Gendered Approach for addressing adaptation capacity to hot weather conditions in Delhi

Final Report

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Abstract	
This project examines women commuters' exposure to high temperatures, focusing on mothers with caregiving responsibilities and limited transport options in Delhi. Findings reveal significant disparities in adaptation capacity by gender and income, with lower-income women experiencing the highest exposure. Through participatory workshops, the study proposes strategies like shaded pathways, green infrastructure, and public awareness to support gender-sensitive climate adaptation in transportation.	
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Contents

Acronyms

AMBI KIT	A toolkit created for gendered adaptation to hot weather conditions.
CCTV	Closed Circuit Television
FCDO	Foreign, Commonwealth & Development Office
HI	Heat Index
HVT	High Volume Transport
IDE	Integrated Development Environment
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LMIC	Low and Middle Income Countries
LST	Land Surface Temperature
MTW	Motorized Two Wheelers
NRDC	Natural Resources Defense Council
RTC	Real Time Clock
UKAID	United Kingdom Aid
UNISDR	United Nations International Strategy for Disaster Reduction
WHO	World Health Organization

Abstract

The project aims to understand the level of exposure of women commuters to high temperatures while trying to access multiple opportunities and the likely adaptation capacity they have. The study specifically focusses on mothers of school-going children who experience heightened vulnerability due to interdependence between household members, increasing caregiving roles, and limited access to motorized transport.

Data were collected through infrastructure audits (walkability, green infrastructure, and shading index), stationart thermal sensors (ambient temperature and relative humidity), CCTV footage (traffic volume count including for pedestrians and bicycles), and repeated surveys (demographic, socioeconomic, and travel characteristics) across comfortable and hot seasons. Walkability score is measured considering safe walking, comfortable working and availability of dedicated walk infrastructure.

Key findings

- **Gender and Income Disparity:** Significant disparity in adaptive capacity exists, with lower-income women facing the highest exposure due to their dependency on walking and limited ability to alter travel choices.
- **Street-Level Variations:** Ambient temperatures and walkability scores vary significantly across streets, with walkability defined by safety from traffic and pedestrian-friendly conditions.

Through participatory workshops, individual-, community-, and government-led strategies were developed to mitigate heat exposure. The key recommendations include –

- **Enhance Shaded Pedestrian Pathways:** Implement shading solutions such as tree canopies, awnings, or shaded walkways to protect pedestrians from heat exposure.
- **Expand Green Infrastructure:** Increase urban greenery, including parks, roadside vegetation, and vertical gardens, to reduce ambient temperatures and improve walkability.
- **Promote Public Awareness:** Launch campaigns to educate the public on adaptive behaviours to mitigate heat exposure during travel.
- **Inclusive and Gender-Sensitive Policies:** Advocate for climate adaptation policies that address the transportation needs of vulnerable groups, particularly women and lower-income communities, during extreme heat.
- **Collaborative Mitigation Strategies:** Employ strategies developed through participatory workshops involving individuals, communities, and government entities to ensure comprehensive solutions to heat exposure.

A shorter policy brief summarising the key findings and recommendations of this study is available here.

Note: The raw data underlying the findings presented in this report is not included due to its extensive volume. Interested readers may contact the project lead, Dr. Deepty Jain, for further discussion.

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1. Introduction

Increasing climate change is leading to rising global temperatures and extreme weather events including higher temperatures and increasing frequency of heat wave events. According to the World Health Organization (2024a), 125 million people were additionally exposed to heat waves between 2006 and 2016. Heat waves can be defined as the conditions of high temperatures, exposure to which can cause morbidity or mortality. In Indian conditions, a heatwave is to be declared when the actual maximum temperature remains 45°C or more, for at least 2 consecutive days irrespective of the normal maximum temperature (World Health Organization, 2024b). Indian cities have recently experienced an increased number of hot days during the summer, affecting the quality of life. Extreme weather events contributed to 6.62 deaths per million people annually between 2001 and 2014 in Delhi, of which 50% were attributed to heat waves (Mahapatra et al., 2018).

Exposure to extremely high temperatures can lead to heat-related illnesses such as heat cramps, heat exhaustion, and heat stroke. This shall impact travel activity and affect infrastructure integrity.

The transport sector is one of the significant contributors to climate change but is also a critical sector that is significantly affected by climate change (Abad et al., 2020; Böcker et al., 2016; IEA, 2021; Zou et al., 2021). The exposure of transport users to high temperatures depends on the type of mode being used, the duration of exposure and the location (Yasumoto et al., 2019). Disaster risk is an outcome of the interaction between hazard level, exposure to the hazard, and vulnerability of people to the hazard (UNISDR, 2015).

In this equation, both the hazard level and exposures are easier to control than the population's vulnerability. This would require adopting mitigation and adaptation strategies (Park et al., 2018; Yasumoto et al., 2019). Mitigation strategies shall include upscaling green and blue infrastructure (Herath et al., 2018), landscaping strategies (Magotra, 2020; Park et al., 2018), provisioning shaded road networks (Dzyuban et al., 2022), changing infrastructure design (Fraser & Chester, 2017; Miao et al., 2019) and changing surface material (Markolf et al., 2019). Adaptation shall include altering choices and lifestyles to reduce exposure and health impacts. The choices are changing mode of transport, changing occupations, staying indoors or cancelling trips, and adopting climate-controlling devices (Böcker et al., 2019; Jain & Singh, 2021; NRDC International India, 2022; Rosenthal et al., 2022).

1.1 Introduction

Women participation in work related activities in Indian cities is less than men (Goel, 2023). They tend to walk more, travel shorter distances and have limited access to public and motorized transport (Jain & Tiwari, 2020; Mahadevia & Advani, 2016). This results in higher exposure of women to hot weather conditions than men. Multiple factors contribute to their vulnerabilities. First, women have limited access to vehicles or motorised vehicles because of limited license ownership and social-cultural norms restrict the usage of certain modes like bicycles and two-wheelers (Buehler & Goel, 2022).

They are majorly dependent on walking to meet their travel needs (Jain & Tiwari, 2020). Secondly, because women take more of household caring and child-rearing responsibilities, they incur short but frequent and complex trips throughout the day (Rosenbloom, 2021). Such activities may include dropping off/picking up children, shopping for daily needs and elder-care responsibilities. The time of travel and travel choices are altered to meet the multiple roles (Manoj & Verma, 2015). With limited resources and multiple responsibilities, women tend to have limited flexibilities and, therefore, limited adaptation capacities.

Physiological Sensitivity	Different physiological responses to heat compared to men, affecting their comfort and health during travel.
Higher dependencies on walking	Higher reliability on walking as their mode of transportation, resulting in greater exposure to environmental conditions like heat.
Daytime Travel Patterns	Engagement in caregiving roles that necessitate travel during daytime, when heat exposure is higher.
Driving Ability and Preferences	Limited driving skills or preferences, influencing their reliance on walking or public transit
Vehicle Ownership Disparities	lower vehicle ownership rates or less access to vehicles within a household, making them more reliant on walking or public transportation
Restricted Mobility Choices	Social, economic, or cultural factors may limit women's ability to choose cooler travel times

Figure 1: Why risk of women to high temperatures while travelling are higher?

1.2 Delhi in context

Delhi is located in North India near Aravalli range, Thar desert and the Himalayan range. The city experiences seasonal variability ranging from hot summers with a mean maximum temperature of 39.5°C and cold winters with a mean minimum temperature of 6.3°C (Sahay, 2018). In the year 2019, 17 days had a maximum temperature of more than 44°C that increased to 31 days in 2022.

As per Delhi Master Plan 2041, 35% of the trips are catered by walk in the city. Women particularly have limited choice of motorized vehicles to meet their mobility needs and are majorly walking in the city (Census of India, 2011).

Research to date has established the variation in thermal comfort conditions by street typologies, studied the variation in thermal comfort conditions of commuters and assessed adaptation behaviour of people during hot weather conditions. Such studies help in identifying priority locations to address thermal discomfort (Yin et al., 2021), in identifying potential heat mitigation solutions on streets to enhance walkability (Jia & Wang, 2021) and understanding potential travel choice adaptation during hot weather conditions (Y. Yang et al., 2022).

However, there is limited understanding of the exposure of commuters to hot weather conditions in arid and semi-arid regions in LMIC and the adaptation practices adopted by commuters to minimize exposure in extreme hot weather conditions (temperatures greater than 35°C and 40°C). There is also a limited understanding of adaptation capacity of women commuters' and the barriers that limit their adaptation. This limits the ability to develop gender-responsive actions to minimize exposure and increase adaptation capacity of women commuters to hot weather conditions.

1.3 Aims and objectives

The project aims to develop a framework for identification of community- and individual-led solutions to reduce vulnerability of women commuters to hot weather conditions.

The objectives are as follows –

1. To understand the daily travel patterns of women and men belonging to varying income groups,
2. To measure the variation in thermal comfort conditions by the time of day and built environment factors,
3. To measure the exposure level to hot weather conditions for non-adaptable trips,
4. To analyse the adaptation capacity of respondents for the recorded trips
5. To codesign community- and individual-led solutions with the community.

2. Data collection methodology

To achieve the desired objectives, we collected data from multiple sources – infrastructure audits (assess existing conditions), CCTV footage (map street usage pattern by season), thermal sensors (assess variations in ambient temperature and relative humidity by street), and questionnaire-based surveys (understand travel choice and adaptation capacity). Except for street infrastructure audit, all other data was collected for two seasons – 1) March - Comfortable season (Season – 1) and 2) May – Hot season (Season – 2).

2.1 Target group

Women are more engaged in caregiving roles. Their activity patterns are, therefore, more likely to be determined by the interdependencies between the household members. These interdependencies shall increase if the woman is a mother of a school-going child. This shall further restrict her activity patterns and limit her travel choices. Against this background, the study focusses on understanding the exposure and adaptation capacity of parents particularly mothers of school-going children for the study.

The study requires a longer-term engagement with respondents using repeated surveys to understand likely changes in travel behaviour between two seasons and further to codesign solutions in the last stage. For this purpose, we selected three schools representing different typologies, localities and land surface temperature (Table 1).

Table 1: Selected three schools in Delhi for study

S.No.	School Code	District	Typology	Level	Gender	Mapped LST in degree Celsius
1	A	South	Recognized Unaided Private	Sr. Secondary	Co-ed	36.4°C
2	B	South East	Recognized Unaided Private	Sr. Secondary	Co-ed	35.9°C
3	C	Central	Government	Sr. Secondary	Girls	39.1°C

We invited participation from parents of the three schools. The residential location of the interested parent for all three schools was mapped using Google Earth. This led to the selection of ten neighbourhoods for the study (Figure 2). From each neighbourhood, two streets were selected to understand the existing condition, challenges and issues and collect data on thermal conditions.

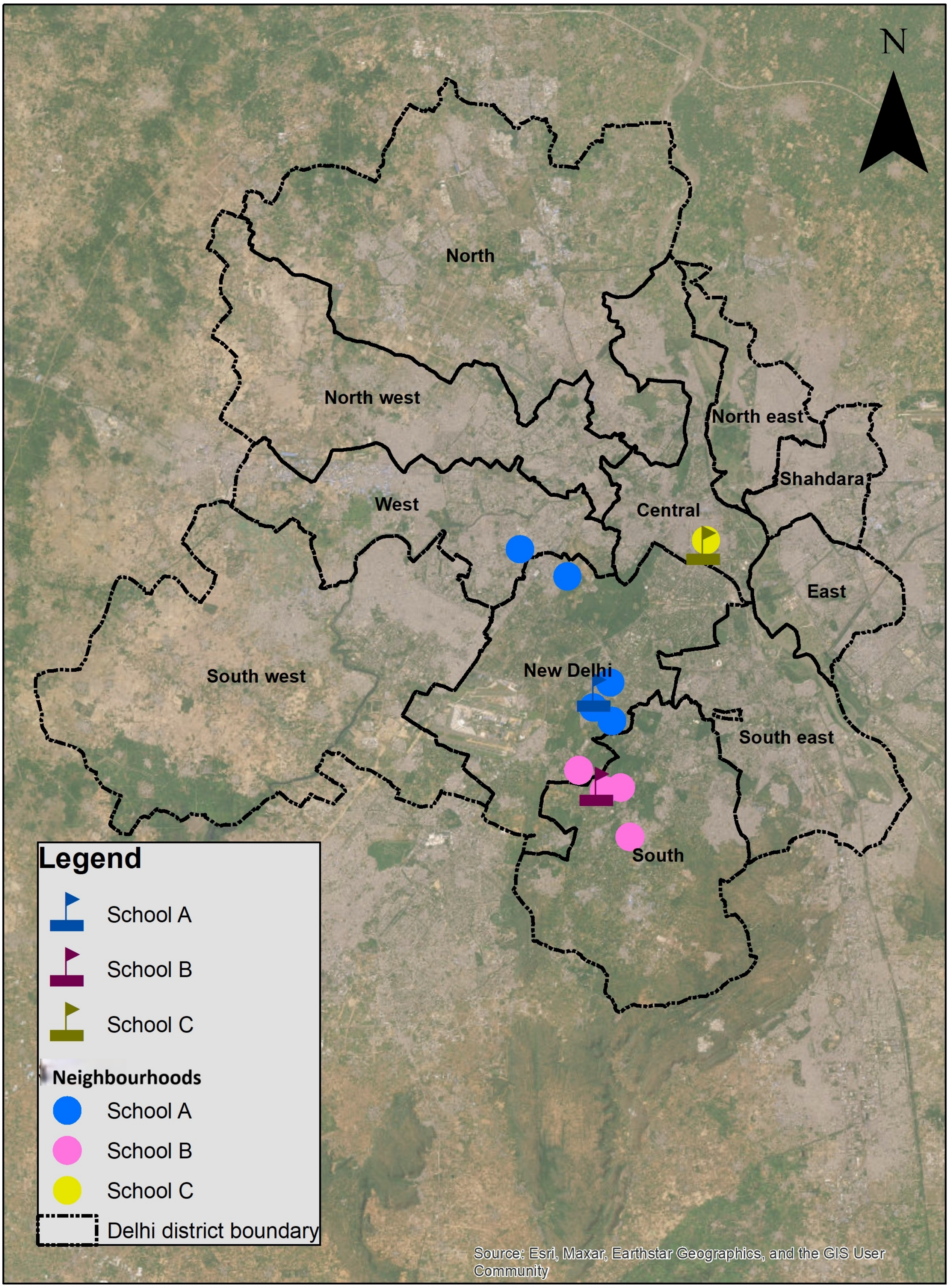

Figure 2: Location of selected neighbourhoods

2.2 Method

The study draws an understanding of the travel patterns of women and their exposure and adaptation to hot weather conditions while travelling. The study integrated data from multiple sources including infrastructure audits, thermal sensors, CCTV camera, and surveys (**Error! Reference source not found.**). The last step of the study is codesign with parents and school community.

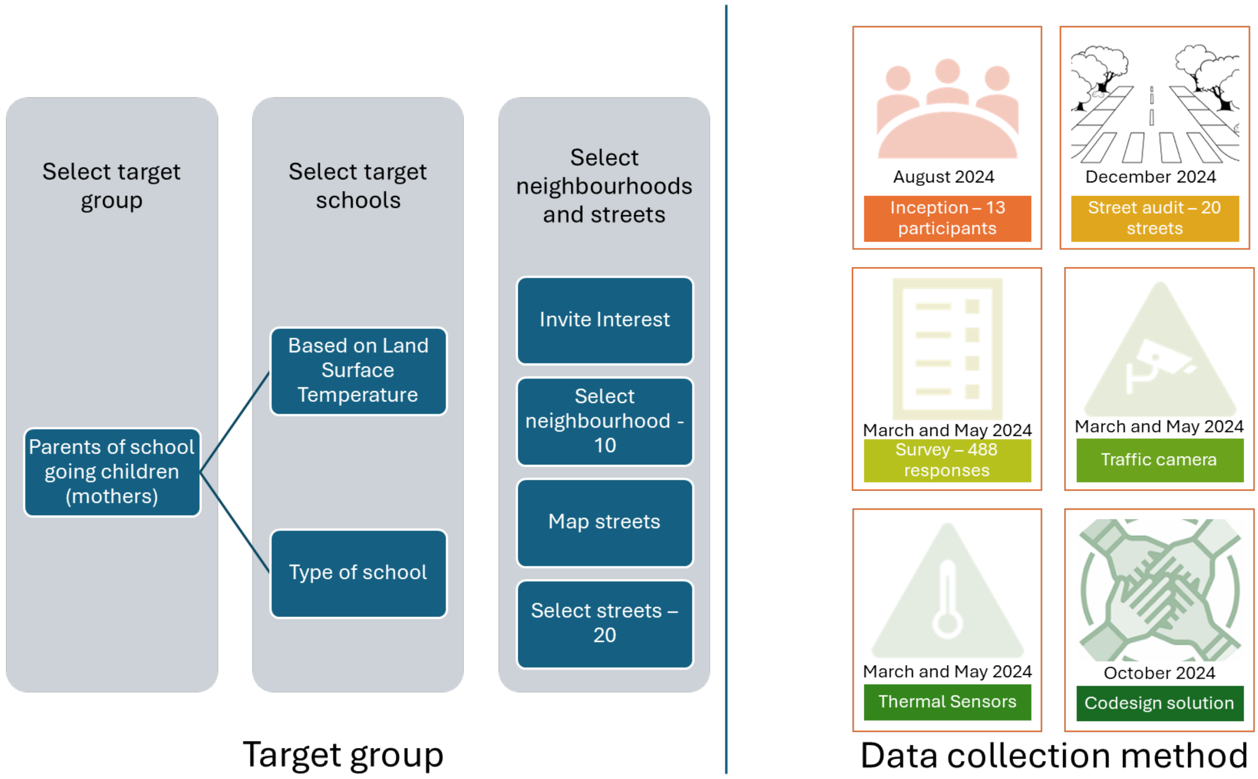

Figure 3: Data collection method

1. Inception

An inception workshop was conducted with stakeholders representing government, practitioners, and school community. During the workshop, we discussed the impact of high temperatures on transport users, and how women are likely to be more affected than men. We also discussed the acceptance, and relevance of various mitigation and adaptation strategies.

2. Infrastructure audits

Infrastructure audits were conducted to gather information on four key factors: abutting land use and building typology, carriageway infrastructure, footpath infrastructure, and green infrastructure using 22 parameters . The streets were audited on weekdays between 8 AM and 1 PM. Land use typology along the streets was mapped using Google Street View and validated through field observations.

The road audit forms were adapted from the "Road Inventory for Motorized Vehicles" (Survey Format 3a) and "Footpath Inventory" (Survey Format 3b) found in the "Toolkit for Preparation of Low Carbon Mobility Plan," as well as the "Footpath and Pedestrian Accessibility" section from the Urban Road Safety Audit (Ministry of Urban Development, 2013; UNEP et al., 2014).

Studies have shown that thermal conditions experienced by pedestrians can be enhanced by appropriate selection of strategies (Jia & Wang, 2021). The experienced thermal conditions depend on street infrastructure, abutting built environment, and the presence of blue and green infrastructure (Abd Elraouf et al., 2022; Ahmadi Venhari et al., 2019; Deng et al., 2023; Kleerekoper et al., 2017; Klemm et al., 2015; Nasrollahi et al., 2020; S & Rajasekar, 2022; L. Yang et al., 2020).

Urban street infrastructure-related parameters include street typology (Abd Elraouf et al., 2022), traffic patterns (Christopoulou & Pitsiava-Latinopoulou, 2012; Pola Aleksandra Berent, 2020), presence and quality of footpaths (Ma et al., 2021; Paul et al., 2024) and shading elements (Lam et al., 2023; Nasrollahi et al., 2020; Necira et al., 2024; Shu et al., 2024) are proven to affect thermal conditions on the street.

To assess pedestrian comfort, especially during hot weather conditions, both thermal conditions and infrastructure like shading and greens were also included. For measuring, traffic speeds and traffic volume counts, a 20-minute video was captured which was divided into 4 segments of 5-minutes each.

Abutting Landuse & Building typology

- Abutting Landuse – With google street view later validates by physical audit
- Abutting building heights – Physical audits

Motorized Infrastructure audit

- Length of street audited
- Number of lanes
- Right of Way
- Segregation between lanes
- If service road, Width of service road
- Traffic speed measurement using laser speed guns
- Traffic volume using videography and manual counting

Footpath Infrastructure audit

- Length of footpath in a Km stretch
- Pavement type
- How wide are the footpaths?
- Height of footpath
- Maintenance of footpath
- Cleanliness of footpath
- Provision of amenities for pedestrians for footpaths
- Provision of Disability friendly Infrastructure
- Barrier free footpaths
- Avaliablity of shading devices on the street

Green Infrastructure

- Average canopy and height of Individual trees
- Length, average canopy diameter and average height of continuous high foliage tree belts
- Length, average canopy diameter and average height of continuous belt of shrubs, planters etc.

Figure 4: Factors and its attributes considered in the street audit

3. Thermal sensors

We assembled and installed a set of low-cost sensor units using Arduino UNO R3 microcontroller boards on selected streets of Delhi (**Error! Reference source not found.**). The unit had three modules - DHT-22 (also named AM2302), Real Time Clock (RTC – DS1307), and Micro SD module. For programming the Arduino boards, we used Arduino IDE, which is an open-source software designed explicitly for programming Arduino microcontroller boards. The C++ programming language is used in the IDE and runs on Windows, Mac OS and Linux operating systems. The sensor was used to measure ambient temperature and relative humidity on different streets of Delhi in two seasons.

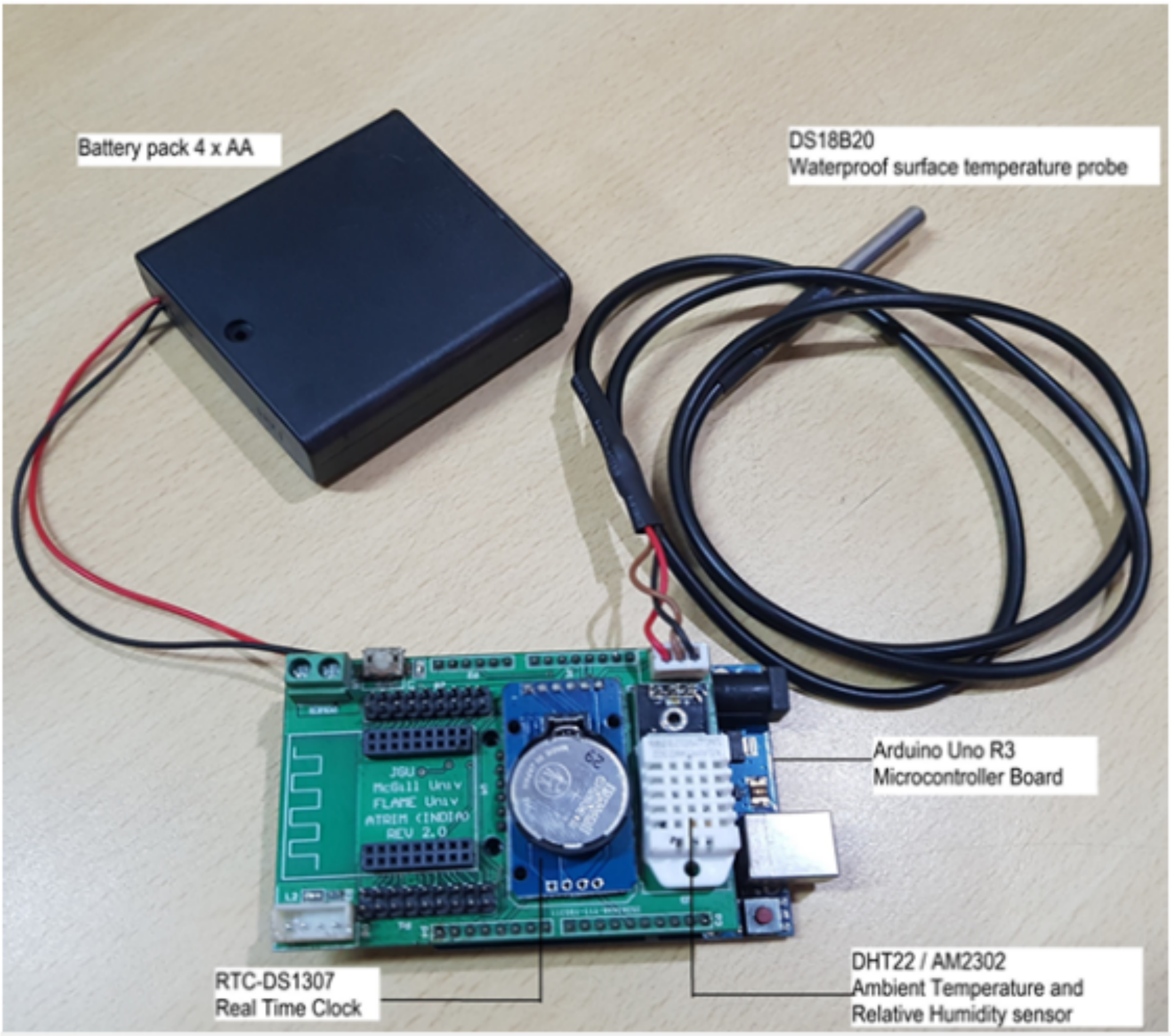

Figure 5: Thermal sensor installed for collecting data

4. CCTV video footage

We used traffic video recordings to observe the change in traffic patterns, particularly pedestrians, by time of day and season. The diurnal variation in the traffic volume count in two seasons is measured using the CCTV footage from local shopkeepers and local agency.

5. In-person surveys

Longitudinal (repeated) surveys are conducted with the recruited sample of individuals from the three schools. The purpose of the repeated surveys is to capture variations in daily activity patterns and travel patterns of parents, particularly women, by season. Two cycles of surveys are conducted with each respondent, one in not-so-hot weather conditions (March - April 2024) and the second in hot weather conditions (May- June 2024). The survey has three sections: 1. Socioeconomic profile, 2. Travel diary survey, and 3. Perception of thermal comfort for different types of trips.

6. Codesign workshops

We developed a codesign toolkit – AMBI kit for engaging with parents and school children in play-based method to cocreate solutions that can help in reducing exposure of people particularly women to high temperature conditions while travelling.

2.3 Sample description

Of the 20 streets audited 55% are lanes, 15% are local streets, 20% are collector, and 10% are sub-arterial. As the selection of streets is based on the neighbourhoods where sample respondents live, most of the audited streets are lanes. A total of 448 responses were achieved in the two seasons, with maximum participation from women (Figure 6).

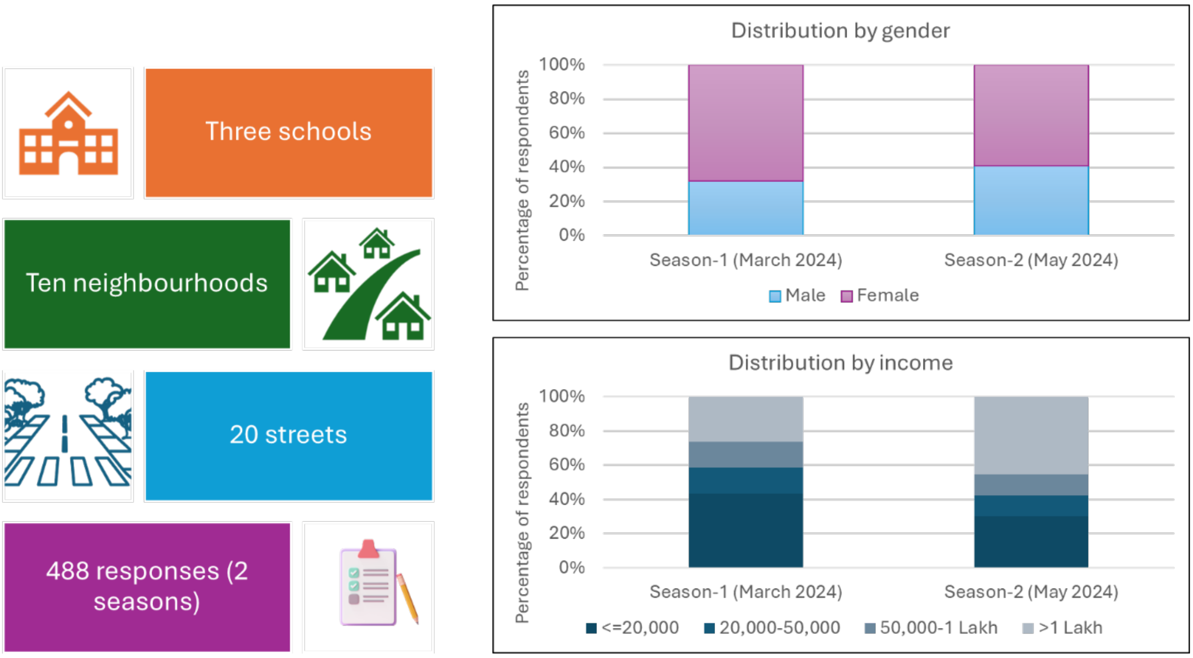

Figure 6: Sample description

3. Key findings

3.1 Safe, walkable and thermally comfortable conditions

3.1.1 Street infrastructure

Pedestrians are most exposed to the direct environmental conditions on roads. The performance of the infrastructure is assessed considering the comfort and safety of pedestrians on the selected streets. For this purpose, we estimate the walkability score, shading index, and green infrastructure (Figure 7).

- **Walkability score** is estimated using three parameters as safe from traffic, quality of infrastructure and amenities to support comfortable walking. Safe from traffic score evaluates the safety of pedestrian in relation to vehicular speed and available infrastructure considering the existing speed limit on the street, speed compliance of vehicles and the availability of separate footpath. Walking infrastructure refers to the availability and quality of walking infrastructure. The parameter here includes footpath width, pavement type and quality of footpath. Infrastructure to support comfortable walking here includes the availability of amenities for pedestrian, encroachment free footpaths and sky view factor. The average of the three parameters is used to determine overall walkability score of the street.
- **Shading index** jointly considers shade because of abutting buildings and respective street orientation with preference given to N-S direction, green infrastructure index which includes both length of green belt or number of trees and canopy width, and availability of shades such as awnings, overhangs, and trellises on the street. Shading index is estimated as the maximum value attained either of the three parameters.
- **Green infrastructure index** is the ratio of total width and length of the trees to the total street length on both road side.

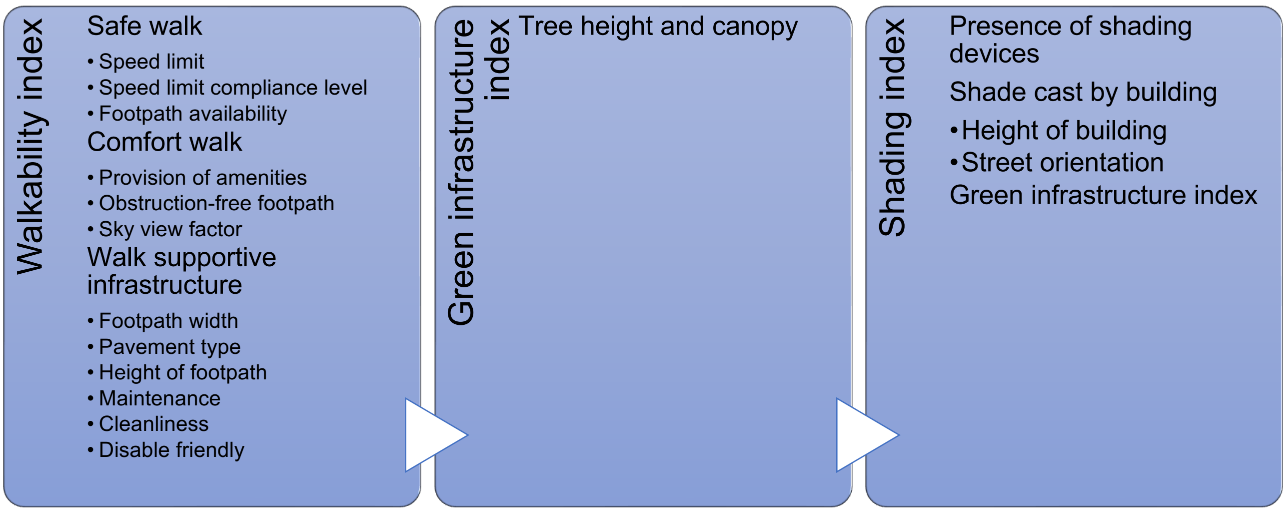

Figure 7: Assessing infrastructure status with regard to safe, walkable and thermally comfortable conditions

As shown in Figure 8, as the hierarchy of streets increases, the density of green infrastructure also increases. Lanes exhibited the lowest green infrastructure density. Collector and sub-arterial roads have the highest level of green infrastructure.

A higher shading index was recorded for most of the audited streets. The average shading index across all street categories varies between 0.6 and 0.8. Majorly, the lanes and local streets are mutually shaded by buildings and collector and sub-arterial roads are shaded by trees.

Walkability index variations were also noted across different street hierarchies. A higher walkability score is observed on collector roads, followed by sub-arterial roads. These roads had better walk infrastructure and pedestrian amenities. As compared to the collector road, sub-arterial streets exhibited a lower walkability index as the vehicular speeds on sub-arterial roads are higher, making the walking experience less comfortable and safe.

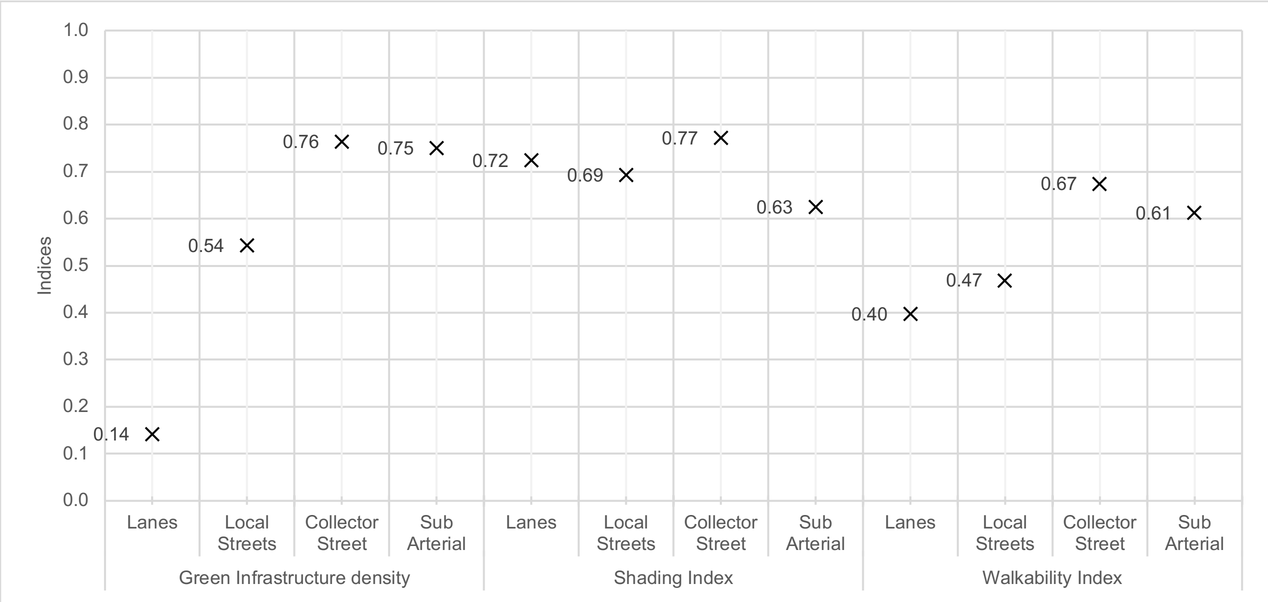

Figure 8: Average street infrastructure indices

3.1.2 Thermal index variations

For hot weather conditions, the ambient temperature and relative humidity are recorded between the 7th and 16th of May 2024 on 13 streets covering all four types of roads classified by right of way. The minimum and maximum temperature recorded in Delhi on 12 May 2024 was 42°C and 31°C. However, the maximum temperature recorded in lanes was 35.5°C in Mehrauli, and the maximum temperature recorded was on a collector road in Rajouri Garden.

The difference between the maximum recorded temperature between different types of streets is 8°C. Three inferences can be drawn from this analysis – 1) within lanes, the maximum recorded temperature varies and depends on the built-up typology abutting the streets; 2) between different types of streets, lanes observed the minimum level of ambient temperatures; and 3) maximum ambient temperature is recorded between 2 PM and 4 PM.

To better understand the variations in the felt temperature and its impact on commuters, we used heat index (HI) as per the equation below. HI is a more straightforward and easier-to-interpret method as it is measured in the same units as temperature, and its estimation is based on ambient temperature and relative humidity, only.

$$HI = -42.379 + 2.04901523 \times Ta + 10.14333127 \times Rh - 0.22475541 \times Ta \times Rh - 0.00683783 \times T^2 - 0.05481717 \times Rh^2 + 0.00122874 \times Ta^2 \times Rh + 0.00085282 \times Ta \times Rh^2 - 0.00000199 * Ta^2 \times Rh^2$$

Where,

HI = Heat Index in (°F)

Ta = Ambient air temperature (°F)

Rh = Relative Humidity (%)

A HI ranging between 105°F and 129°F (≈ (between 40°C and 54°C)) corresponds to very hot conditions, and a HI ranging between 90°F and 104°F (≈ (between 32°C and 39°C)) corresponds to hot conditions. Prolonged exposure and/or physical activity in 'hot conditions' shall possibly lead to heat cramps, heat exhaustion, and heat stroke. Except for the local street, the maximum HI on 10th May 2024 was more than 32°C on all the streets. The highest HI is observed on the collector road in Rajouri Garden (Figure 9). On the sub-arterial roads, the HI exceeds 32°C for three hours, whereas on the collector roads, this condition persists for seven hours. Therefore, commuters on the sample collector street are more exposed to the impacts of high temperatures.

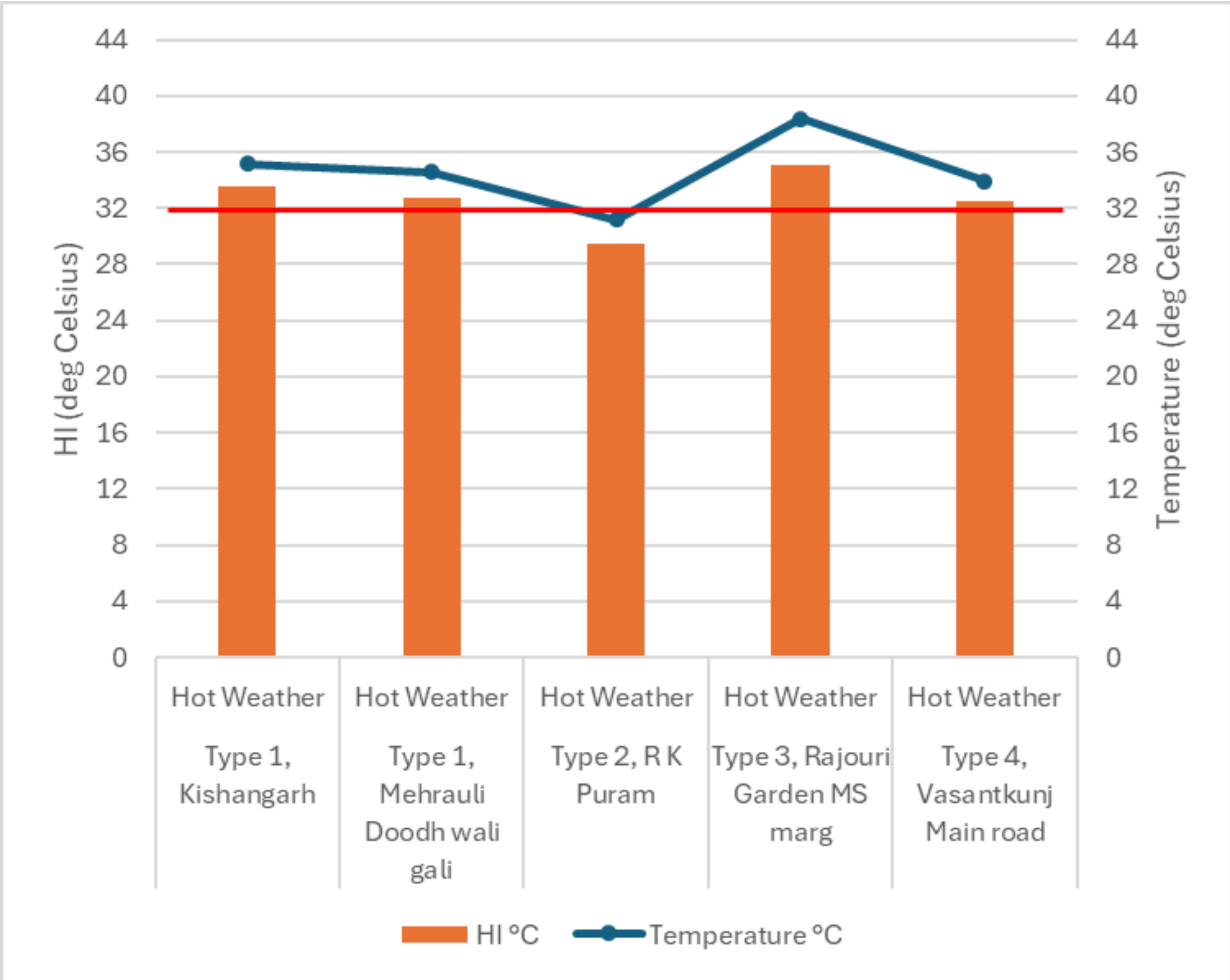

Figure 9: Maximum Heat Index on 10th May 2024

3.1.3 Seasonal and diurnal variation in traffic patterns

The traffic volume count (TVC) data was extracted from CCTV footage on selected streets for two seasons. For comfortable seasons, CCTV footage could be procured from nine streets; however, for the hot season, the same was available only for six streets.

To assess the variation in commuters' exposure, we focused on the three groups that were most exposed: pedestrians, bicyclists, and motorised two-wheelers. The analysis shows that the hourly average number of pedestrians does not vary significantly between the two seasons.

Figure 10 shows the variation in pedestrians, bicyclists and MTW counts by time of day and season on lanes. As can be observed, more pedestrians are present during evenings than in mid-day during hotter weather (May 2024). While during more comfortable weather (Feb-March 2024), we found that the number of pedestrians does not vary by the time of day on lanes.

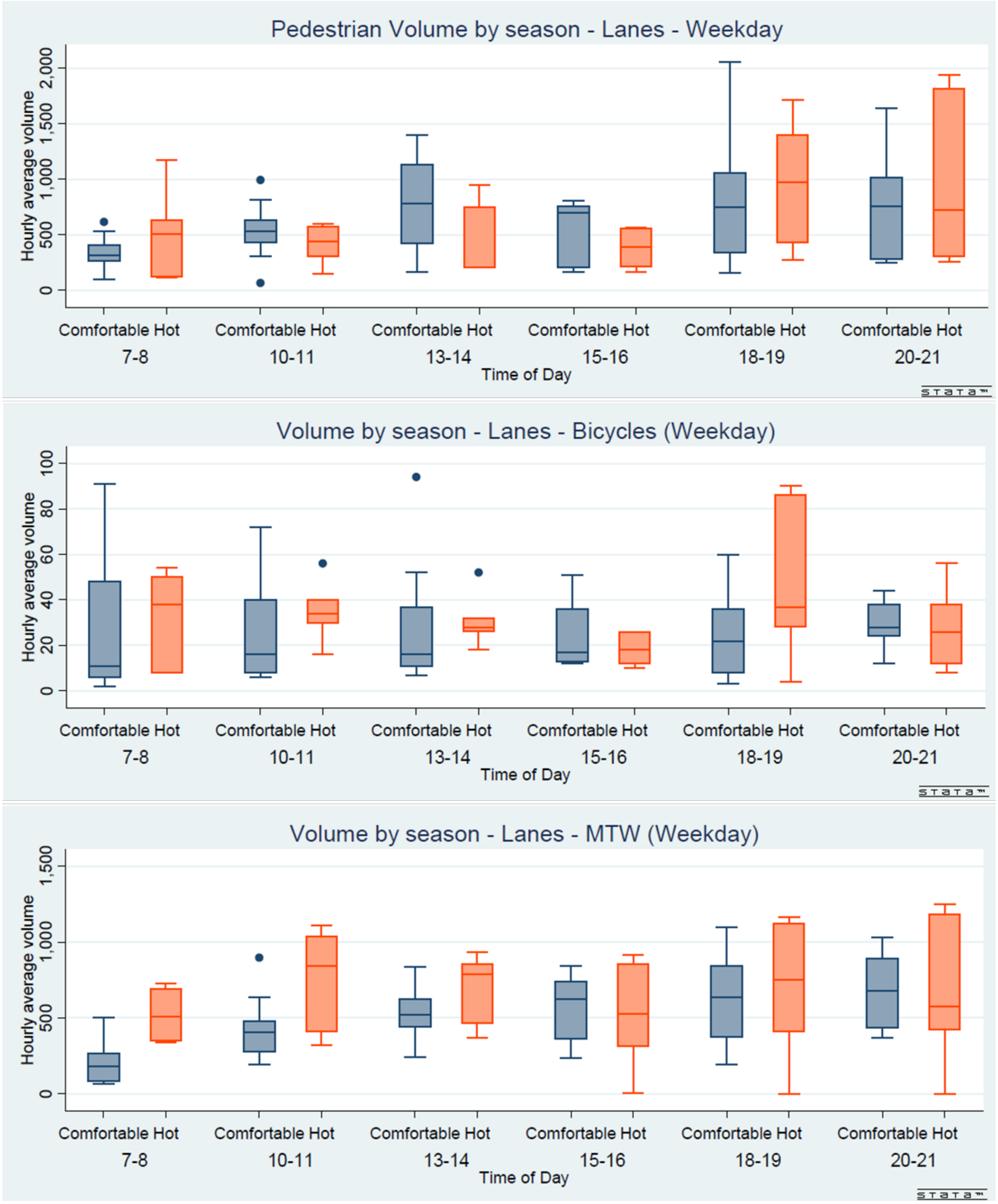

Figure 10: Diurnal variation in traffic volume count by modes on lanes for two seasons

3.1.4 Transport Business Association/Ownership Onboarding

Bringing transport business associations like the Masaka Taxi Operators group on board with the project has led to the opportunity for high level engagement with a range of decision-makers including NGOs and non-profit making transport groups.

These are the key targets to push the innovation and research agenda, and further the cause for adapting to better measures and recommendations towards the alleviation of road accidents and vehicular pollution.

3.2 Travel pattern analysis

A detailed travel diary was collected from the respondents for the previous working day. We possibly collected data for every short-distance trip, including where the respondents walked for less than 50m to buy vegetables from a local vendor. Data collection was in an order of tour >> trip >> trip segment. A tour is regarded as a round trip where the starting and ending locations are the same. Each tour can have multiple trips. For a leisure trip like morning or evening walks, there is only one trip. Trips have different starting and destination locations, like work to shop and shop to home. A trip segment helps in measuring multimodal trips.

3.2.1 Overall travel behaviour

Overall, data for 789 tours (both seasons) was collected, with men making 1.8 tours per person and women incurring 1.7 tours per person. This relates to 3.7 and 3.5 trips per capita by men and women, respectively. On average, the respondents spend 23 minutes per trip, with men and women spending 26 and 21 minutes per trip.

Figure 11 shows the difference in modal share by gender group. A larger share of trips (65%) made by women are on foot, with lesser dependency on two-wheelers. While majority of the trips incurred by men are catered by motorized two-wheelers and walk, followed by cars.

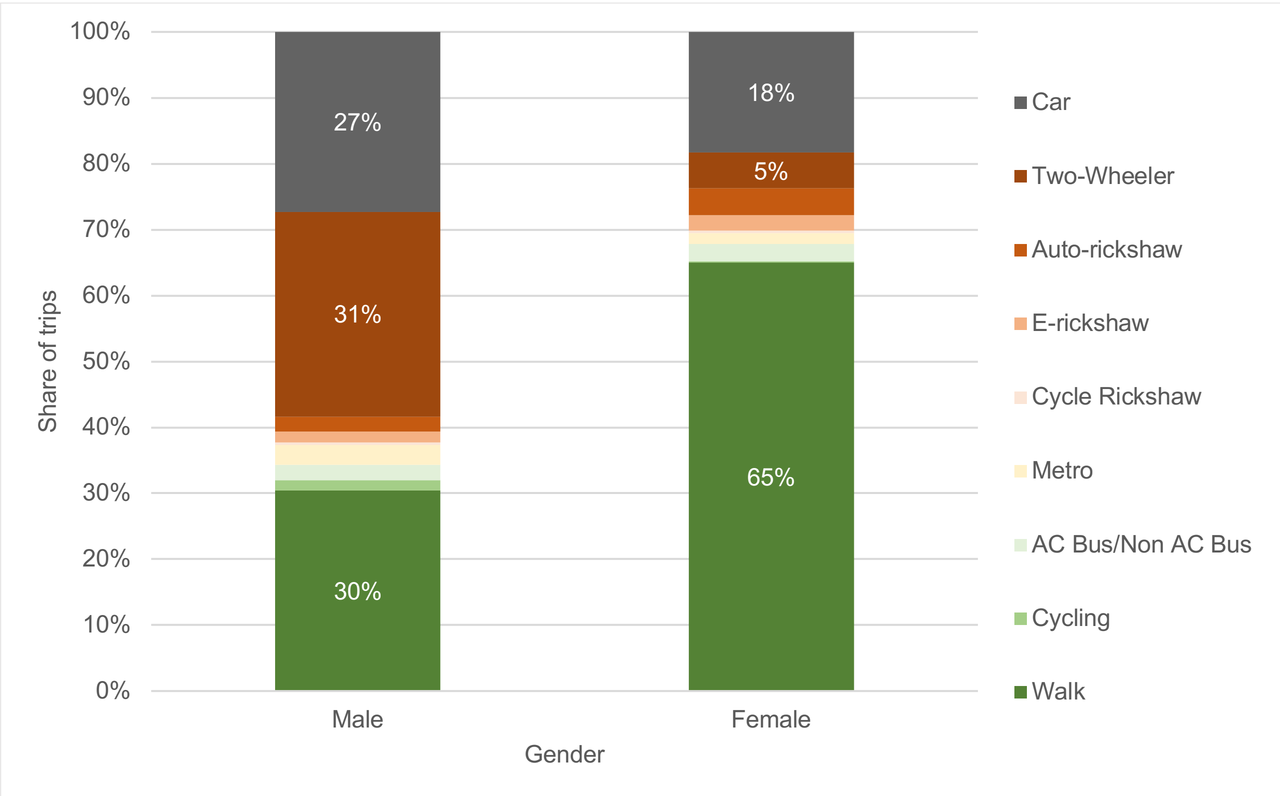

Figure 11: Modal share by gender

Similar differences are also observed when compared by income (Figure 12). Seventy-seven per cent of trips incurred by the lower-income groups (households with monthly income less than INR 20,000) are by walking, and this share reduces with increasing income levels. The respondents belonging to the middle-income group (households with monthly income between INR 20,000 and INR 50,000) depend on both walking and motorised two-wheelers. The respondents of the higher-income groups undertake 54% of their trips by car, with only 27% being by walking. As per Figure 13, women undertake more trips during the daytime than males and they travel more for pick-up or drop-off of kids, shopping and doctor visits. While men make more trips for work, recreation and social purposes (Figure 14).

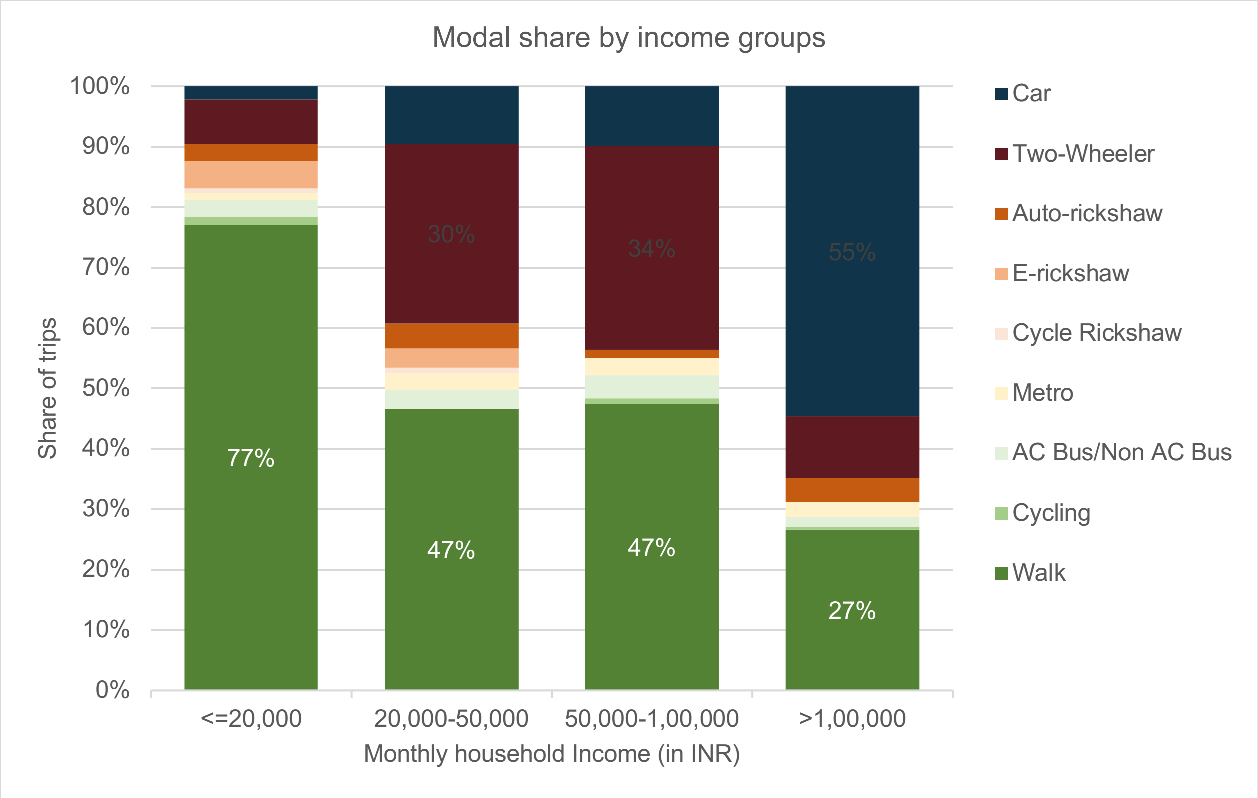

Figure 12: Modal share by income groups

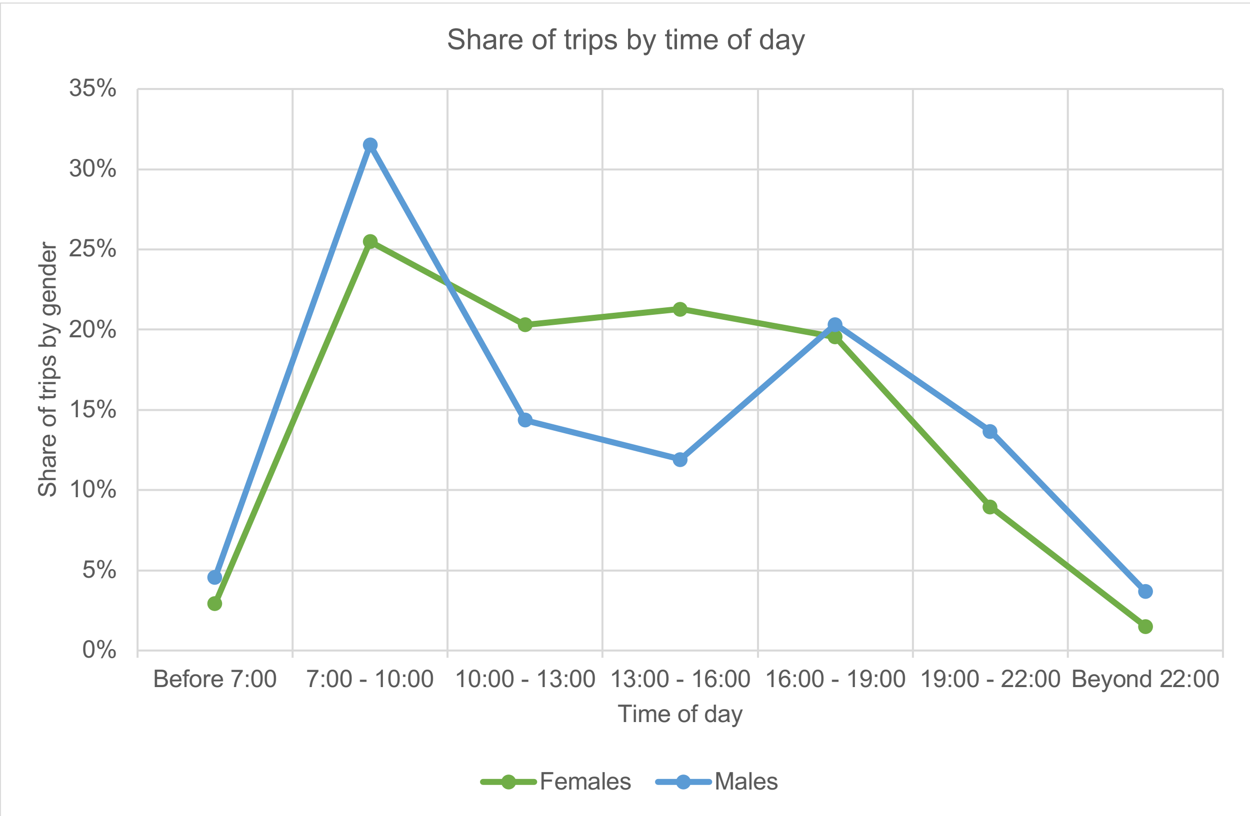

Figure 13: Trip distribution by gender and time of day

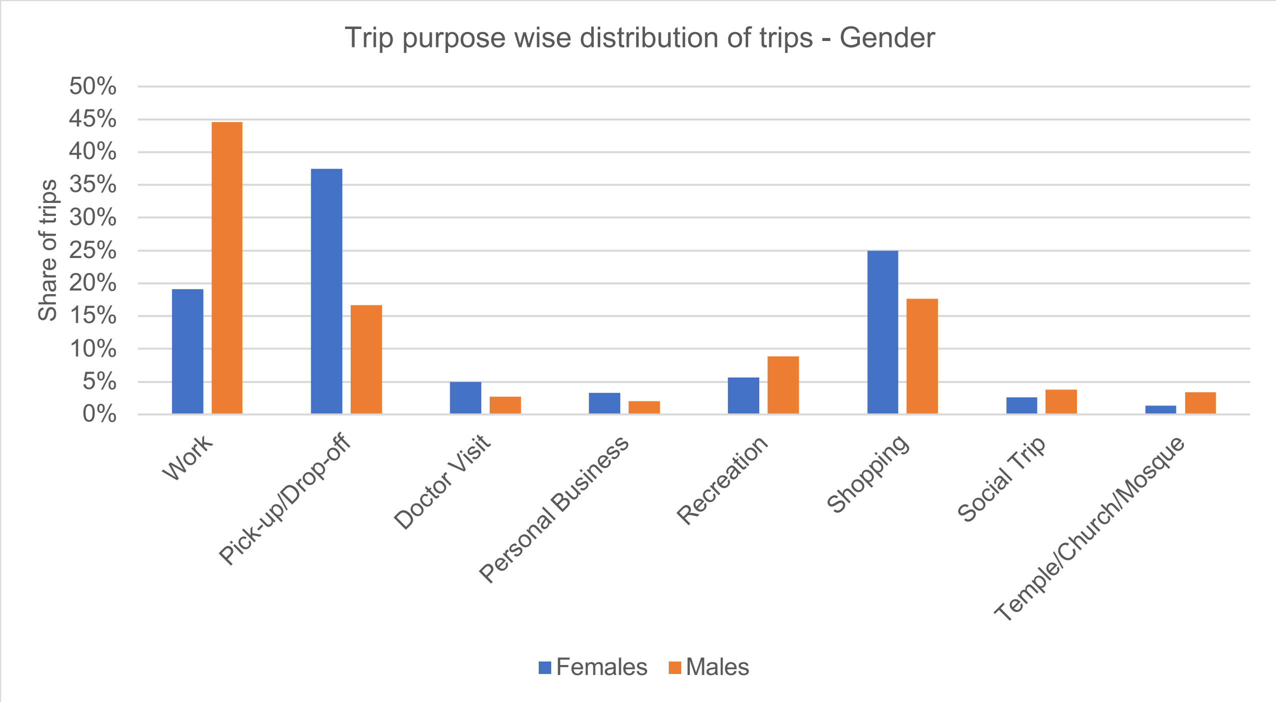

Figure 14: Trip purpose-wise distribution of trips by gender

3.2.2 Difference in travel behaviour between two seasons

Women primarily travel by walk and are therefore exposed more to the ambient environmental conditions than men. Between the two seasons, their modal split distributional also does not change significantly. While, the study shows that the men are more likely to change their mode of transport during hot season resulting in increased car share and decreased walk share as compared to the comfortable season (Figure 15).

This gap in vulnerability is also evident when compared with respect to the income. There is no change in modal split distribution between two seasons for the lowest income group (Figure 16). However, as the income level increases, the variation in the modal split by season also increases. For those with monthly incomes between INR 20,000 and INR 1,00,000, the personal motorized vehicle share (motorized two-wheelers (MTW)) increases with reduced walk share during the hot season than the comfortable season.

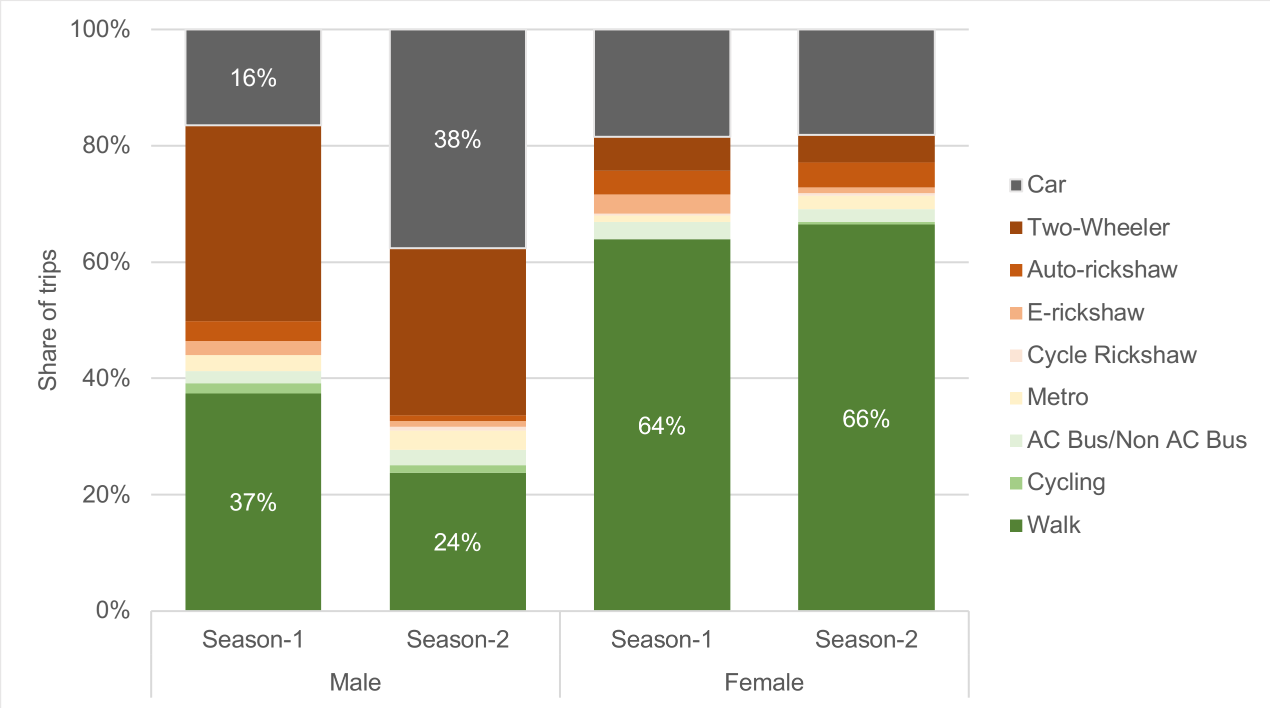

Figure 15: Modal share by gender – comparison between two seasons

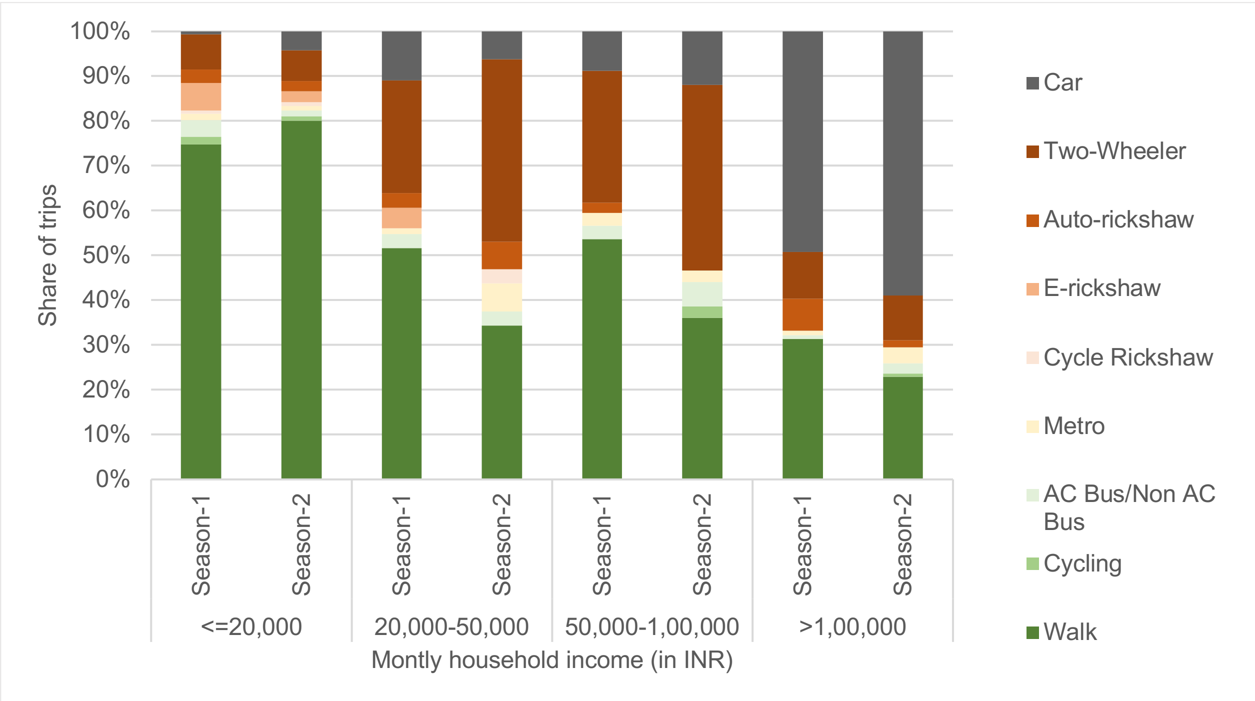

Figure 16: Modal share by income groups – comparison between two seasons

3.2.3 Who is more vulnerable amongst women

Vulnerability is determined by the income and socioeconomic status because of which people will have lesser adaptation capacity. While significant variation in modal split distribution is not observed between two seasons for women, however, some are more vulnerable because of no choice. Women belonging to the lowest income group continue to walk irrespective of the season. Within women, those belonging to households with monthly incomes ranging between INR 20,000 and 50,000, have more choices than the lowest income groups.

Their walk share reduces to 48% in hot season from 75% in the comfortable season (Figure 17). For very high-income groups (income more than INR 1,00,000 per month), there is an increased dependency on cars (55%) during the hot season as compared to the comfortable season (45%). While the walk share in this income group of women remains the same across the two seasons

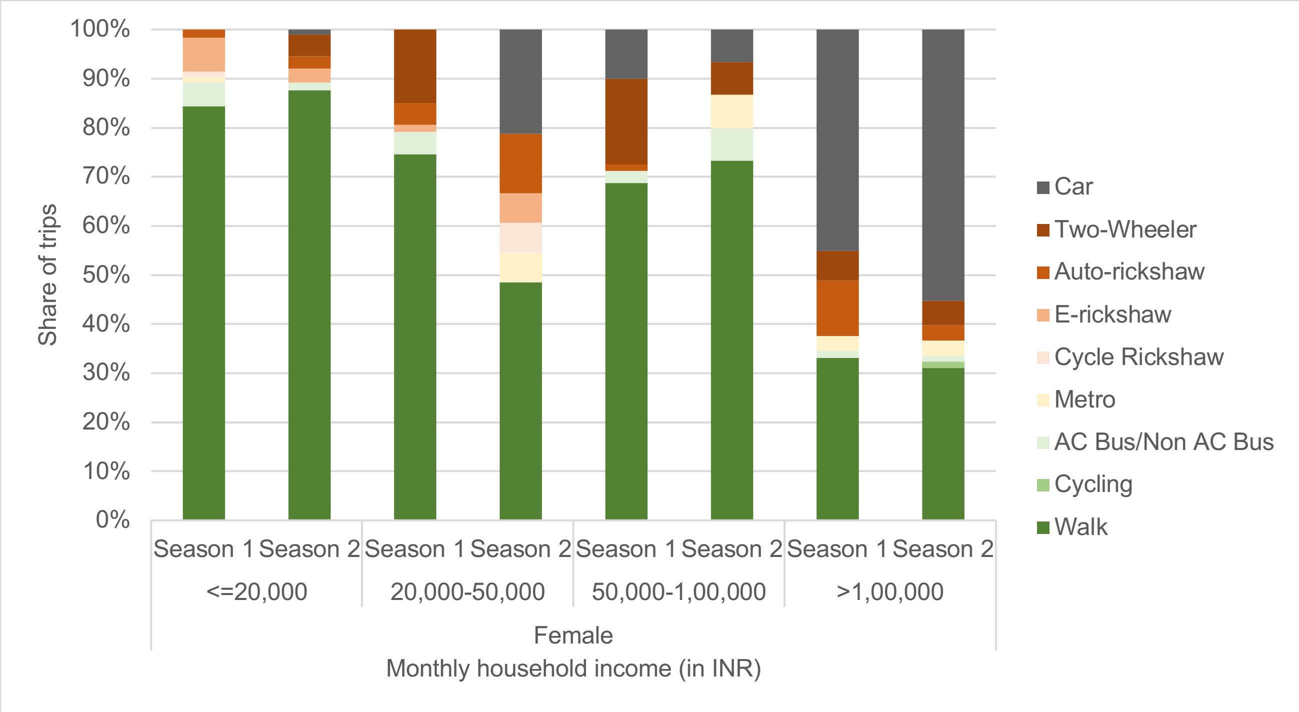

Figure 17: Difference in modal split distribution by income within females between two seasons

Not only women are more dependent on walking to meet their travel needs. But they also tend to incur travel more during the daytime when the ambient temperatures are the highest. During May (hot season), women incur more trips during the daytime than in the comfortable season. This may be related to the period in which the data was collected. During the comfortable weather (March), the schools were closed for most of the kids, impacting the need for travel to pick up / drop off the kids (Figure 18). While during May (hot season), schools are open, requiring parents to incur trips for pick-up/drop-off.

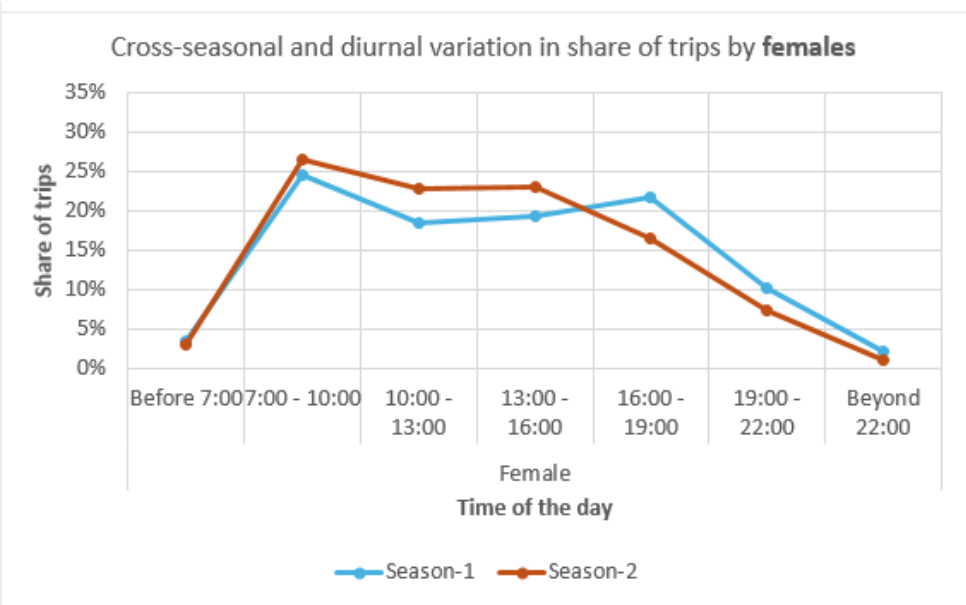

Figure 18: Trip share by time of day and gender - two seasons

3.3 Exposure intensity and resulting exposure levels

IPCC (2022) defines risk as “the potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems”. In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system.

As per IPCC (2022), vulnerability is a function of three factors – exposure, sensitivity, and adaptive capacity. In the framework, exposure refers to the extent and duration of climate-related stresses, such as droughts or changes in precipitation. Sensitivity describes how significantly a system is impacted by these climate stresses or extreme events. Adaptive capacity, on the other hand, is the system's ability to endure or bounce back from the damage caused by these extreme events.

3.3.1 Exposure intensity to high temperatures in transport

Exposure intensity is measured as the average time spent per capita in different modes during the hottest hours of the day (between 1-4 pm) in season 2 (May). Walk is the primary mode of transport for women and is also the mode in which the exposure to ambient environmental conditions is the highest. Eighty-five percent of the mother respondent belonging to the lowest income group travel by walk during the hottest hours of the day in season 2 incurring 0.7 trips per capita and walking for an average of 18 minutes per trip (Figure 19).

The resulting exposure intensity per capita while walking is 11, 9, 12 and 2 minutes for women belonging to the lowest (<=20,000), low-middle (INR 20,000 – 50,000), middle-high (INR 50,000 – 100,000) and the highest (> INR 100,000) income groups, respectively.

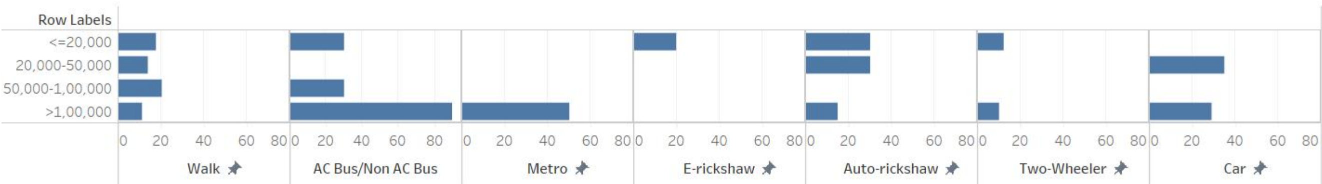

Figure 19: Average time spent in different modes by income in season 2 during the hottest hour of the day (women)

3.3.2 Change in exposure intensity between two seasons for women

As defined by IPCC (2022), adaptation capacity is the ability to change behaviour in accordance with climate change to minimise risk. The change in exposure intensity is estimated as the difference in exposure intensity by modes between season 1 (comfortable season) and season 2 (hot season). Here, recorded travel patterns in season 1 are considered the base case scenario. If people can reduce their exposure intensity in a particular mode of transport from comfortable season to hot weather conditions, it can be said that they have adaptation capacity.

As expected, women belonging to the lowest income group are experiencing the least change in the exposure intensity (Figure 20). Maximum change in exposure intensity across all modes is observed for the women belonging to incomes ranging between INR 20,000 and 50,000. The exposure intensity is likely to increase by motorised modes of transport across income groups.

3.3.3 Exposure levels during season 2

The exposure level for an individual is determined considering the exposure intensity in different modes and the hazard level. This is given as per the equation below. For the hazard level to which individual is exposed in different modes, ratios similar to air pollution studies are considered.

$$EL_{s_t} = \sum_{m=1}^{n} EI_{m_{s_t}} \; X \; HL_{m_{s_t}}$$

Where,

EL_{s_t} is the exposure level of an individual in a season *s* and time *t*,

$EI_{m_{s_t}}$ is the exposure intensity per capita measured in minutes in the mode *m* in season *(s)* in time period *t, and*

$HL_{m_{s_t}}$ is the hazard level in a mode of transport *m* in a season *s* and time *t*.

As per the Figure 21, the overall exposure levels do not vary by income between women in season 2, except for the women belonging to households with a monthly income of more than INR 1,00,000. The figure also shows that exposure levels reduced only for women belonging to households with monthly incomes between INR 20,000 and INR 50,000 by 36%. Meanwhile, exposure levels per capita increased from season 1 to season 2 for other income groups.

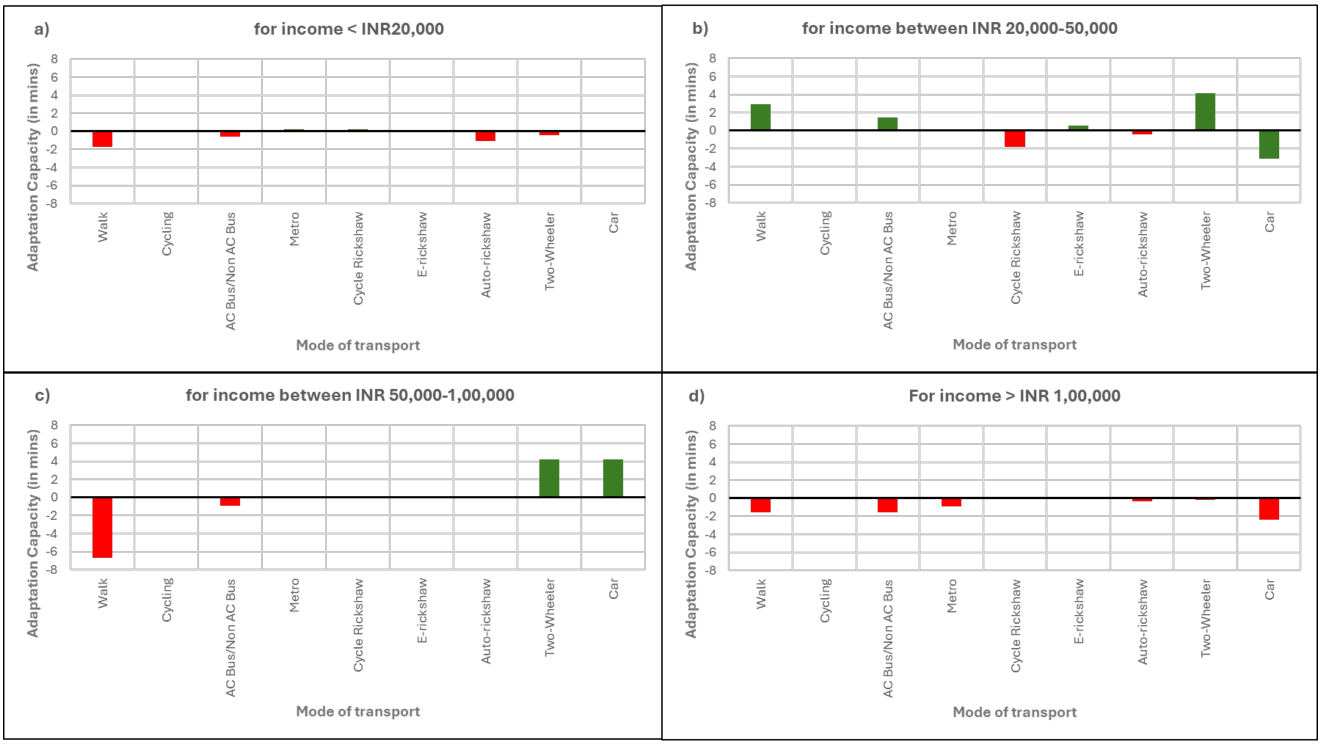

Figure 20: Change in exposure intensity by mode of transport and income for women

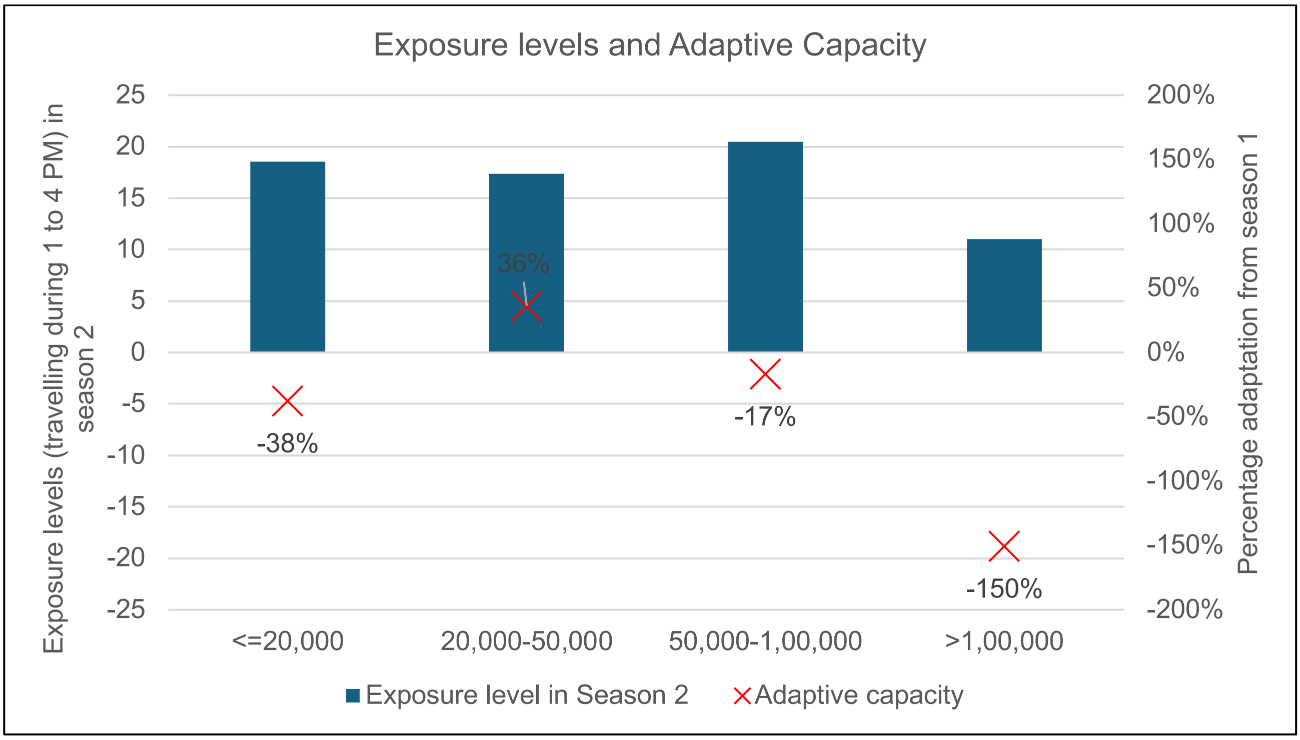

Figure 21: Exposure levels per capita for women by income and relative adaptation capacity

3.4 Indentified problems and challenges

Overall, cities are experiencing the issue of rising temperatures, exposing people to harmful health impacts. The street level data shows that the sample streets in Delhi had poor walkability score. The majority of the streets are shaded but walking is not convenient and comfortable. Those who need to travel during the hottest hours of the day and especially by walk are more affected. Overall, there is a change in traffic pattern between comfortable and hot season where pedestrian count increases during the morning and evening hours in the hot season.

However, the travel behaviour data collected from selected parents of school-going children shows disparity in the travel choices and exposure levels by gender and income. Particularly, women walk more then men and majority of their trips are done during the daytime. Majority of the women travel for pick-up/drop-off and shopping purpose catering to the household care needs. Even during the hot season, the travel pattern does not change. Schools are closed during March (when the weather is comfortable) requiring mothers to incur comparatively lesser trips than in May (when weather is hot). This overall results in increased exposure levels.

It is observed that the street environment varies between locations and by type of roads that renders different walking experience to people. The maximum ambient temperature also varies by 7 to 8°C. However, because of limited data set, an association between street infrastructure and abutting built environment with ambient thermal conditions could not be measured. Yet, street level measures can be identified to mitigate high temperatures.

4. Potential solutions – participatory approach

Two types of approaches are used to identify individual-, community-, and government-led strategies to enable mitigation and adaptation and reduce exposure to high temperature conditions while travelling. In the first phase, we collected stakeholder perspectives on relevance and acceptance of the potential strategies identified from literature. In the second phase, we conducted workshops with parents (of school going children) and their children to define potential set of relevant strategies.

4.1 Stakeholder workshop

Inception meeting was conducted in August 2023 with 13 stakeholders including government, community (schools), and practitioners to discuss about the project and the potential strategies to mitigate and adapt to high temperatures (Figure 22).

The workshop aimed to determine the relevance, acceptability, and degree of influence of stakeholders on individual, community, and government-led strategies. Key findings highlight the level of consensus and conflicts among stakeholders, which include community members, government representatives, and practitioners.

Figure 22: Glimpses of inception meeting with stakeholders

4.1.1 Methodology

The workshop used structured surveys and Likert scales to gather stakeholder feedback. Analysis identified levels of relevance, acceptance, and influence. An acceptance threshold of 75% was set to indicate consensus.

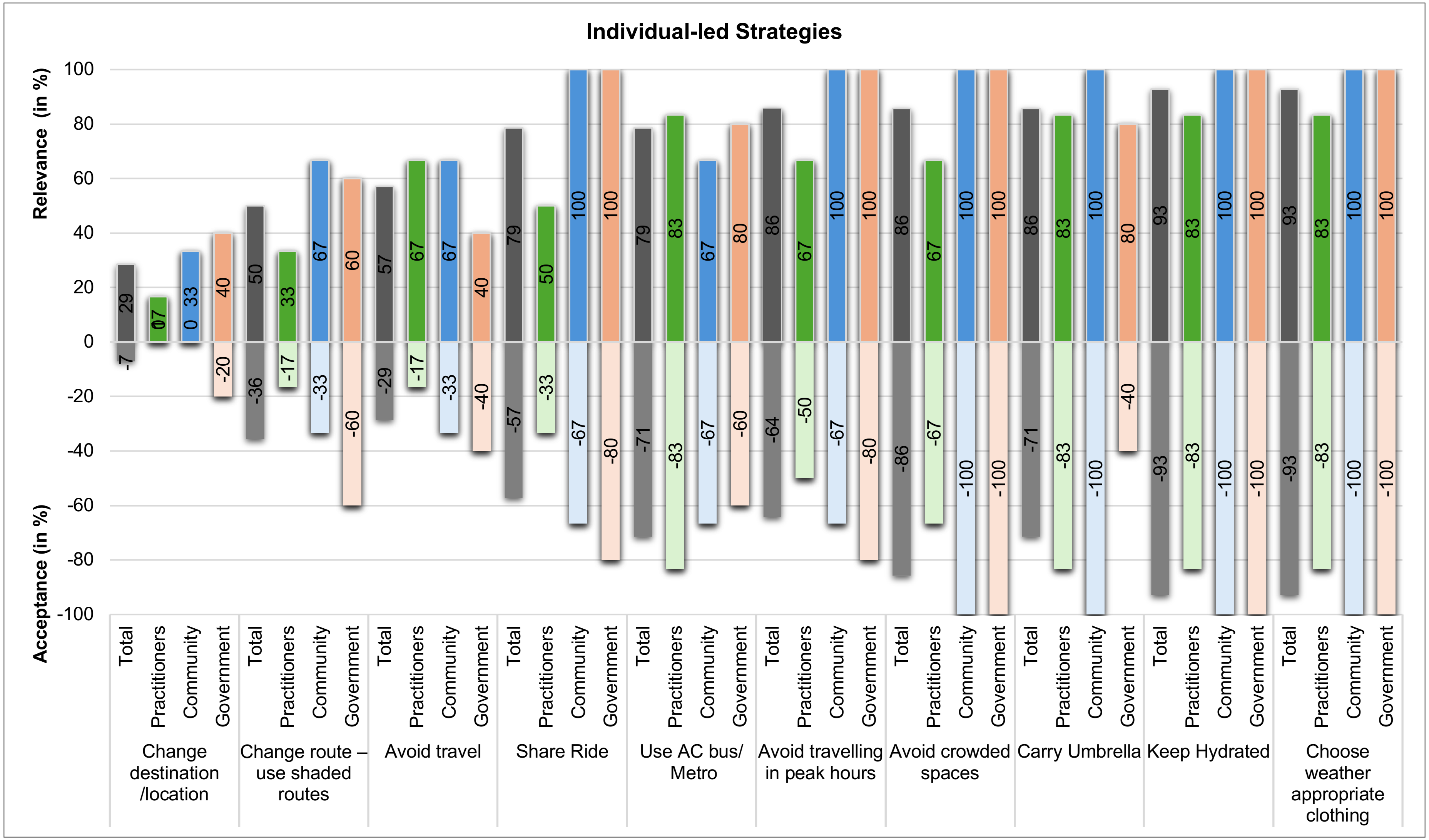

Figure 23: Relevance and acceptance of individual-led strategies

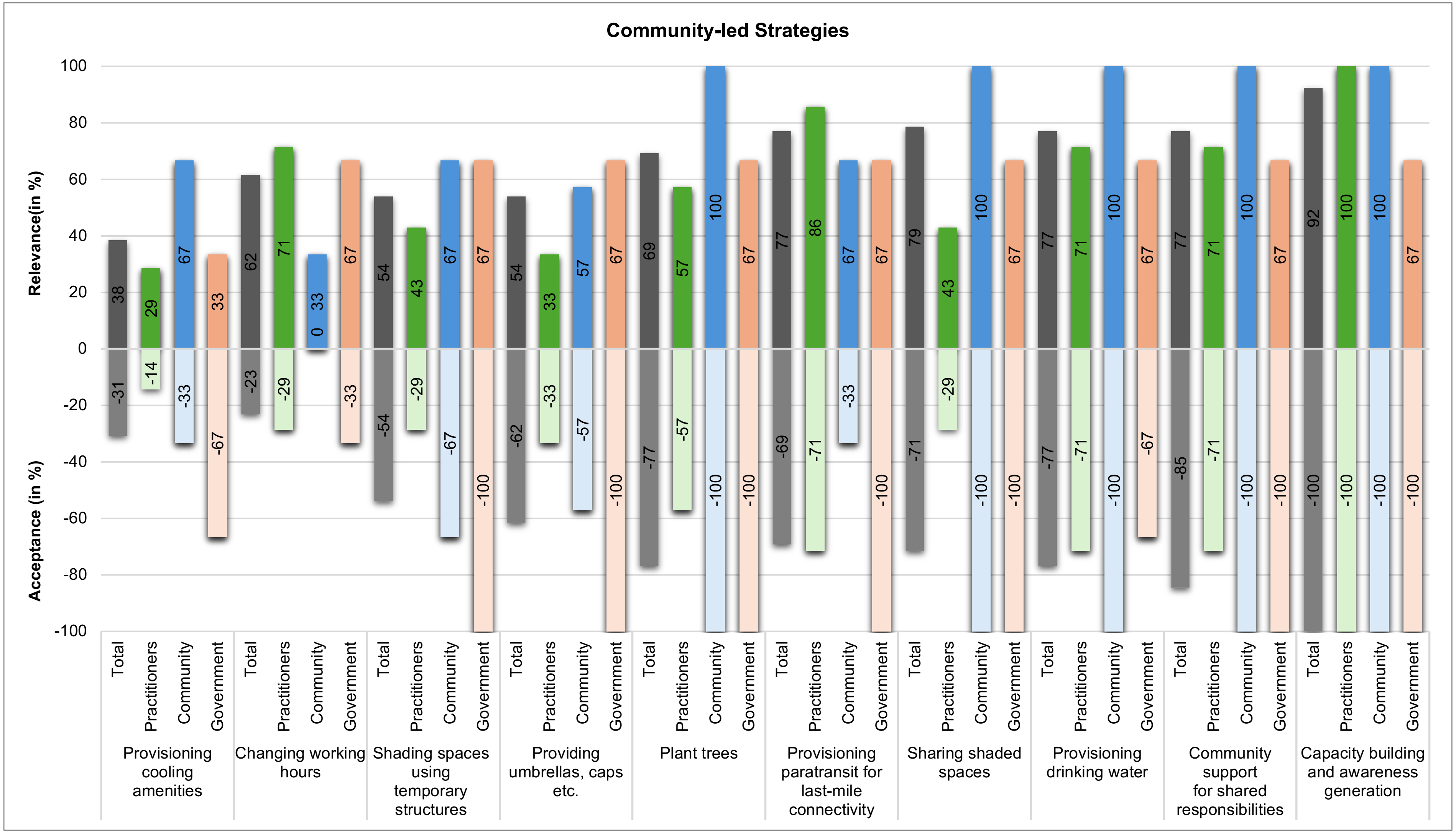

Figure 24: Relevance and acceptance of community-led strategies

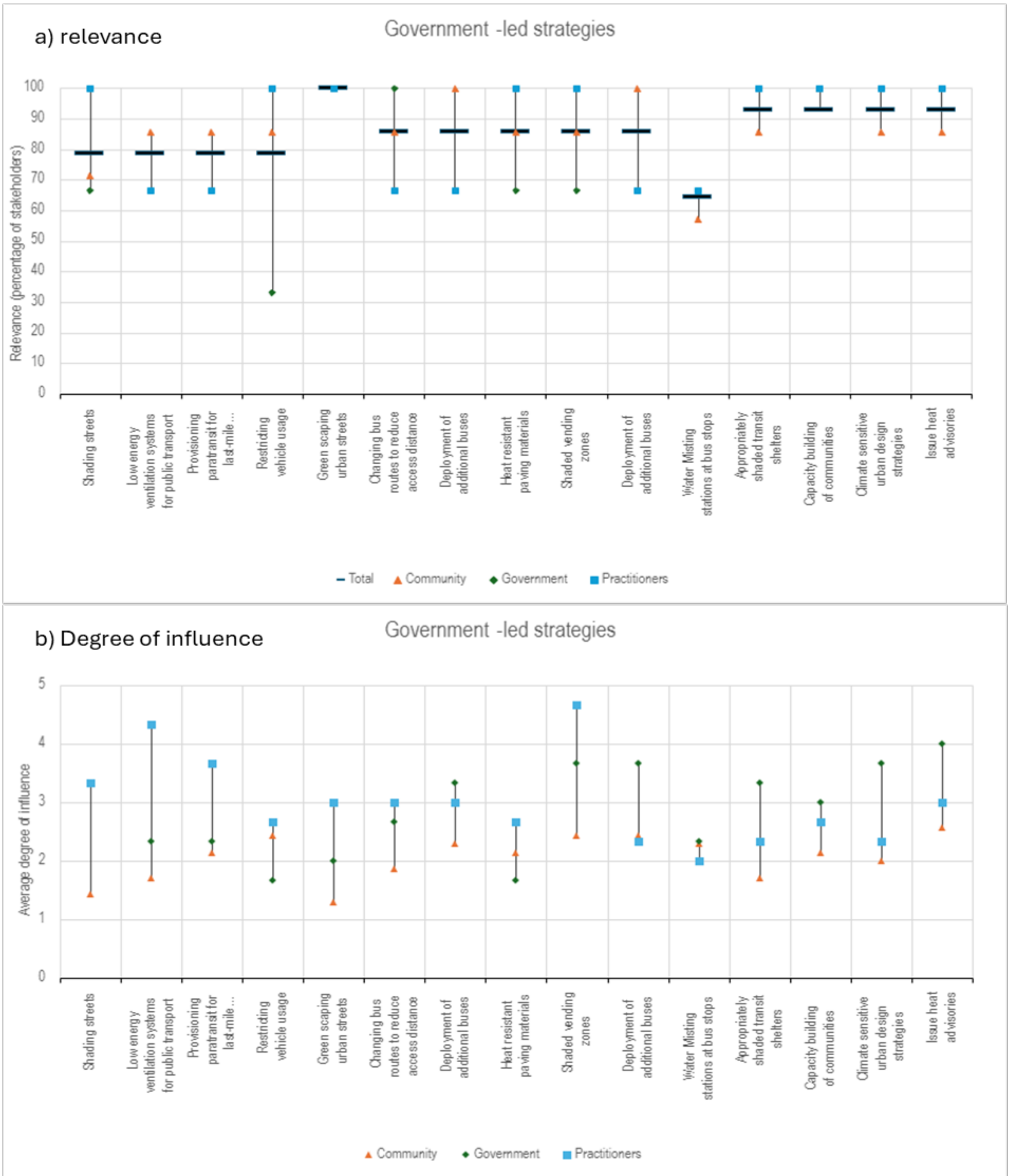

Figure 25: Government-led strategies, a) level of relevance; b) degree of influence

4.1.2 Key findings

1. **Individual-Led Strategies**:
    - Strategies like wearing weather-appropriate clothing, staying hydrated, and carrying umbrellas received broad support due to ease of implementation.
    - Other strategies, such as avoiding crowded spaces and peak heat travel, were relevant but faced acceptability challenges, indicating a need for supportive policies.
2. **Community-Led Strategies**:
    - Capacity building, awareness programs, providing drinking water, and sharing shaded spaces achieved high levels of consensus, with stakeholders recognizing these as feasible and beneficial.
    - However, adjusting working hours generated mixed views, particularly among practitioners and community members. Adopting such strategy my require pilot programs to build acceptance.
3. **Government-Led Strategies**:
    - High consensus was achieved on infrastructure improvements, including shaded streets, heat-resistant materials, and public green spaces.
    - Restricting vehicle use faced resistance, especially from community members, who cited limited alternatives and safety concerns. This suggests the importance of public transport and street shading as supportive measures.

The findings emphasize the need for comprehensive, collaborative efforts to address extreme heat impacts through a blend of awareness campaigns, policy support, and infrastructure improvements.

4.2 Codesign workshop

The co-design workshops were conducted in collaboration with HumanQind to create solutions for climate change adaptation at individual and community levels. The workshop design is based on the project data gathered from 448 responses (63% female) across three schools and infrastructure audits of 20 streets in Delhi neighbourhoods. The workshops, designed with insights from field research, focused on gender-sensitive approaches to hot weather adaptation.

Four personas of women were developed based on income and lifestyle patterns, informing the creation of the AMBI-KIT. The toolkit used a play-based approach to foster engagement, including steps for identifying personal experiences, selecting streets, co-creating solutions, assigning responsibilities, and adapting strategies (Figure 26). The steps enabled participants to assess their neighbourhood conditions, envision improvements, and assign roles for implementing changes.

Figure 26: AMBI KIT (1: Information Booklets; 2: Action Booklet; 3: Worksheet; 4: Solution Cards; 5: Woman Persona Cards; 6: Stickers; 7: Badge)

Workshops engaged 43 adults and 56 children, encouraging intergenerational discussions (Figure 27). Participants preferred solutions like drinking water, shaded areas, and improved pavement. The workshops fostered empathy and support, with male participants expressing willingness to share responsibilities. Cultural factors, such as work breaks and community green spaces, were also discussed. Overall, the workshops highlighted the need for gendered, community-driven approaches to climate adaptation.

School A		
School B		

School C		
		

Figure 27: Glimpses of codesign workshops

5. Recommendations and conclusion

The project shows that the women are more exposed to high temperatures. This is because they -

1. walk more to meet their travel needs exposing them to high temperatures while commuting.
2. tend to travel more during the day when ambient temperatures are higher for various purpose including for caregiving duties, increasing their exposure.
3. those, particularly from lower income groups are primarily dependent on walking.

The study shows that women (mothers of school going children) do not consider changing either their mode of transport or changing time of activity between seasons. While men are more likely to choose motorized modes of transport during hot weather.

Infrastructure audit shows that the thermal comfort, walkability, and shading index varies by the type of street. Collector roads provide better pedestrian amenities and green infrastructure than local lanes. While minimum of the maximum temperatures is recorded on lanes.

There is a need to provide for safe, walkable and thermally comfortable walking environment to address the identified challenges. Furthermore, actions are needed to enable better adaptation practices amongst women. This would require individual-, community-, and government led strategies ranging from self-adaptation practices to infrastructure development interventions.

Some of the potential solutions identified based on stakeholder and cocreate workshops are listed below:

- **Individual Actions:** Using weather-appropriate clothing, staying hydrated, and carrying umbrellas received broad support.
- **Community Initiatives**: Suggested actions included awareness campaigns, provision of shaded rest areas, and drinking water.
- **Government-Led Strategies**: Infrastructure improvements like shaded streets, green spaces, and public cooling amenities were widely supported. However, restricting vehicle use faced resistance, especially due to safety concerns.

To improve thermal comfort and safety, the study recommends increasing green canopy cover, enhancing public transport, promoting active mobility, and implementing shaded pedestrian pathways. These strategies, developed through stakeholder engagement, can reduce exposure and support sustainable urban mobility.

As the temperatures continue to rise, the population is increasingly exposed to the risk. Particularly those who continue to travel during high temperatures are exposed to the high temperatures on streets. This study, through sample data discusses the exposure levels of women (mothers of school going children) and the status of street infrastructure in terms of providing safe, walkable, and thermally comfortable experience.

The study emphasises the need for interventions to enable reduction of hazard levels (high temperatures) and adoption of adaptation practices. The strategies need to be equitable and especially consider the needs of vulnerable groups like women.

The study and its findings are limited to a sample of mothers of school going children of three schools of varying type (government-aided and unaided) and 20 streets belonging to 10 neighbourhoods in Delhi. There is a need to expand the understanding of the exposure levels, adaptation capacity, and related vulnerability to include multiple cohorts and considering larger sample. There is also a need to understand the variations in thermal comfort conditions with respect to street typology and infrastructure. This would require larger dataset and inclusion of multiple types of streets across street. We measured exposure levels in different seasons. Determining risk and vulnerabilities would require understanding of hazard levels to which different mode users are exposed to in different street conditions.

Nevertheless, the project has provided a good understanding of the exposure levels, adaptation capacity and potential strategies for addressing heat stress particularly for women and mothers of school going children. The project has used AMBI-kit and participatory approaches to engage with multiple stakeholders including parents and school children to develop potential strategies. Such a method can help in the development of inclusive and equitable heat action plans and solutions. The insights developed from the project are necessary to engage with policy makers and enable development of an inclusive heat action plan by considering transport sector.

5.1 Final workshop and way forward

A final workshop was conducted on 18th December 2024, bringing together 24 participants representing researchers, policymakers, practitioners, and school community. The workshop was designed to explore actionable strategies for mitigating and adapting to the rising impact of heat on urban populations, focusing on women. The discussions highlighted how intersecting vulnerabilities, such as women's higher share of walking trips and socio-economic challenges, exacerbate their exposure to extreme heat. The workshop was divided into three sessions. The first session provided the participants an overview of the project and key findings. Thereafter, two panel discussions were organized to discuss long-term and short to medium-term strategies. Session Discussions:

Key insights from stakeholders and future work shall include –

- The critical role of governance, funding, and multi-scale planning in operationalising heat action plans.
- Recommendations for integrating gender dimensions into transport, urban planning, and heat resilience frameworks to address barriers women face in accessing public infrastructure and employment.
- Specific challenges, such as the lack of inclusive public transport amenities during peak heat hours and limited attention to non-heat wave events like humidity, were highlighted.

The workshop also led to discussing –

1. Need for integrating GIS-based mapping
2. Need to consider sustainable materials in infrastructure
3. To enhance gender-inclusiveness in heat action plans.
4. To consider innovative solutions such as utilising water bodies for cooling.
5. Need for collaboration among researchers, policymakers, and community members
6. Scaling up such studies, improving policy integration, and ensuring equitable and practical interventions to enhance resilience for vulnerable groups, particularly women.

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