate and coupled with financial constraints, they lead to adaptation deficits. Several similar measures were documented by the study, indicating their widespread use, affordability and easy availability is what motivates their adoption. Acclimatization to heat though helps in preventing illnesses but lowers perception with “being used to the high temperatures” being the main reason why street vendors do not take adaptations.

5.2 CONCLUSIONS

- Heat risk is increasing globally with increasing global temperatures as well as the frequency and severity of heat waves. There is an increased risk of mortality and morbidity for vulnerable populations such as street vendors and outdoor workers.

- The use of realistic, feasible, and often affordable interventions can save lives at every level: individual, group, community, organizational, governmental, and societal. In order for adaptation to be practical, it must be tailored to accommodate a variety of needs, which is more likely to succeed when it is based on shared indigenous and local knowledge.

- There are differences in the nature and composition of the marketplaces in Nagpur between the city, sub-city, and neighbourhood levels. As a result, coping mechanisms differ, with protective behaviours such as taking a day off during a heatwave and taking a break in the afternoon being more feasible, and therefore prevalent in neighbourhoods level vendor clusters.

- There is a high sensitivity to heat among the vendors, as well as a high heat tolerance. The neutral physiologically equivalent temperature (PET) in this study was higher than in other studies in similar climate zones, suggesting a significant level of acclimatization due to the prolonged exposure to intense heat in the city.

- Vast majority (70%) of vendors in Nagpur perceive extreme heat as a risk, with the mean of the HRP index at 0.72. Perceived vulnerability is the most important predictor of risk perception.

- The findings make it apparent that societal vulnerability to extreme heat is not only a function of demographics and resource availability but also of risk perception and awareness. They are therefore crucial to effective adaptation strategies against extreme heat.

- Heat risk perception and adaptive measures are interdependent. Vendors who perceive heat as a risk will be more inclined to mitigate its negative effects through lifestyle and physical adaptation.

- Documented adaptations show measures are being adopted largely based on economic feasibility. A thorough assessment of the effectiveness of these strategies is needed, so that only the most useful adaptation strategies are proposed to the vendors, in order to fill the adaptation deficits and prevent maladaptation.

- Since this study was limited to Nagpur, it may not be advisable to assume that the findings apply to all street vendors nationwide.It has already been discussed that heat risk perception is highly subjective and influenced by a wide range of factors, including local conditions. In order to get a more accurate idea of how vulnerable groups perceive heat risk in that particular region, more local and regional studies are needed.

5.3 RECOMMENDATIONS FOR HAP

The primary aim of the Heat Action Plan is to reduce mortality and morbidity. The review of the HAP of Nagpur shows that outdoor workers and street vendors have been identified as vulnerable groups when it comes to extreme heat. However, the current study shows that it is important for street vendors to perceive the risk of extreme heat to take adaptive measures and reduce the negative consequences. The HAP should therefore focus on identifying methods to increase risk perception through awareness and capacity-building programmes. Additionally, the study found that the vendors who had access to training or awareness programmes had a higher risk perception. This is particularly important because, though the vendors have traditional knowledge, it is important for them to understand the increased heat risk and new risks posed by global warming and climate change. In addition, it is important to recognize that they are more vulnerable than before, and failure to take adaptive measures on a regular basis could result in elevated health and economic risk.

As discussed in the study, heat, by itself is not a new phenomenon in the city. Local vendors, exposed to the sun throughout the day, have been experiencing high temperatures for many years and take common-sense adaptive measures such as drinking more water, consuming lemon-sugar-salt drinks, buttermilk etc, and staying in shade. HAP risk communication campaigns commonly offer this common-sense advice as part of heat-related health advice, which the vendors don't consider useful. Thus, it is recommended to include information more targeted to the street vendors, explaining the risks that they face. Since each vulnerable group has a unique level of vulnerability, it is crucial that the HAP specifically target each one. For example, the heat vulnerability of older people may be reduced by advising them to remain indoors and avoid outdoor exposure during heatwave days, but this may not be feasible for outdoor workers who need to earn their living.

Heat action plans of other developed countries were used as precedents for the city's HAP, as for Ahmedabad HAP, the first one in the country. India faces different heat-related problems from the developed world, which means that the plan needs to be tailored to regional concerns and take into account local circumstances. It is recommended that the plan includes local and indigenous people while formulating. It will assist in solidifying the policies and incorporating local knowledge, which may be better for the populace. To give an example, the street vendors, like many people in the city, do not rely on heat warnings to take adaptive measures. The heat wave warnings never reach them, due to reasons discussed in the study. Their actions are more-or-less based on the local and indigenous knowledge that they possess and have been quite effective in preventing mortality.

Indigenous knowledge is strongly associated with family values and the community overall. Nonetheless, it can be said that fewer role models are available to people, and they lack a strong support network to assist them in times of need, since people have shifted from large, interconnected, and extended families to smaller, detached nuclear families. Similarly, for street vendors, it means that they have less access

to local knowledge and have to rely more on institutional knowledge. As a result, achieving a holistic policy is crucial for the Heat Action Plan.

Based on the findings of the adaptive measure study, vendors lack comprehensive knowledge about physical adaptations, so they choose the most affordable and accessible option. This leads to maladaptation. As a precaution, it is recommended that the HAP develops a guideline or a DIY kit to provide vendors with information on the best practices so they can compare them. Street vendors also lack access to cooling centres or lack sufficient information about them, the study found. For this reason, it is crucial that the HAP expand its reach and inform vendors about the facilities so that they can be used effectively, and heat stress can be avoided.

The Heat Action Plan should formulate its policies and campaigns based on similar studies where the risk perception, awareness and adaptive behaviours of identified vulnerable groups have been specifically studied. This will make the plan more comprehensive and effective to prevent the negative consequences of extreme heat.

5.4 DISCUSSION

In Nagpur, street vendors have high perceptions of heat risk, consistent with findings by Howe et al. (2019) indicating that populations living in warmer climates have higher perceptions of risk. A high level of exposure to heat may have reduced perception, but is not enough to hinder adaptation for most. Social factors like age, income, education etc. were found have very little impact on the heat risk perception in contrast to the findings of studies by Ban et al., 2017; Rauf et al., 2017; Liu et al., 2013; Williams et al., 2019 etc. Most likely, this is because all vendors are of similar social status and earn comparable incomes.

Likewise, no strong associations were observed for gender, in contrast to Akompab et al., 2013, Howe et al., 2019, Liu et al., 2013, Rauf et al., 2017, and Williams et al., 2019, which found that women perceive more heat risk than men. The current study found statistically strong associations between percieved vulnerability and heat risk perception, which do not support previous research by Howe et al., 2019; Lane et al., 2014; Liu et al., 2013; Williams et al., 2019. The study, however, was unable to find enough evidence to support Messeri et al. (2019) who reported that migrants perceive less heat.

This study finds that workers' feelings of helplessness and lack of autonomy make heat safety at work a lower priority, as observed in many cases during the study. This finding supports Singh et al.'s (2015) study from Australia. The study also confirms the association between HRP and occupational exposure to heat and chronic illness as found by Hass and Ellis, 2019b; Liu et al.,2013; Zander et al., 2017. Concern about family or vulnerable members within the family increased the heat risk perception which is in agreement with the findings of Akompab et al., 2013.

The study confirms the finding of large number of studies (Akompab et al., 2013a; Ban et al., 2017; Esplin et al., 2019; Hass and Ellis, 2019; Rauf et al., 2017; Zander et al., 2017) that the likelihood of adaptive behaviours increases when someone has experienced heat and heat health effects in the past or knows someone who has. The main reason why street vendors do not take adaptations was identified as "being used to the high temperatures" supporting the findings of Hass and Ellis, 2019b; Lane et al., 2014; Williams et al., 2019.

5.5 APPLICATIONS OF THE STUDY AND FURTHER AREAS OF RESEARCH

Below are some examples of how the study can be applied:

- In India, where such studies are rare, the study offers insight into the HRP over various groups of individuals.
- The study creates a framework for investigating climatic variables in relation to informal workforce.
- It confers the ability to broaden the Heat Action Plan's focus beyond only heat and vulnerability. It facilitates the refinement of a framework that connects the risk of exposure to excessive heat to the sensitive population and other population.
- The study goes into detail about bridging the gaps between institution/authority, objective meteorological parameter calculation, and individual risk perception.

This page intentionally left blank

APPENDIX

APPENDIX A1: OTC SURVEY QUESTIONNAIRE

Outdoor Thermal Comfort Survey Questionnaire

Date: Time: Place:

Gender: ☐ Male ☐ Female **Age:** ☐ ≤20 ☐ 21-35 ☐ 36-50 ☐ 51-65 ☐ 66-80 ☐ >80

1. How much time have you been outdoors?

☐ 0-10 min ☐ 10-20 min ☐ 20-30 min ☐ More than 30 min

Occupation?

☐ Informal Vendor ☐ Labour ☐ Other

2. What brings you to this neighbourhood?

☐ Live in neighbourhood ☐ Work in neighbourhood

☐ Both of them ☐ Neither of them

3. How often do you pass by this place?

☐ Daily ☐ A few times/weekly ☐ A few times/monthly ☐ Rarely ☐ First time

4. How do you spend your working hours?

☐ Indoor ☐ Outdoor ☐ Both

5. Where were you the last half hour?

☐ Outdoors in the sun ☐ Outdoors in shade ☐ Indoors without AC/cooler ☐ Indoors with AC/cooler

6. How did you spend the last half hour?

☐ Sitting ☐ Standing ☐ Walking ☐ Cycling/Riding ☐ Intense Activity

7. Would you prefer to spend half an hour in this environment?

☐ Yes ☐ No

8. How do you feel at this precise moment?

very cold	cold	cool	slightly cool	neither hot nor cold	slightly warm	warm	hot	very hot
☐	☐	☐	☐	☐	☐	☐	☐	☐

9. How comfortable do you feel at this precise moment?

comfor-table	slightly uncomfor-table	uncomfor-table	very uncomfor-table	extremely uncomfor-table
☐	☐	☐	☐	☐

10. Taking into account your personal preference only, would you accept rather than reject this climatic environment?

☐ Yes ☐ No

11. Is this environment, in your opinion...?

perfectly bearable	slightly difficult to bear	fairly difficult to bear	very difficult to bear	un-bearable
☐	☐	☐	☐	☐

12. How would you prefer the climate in this place?

Temperature

☐ Warmer ☐ No Change ☐ Cooler

Sun

☐ More Sunny ☐ No Change ☐ More Shady

Humidity

☐ More Humid ☐ No change ☐ Less Humid

Wind

☐ More Windy ☐ No Change ☐ Less Windy

13. Where do you prefer to spend your free time?

☐ Indoor ☐ Outdoor ☐ Both

14. What cooling system do you have at home?

☐ AC ☐ Cooler ☐ Fan ☐ None

15. What cooling system do you have at workplace?

☐ AC ☐ Cooler ☐ Fan ☐ None

16. What type of clothing do you wear?

☐ Shirt-Short Sleeves ☐ Shirt-Long Sleeves ☐ Shirt-Singlet Top

☐ Trousers-Shorts/Skirt ☐ Trousers Long ☐ Trousers-Bermuda

☐ Saree ☐ Footwear-Sandals ☐ Footwear-Shoes

☐ Jacket ☐ Sweater ☐ Umbrella

☐ Hat ☐ Other:

17. Clothing Colour?

☐ Light ☐ Dark ☐ Other:

18. Body Temperature:

This page intentionally left blank

APPENDIX A2: HRP SURVEY QUESTIONNAIRE

Section A. Sociodemographic Information

Q1. Gender
- a. Male
- b. Female

Q2. Occupation
- a. Fruit Vendor
- b. Vegetable Vendor
- c. Flower Vendor
- d. Food and Drinks Vendor (Lemonade. Fruit Juice, Cookies, Snacks, Grains, Spices)
- e. Metal Article Vendor
- f. Chai/Coffee/Pan Stall
- g. Clothes Vendor
- h. Clothing Accessories
- i. Books, Stationery and Paper
- j. Puncture & Repairing
- k. Autorickshaw
- l. Cart Puller/Handyman/Porters
- m. Miscellaneous (Disposables, Barber, Butcher, Cobbler, Band Musician, Pooja Samagri, Potter, Laundryman, Key Maker, Handmade Items, Mobile Accessories, Home Accessories, Scarp Vendor, Security Guard, Shoe Polish, Tailor)

Q3. Age
- a. ≤20
- b. 21-35
- c. 36-50
- d. 51-65
- e. 66-80

Q4. Highest Education
- a. No formal education
- b. Primary School (Till 4th)
- c. Middle School (Till 7th)
- d. High School (Till10th)
- e. Junior College (Till 12th)
- f. Undergraduate
- g. Postgraduate

Q5. Does your family have children below 15 or elders above 65?
- a. Yes
- b. No

Q6. Have you migrated to Nagpur?
- a. Yes
- b. No

Q7. If yes, where are you from?
- a. Madhya Pradesh
- b. Delhi

c. Rajasthan
d. Bihar
e. Chhattisgarh
f. Karnataka
g. Uttar Pradesh
h. Gujarat

Q8. Do you have any chronic illness?
a. Yes
b. No

Section B. Awareness, Sensitivity and Past Experience **(Knowledge of heat and related risks)**

Q9. How do you define heat/hot weather?
- When temperature rises above a certain threshold
- When changes are needed in normal behaviours or activities
- When discomfort is felt
- When health effects are experienced

Q10. Do you check the weather forecast daily before leaving your house?
a. Yes
b. No
c. Sometimes

Q11. Have you heard about “heatwaves” in the past?
a. Yes
b. No
c. Maybe

Q12. Have you ever experienced a heatwave?
a. Yes
b. No
c. Maybe

Q13. Do you receive heat warnings?
a. Yes
b. No

Q14. If yes, how did you get this information?
a. Past Experience
b. Word of mouth
c. Newspaper
d. Internet
e. TV/ Radio
f. Mobile broadcast

Q15. Did you ever have access to a training/awareness program for heat related risks?
a. Yes
b. No

Q16. In the past several years, did you feel the weather was hotter than before?

a. Yes
b. No
c. I don't know

Q17. Have you ever experienced a heat illness at work?

a. Yes
b. No

Q18. If yes, which have you experienced?

- ☐ Do not remember
- ☐ Heavy Sweating
- ☐ Cold, pale, clammy skin
- ☐ Heat Rash
- ☐ Nausea or vomiting
- ☐ Muscle cramps
- ☐ Tiredness or weakness
- ☐ Dizziness
- ☐ Headache
- ☐ Fainting
- ☐ Feeling hot
- ☐ Thirsty
- ☐ Cough
- ☐ Other:

Q19. If yes, what measures did you take to combat your heat-related illness?

Section C. Heat Risk Perception Variables

Perceived Aspect	Question	Response
LIKELIHOOD	How frequent do you think the heatwaves are in Nagpur?	• 1 (Never) • 2 (Rarely) • 3 (Sometimes) • 4 (Often) • 5 (Always)
SEVERITY	How severe do you think the heatwaves are in Nagpur?	• 1 (None) • 2 (Very Mild) • 3 (Mild) • 4 (Moderate) • 5 (Severe)
CONCERN / WORRY (HEALTH)	How dangerous are heat waves to your own health?	• 1 (Low) • 2 (Moderate) • 3 (Considerable) • 4 (High) • 5 (Severe)
	Are you concerned about heat related risks that can affect your family?	• Yes • No
	Are you concerned about heat related risks that can affect the community?	• Yes • No
CONCERN / WORRY (ECONOMIC)	Do you worry that extreme heat will affect your general expenses?	• Yes • Maybe • No
	Do you worry that extreme heat will affect your household expenses?	• Yes • Maybe • No
	Do you worry that extreme heat will affect your employment and productivity?	• Yes • Maybe • No
FEAR (HEALTH)	Are you scared of heat-health illnesses?	• Yes • Maybe • No
VULNERABILITY	Would you consider yourself to be vulnerable to extreme heat?	• Yes • No

Section D. Adaptive Measures and Protective Behaviours

Q20. Immediate environment of the vendor.

a. Unshaded
b. Partially Shaded
c. Completely Shaded

Q21. Describe your hydration frequency.

a. I drink plenty of fluids before starting work (0-1 liters)
b. I only drink when thirsty (1-2 liters)
c. I drink fluids regularly while at work (2-4 liters)
d. All of the above (4 liters and above)

Q22. Do you think you should adjust your work habits personally to reduce the risk of heat illnesses when working during very hot weather?

a. Don’t Know
b. No
c. Sometimes
d. Yes

Q23. Does a heat wave warning make a difference to your daily routine?

a. Yes
b. No

Q24. How often do you take adaptive measures when you step outside your home?

a. Always
b. Often
c. Sometimes
d. Rarely
e. Never

Q25. If yes, what measures do you take?

- Nothing
- Don’t know
- Wear appropriate clothing
- Modify diet
- Schedule outdoor activities carefully
- Change in work schedule
- Long lunch break to avoid noon heat
- Apply traditional methods (home made medicines)
- Stay hydrated
- Stay in shade or near coolth
- Check for updates in weather forecast
- Learn the signs and symptoms
- Other:

Q26. If no, why not?

a. The weather was not hot enough
b. Heat waves had no effect on me
c. I am used to the hot weather
d. I have no capacity to change my behaviors

Q27. What measures have you taken to modify your workspace?

- Sun Shade Net
- Umbrella
- Gunny Bags
- None
- Other:

Q28. Are the adaptive measures you take, satisfactory?

a. Yes
b. No
c. Maybe

Q29. Do you have a cooler at home?

a. Yes
b. No

Section E. Other

Q30. Would you say your job is physically demanding? (strenuous activity)

a. Yes
b. No
c. Sometimes

Q31. Duration of exposure to sun in a day.

a. 0-1 hour
b. 1-3 hours
c. 3-5 hours
d. More than 5 hours

Q32. Can you spend more time in this hot weather environment?

a. Yes, easily
b. Yes, but would be difficult
c. No

Q33. Does your occupation change throughout the year (depending on season)?

a. Yes
b. No

LIST OF ABBREVIATIONS

APMC Agricultural Produce Market Committee

ASHRAE American Society of Heating, Refrigerating and Air-Conditioning Engineers

AT Air Temperature

C Convective heat flow

CBD Central Business District

CIOMS Council for International Organizations of Medical Sciences

CMKT Cotton Market

CSO Central Statistical Organisation

DIY Do it yourself

E_{Re} Sum of heat flows to heat humidify the inspired air

ED Latent heat flow to evaporate water diffusing through the skin

E_{Sw} Heat flow resulting from sweat evaporation

GKP Gokulpeth

GPL Gopal Nagar

GT Grey Globe Temperature

HAP Heat Action Plan

HDPE High Density Polyethylene

HRP Heat Risk Perception

IK Indigenous Knowledge

ILO International Labour Organisation

IPCC Intergovernmental Panel on Climate Change

JYT Jaitala

LK Local knowledge

MEMI Munich energy balance model for individuals

MIDC Maharashtra Industrial Development Corporation

MRT Mean Radiant Temperature

MSME Medium, Small and Micro Enterprises/ Industries

MTSV Mean thermal sensation votes

NDMA National Disaster Management Authority

NMC Nagpur Municipal Corporation

NPET Neutral Physiological Equivalent Temperature

NPETR Neutral Physiological Equivalent Temperature Range

ORS Oral Rehydration Solution

OSHA Occupational Safety and Health Administration

OSH Occupational Safety and Health

OTC Objective Thermal Comfort

PET Physiological Equivalent Temperature

PHS Predicted Heat Strain

PPE Personal Protective Equipment

RH Relative Humidity

RTPL Rational Technologies Pvt. Limited

S Storage heat flow to heat or cool the body mass

SDG Sustainable Development Goals

SVF Sky View Factor

Ta Air Temperature

THI Temperature Humidity Index

Tmax Maximum temperature

Tmrt Mean radiant temprature

UHI Urban Heat Island

UTCI Universal Thermal Climatic Index

UV Ultra violet

V Air velocity

VP Vapour Pressure

WBGT Wet Bulb Globe Temperature

WHO World Health Organisation

WMO World Meteorological Organisation

BIBLIOGRAPHY

Abreu-Harbich, L.V., Labaki, L.C. and Matzarakis, A. (2013). Thermal bioclimate as a factor in urban and architectural planning in tropical climates—The case of Campinas, Brazil. *Urban Ecosystems*, 17(2), pp.489–500. doi:10.1007/s11252-013-0339-7.

Adger, W. & Dessai, Suraje & Goulden, Marisa & Hulme, Mike & Lorenzoni, Irene & Nelson, Don & Naess, Lars & Wolf, Johanna & Wreford, Anita. (2008). Are There Social Limits to Adaptation to Climate Change?. Climatic Change. 93. 335-354. 10.1007/s10584-008-9520-z.

AHMEDABAD HEAT ACTION PLAN 2016 GUIDE TO EXTREME HEAT PLANNING IN AHMEDABAD, INDIA EASY READ VERSION. (2016). [online] Available at: https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2016.pdf.

Akompab, D., Bi, P., Williams, S., Grant, J., Walker, I. and Augoustinos, M. (2012). Awareness of and Attitudes towards Heat Waves within the Context of Climate Change among a Cohort of Residents in Adelaide, Australia. *International Journal of Environmental Research and Public Health*, [online] 10(1), pp.1–17. doi:10.3390/ijerph10010001.

Alhadad, S.B., Tan, P.M.S. and Lee, J.K.W. (2019). Efficacy of Heat Mitigation Strategies on Core Temperature and Endurance Exercise: A Meta-Analysis.?*Frontiers in Physiology*, 10. doi:10.3389/fphys.2019.00071.

American Society Of Heating, Refrigerating And Air-Conditioning Engineers (2001). *2001 ASHRAE handbook : fundamentals.* Atlanta, Ga: American Society Of Heating, Refrigerating, And Air-Conditioning Engineers, Inc.

ASHRAE STANDARD 55-2004. (2004).

Bakhsh, K., Rauf, S. and Zulfiqar, F. (2018). Adaptation strategies for minimizing heat wave induced morbidity and its determinants.?*Sustainable Cities and Society*, 41, pp.95–103. doi:10.1016/j.scs.2018.05.021.

Banerjee, S., Middel, A. and Chattopadhyay, S. (2022). Validating ENVI-met for Relative Humidity (RH) in high-density temporary encroachment spaces in the streets of tropical Indian megacities. doi:10.5194/egusphere-egu22-3434.

Ban, J., Huang, L., Chen, C., Guo, Y., He, M.Z. and Li, T. (2017). Integrating new indicators of predictors that shape the public's perception of local extreme temperature in China. *Science of The Total Environment*, 579, pp.529–536. doi:10.1016/j.scitotenv.2016.11.064.

Beckmann, S.K. and Hiete, M. (2020). Predictors Associated with Health-Related Heat Risk Perception of Urban Citizens in Germany. *International Journal of Environmental Research and Public Health*, 17(3), p.874. doi:10.3390/ijerph17030874.

Bhargava, A., Lakmini, S. and Bhargava, S. (2017). Urban Heat Island Effect: It's Relevance in Urban Planning. *Journal of Biodiversity & Endangered Species*, [online] 05(02). doi:10.4172/2332-2543.1000187.

Bourbia, F. and Awbi, H.B. (2004). Building cluster and shading in urban canyon for hot dry climate. *Renewable Energy*, 29(2), pp.249–262. doi:10.1016/s0960-1481(03)00170-8.

Brooks, Nick & Adger, W. & Khan, S.. (2004). Assessing and enhancing adaptive capacity.

Brown, R.D., Vanos, J., Kenny, N. and Lenzholzer, S. (2015). Designing urban parks that ameliorate the effects of climate change. *Landscape and Urban Planning*, 138, pp.118–131. doi:10.1016/j.landurbplan.2015.02.006.

B.S. Iso 10551:1995. (n.d.).

Bunker, A., Wildenhain, J., Vandenbergh, A., Henschke, N., Rocklöv, J., Hajat, S. and Sauerborn, R. (2016). Effects of Air Temperature on Climate-Sensitive Mortality

and Morbidity Outcomes in the Elderly; a Systematic Review and Meta-analysis of Epidemiological Evidence.?*EBioMedicine*, [online] 6, pp.258–268. doi:10.1016/j.ebiom.2016.02.034.

Carvalho, A. (2007). Ideological cultures and media discourses on scientific knowledge: re-reading news on climate change. *Public Understanding of Science*, 16(2), pp.223–243. doi:10.1177/0963662506066775.

Chandran, R. (2016). Bonded laborers in India brick kilns slowly learn they have rights. *Reuters*. [online] 22 Mar. Available at: https://www.reuters.com/article/us-india-labour-bricks-idUSKCN0WO0D0 [Accessed 28 Oct. 2022].

Charalampopoulos, I., Tsiros, I., Chronopoulou-Sereli, A. and Matzarakis, A., 2013. Analysis of thermal bioclimate in various urban configurations in Athens, Greece. *Urban Ecosystems*, *16*(2), pp.217-233.

Chen, L., Wen, Y., Zhang, L. and Xiang, W.-N. (2015). Studies of thermal comfort and space use in an urban park square in cool and cold seasons in Shanghai. *Building and Environment*, 94, pp.644–653. doi:10.1016/j.buildenv.2015.10.020.

Cheung, P.K. and Jim, C.Y. (2017). Determination and application of outdoor thermal benchmarks. *Building and Environment*, 123, pp.333–350. doi:10.1016/j.buildenv.2017.07.008.

Coleman, J. (2022). Climate change made South Asian heatwave 30 times more likely. *Nature*. [online] doi:10.1038/d41586-022-01444-1.

Coppola, D.P. (2020).?Introduction to international disaster management. Amsterdam: Butterworth-Heinemann.

Costa, H., Floater, G., Hooyberghs, H., Verbeke, S. and De Ridder, K., 2016. Climate change, heatstress and labour productivity: A cost methodology for city economies. Centre for Climate Change Economics and Policy

Coutts, A.M., Beringer, J. and Tapper, N.J. (2007). Impact of Increasing Urban Density on Local Climate: Spatial and Temporal Variations in the Surface Energy Balance in Melbourne, Australia. *Journal of Applied Meteorology and Climatology*, 46(4), pp.477–493. doi:10.1175/jam2462.1.

Cutler, M.J., Marlon, J.R., Howe, P.D. and Leiserowitz, A. (2018). The Influence of Political Ideology and Socioeconomic Vulnerability on Perceived Health Risks of Heat Waves in the Context of Climate Change. *Weather, Climate, and Society*, [online] 10(4), pp.731–746. doi:10.1175/WCAS-D-17-0105.1.

Daniel, M., Lemonsu, A., Déqué, M., Somot, S., Alias, A. and Masson, V., 2019. Benefits of explicit urban parameterization in regional climate modeling to study climate and city interactions. *Climate Dynamics*, *52*(5), pp.2745-2764.

Das, M., Das, A. and Mandal, S. (2020). Outdoor thermal comfort in different settings of a tropical planning region: A study on Sriniketan-Santiniketan Planning Area (SSPA), Eastern India. *Sustainable Cities and Society*, 63, p.102433. doi:10.1016/j.scs.2020.102433.

Das, S., 2016. Television is More Effective in Bringing Behavioral Change: Evidence from Heat-Wave Awareness Campaign in India.?*World Development*, 88, pp.107-121.

De, B. and Mukherjee, M., 2017. Optimizing Street Canyon Orientation for Rajarhat Newtown, Kolkata, India. *Rigas Tehniskas Universitates Zinatniskie Raksti*, *21*(1), pp.5-17.

Deevi, B. and Chundeli, F.A. (2020). Quantitative outdoor thermal comfort assessment of street: A case in a warm and humid climate of India. *Urban Climate*, 34, p.100718. doi:10.1016/j.uclim.2020.100718.

Dellasala, D.A. and Goldstein, M.I. (2018). *Encyclopedia of the Anthropocene*. Oxford, Gb: Elsevier.

DERESSA, T., HASSAN, R. and RINGLER, C., 2010. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia.?*The Journal of Agricultural Science*, 149(1), pp.23-31.

Di Falco, S., Veronesi, M. and Yesuf, M. (2011). Does Adaptation to Climate Change Provide Food Security? A Micro-Perspective from Ethiopia.?*American Journal of Agricultural Economics*, 93(3), pp.829–846. doi:10.1093/ajae/aar006.

Dow, K., Berkhout, F., Preston, B.L., Klein, R.J.T., Midgley, G. and Shaw, M.R. (2013). Limits to adaptation. *Nature Climate Change*, 3(4), pp.305–307. doi:10.1038/nclimate1847.

Ebi, K.L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., Honda, Y., Kovats, R.S., Ma, W., Malik, A., Morris, N.B., Nybo, L., Seneviratne, S.I., Vanos, J. and Jay, O. (2021). Hot weather and heat extremes: health risks.?*The Lancet*, [online] 398(10301), pp.698–708. doi:10.1016/s0140-6736(21)01208-3.

Elnabawi, M.H. and Hamza, N. (2020). Outdoor Thermal Comfort: Coupling Microclimatic Parameters with Subjective Thermal Assessment to Design Urban Performative Spaces. *Buildings*, 10(12), p.238. doi:10.3390/buildings10120238.

El-Shafei, D.A., Bolbol, S.A., Awad Allah, M.B. and Abdelsalam, A.E. (2018). Exertional heat illness: knowledge and behavior among construction workers. *Environmental Science and Pollution Research*, 25(32), pp.32269–32276. doi:10.1007/s11356-018-3211-8.

Emmanuel, R. and Johansson, E. (2006). Influence of urban morphology and sea breeze on hot humid microclimate: the case of Colombo, Sri Lanka. *Climate Research*, 30, pp.189–200. doi:10.3354/cr030189.

Emmanuel, R., Rosenlund, H. and Johansson, E., 2007. Urban shading—a design option for the tropics? A study in Colombo, Sri Lanka. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *27*(14), pp.1995-2004.

Encyclopedia of Environmental Health (Second Edition). (2019). Elsevier Uuuu-Uuuu, p.573.

Esplin, E.D., Marlon, J.R., Leiserowitz, A. and Howe, P.D. (2019). 'Can You Take the Heat?' Heat-Induced Health Symptoms Are Associated with Protective Behaviors. *Weather, Climate, and Society*, 11(2), pp.401–417. doi:10.1175/wcas-d-18-0035.1.

Fanger, P.O., 1972. Thermal comfort. Analysis and applications in environmental engineering. *Thermal comfort. Analysis and applications in environmental engineering.*

G, L. and M, M. (2016). *Climate change and extreme heat events*. [online] National Library of Medicine. Available at: https://pubmed.ncbi.nlm.nih.gov/18929969/.

Hancock, P.A., Ross, J.M. and Szalma, J.L. (2007). A Meta-Analysis of Performance Response Under Thermal Stressors. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 49(5), pp.851–877. doi:10.1518/001872007x230226.

Han, SR., Wei, M., Wu, Z.?*et al.*?Perceptions of workplace heat exposure and adaption behaviors among Chinese construction workers in the context of climate change.?*BMC Public Health*?21, 2160 (2021). https://doi.org/10.1186/s12889-021-12231-4

Hass, A.L. and Ellis, K.N. (2019). Motivation for Heat Adaption: How Perception and Exposure Affect Individual Behaviors During Hot Weather in Knoxville, Tennessee. *Atmosphere*, 10(10), p.591. doi:10.3390/atmos10100591.

Heat Stress University of Tennessee Safety Guide IH-020. (2016). [online] Available at: https://ehs.utk.edu/wp-content/uploads/2018/03/IH-020-Heat-Stress.pdf [Accessed 28 Oct. 2022].

Heng, S.L. and Chow, W.T.L. (2019). How 'hot' is too hot? Evaluating acceptable outdoor thermal comfort ranges in an equatorial urban park. *International Journal of Biometeorology*, 63(6), pp.801–816. doi:10.1007/s00484-019-01694-1.

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

Horton, R.M., Mankin, J.S., Lesk, C., Coffel, E. and Raymond, C. (2016). A Review of Recent Advances in Research on Extreme Heat Events. *Current Climate Change Reports*, 2(4), pp.242–259. doi:10.1007/s40641-016-0042-x.

Howe, P.D., Marlon, J.R., Wang, X. and Leiserowitz, A. (2019). Public perceptions of the health risks of extreme heat across US states, counties, and neighborhoods. *Proceedings of the National Academy of Sciences*, [online] 116(14), pp.6743–6748. doi:10.1073/pnas.1813145116.

Howe, P., Marlon, J., Wang, X. and Leiserowitz, A., 2019. Public perceptions of the health risks of extreme heat across US states, counties, and neighborhoods. Proceedings of the National Academy of Sciences, 116(14), pp.6743-6748.

https://www.nmc.org.in/. (2015). *City Development Plan for Nagpur, 2041*. [online] Available at: https://www.nmcnagpur.gov.in/assets/250/2018/10/mediafiles/Final_CDP_Nagpur_-Mar_15.pdf.

Huang, L., Yang, Q., Li, J., Chen, J., He, R., Zhang, C., Chen, K., Dong, S.G. and Liu, Y. (2017). Risk perception of heat waves and its spatial variation in Nanjing, China. *International Journal of Biometeorology*, 62(5), pp.783–794. doi:10.1007/s00484-017-1480-4.

Höppe, P. (1999). The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. *International Journal of Biometeorology*, 43(2), pp.71–75. doi:10.1007/s004840050118.

Ignatowski, J.A. and Rosales, J. (2013). Identifying the exposure of two subsistence villages in Alaska to climate change using traditional ecological knowledge. *Climatic Change*, 121(2), pp.285–299. doi:10.1007/s10584-013-0883-4.

IH.?Zhi-hui,?L.?Tao,?X.?Yan-jun,?S.?Xiu-ling,?Y.?Qing-hua,?X.?Hui-yan?et al. ,2013. Investigation on adaptation behaviors to heat wave and its relative factors in residents of Guangdong Province . South China Journal of Preventive Medicine,?39?(2013), pp.?12-17

Improving the SDG energy poverty targets: Residential cooling needs in the Global South. (2019).?*Energy and Buildings*, [online] 186, pp.405–415. doi:10.1016/j.enbuild.2019.01.015.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of theIntergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

IPCC, 2022: *Climate Change 2022: Impacts, Adaptation, and Vulnerability.* Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

ISO 7726. (1998).

Jamei, E., Rajagopalan, P., Seyedmahmoudian, M. and Jamei, Y. (2016). Review on the impact of urban geometry and pedestrian level greening on outdoor thermal comfort. *Renewable and Sustainable Energy Reviews*, 54, pp.1002–1017. doi:10.1016/j.rser.2015.10.104.

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

Jones L, Boyd E. Exploring social barriers to adaptation: insights from western Nepal. Global Environmental Change 2011;21:1262–74

Kariminia, S., Shamshirband, S., Motamedi, S., Hashim, R. and Roy, C. (2016). A systematic extreme learning machine approach to analyze visitors′ thermal comfort at a public urban space. *Renewable and Sustainable Energy Reviews*, 58, pp.751–760. doi:10.1016/j.rser.2015.12.321.

Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M. and Hyatt, O. (2016). Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. *Annual Review of Public Health*, 37(1), pp.97–112. doi:10.1146/annurev-publhealth-032315-021740.

Klinke, A. and Renn, O. (2002). A New Approach to Risk Evaluation and Management: Risk□Based, Precaution□Based, and Discourse□Based Strategies
1. *Risk Analysis*, [online] 22(6), pp.1071–1094. doi:10.1111/1539-6924.00274.

Krauß, W. and Bremer, S. (2020). The role of place-based narratives of change in climate risk governance.?*Climate Risk Management*, p.100221. doi:10.1016/j.crm.2020.100221.

Kántor, N. (2016). Differences between the evaluation of thermal environment in shaded and sunny position. *Hungarian Geographical Bulletin*, 65(2), pp.139–153. doi:10.15201/hungeobull.65.2.5.

Kántor, N., Égerházi, L. and Unger, J. (2012). Subjective estimation of thermal environment in recreational urban spaces—Part 1: investigations in Szeged, Hungary. *International Journal of Biometeorology*, 56(6), pp.1075–1088. doi:10.1007/s00484-012-0523-0.

Kántor, N., Unger, J. and Gulyás, Á. (2012). Subjective estimations of thermal environment in recreational urban spaces—Part 2: international comparison. *International Journal of Biometeorology*, 56(6), pp.1089–1101. doi:10.1007/s00484-012-0564-4.

Kumar, P. and 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), pp.77–92. doi:10.11113/ijbes.v8.n3.786.

Kumar, P. and Sharma, A. (2022). Assessing the outdoor thermal comfort conditions of exercising people in the semi-arid region of India. *Sustainable Cities and Society*, [online] 76, p.103366. doi:10.1016/j.scs.2021.103366.

Lancet Countdown. (2022). *1.1.1: Exposure to Warming*. [online] Available at: https://www.lancetcountdown.org/data-platform/health-hazards-exposures-and-impacts/1-1-health-and-heat/1-1-1-heat-vulnerability [Accessed 27 Oct. 2022].

Lane, K., Wheeler, K., Charles-Guzman, K., Ahmed, M., Blum, M., Gregory, K., Graber, N., Clark, N. and Matte, T. (2013). Extreme Heat Awareness and Protective Behaviors in New York City. *Journal of Urban Health*, 91(3), pp.403–414. doi:10.1007/s11524-013-9850-7.

Lao J, Hansen A, Nitschke M, Hanson-Easey S, Pisaniello D. Working smart: an exploration of council workers' experiences and perceptions of heat in Adelaide. Saf Sci. 2016;82:228–35.?https://doi.org/10.1016/j.ssci.2015.09.026.

Lin, T.P. and Matzarakis, A., 2008. Tourism climate and thermal comfort in Sun Moon Lake,

Taiwan. *International journal of biometeorology*, *52*(4), pp.281-290.

Lin, T.P., Matzarakis, A. and Hwang, R.L., 2010. Shading effect on long-term outdoor thermal comfort. *Building and environment*, *45*(1), pp.213-221.

Liu, T., Xu, Y.J., Zhang, Y.H., Yan, Q.H., Song, X.L., Xie, H.Y., Luo, Y., Rutherford, S., Chu, C., Lin, H.L. and Ma, W.J. (2013). Associations between risk perception, spontaneous adaptation behavior to heat waves and heatstroke in Guangdong province, China. *BMC Public Health*, 13(1). doi:10.1186/1471-2458-13-913.

Liu, Z., Cheng, W., Jim, C.Y., Morakinyo, T.E., Shi, Y. and Ng, E. (2021). Heat mitigation benefits of urban green and blue infrastructures: A systematic review of modeling techniques, validation and scenario simulation in ENVI-met V4. *Building and Environment*, 200, p.107939. doi:10.1016/j.buildenv.2021.107939.

Löf, A., 2006. More than meets the eye? Exploring how social constructions impact adaptive capacity to climate change.?*Unpublished Masters Thesis, Centre for Transdisciplinary Environmental Research, Stockholm University*.

Lohrey, S., Chua, M., Gros, C., Faucet, J. and Lee, J.K.W. (2021). Perceptions of heat-health impacts and the effects of knowledge and preventive actions by outdoor workers in Hanoi, Vietnam. *Science of The Total Environment*, 794, p.148260. doi:10.1016/j.scitotenv.2021.148260.

Luber, G. and McGeehin, M. (2008). Climate Change and Extreme Heat Events. *American Journal of Preventive Medicine*, [online] 35(5), pp.429–435. doi:10.1016/j.amepre.2008.08.021.

Lundgren-Kownacki, K., Hornyanszky, E.D., Chu, T.A., Olsson, J.A. and Becker, P. (2018). Challenges of using air conditioning in an increasingly hot climate. *International Journal of Biometeorology*, [online] 62(3), pp.401–412. doi:10.1007/s00484-017-1493-z.

Madrigano, J., Lane, K., Petrovic, N., Ahmed, M., Blum, M. and Matte, T. (2018). Awareness, Risk Perception, and Protective Behaviors for Extreme Heat and Climate Change in New York City. *International Journal of Environmental Research and Public Health*, 15(7), p.1433. doi:10.3390/ijerph15071433.

Manavvi, S. and Rajasekar, E. (2021). Evaluating outdoor thermal comfort in 'Haats' – The open air markets in a humid subtropical region. *Building and Environment*, 190, p.107527. doi:10.1016/j.buildenv.2020.107527.

Matzarakis, A., Mayer, H. (1996) Another Kind of Environmental Stress: Thermal Stress. WHOColloborating Centre for Air Quality Management and Air Pollution Control. NEWSLETTERS18: 7-10.

Matzarakis, A., Mayer, H., and Iziomon, M.G. (1999) Applications of a universal thermal index:physiological equivalent temperature, Int. J. Biometeorol. 43: 76-84.

Matzarakis, A., Rutz, F. and Mayer, H., 2007. Modelling radiation fluxes in simple and complex environments—application of the RayMan model. *International journal of biometeorology*, *51*(4), pp.323-334.

Mayer, H. and Hoppe, P. (1987). Thermal comfort of man in different urban environments. *Theoretical and Applied Climatology*, 38(1), pp.43–49. doi:10.1007/bf00866252.

Mellegård, V. and Boonstra, W.J. (2020). Craftsmanship as a Carrier of Indigenous and Local Ecological Knowledge: Photographic Insights from Sámi Duodji and Archipelago Fishing. *Society & Natural Resources*, 33(10), pp.1252–1272. doi:10.1080/08941920.2020.1729911.

Mills, G. (2014). Urban climatology: History, status and prospects. *Urban Climate*, 10, pp.479–489. doi:10.1016/j.uclim.2014.06.004.

Monirul Islam, M., Sallu, S., Hubacek, K., & Paavola, J. (2014).?*Limits and barriers to adaptation to climate variability and change in Bangladeshi coastal fishing communities.*

Marine Policy, 43, 208–216.?doi:10.1016/j.marpol.2013.06.007

Moser, S. and Ekstrom, J., 2010. A framework to diagnose barriers to climate change adaptation.?*Proceedings of the National Academy of Sciences*, 107(51), pp.22026-22031.

Nasrollahi, N., Namazi, Y. and Taleghani, M., 2021. The effect of urban shading and canyon geometry on outdoor thermal comfort in hot climates: A case study of Ahvaz, Iran. *Sustainable Cities and Society*, *65*, p.102638.

NATIONAL DISASTER MANAGEMENT PLAN NATIONAL DISASTER MANAGEMENT AUTHORITY MINISTRY OF HOME AFFAIRS GOVERNMENT OF INDIA. (2019). [online] Available at: https://ndma.gov.in/sites/default/files/PDF/ndmp-2019.pdf.

Ndetto, E.L. and Matzarakis, A. (2016). Assessment of human thermal perception in the hot-humid climate of Dar es Salaam, Tanzania. *International Journal of Biometeorology*, 61(1), pp.69–85. doi:10.1007/s00484-016-1192-1.

Ng, E. and Cheng, V. (2012). Urban human thermal comfort in hot and humid Hong Kong. *Energy and Buildings*, 55, pp.51–65. doi:10.1016/j.enbuild.2011.09.025.

Ngwenya, B. (2018). Heat Stress and Adaptation Strategies of Outdoors Workers in the City of Bulawayo, Zimbabwe.?*Community Medicine and Public Health Care*, 5(1), pp.1–6. doi:10.24966/cmph-1978/100034.

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

NIOSH [2016]. NIOSH criteria for a recommended standard: occupational exposure to heat and hotenvironments. By Jacklitsch B, Williams WJ, Musolin K, Coca A, Kim J-H, Turner N. Cincinnati,OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention,National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication 2016-106.

Nunez, M. and Oke, T.R., 1977. The energy balance of an urban canyon. *Journal of Applied Meteorology and Climatology*, *16*(1), pp.11-19.

Ohman, S. (2017). Previous Experiences and Risk Perception: The Role of Transference. *Journal of Education, Society and Behavioural Science*, 23(1), pp.1–10. doi:10.9734/jesbs/2017/35101.

Oke, T.R., Mills, G., Christen, A. and Voogt, J.A. (2017). Urban Climates. *Urban Climates*. [online] doi:10.1017/9781139016476.

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M. and Solecki, W. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century.?*Global Environmental Change*, [online] 42, pp.169–180. doi:10.1016/j.gloenvcha.2015.01.004.

On, P. and On, P. (2008). *Climate change 2007 : impacts, adaptation and vulnerability : Working Group II contribution to the Fourth Assessment Report of the IPCC Intergovernmental Panel on Climate Change.* Geneva: Ipcc Secretariat.

Osborne, M. (2022). *'Zoe' Becomes the World's First Named Heat Wave*. [online] Smithsonian Magazine. Available at: https://www.smithsonianmag.com/smart-news/zoe-becomes-the-worlds-first-named-heat-wave-180980512/#:~:text=Zoe%20follows%20an%20extreme%20heat [Accessed 27 Oct. 2022].

Othman, H.A.S. and Alshboul, A.A. (2020). The role of urban morphology on outdoor thermal comfort: The case of Al-Sharq City – Az Zarqa. *Urban Climate*, 34, p.100706. doi:10.1016/j.uclim.2020.100706.

Peng, L. and Jim, C. (2013). Green-Roof Effects on Neighborhood Microclimate and Human Thermal Sensation. *Energies*, 6(2), pp.598–618. doi:10.3390/en6020598.

Perini, K. and Magliocco, A. (2014). Effects of vegetation, urban density, building height, and atmospheric conditions on local temperatures and thermal comfort. *Urban Forestry & Urban Greening*, [online] 13(3), pp.495–506. doi:10.1016/j.ufug.2014.03.003.

Priyadarsini, R., Hien, W.N. and Wai David, C.K. (2008). Microclimatic modeling of the urban thermal environment of Singapore to mitigate urban heat island. *Solar Energy*, 82(8), pp.727–745. doi:10.1016/j.solener.2008.02.008.

Rajan, E.H.S. and Amirtham, L.R. (2021). Urban heat island intensity and evaluation of outdoor thermal comfort in Chennai, India. *Environment, Development and Sustainability*. doi:10.1007/s10668-021-01344-w.

Rauf, S., Bakhsh, K., Abbas, A., Hassan, S., Ali, A. and Kächele, H. (2017). How hard they hit? Perception, adaptation and public health implications of heat waves in urban and peri-urban Pakistan. *Environmental Science and Pollution Research*, [online] 24(11), pp.10630–10639. doi:10.1007/s11356-017-8756-4.

Reid, C.E., O'Neill, M.S., Gronlund, C.J., Brines, S.J., Brown, D.G., Diez-Roux, A.V. and Schwartz, J. (2009). Mapping Community Determinants of Heat Vulnerability. *Environmental Health Perspectives*, 117(11), pp.1730–1736. doi:10.1289/ehp.0900683.

Renn, O. and Klinke, A. (2013). A Framework of Adaptive Risk Governance for Urban Planning. *Sustainability*, 5(5), pp.2036–2059. doi:10.3390/su5052036.

Rodríguez Algeciras, J.A. and Matzarakis, A. (2015). Quantification of thermal bioclimate for the management of urban design in Mediterranean climate of Barcelona, Spain. *International Journal of Biometeorology*, 60(8), pp.1261–1270. doi:10.1007/s00484-015-1121-8.

Romanello, M., McGushin, A., Napoli, C.D., Drummond, P., Hughes, N., Jamart, L., Kennard, H., Lampard, P., Rodriguez, B.S., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Chu, L., Ciampi, L., Dalin, C. and Dasandi, N. (2021). The 2021 report of the Lancet Countdown on health and climate change: code red for a healthy future. The Lancet, [online] 0(0). doi:10.1016/S0140-6736(21)01787-6.

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/.

Salata, F., Golasi, I., de Lieto Vollaro, R. and de Lieto Vollaro, A. (2016). Outdoor thermal comfort in the Mediterranean area. A transversal study in Rome, Italy. *Building and Environment*, 96, pp.46–61. doi:10.1016/j.buildenv.2015.11.023.

Seepana, P. (2022). *URBAN STREET VENDORS IN INDIA*. Academic Foundation, New Delhi.

Sett, M. and Sahu, S. (2014). Effects of occupational heat exposure on female brick workers in West Bengal, India. *Global Health Action*, 7(1), p.21923. doi:10.3402/gha.v7.21923.

Sharmin, T. and Steemers, K. (2018). Effects of microclimate and human parameters on outdoor thermal sensation in the high-density tropical context of Dhaka. *International Journal of Biometeorology*, 64(2), pp.187–203. doi:10.1007/s00484-018-1607-2.

Singh, R., Arrighi, J., Jjemba, E., Strachan, K., Spires, M., Kadihasanoglu, A., Heatwave Guide for Cities. 2019.

Singh, S., Hanna, E.G. and Kjellstrom, T. (2013). Working in Australia's heat: health promotion concerns for health and productivity. *Health Promotion International*, 30(2), pp.239–250. doi:10.1093/heapro/dat027.

Slovic, P. (2015). Understanding Perceived Risk: 1978–2015. *Environment: Science and Policy for Sustainable Development*, 58(1), pp.25–29. doi:10.1080/00139157.2016.1112169.

Slovic, P., Fischhoff, B. and Lichtenstein, S., 1982. Why Study Risk Perception?. Risk Analysis, 2(2), pp.83-93.

S, M. and Rajasekar, E. (2022). Evaluating outdoor thermal comfort in urban open spaces in a humid subtropical climate: Chandigarh, India. *Building and Environment*, 209, p.108659. doi:10.1016/j.buildenv.2021.108659.

Spagnolo, J. and de Dear, R. (2003). A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia. *Building and Environment*, 38(5), pp.721–738. doi:10.1016/s0360-1323(02)00209-3.

Stanberry, L.R., Thomson, M.C. and James, W. (2018). Prioritizing the needs of children in a changing climate. *PLOS Medicine*, 15(7), p.e1002627. doi:10.1371/journal.pmed.1002627.

Stocker TF, Qin D, Plattner G-K, et al. Climate change 2013: the physical science basis. UK and New York, NY: Cambridge University Press, 2013; 1535.

Sun, C., Lian, W., Liu, L., Dong, Q. and Han, Y., 2022. The impact of street geometry on outdoor thermal comfort within three different urban forms in severe cold region of China. *Building and Environment*, *222*, p.109342.

Tambo, J.A. and Abdoulaye, T. (2012). Smallholder farmers' perceptions of and adaptations to climate change in the Nigerian savanna.?*Regional Environmental Change*, 13(2), pp.375–388. doi:10.1007/s10113-012-0351-0.

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

Toloo, G., FitzGerald, G., Aitken, P., Verrall, K. and Tong, S. (2013). Are heat warning systems effective? *Environmental Health*, 12(1). doi:10.1186/1476-069x-12-27.

Turek-Hankins, L.L., de Perez, E.C., Scarpa, G., Ruiz-Diaz, R., Shwerdtle, P.N., Joe, E.T., Galappaththi, E.K., French, E.M., Austin, S.E., Singh, C., Siña, M., Siders, A.R., van Aalst, M.K., Templeman, S., Nunbogu, A.M., Berrang-Ford, L., Agrawal, T. and Mach, K.J. (2021). Climate change adaptation to extreme heat: A global systematic review of implemented action.?*Oxford Open Climate Change*. doi:10.1093/oxfclm/kgab005.

Turek-Hankins, L.L., de Perez, E.C., Scarpa, G., Ruiz-Diaz, R., Shwerdtle, P.N., Joe, E.T., Galappaththi, E.K., French, E.M., Austin, S.E., Singh, C., Siña, M., Siders, A.R., van Aalst, M.K., Templeman, S., Nunbogu, A.M., Berrang-Ford, L., Agrawal, T. and Mach, K.J. (2021). Climate change adaptation to extreme heat: A global systematic review of implemented action. *Oxford Open Climate Change*, 1(1). doi:10.1093/oxfclm/kgab005.

United Nations Environment Programme (2021). Adaptation Gap Report 2021: The gathering storm – Adapting to climatechange in a post-pandemic world. Nairobi.

United Nations Office for Disaster Risk Reduction (2022). Global Assessment Report on Disaster Risk Reduction 2022: Our World at Risk: Transforming Governance for a Resilient Future. Geneva.

van der Linden, S. (2015). The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology*, [online] 41, pp.112–124. doi:10.1016/j.jenvp.2014.11.012.

vcd: Visualizing Categorical Data. R package version 1.4-10.

Wilhelmi, O.V. and Hayden, M.H. (2010). Connecting people and place: a new framework for reducing urban vulnerability to extreme heat. *Environmental Research Letters*, 5(1), p.014021. doi:10.1088/1748-9326/5/1/014021.

Williams, S., Hanson-Easey, S., Nitschke, M., Howell, S., Nairn, J., Beattie, C., Wynwood, G. and Bi, P. (2018). Heat-health warnings in regional Australia: examining public perceptions and responses. *Environmental Hazards*, 18(4), pp.287–310. doi:10.1080/1747

7891.2018.1538867.

Working on a WARMER planet. (2019). [online] Available at: https://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_711919.pdf.

Wilson, R., Zwickle, A. and Walpole, H., 2018. Developing a Broadly Applicable Measure of Risk Perception. Risk Analysis, 39(4), pp.777-791.

Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work, International Labour Organization, Geneva (2019)

World Health Organization (2021). *Climate change and health*. [online] who.int. Available at: https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health.

World Health Organization (2022). *Heatwaves*. [online] www.who.int. Available at: https://www.who.int/health-topics/heatwaves#tab=tab_1.

World Health Organization and Council For International Organizations Of Medical Sciences (2017). *International ethical guidelines for health-related research involving humans*. Geneva: Cioms.

www.osha.gov. (n.d.). *Heat - Case Studies | Occupational Safety and Health Administration*. [online] Available at: https://www.osha.gov/heat-exposure/case-studies.

www.sciencedirect.com. (n.d.). *World Meteorological Organization - an overview | ScienceDirect Topics*. [online] Available at: https://www.sciencedirect.com/topics/earth-and-planetary-sciences/world-meteorological-organization [Accessed 27 Oct. 2022].

Yahia, M.W. and Johansson, E. (2012). Evaluating the behaviour of different thermal indices by investigating various outdoor urban environments in the hot dry city of Damascus, Syria. *International Journal of Biometeorology*, 57(4), pp.615–630. doi:10.1007/s00484-012-0589-8.

Young, E., 1998. Dealing with hazards and disasters: risk perception and community participation in management. *Australian Journal of Emergency Management, The*, *13*(2), pp.14-16.

Zander, K.K., Moss, S.A. and Garnett, S.T. (2017). Drivers of self-reported heat stress in the Australian labour force. *Environmental Research*, 152, pp.272–279. doi:10.1016/j.envres.2016.10.029.

Zaninović, K. and Matzarakis, A. (2009). The bioclimatological leaflet as a means conveying climatological information to tourists and the tourism industry. *International Journal of Biometeorology*, 53(4), pp.369–374. doi:10.1007/s00484-009-0219-2.