HEAT EXPOSURE AND HEALTH RISKS in the Minibus Taxi Sector in Durban

Scientific Report

REPORT PREPARED BY THE SOUTH AFRICAN MEDICAL RESEARCH COUNCIL FOR THE WORLD BANK

(Caradee Y Wright, Thandi Kapwata, Ngwako Kwatala, Siyathemba Kunene, Nomfundo Mahlangeni, Candice Webster, Tracey Laban, Semakaleng Monyai and Muthise Bulani)

6 November 2024

Acknowledgements

The ‘Heat exposure and health risks in the Durban Minibus Taxi Sector’ study was conducted by the Climate Change and Health Research Programme of the Environment and Health Research Unit at the South African Medical Research Council in partnership with the World Bank Group and the Chesterville Taxi Association (CTA). We would like to express our gratitude to Mr. Mkhize (CTA chairperson), Mr. Gumede (CTA chairperson’s second in command), Mr. Mbambo (English Market Taxi Rank), Qiniso Protection Services, and the taxi drivers who agreed to take part in the study.

Funding

This work was funded by the State Secretariat for Economic Cooperation of Switzerland (SECO) under the Urban Multi-Donor Trust Fund for South Africa and by the City Resilience Program, Global Facility for Disaster Reduction and Recovery (administered by the World Bank).

Contents

List of Figures

List of Tables

Executive summary

Exposure to high temperatures is associated with increased risk of dehydration, heat-stroke, exacerbation of existing chronic conditions and in extreme cases, death. Vulnerability to health impacts of heat is influenced by factors that include occupation and the immediate environment. This study investigated how heat inside taxis and taxi ranks impacts the health of taxi drivers to provide evidence to influence policy amendments and build partnerships and coordination across all stakeholders to mitigate against heat-related health risks.

Temperatures inside and outside taxis from the Chesterville Taxi Association (in Durban) were measured hourly for 5 days to assess heat exposure. Indoor and outdoor apparent temperature (a real-feel heat metric) was also calculated to estimate potential health risks. A questionnaire was administered to taxi drivers to understand their perceptions and experiences of heat.

Taxi drivers were exposed to temperatures between 24 – 39°C inside taxis, therefore increasing their risk of dehydration and heat exhaustion which could affect their concentration and thus ability to drive safely. Temperatures above 39°C are associated with heat stress during extended periods of exposure. In summary:

- Temperatures inside minibus taxis reached up to 39°C which is HOT and risky to health!
- The temperatures inside minibus taxis were between 3-4°C warmer than outdoors!
- For around 11 hours every day, temperatures inside minibus taxis were warmer than 27°C – the first temperature threshold that is linked to heat-health risks associated with apparent or real-feel temperature.

What do these findings mean for authorities, funders, researchers and the taxi industry?

To protect the health and well-being of minibus taxi drivers as well as commuters urgent action is needed to address heat risks in the transport sector; raising awareness about drinking water to stay hydrated; increasing shade and cool places for parked taxis; addressing heat inside the HiAce itself by using ventilation or tinting; and supporting research around evidence generation and assessment of interventions are all necessary steps to take.

Introduction

Background

Climate change is causing warming of ambient temperatures and certain settings are at risk. For example, the thermal environment of an enclosed vehicle is influence by meteorological conditions such as solar radiation, ambient air temperature, relative humidity and wind speed (Zhou et al. 2019). Additionally, thermal comfort of humans inside vehicle is also related to environmental factors such as air temperature, relative humidity, mean radiant temperature and air velocity (Simion et al. 2016, Kim et al. 2021). According to a study by McLaren et al. (2005), temperatures in stationary vehicles can increase significantly within the first 15 to 30 minutes with an average of a 4°C increase regardless of ambient temperature. Exposure to excessive heat can cause thermal discomfort and affects the thermoregulatory capacity of the body (Khan 2019; Ninan et al. 2020).

Thermoregulation is the ability of the body to maintain a core body temperature at about 37°C (Geneva et al. 2019). A core body temperature at above 39°C can lead to heat-related illnesses such as heat cramps, heat exhaustion or heat stroke. Moreover, heat can worsen existing chronic conditions such as cardiovascular and respiratory diseases. Heat exposure can also be measured using thermal comfort indices where above normal values indicate thermal discomfort or heat stress (Yilmaz et al. 2024). Extreme heat stress has also been shown to increase the risk of cognitive impairment and reduce physical activity (Ebi et a. 2021). As the frequency and intensity of extreme heat events are projected to increase due to climate change, vulnerable populations are at risk of heat-related illness and death (Zeppetello et al. 2022).

Public transportation is a convenient travel option for citizens worldwide. Rising temperatures can cause thermal discomfort for drivers and passengers in vehicles. The location, infrastructure and design of transit waiting areas (e.g. taxi ranks), and transit shelters can contribute to heat exposure in transit riders and drivers (Fraser & Chester 2017). Minibus taxi drivers in particularly are regarded as high-risk group for several health concerns due to exposure to poor working conditions (Ramukumba et al. 2016). A previous report showed that minibus taxi drivers in South Africa work an average of 14 hours per day (Barret, 2003). The long hours spent by the drivers in the vehicles increase the risk of health concerns. Given the possible risks from heat exposure among this vulnerable group, the aim of the study was to understand the heat exposure and experiences of taxi drivers in the city of Durban, KwaZulu-Natal, during hot weather.

Objectives of the Study

As part of the City Resilience Program ‘Cool Cities Living Lab,’ the objective of this work was to quantify extreme heat exposure in minibus taxi transport in one selected city to inform design of strategic actions to reduce adverse impacts on taxi drivers and passengers. This was done by carrying out a feasibility campaign to measure the temperature in minibus taxis and taxi ranks in the city of Durban.

Purpose of the Study and Research Questions

The main purpose of the study was to determine the feasibility of assessing how heat impacts health of taxi drivers inside taxis and at taxi ranks, and to also provide qualitative evidence to influence policy amendments and build partnerships and coordination across all stakeholders (i.e. city government, transport sector, health departments, etc.). Fieldworkers worked side-by-side with a taxi association to acquire all the information in this study.

This study was guided by the three research questions:

1. Are taxi drivers and commuters exposed to extreme heat during taxi journeys?\
2. What is the extent and characteristics of dangerous heat exposure within taxis?
3. How does the heat within taxis compare to heat outside taxis?

The following section describes a literature review and is followed by the study methods.

Literature review

Climate Change and Heat

Climate change is a pressing global challenge and projections for Africa are estimated to be greater than the global annual mean warming for all seasons (Christensen et al., 2007). The Paris Agreement, established in 2015, seeks to limit global average temperatures below 2.0 °C, and preferably below 1.5 °C above pre-industrial levels (United Nations Climate Change, 2024). Over the past few decades, observations show that Africa has experienced warmer and drier conditions (Engelbrecht et al., 2015; Scholes & Engelbrecht, 2021).

Climate change-related extreme weather events, such as heatwaves, are becoming more frequent and intense than before in Africa, including in South Africa (Engelbrecht et al., 2015; Trisos et al., 2022). Observations show that maximum temperatures are on the rise, particularly in the summer season (Thornton et al., 2014) and with significant increases in minimum temperatures across South Africa over the past few decades (Kruger & Shongwe, 2004; Mbokodo et al., 2020).

Heatwaves

Heatwaves are common in South Africa and are declared when the maximum temperature is expected to be greater than 5 °C above the average maximum temperature of “the hottest month” for that particular town and are persistent for at least three days (South African Weather Services, 2024). The number of heatwaves in the country over the last 15 years has increased relative to the 1961-1980 period (Russo et al., 2016). Furthermore, heatwaves will not only increase in the number of occurrences, but also increase in intensity and duration in the future (Mbokodo et al., 2020; Perkins-Kirkpatrick & Lewis, 2020; Russo et al., 2016).

Impact of heat on human health

> The thermoregulatory system uses physiological mechanisms to adjust the rate of dry heat loss and evaporative heat loss to the environment to balance the rate at which heat is gained and/or produced within the body (Kenny et al., 2024).

Thermoregulation is a homeostasis process that controls the body’s ability to maintain its body temperature regardless of changes in environmental conditions (Périard et al., 2021). Exposure to hot environments or an increase in metabolic heat production creates an imbalance to the body (Kenny et al., 2024; Périard et al., 2021). The human body is divided into two parts when it comes to body temperature, namely, internal / core temperature and skin temperature (Périard et al., 2021). Internal human body is regulated, while the skin temperature is unregulated and different across the body depending on thermal exposure relative to the environment (Périard et al., 2021). Internal human body temperature is approximately 37 °C, with a daily deviation of approximately 0.5 °C (Kenny et al., 2024; Presbitero et al., 2021). Environmental temperatures exceeding the skin temperature leads to the body gaining heat which increases sweating (Nakayoshi et al., 2015) and circulation adjustments that seeks to discard excess heat and restore heat balance and stable internal body temperature (Kenny et al., 2024). Evaporation of sweat is a heat loss mechanism preventing internal body temperature rising to dangerous levels (Kenny et al., 2024). The heat loss and heat gain in humans' thermal comfort is influenced by environmental (i.e., ambient temperature, humidity), personal (i.e., body mass), and task-dependent (i.e., clothing, metabolic rate) (Périard et al., 2021).

The impacts of heat exposure on health are wide-ranging including heat-related illnesses, exacerbation of pre-existing chronic health conditions and in some cases death (Ebi et al., 2021; I. L. Mbokodo et al., 2023). Personal factors that play a significant role in susceptibility to heat exposure are age, gender, ethnicity, race, and social isolation (Bayomi & Fernandez, 2023). Vulnerability to heat is higher among the elderly population (> 65 years old) and children (< 5 years old) (Bayomi & Fernandez, 2023). The elderly population's risk is due to their body's thermoregulation impairment and their inability to stabilize blood pressure during extreme heat exposure (Bayomi & Fernandez, 2023). Children are at risk due to dehydration as their bodies have underdeveloped functionality of thermoregulation, and they have a small body mass (Bayomi & Fernandez, 2023).

Extreme heat exposure is projected to increase in urban populations due to the combination of the expanding extent of impervious surfaces and increasing temperature as well as the heat island effect (IPCC, 2012). Health factors that play a role in increased risk to heat exposure include physical disability, medical condition, alcohol and drug abuse, and mental health (Bayomi & Fernandez, 2023). Environmental factors such as temperature, humidity, wind speed, land use, and vegetation also contribute towards thermal comfort (Ghani et al., 2021).

Heat indices and thermal comfort

Thermal comfort indices are tools used to evaluate thermal comfort in hot and arid indoor and outdoor environments (Ghani et al., 2021). Several thermal comfort indices have been developed in the last 70 years (Havenith & Fiala, 2016). Some of these thermal comfort indices commonly used to evaluate outdoor environments are physiological effective temperature (PET), predicted mean vote (PMV), standard effective temperature (SET), humidex, wet bulb globe temperature (WBGT), and universal temperature climate index (UTCI) (Ghani et al., 2021). One South African study considered heat stress among school students during physical education lessons and after-school sports activities using four heat stress indices: humidex, heat index, WBGT and UTCI (Raines and Fitchett, 2024). They found that students were at-risk of heat stress especially between 11h00-15h00.

Another is heat metric is apparent temperature that aims to describe the ability of the body to cool itself by perspiration and evaporation by accounting for multiple meteorological variables (*i.e.*, temperature, relative humidity and wind speed) in a single index (Steadman, 1979). Apparent temperature has been used extensively in previous studies on the association between health and high temperatures (e.g., Zanobetti and Schwartz, 2008; Basu et al., 2008). Since there are many areas across Africa with high levels of relative humidity that could potentially impact human health, it was deemed important to use an index that accounts for relative humidity in this study.

The Minibus Transport Sector in South Africa

The public transport sector in South Africa is made up of three modes of transport, namely, trains, buses, and minibus taxis. Trains account for 3.2% of the public transportation, buses account for 16.6% of the transportation, and taxis account for 80.2% of the transportation, making minibus taxis the most widely used mode of public transportation in the country (StatsSA 2020). Key challenges that the rail and bus system face include overcrowding, poor punctuality and lack of reliability of the services, as well as limited geographical coverage.

Taxis are the considered the backbone of South African transport industry. Taxis are the most accessible and affordable mode of transport in South Africa. It is estimated that taxis service over 16 million people every day and that there are about 2 600 taxi ranks and 283 000 taxis operating in the country. Moreover, the taxi industry creates over 960 000 jobs (Kgwedi and Krygsman, 2017) ranging from taxi drivers, marshals, car washers, mechanics, petrol attendants, to food and drinks vendors. The taxi industry is an informal economy as it operates on a cash-only business model. Approximately 5.4 million trips are made daily by the taxis (Kgwedi and Krygsman, 2017).

The Toyota HiAce is the most purchased and most common minibus taxi in South Africa. Toyota HiAce minibuses are used across small area level (i.e. wards) and for inter-provincial travel. Most small area levels are phasing out seven-seater minibus' and replacing them with the Toyota HiAce; and the Toyota HiAce is preferred for all long-distance travel. Toyota HiAce is a minibus manufactured by Toyota automobile company. The first make of Toyota HiAce was manufactured in the 1960s and it was assembled in Japan and Asia. In 1982, a third generation Toyota HiAce was introduced to South Africa and a plant to assemble the minibus was built in Durban. The third generation Toyota HiAce was a 16-seater and had ten windows.

The fifth generation Toyota HiAce was produced in 2012 as a successor of the third generation Toyota HiAce. The fifth generation Toyota HiAce is longer and wider than its predecessor, and their similarity is that they are both 16 seaters without a fan or air conditioning. The fifth generation Toyota HiAce has of six windows and a panoramic window installed and the panoramic window acts as an emergency escape hatch. The fifth generation Toyota HiAce is aesthetically pleasing and has a minimalistic design but it has less ventilation capabilities and exposure to direct sunlight through panoramic window, which could both be contributing to increased heat inside the taxi. When Toyota created a

new model of HiAce, they called it Quantum; and later they started calling it HiAce (back to its predecessor); and gave the Quantum name to the nine-seater shuttle bus.

It is estimated that over 200 000 taxis drivers operate hundreds of routes daily nationally (Kgwedi and Krygsman, 2017). Taxi drivers work irregular hours often totalling 12 hours daily (Kgwedi and Krygsman, 2017). Taxi drivers spend most of their working hours in a sitting position inside a taxi, either on the road or binding. “Binding” is the colloquial term (taxi industry jargon) referring to taxis waiting to load passengers in the taxi line at the taxi rank. Having described the minibus taxi industry in South Africa, we now identify gaps in the literature and propose the rationale for this study.

Rationale

Globally and in Africa, there has been an increase in the number of days with extreme heat and heatwaves (WHO, 2020). Heat has adverse impacts on human health and well-being. These effects include dehydration, heat stroke, heat cramps and even death (NIEHS, 2020). Heat can also affect people with pre-existing diseases as well as vulnerable groups, such as infants, children, the elderly, outdoor workers and athletes (CDC, 2020).

Urban areas are projected to increase in geographical size and population growth in the future as people move away from rural areas to seek better job opportunities and services (UN, 2018). As a consequence of climate change, the urban heat island effect (where the city or metropolitan area is much warmer than the surrounding rural areas) is likely to intensify (Masson et al., 2020). Urban spaces where many people gather and have not been designed to protect users from heat, may exacerbate heat-health risks. One such space is a minibus taxi rank and minibus taxis who frequent these ranks.

In South Africa, minibus taxis are the most common mode of public transport where about 70% of households rely on these taxis daily (TETA, 2020). Minibus taxis drive between taxi ranks where passengers embark or disembark from the taxis. Most minibus taxi ranks are on land legally owned by the city in which they are located. These taxi ranks range from open lots to formally designated paved areas with overhead metal roofing. However, even the formal taxi ranks were not structurally designed to be climate resilient or to protect against climate variables such as extreme heat. While the environmental impacts of taxi ranks have been assessed in one taxi rank in the Eastern Cape (Noah, 2002), no assessments have been done of the heat-health risks experienced by users of taxi ranks and minibus taxis.

Assessment of thermal comfort at taxi ranks is essential for taxi drivers, vendors, marshals and commuters to better understand heat-health risks (Ghani et al., 2021).

Public urban spaces, such as minibus taxi ranks, which people visit daily and can spend significant time at, may become a zone of discomfort, and pose a threat to public health if they are not ‘climate-proofed’ to protect people against the health threats associated with high ambient temperature. As garnered from the literature, several pieces of information are missing and these are the gaps to be filled – what are the temperatures experienced in taxis and taxi ranks; what are the heat-health risks present in taxis and taxi ranks; and what are the most appropriate interventions needed in taxis and taxi ranks to protect people from heat-health risks? These puzzle pieces will help provide the evidence needs to develop guidelines for climate-proofed public transport spaces that protect public health.

Methods

Study area

The study was conducted in Durban, a city in KwaZulu-Natal Province of South Africa (Fig. 1). Durban is the third most populous city in South Africa with a population of 4.2 million people (National Government Handbook – South Africa 2021). The population density is 2 600 people per km^2 in a total area of 2 556 km^2.

The climate in Durban is characterized as a humid subtropical climate with hot humid summers and warm moderate dry winters (Koppen climate classification Cfa) (Kottek et al. 2006). Durban is boarded by the Indian ocean and inland, and as a result, the differences of summer maximum and winter minimum temperatures are comparably small. Durban lies at an altitude of 101 meters. The influence of the surrounding ocean and topography creates micro and macroclimates in the area. The average mean temperature ranges between 13 °C and 27 °C (Mncube, Adelabu & Adagbasa 2023). Weather systems such as coastal low and El Nino events tend to increase temperatures. In addition, heatwaves (with a threshold of 34 °C in Durban) have been more common in the city than ever before, and this might be due to the effect of climate change.

Data collection

This study was based on qualitative and quantitative research methods, namely temperature measurements inside taxis and taxi ranks, questionnaires administered to participants, and surrounding environment observation.

Prior to the execution of the fieldwork, the data collection protocols were piloted in Johannesburg among commuters and drivers of minibus taxis. The main study was conducted in Durban from 19 March - 20 March 2024 when temperature and relative humidity levels were measured in 16 minibus taxis and several ranks and the Taxi Driver Questionnaire and Taxi Rank Observation Checklist were administered. The taxi driver questionnaire was developed by the research team to comprehend the experiences of taxi drivers associated with heat during their daily working routine. In-person questionnaires were administered to taxi drivers and took approximately 10 minutes. Fieldworkers entered the taxi drivers' responses on RedCap software installed on the tablet. The taxi rank observation checklist was completed by fieldworkers on RedCap software while on site.

Sampling procedure

A detailed description of the sampling procedure is found in the fieldwork feedback report. In brief, the sampling procedure was done for the Chesterville Taxi Association (CTA) taxis operating from Durban central to other destinations. At least one taxi was selected per taxi route that the CTA operate in. Taxi routes were selected to maximize contrasts in heat levels to the different environments. The CTA operates in seven taxi routes around Durban.

The inclusion criteria for installing temperature sensors inside a taxi included: (i) a Toyota HiAce minibus, (ii) nothing should be placed under the seats (e.g. speakers), (ii) availability of empty space for deployment on the third-row seat and last row seat and (iii) the taxi should operate daily. Taxis operating less than four days were excluded.

The inclusion criteria for installing at a taxi rank included: (i) it should be within ten meters from where the taxis are parked and (ii) there should be at least more than three taxis queuing to pick up passengers at any given time.

The study was conducted across 12 taxi ranks that service seven taxi routes in Durban. Four taxi ranks were classified as the main taxi ranks while eight taxi ranks were classified as satellite taxi ranks. Main taxi rank is defined as a piece of land with approved land zoning certificate and sheltered taxi rank structure, while a satellite taxi rank is defined as land with a different zoning but used as an informal taxi rank without infrastructure (i.e. shelter, rest rooms). Of the 12 taxi ranks, four of the taxi ranks were located in the city centre, five taxi ranks were located in the shopping centres and government institutions (i.e. hospital or university), and three taxi ranks were located in the residential areas. Toyota HiAce model was selected to partake in the study as they are a popular brand. This study's sampling size was 16 taxis at most due to availability of sensors; thus, no randomized or stratified sampling was used.

Temperature and humidity data collection

The Thermochron iButton is a low-cost sensor used to measure temperature and humidity (Figure 2). The device has a temperature resolution of approximately ±1 °C, and its sensitivity range is -30 °C to +70 °C for temperature (iButton Link Technologies 2024) – no information was provided by the manufacturer regarding relative humidity. iButtons can store 2 048 temperature datapoints at a sampling rate of 1 min to 255 minutes. The device is the size of a small disc battery and is powered by a lithium battery that should operate for at least 10 years without maintenance. The device is held in a specially designed plastic fob and a steel chip is inserted on a plastic tag. Temperature and humidity are measured by the steel chip and the device saves the recorded data in-situ. The size of the tag is approximately 8 cm in height and 2 cm width. The tag has a small opening that is used to secure the iButton with a cable tie.

Figure 1. Illustration of the Thermochron iButton.

iButtons were installed on 19 – 20 March in 16 taxis and removed on 22 - 23 March in taxis, while iButtons were installed on 20 March in 3 taxi ranks and removed on 23 March on the taxi ranks. The iButtons were programmed to record temperatures every hour. To access the data recorded, the iButton is loaded on a software interface to download the data and save the data in a readable format. Each iButton is marked with a unique serial number and it is programmed using the software supplied. The device does not have an ON/OFF switch; however, the device is set to start measurements at a specified date and time using the software supplied.

For this study, iButtons were installed in different settings. The main placement for measurements was inside the taxi. However, we also installed iButtons outdoors in taxi ranks but these iButtons did not record correctly and only one set of data from one rank was applied in the study. Cable ties were used to secure the iButtons in place and ensure they could not be moved around or fall off. The taxi drivers were requested to check for the sensor daily and report if devices were missing. The date and time of installation of the iButton were recorded on log sheets for record keeping purposes. Data quality control procedures included checking for incorrect / impossible readings, completeness of data and deleting data recorded before the installation date and time as per the log sheets records.

Ambient (outdoor) temperature and relative humidity data

Hourly measurements for daily ambient temperature, humidity and wind speed data were obtained from the South African Weather Service (SAWS) from an automated weather monitoring station located at the King Shaka Airport in KwaZulu Natal (Figure 2). Data were provided from 1 March to 31 March 2024 in an Excel format. SAWS has procedures in place for data quality assurance and quality control. These included removing impossible values resulting from human error or instrument malfunction, outliers and duplicated values.

Data from 19 to 23 March were extracted for comparison to temperatures inside taxis and one taxi rank. Data were presented descriptively as boxplots and line charts. A Pearson correlation analysis was conducted to investigate the relationship between temperature inside taxis and outdoor ambient temperature, $p<0.05$ was considered statistically significant.

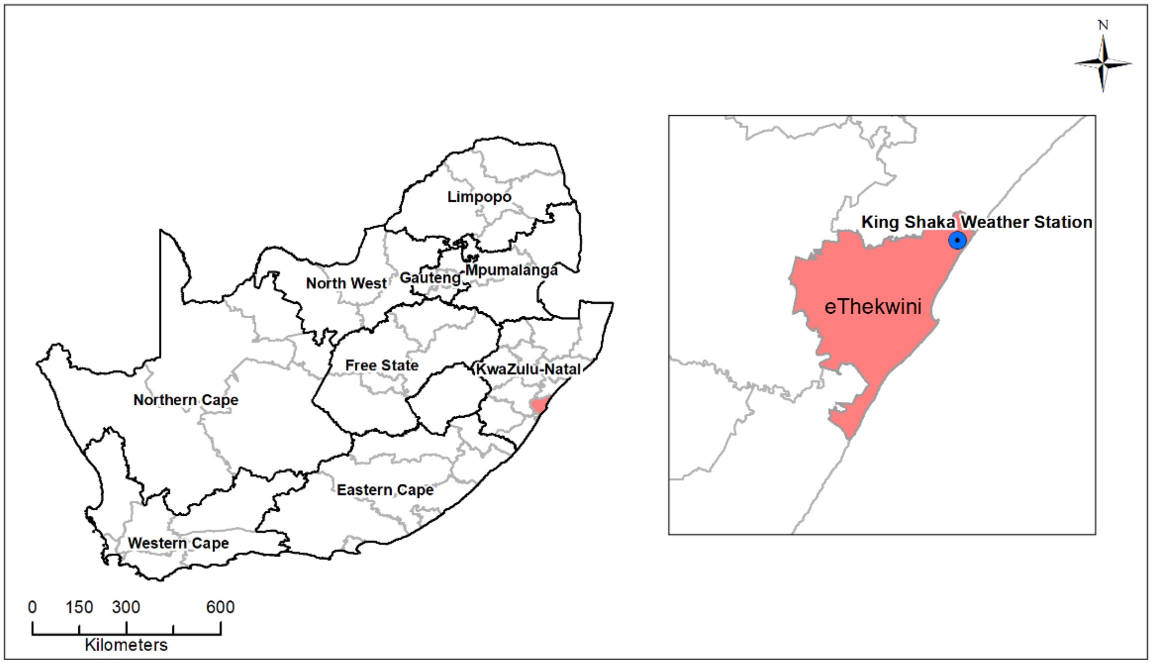


Figure 2. Map of the location of eThekwini Municipality and the SAWS King Shaka Weather Station which is the station for which we obtained ambient (outdoor) temperature and relative humidity data for this study. These data were compared to the temperature and relative humidity measurements made in the taxis.

Apparent temperature

We used temperature and relative humidity measurements to calculate apparent temperature. Apparent temperature is an indicator that is often used to measure thermal comfort (Steadman, 1979). It combines temperature, wind speed and humidity to obtain a metric that is considered as “real-feel” i.e. what the temperature feels like to the human body. The equation is as follows:

$$AT = Ta + 0.33 \times e - 0.70 \times ws - 4.00$$

Where:

- Ta = dry bulb temperature (°C)
- e = water vapour pressure (hPa)
- ws = wind speed (m/s) at an elevation of 10 m (set to 0 because this was an indoor setting)

and:

$$e = \frac{rh}{100} \times 6.105 \times e^{(17.27 \times \frac{Ta}{237.7+Ta})} \quad (2)$$

where rh = relative humidity (%).

Apparent temperature can be interpreted according to the four classifications in Table 1 (Steadman, 1979). Possible health risks for apparent temperature were evaluated using temperature ranges developed by the United States National Weather Service (USNWS) and the National Oceanic and Atmospheric Administration (NOAA) (Steadman, 1979). These ranges are categorized into 'caution', 'extreme', 'danger', and 'extreme danger' and potential health impacts are also provided for each warning level.

Table 1. Apparent temperature thresholds and potential health impacts (Steadman, 1994).

Symptom Band	Classification	Apparent Temperature Range (°C)	Possible health effects on the body
I	Caution	27–32	Fatigue possible with prolonged exposure and/or physical activity
II	Extreme caution	32–39	Heat stroke, heat cramps, or heat exhaustion possible with prolonged exposure and/or physical activity
III	Danger	39–51	Heat cramps or heat exhaustion likely, and heat stroke possible with prolonged exposure and/or physical activity
IV	Extreme Danger	51	Heat stroke highly likely

Heat metrics and calculations

Exposure metrics are quantitative values that indicate an individual's exposure to environmental heat. Five individual experienced temperature (IET), namely, Mean IET, Maximum IET, Longest Exposure Period (LEP), Percentage Hour Above Threshold (PHAT), and Degree Hour Above Threshold (DHAT) were applied to estimate the exposure intensity, duration, and frequency of individual's heat exposure (Hondula et al., 2021). The intensity of heat exposure is best determined by Mean IET and Maximum IET. The duration of heat exposure is best determined by LEP.

The frequency of heat exposure is best determined by PHAT and DHAT. LEP, PHAT, and DHAT are dependent on a temperature threshold considered risky for persons in a given region. Higher values of exposure metrices indicate higher heat exposure. These metrices' temporal units are either minutes, hours or days, however, for the purposes of explanations here, hours were used. Note that the temporal units change the names of the metrices i.e., minutes dataset will be used to calculate degree minutes (DMAT) or daily dataset will be used to calculate degree days (DDAT).

Mean IET refers to the average magnitude of heat exposure in a given time period:

$$Mean\ IET = \frac{\sum(\overline{IET})}{n}$$

Where $\overline{IET}$ is the sum of the temperature observations, and n is the sample size of the observations. $Mean\ IET$ is effectively the mean of an individual participant.

Maximum IET refers to the hottest hour in a given time period:

$$Maximum\ IET = \ maximum\ value\ of\ temperature\ observations$$

Where $maximum\ value\ of\ temperature\ observations$ is the highest observed temperature reading from the observations. $Maximum\ IET$ is effectively the maximum of an individual participant.

LEP refers to the continuous amount of time the individual is exposed to heat above the temperature threshold. LEP is determined by calculating the continuous hours above the temperature threshold; and ranking those hours by ascending order. The highest number in the ascending order is LEP.

DHAT (also known as Degree Hour) refers to when environmental temperature measured is one degree above threshold temperature for one hour (Snyder et al., 1999). DHAT is the sum of IET observations above temperature threshold and it determines the amount of heat exposed to the person during the entire study period. The impact of heat below the temperature threshold is assumed to be insignificant (Snyder et al., 1999). DHAT is calculated as:

$$DHAT = \sum (> \overline{IET})$$

Where $\overline{> IET}$ is the sum of the mean observations above temperature threshold of the sample. The units for $DHAT$ is degree hours.

PHAT refers to the percentage environmental temperature measured above threshold temperature for one hour. PHAT is the ratio of IET observations above temperature threshold to the total number of observations and it determines the percentage of heat exposed to the person during the entire study period:

$$PHAT\ IET = \frac{number\ of\ observations\ above\ threshold}{n} \times 100$$

Where n is the sample size.

In this study, the threshold temperature used was 30.6°C, derived from (Kapwata et al., 2024) as the riskiest temperature for heat exposure in Durban. Previous studies (Hondula et al., 2021) have used the mean of means of the sample data to define the threshold temperature, however, this study seeks to determine the risk of humans to heat-related illnesses in Durban, hence the temperature threshold related to risk.

The five IET exposure metrices were compiled using mean of means. That translates to finding the mean of the observations for each participant and deriving the metrices from the means instead of individual observations. This study had a sample size of 30 (two loggers per minibus taxi). The time frame (day hours) for hot days were used in the study. Day hours refer to the moment of sunrise to sunset (i.e., 6am – 6pm in summer months). There were four observed hot days during the study (e.g. 19, 20, 22, 23 March 2024). 21 March 2024 was not regarded as a hot day due to low temperatures.

REDCap Questionnaires for Heat Perceptions and Interventions

The Taxi Driver Questionnaire and Taxi Rank Observation Checklist were used as primary methods to data collection. The Taxi Driver Questionnaire was conducted on 19 March - 20 March 2024. The questionnaire was developed by the research team to understand the experiences of taxi drivers associated with heat during their daily working routine. In-person questionnaires were administered to drivers and took about 10 minutes.

The questionnaire was grouped into four themes comprising questions concerned with (1) demographics, (2) personal experiences with heat, (3) thoughts on the rank structure and lack of, and (4) ways in which heat can be mitigated in the taxi and the rank. The demographics information collected was age and gender; individual heat experience while inside the taxi or at a taxi rank, times of day when heat is high, heat coping mechanisms used to alleviate body heat and heat inside the taxi, and advice on actions to keep the body and the taxi cooler; thoughts on rank structure and taxi design information collected was an open ended question where taxi drivers share their knowledge and thoughts on improving the cooling at taxi ranks and in taxis. Fieldworkers entered the participant responses on RedCap software installed on a tablet. The questionnaire is available in the supplementary section.

Taxi Rank Observation Checklist

The Taxi Rank Observation Checklist (please see supplementary material) was conducted on 19 March – 20 March by the fieldworker. The Taxi Rank Observation Checklist was used to capture the surrounding environment and attributes of a taxi rank. The observation sheet was divided into three themes: (1) taxi rank infrastructure, (2) commuter needs and accommodation, and (3) land cover. Data collected on the taxi rank infrastructure included the type of taxi rank, peak service times, taxi rank shelter, and number of taxis operating in the taxi rank. Data collected on taxi rank commuters included responses to questions pertaining to the presence of a shade in the waiting area, seating area, vendor stalls, toilet facilities, and running water. Data collected on taxi rank land use included number of trees around the taxi rank, type of vegetation around the taxi rank, and type of land cover.

Research Ethics Approval

Since this study entailed working with participants, the study protocol was reviewed and approved by the SAMRC Human Research Ethics Review Board (Ethics number: EC019-9/2022).

The results section presenting the study findings by research question (see the end of the introduction on page 9) follows.

Results

Are taxi drivers and commuters exposed to extreme heat during taxi journeys?

Temperatures measured inside minibus taxis

Temperatures inside taxis during the study period ranged from 19°C – 39°C, with a mean of 27°C. The lowest temperatures were observed between the 21st and 22nd of March. A study by Kapwata et al. (2024) found that in the eThekwini District of KwaZulu-Natal (where the city of Durban is located), the risk of daily all-cause mortality increased significantly when temperatures exceeded 30.6°C. The temperatures measured in this study show that taxi drivers and commuters are often exposed to temperatures beyond this threshold which is likely to increase the risk of adverse impacts on their health.

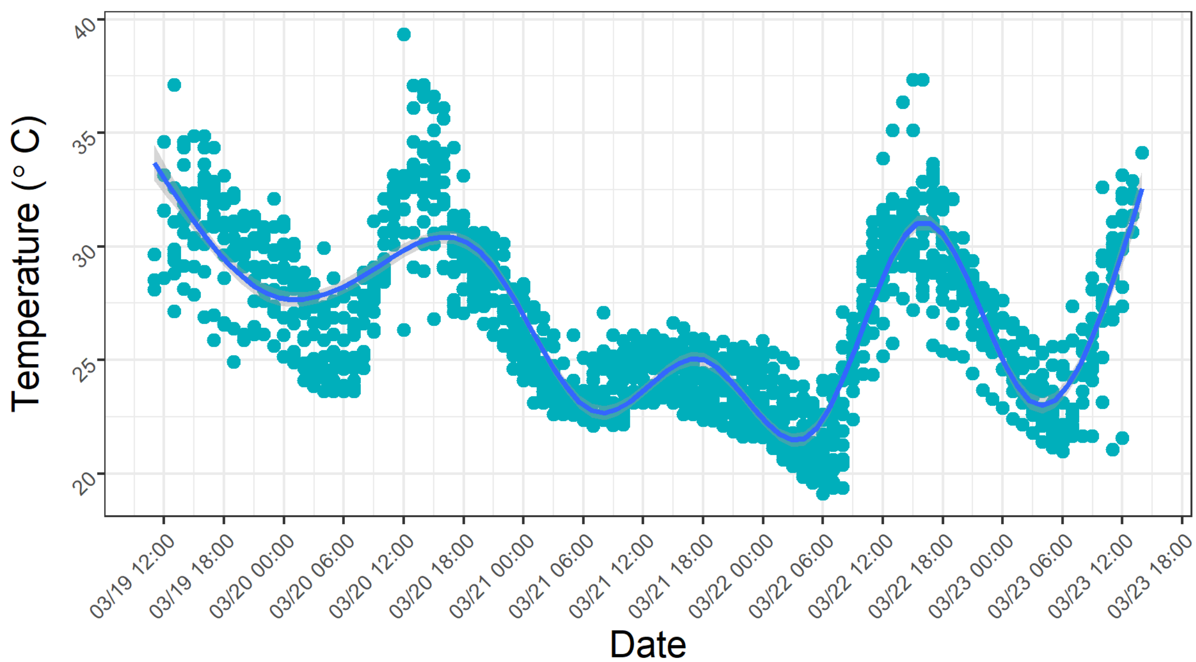


Figure 3. Temperatures inside taxis from the 19th to the 23rd of March 2024 (iButtons recorded measurements every hour).

Average hourly temperature inside taxis ranged from 21°C - 32°C and displayed a diurnal pattern with low temperatures observed in the early morning and evening and peaks occurring between 12:00 – 15:00 in all taxis (Figure 4). The higher temperatures also coincided with periods of high commuter volumes meaning that during these times both passengers and commuters could be at increased risk of adverse heat related health outcomes.

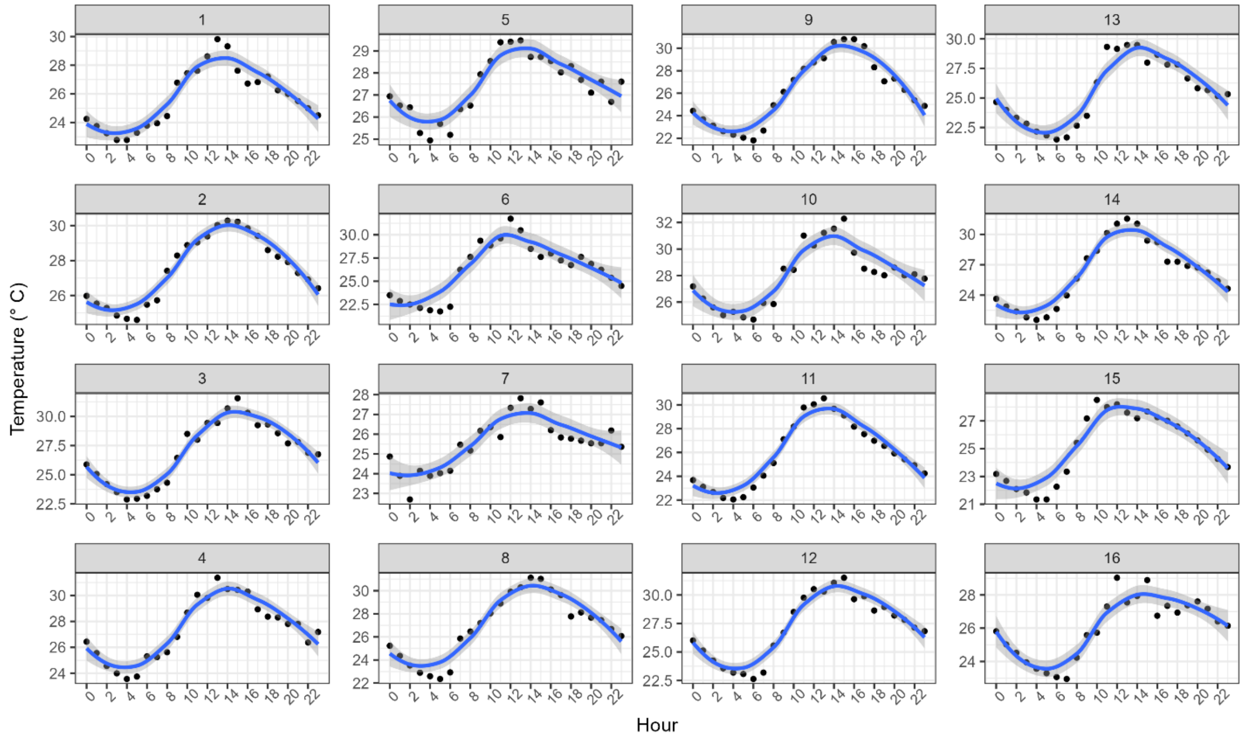


Figure 4. Average hourly temperature inside all of the taxis in the study. Each plot represents the data for one of the 16 minibus taxis. Temperatures steadily increase from the early hours of the morning and reach peaks around 14h00 or 15h00 each day.

What are the extent and characteristics of dangerous heat exposure within taxis?

Apparent temperatures and possible health risks when inside minibus taxis

Daily mean apparent temperature inside taxis was above 27°C on all five days, with the highest mean being 35°C on the 19 March (Figure 5). Therefore, taxi drivers were exposed to mean apparent temperatures that could result in health impacts ranging from mild (fatigue and discomfort) to moderate / severe (heat stroke, sun stroke, heat cramps, or heat exhaustion) (see Table 1 on page 19 for full details of heat symptoms associated with health risks).

A similar pattern is observed in Figure 6 which shows that hourly temperatures on the 19 March were all within the "extreme caution" heat warning category. Similar to temperature, apparent temperature also exhibits a diurnal pattern with distinct differences between morning, afternoon and night. The plots for the 19 and the 23 March are incomplete because these were the iButton installation and removal dates.

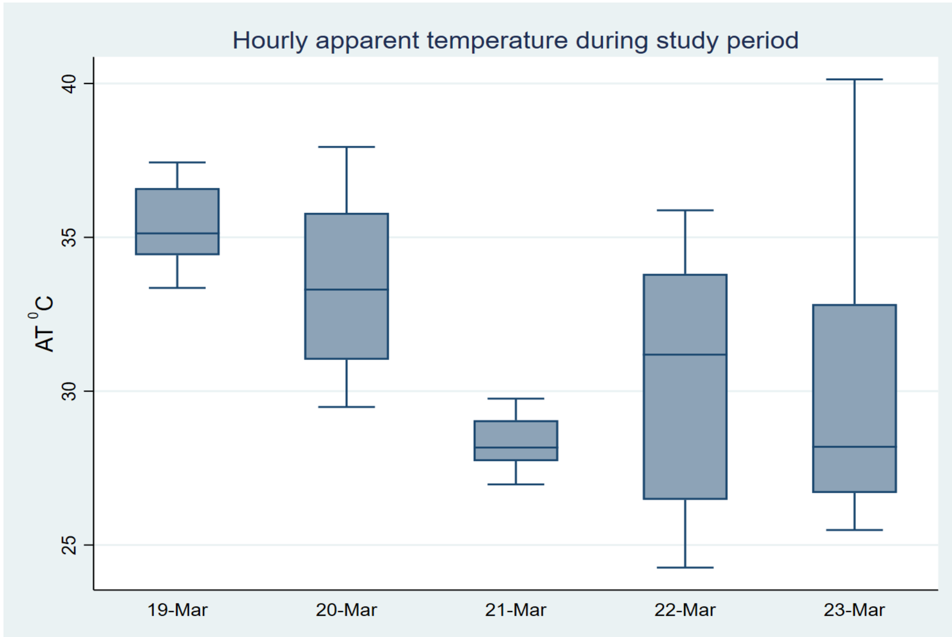


Figure 5. Boxplot of apparent temperatures inside taxis showing the range in temperatures measured inside the taxis on each day through the study. Three out of the five days showed mean apparent temperatures greater than 30°C with extreme temperatures well above 35°C and even 40°C on the last study day.

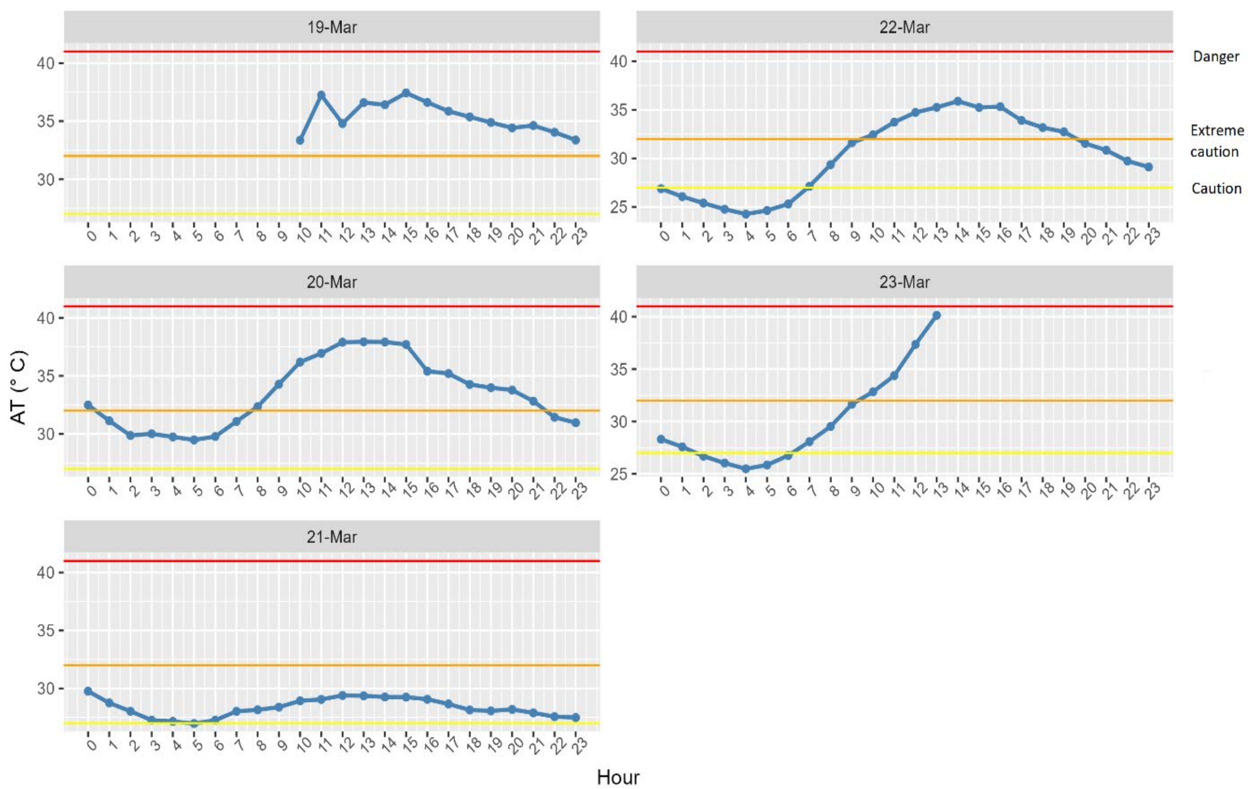


Figure 6. Hourly apparent temperatures inside taxis overlaid with lines to indicate the thresholds for possible health risks: red line: Danger at greater than 39°C; orange line: extreme caution at between 32-39°C; and yellow line: caution at between 27-32°C. For possible health risks, see Table 1.

As expected, Figure 7 shows that average hourly apparent temperature (“real feel temperature”) was consistently significantly higher than average temperature. On average, apparent temperature was 4.7°C higher than temperature. This shows that once humidity is also considered, the human body’s perception of temperature experiences a noticeable change. Therefore, it is important to take other meteorological variables, such as humidity, into account when assessing heat exposure. In minibus taxi ranks, solar radiation may be reflected from the white paint of the taxis, the roofs of the ranks etc. and this would likely ad additional thermal stress. However, additional measurements are needed to substantiate these possibilities.

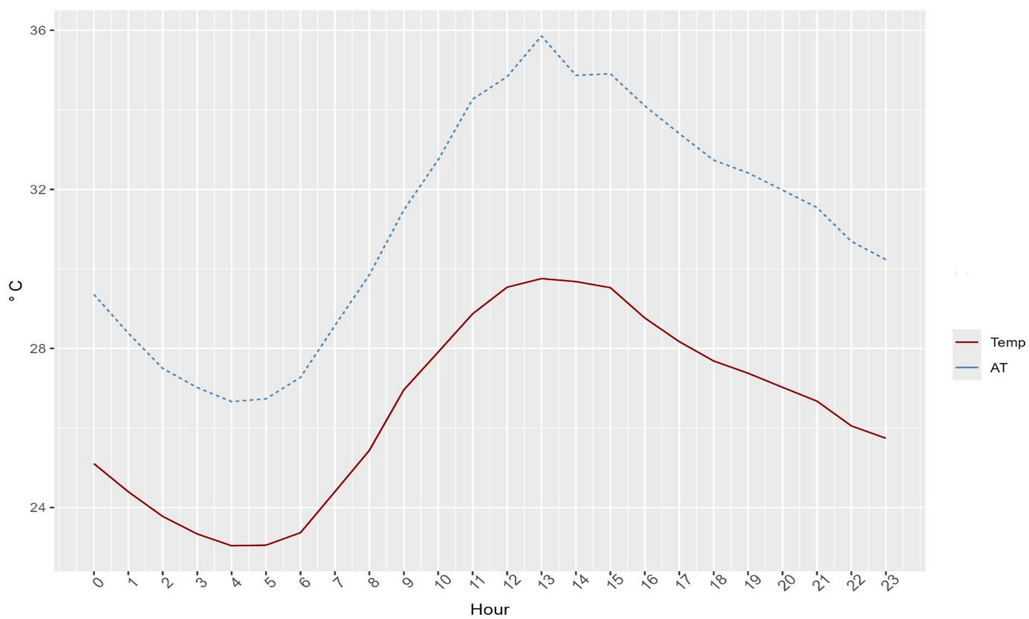


Figure 7. Diurnal pattern of the average hourly apparent temperature and temperature inside all the taxis. A similar pattern shows that apparent temperature is expectedly higher than temperature alone since it takes into account relative humidity. The real feel temperature experienced by people inside the taxis was highest around 13h00.

How does heat exposure within taxis compare to heat outside taxis (outdoors)?

Comparison of temperatures inside taxis and ambient (outdoor) temperatures

A Pearson correlation analysis showed that average hourly outdoor ambient temperature (from the SAWS station) and temperature inside taxis were positively correlated and the association was statistically significant ($R = 0.97$, $p<0.001$). This shows that temperatures inside taxis mimic the outdoor temperatures but tend to be higher than ambient temperatures by between 3 and 4°C.

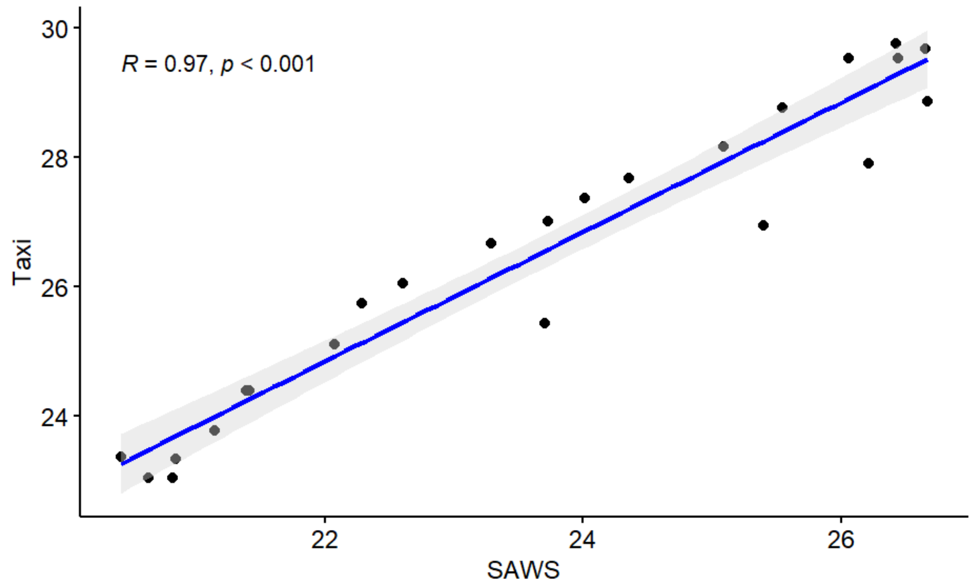


Figure 8. Pearson correlation for hourly outdoor ambient temperatures and temperatures inside taxis humidity in Durban, KwaZulu-Natal from 19 March - 23 March 2024, showing a positive correlation.

Comparison of apparent temperatures inside taxis and ambient (outdoor) temperatures

Mean apparent temperature inside taxis was on average 6°C higher than outdoor ambient apparent temperature (Figure 9). The difference varies by time of day and tends to be highest in the afternoon between 13h00 and 14h00.

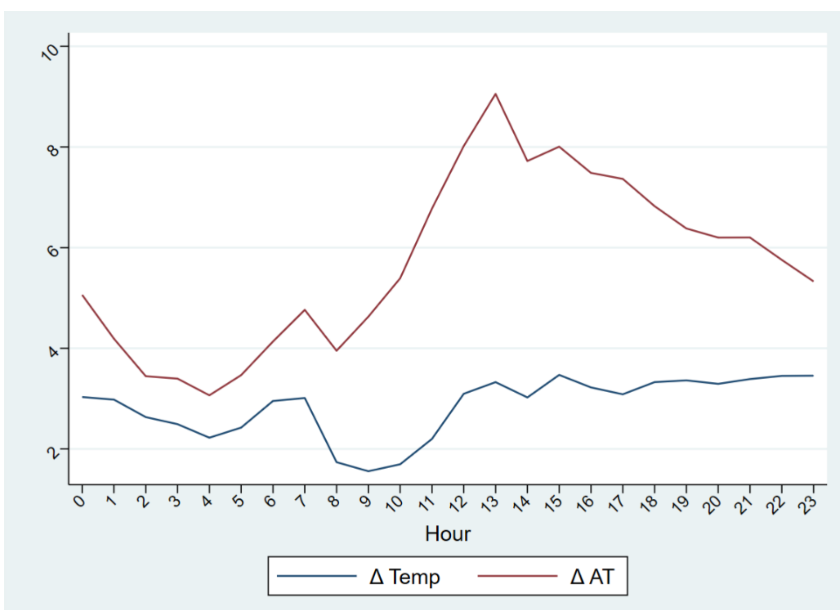


Figure 9. Difference in temperatures and apparent temperatures measured inside taxis and ambient conditions. The difference varies by time of day and is greatest in the afternoon around 13h00-14h00.

Figure 10 shows average hourly apparent temperatures inside taxis and outside during peak taxi operating hours from 6h00-18h00. Apparent temperature inside taxis rises to above 30°C as early as 9am and continues to increase as the day progresses, reaching a peak of 35.9°C at 13h00.

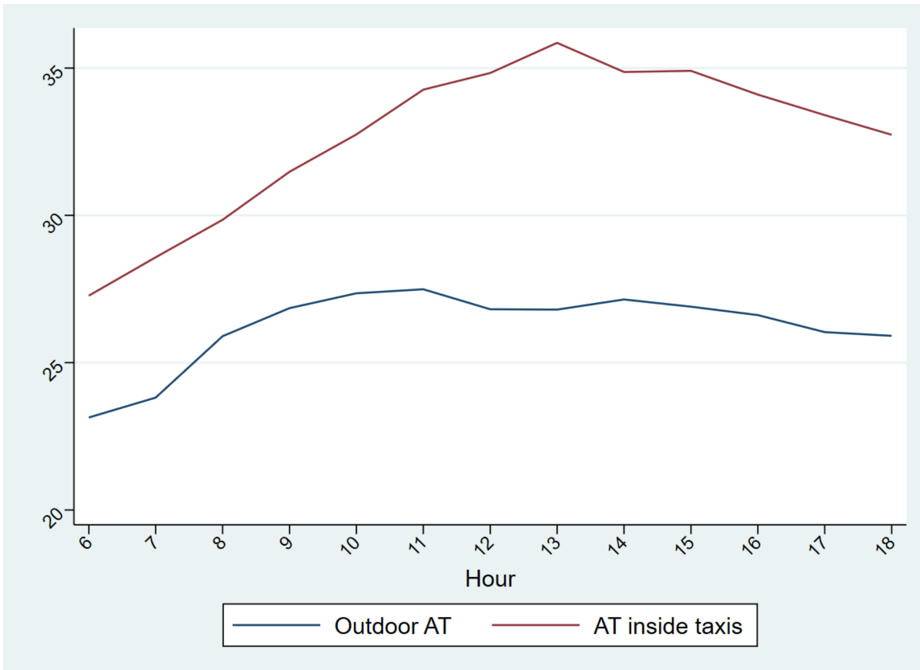


Figure 10. Apparent temperature inside and outside taxis during peak taxi operating hours of 6h00 to 18h00. Temperatures were warmer inside taxis compared to outdoors.

Temperatures measured in taxis, in a taxi rank and in the ambient environment

Figure 11 shows that apparent temperature inside taxis and at the taxi rank where the taxis were parked as well as the ambient temperature (from the local weather station). Apparent temperature inside taxis and at the taxi rank were both higher than outdoor ambient temperatures. Apparent temperature was lower in taxi ranks compared to inside taxis which suggests passengers were at reduced risk of heat related illnesses / symptoms while waiting outside (so long as they were not standing in direct sunlight) for a taxi compared to when they were inside the taxi.

Figure 11. Mean hourly apparent temperature inside taxis at a rank, in the taxi rank and the ambient outdoor apparent temperature measured at the SAWS monitoring station.

Apparent temperatures inside taxis were significantly higher than outdoor apparent temperatures – in this case for one of the taxi ranks outdoor temperature measurements and the SAWS ambient measurements (Figure 12). Outdoor temperature was generally below all apparent temperature symptom thresholds (see Table 1 on page 19). However, apparent temperatures inside taxis were within the "Caution" and "Extreme caution" bands. This indicates that health risks due to extreme heat are more likely for people inside taxis compared to those outside.

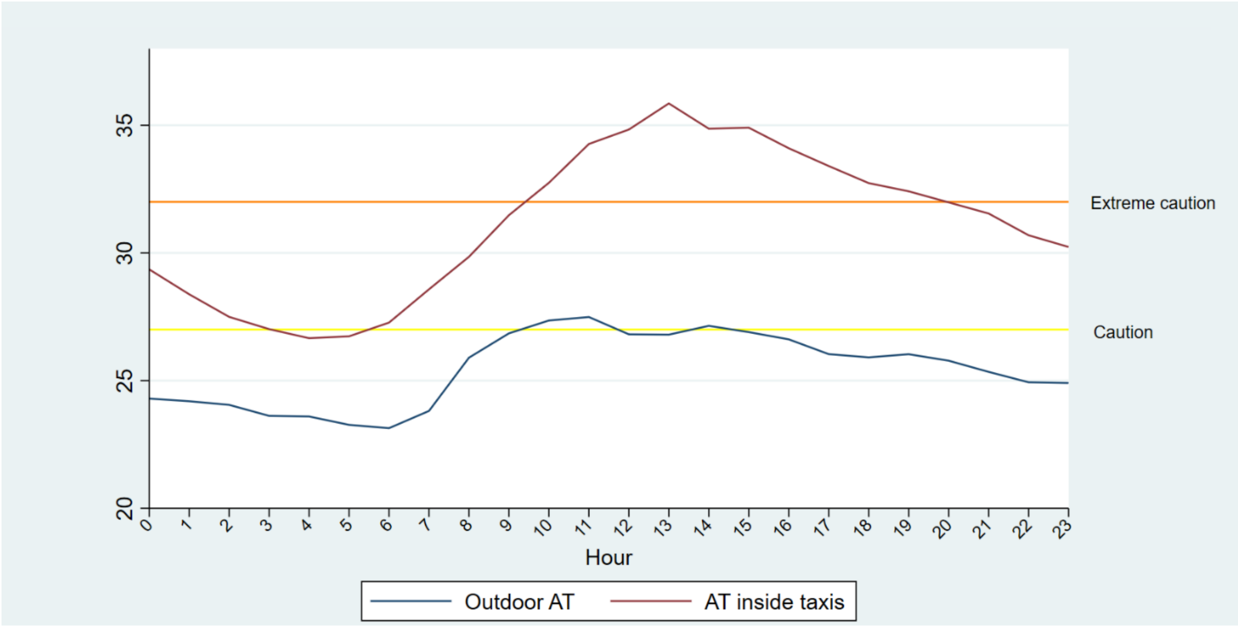


Figure 12. Combined hourly apparent temperature for all taxis (n=16) and outdoor apparent temperature during the study period for each hour of the day throughout the day. Health risks were possible among commuters and drivers of minibus taxis between 9h00 and 19h00 and those vulnerable to heat exposure, such as infants, pregnant women, the elderly and people with pre-existing diseases would be at greatest risk.

Heat exposure metrics

The statistics summary was compiled using four hot days (excluding 21 March which was cold) from 6h00 to 18h00. The statistics summary was compiled for mean IET, maximum IET, PHAT, DHAT, and LEP (Table 2).

Table 2. Summary statistics of heat exposure metrics from four hot days inside taxis in Durban (n = 985).

Metric	Mean	Min	Max	Median	Std dev
Mean IET (°C)	29.0	22.3	32.5	30.2	2.5
Max IET (°C)	34.4	23.6	43.6	34.6	3.5
PHAT (%)	36.3	0	68.4	43.0	19.3
DHAT (°C)	24.1	0	77.9	25.8	16.9
LEP (min)	5.3	0	10.0	6.0	2.7

For this study, to calculate the mean IET, we calculated the mean for each iButton in every taxi; and from the calculated means we could extract the descriptive statistics. The mean and maximum of mean IET were 29.0 °C and 32.5 °C, respectively. Mean and maximum max IET were 34.4 °C and 43.6 °C, respectively. For this study, to calculate the max IET, we extracted the maximum temperature reading for each iButton in every taxi; and then we extracted the descriptive statistics from the dataset. These two metrics indicate that temperatures observed were greater than the Durban historical daily maximum temperature of 24°C.

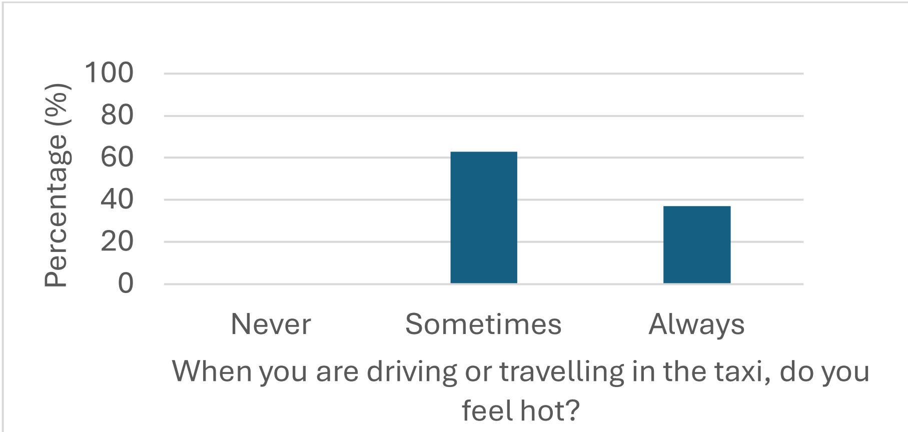
LEP is the maximum continuous duration that the taxis are exposed to heat. For this study, LEP is maximum cumulative hours of exposure above threshold. The descriptive statistics, particularly the mean LEP and max LEP over temperature threshold of 30.6 °C were 5 hours and 10 hours per four days, respectively. Prolonged periods of cumulative heat exposure above threshold elevates the risk of adverse heat-related illnesses (Seong et al., 2023). Spending long periods in environments with limited ventilation or no cooling equipment promotes morbidity in vulnerable groups (Seong et al., 2023).

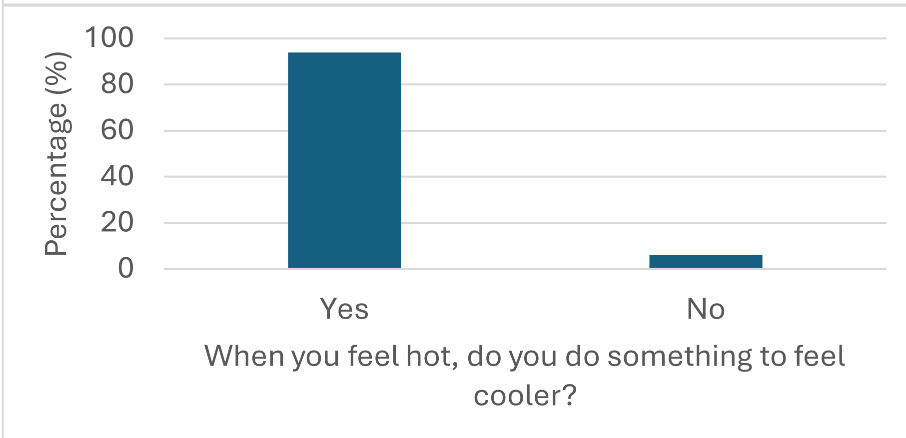
DHAT is the cumulative magnitude of temperature that the taxis were exposed to above heat threshold. The descriptive statistics, particularly the mean DHAT and max DHAT over temperature threshold of 30.6 °C were 24.2 °C and 77.9 °C per four days, respectively. Consecutive days of cumulative heat exposure increase physiological (i.e., increased core temperature, heart rate, etc.) and perceptual (i.e., perceived exertion, thermal discomfort, etc.) heat strain (Schlader et al., 2017). Cumulative heat exposure above threshold accelerates a decline in cognitive performance quicker in African-male populations and people who reside in disadvantaged neighborhoods (Choi et al., 2023). The taxi industry is modelled in a way that taxi drivers must work long hours, reducing their chances of visiting health facilities leading to possible delayed diagnosis and treatment for cognitive disorders potentially associated with heat exposure. Cognitive disorders or reduced cognitive performance increases the risk of road accidents and body injuries (Schlader et al., 2017). Cumulative heat exposure above threshold for consecutive days may lead to thermoregulatory impairments due to a decrease in thermoregulatory functions (Notley et al., 2018).

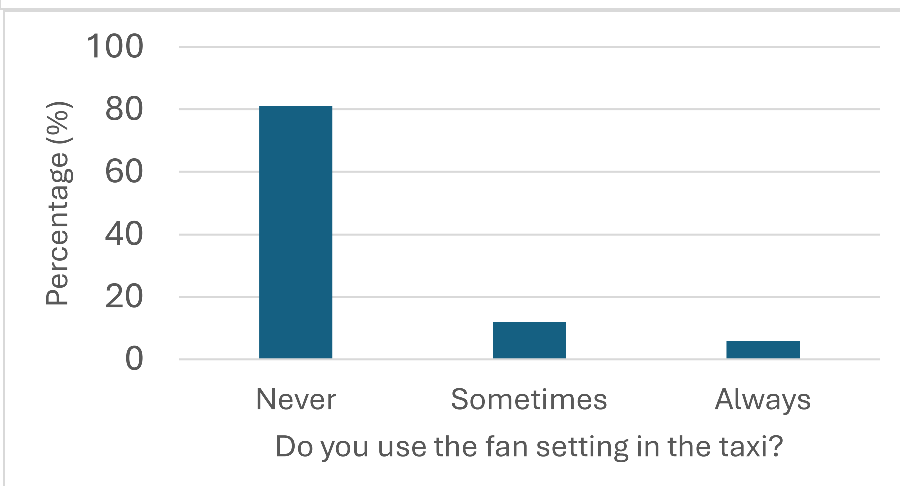
PHAT is the cumulative ratio that the taxis are exposed to above heat threshold. The descriptive statistics, particularly the mean PHAT and max PHAT over temperature threshold of 30.6 °C were 36.3% and 68.4% per four days, respectively. Max PHAT is above 60%, suggesting that for more than two-thirds of the time of the study, temperatures were above the threshold and posed a risk to health and wellbeing of the people in minibus taxis.

Questionnaire findings

The taxi driver questionnaire sought to understand the demographics and heat experiences of taxi drivers (Figure 13). Taxi driver questionnaire was administered to 16 taxi drivers. All taxi drivers were men and majority (56%) were youth (Table 3). At least 69% of taxi drivers worked more than five hours daily. All taxi drivers responded that they experienced heat in their line of work and most (93%) taxi drivers either open a taxi window or drink water in an attempt to cool their bodies down. All taxis are not manufactured with an air conditioner.


Percentage (%)
100
80
60
40
20
0
Never
Sometimes
Always
When you are driving or travelling in the taxi, do you feel hot?


Percentage (%)
100
80
60
40
20
0
Yes
No
When you feel hot, do you do something to feel cooler?


Percentage (%)
100
80
60
40
20
0
Never
Sometimes
Always
Do you use the fan setting in the taxi?

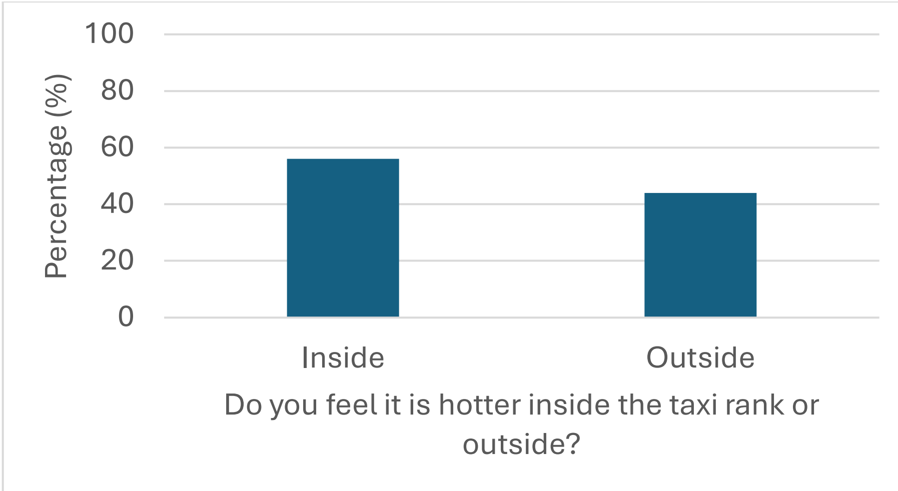


Figure 133. Perceptions around heat among the participants in the study showed that heat is a problem in taxis and ranks.

Table 3. Results of the questionnaire administered to the taxi drivers.

Total number of taxi drivers (N= 16)	**Frequency**	
Question	**Number (n)**	**Percentage (%)**
How old are you?		
18-25 years	0	0
26-35 years	9	56
36-45 years	5	31
46-55 years	1	6
56-65 years	0	0
Older than 66 years	0	0
What are the pick times at the rank?		
1-4 hours	1	6
5-8 hours	6	38
9-12 hours	5	31
13-16 hours	4	25
What do you do to cool down when it’s hot in a minibus taxi? You can mention as many ways of coping as you like.		
Drink water	15	94
Drink cold drinks / fizzy drinks	4	25
Drink an energy drink	4	25
Take off an item of clothing	5	31
Fan yourself (e.g. with your hand, a paper)	2	12
Open a window	15	93
None of the above	1	6
Other (discussed in text) *i.e. place a towel over their heads*	2	12
How many hours a day do you spend inside a taxi rank?		
1-4 hours	5	31
5-8 hours	6	38
9-12 hours	4	25
Missing data	1	6

Taxi drivers also provided suggestions on what they think could be done to help reduce heat inside taxis and at taxi ranks (Table 4).

Table 4. Things study participants said could be done to stay cool when it's hot.

What do you think can be done to make taxi ranks cooler and more comfortable when it is hot?
"Put aircon in the taxi."
"Aircons in the taxi, there's no rank for Pavilion so they would like to get a rank with shelter as they operated from the streets."
"Bigger taxi ranks, more space would allow for air to come in."
"Bigger space to accommodate the number of taxis. Lots of taxis make the rank to very hot."
"Undercover parking."
"Having more shelters in the ranks."
"Having more undercover shelter and areas with more trees."
"Restrict areas for taxis and vendors in ranks to accommodate for sufficient ventilation. Ranks are overcrowded."
"Make it higher and more open for more ventilation."
"Type of roofing material should be reconsidered. E.g. a lot of ranks use corrugated iron which makes the ranks very hot."
"For the open ranks a shelter is required. There is a need for running water supply taps."

Taxi Rank Observations

The purpose of the taxi rank observation checklist was to understand how the infrastructure and land cover in and around the rank could impact heat exposure (Table S1). Seventy percent of the taxi ranks were covered with high heat absorbing surfaces (i.e. tar, concrete, and paving). Only 25% percent of taxi ranks had shelters. Custom designated shelter roofs differ by pattern and height. Corrugated iron was the most common roofing material used, followed by concrete for the taxi rank located at the ground floor. Custom designated shelters had queuing rails for commuters, vendor stalls, restroom facilities, rubbish bins, however, no running water.

Seventy five percent of taxi rank did not have a rank shelter. Taxis waited in the sun or under tree shade if the direction of the sun allows. Informal taxi ranks have no reticulation therefore no running water is available. Some taxi ranks with no custom rank shelter have a commuter waiting shelter, while others had trees for shade, and others had no shade at all. Ninety one percent of taxi ranks with no custom rank shelter had enough space to install the rank shelters in the future.

Discussion

The impacts of heat on health extend from worsening physiological outcomes to affecting mental health (Ebi et al., 2021). Vulnerability to heat is influenced by factors such as age, health status, occupation and socio-economic conditions (rJurgilevich et al., 2023).

Our study found that taxi drivers are at increased risk of dehydration, heat-related illnesses or exacerbation of existing chronic conditions because of the high temperatures they are exposed to and the long duration of exposure. Temperatures inside taxis reached 39°C and mean relative humidity in taxis during the study period was 72%. These values exceed the thresholds of 32°C for temperature and 50 % for humidity which were found to be associated with extreme to lethal heat stress during extended exposure (Asseng et al., 2021). Previous studies show that the impacts of heat last for as long as four days after exposure (WHO, 2024) further compounding the health risks faced by taxi drivers and commuters alike.

Temperatures inside taxis were consistently higher than outdoor temperatures. This highlights the need for attention to be directed towards the design and implementation of heat reduction or prevention strategies inside public modes of transport. This is particularly important in the context of climate change as rising outdoor temperatures are likely to further increase temperatures inside taxis.

Driving is an occupation that requires immense concentration and taxi drivers in the taxis that were part of our study were exposed to apparent temperatures (real-feel temperatures combining temperature and relative humidity) between 24 – 40 °C. Heat-health guidelines for workplaces state that once apparent temperature reaches and exceeds 40°C, dehydration and risk of heat exhaustion are significantly increased resulting in a reduction in productivity and increased errors (Safety Culture, 2024; WMO, 2015). Therefore, both passive and active cooling interventions should be considered to increase thermal comfort inside taxis.

Recommendations

Several recommendations should be evaluated and implemented to protect the health of drivers, and commuters, in the minibus taxi industry sector in South Africa:

In the HiAce: The positioning of the engine under the driver could be reconsidered to reduce heat from the engine contributing to hot temperatures inside the taxi.

The windows could be tinted to reduce sunlight from entering the interior of the taxi and warming temperatures inside the taxi.

Fans could be placed at the front, middle and rear of the taxi to ensure air movement and windows should open wide to allow ventilation.

In the taxi rank: Have water for consumption readily available at drinking fountains or at the very least bathrooms with taps from which people can drink water.

Provide cooling centres where taxi drivers and communities can sit or stand to wait for the next trip. A cooling centre usually has fans or air conditioning.

Ideas for Future Research

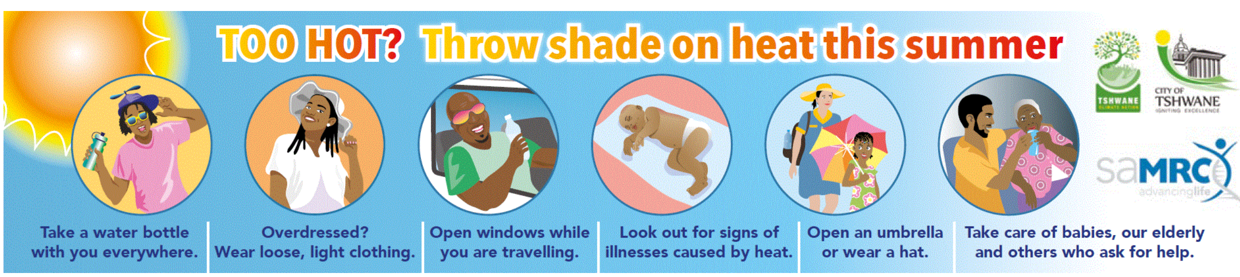
There are several possibilities for further research:

- Minibus taxis exist across the country, and this means an opportunity for a bigger study to be conducted simultaneously across the country during the summer to increase the sample size. Data from a study like this could be used to link health assessments with heat exposure to show the link between heat and health.
- To address the methodology used, future studies can place loggers in various points in the taxis. Recommendations from the participants can be put to the test by introducing controlled taxis with air conditioning and open windows.
- Studying different taxis rank structures; formal and informal to assess the difference in temperatures and to consider using multiple participants such as taxi rank marshals to get different perspectives.
- There is a potential of linking the loggers' data to the SAWS weather station or installing mobile weather stations ate taxi ranks to check the difference between the outside and inside temperatures, however, challenges such as taxis not being centrally located and the risk of placing mobile weather stations at taxi ranks will have to be addressed.
- Awareness can be raised through stakeholder engagement and distribution of awareness materials (e.g., flyers, posters). Examples of these were prepared for the City of Tshwane (see below).

Throw shade on heat this summer
Take a water bottle with you everywhere.
Overdressed? Wear loose, light clothing.
Open windows while you are travelling.
Look out for signs of illnesses caused by heat.
Open an umbrella or wear a hat.
Take care of babies, our elderly and others who ask for help.
Stay cool, people.
WATER
Let's look after ourselves and each other in the heat.

Throw shade on heat this summer
Drink water
Keep cool


2024
Throw shade on heat this summer
saMRC
TSHWANE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Stay cool, people.
WATER
Let's look after ourselves and each other in the heat.
TOO HOT?
Take a water bottle with you everywhere.
Overdressed? Wear loose, light clothing.
Open windows while you are travelling.
Look out for signs of illnesses caused by heat.
Open an umbrella or wear a hat.
Take care of babies, our elderly and others who ask for help.


TOO HOT? Throw shade on heat this summer
TSHWANE
CITY OF TSHWANE
saMRC
advancing life
Take a water bottle with you everywhere.
Overdressed? Wear loose, light clothing.
Open windows while you are travelling.
Look out for signs of illnesses caused by heat.
Open an umbrella or wear a hat.
Take care of babies, our elderly and others who ask for help.

Conclusions

The objective of this study was to understand heat exposure in minibus taxis in the city of Durban in order to recommend context specific adaptation actions to reduce adverse impacts on taxi drivers and passengers. This study found that taxi drivers experience temperatures above 30°C and that this heat can prevail for more than 2/3rd of a day during hot weather – such heat could impact their health during taxi journeys or while waiting for passengers.

Currently, their heat coping mechanisms include opening a taxi window or drinking water to cool down and stay hydrated. The lack of access to water at taxi ranks is a significant concern as remaining hydrated is crucial to combat heat stress.

The current taxi rank infrastructure, such as shelters, are not able to accommodate the high volumes of taxis and passengers. Taxi ranks are often built without consideration of shade or access to drinkable water.

With more than 16 million people in minibus taxis every day, including drivers, marshals and commuters, the potential burden of heat-health related risks is great. There are three take-away messages:

- Temperatures inside minibus taxis reached up to 39°C which is HOT!
- The temperatures inside minibus taxis were between 3-4°C warmer than outdoors!
- For around 11 hours every day, temperatures inside minibus taxis were warmer than 27°C – the temperature that is linked to heat-health risks.

With the projected increase in temperatures caused by climate change, it is imperative to co-develop mitigation and adaptation strategies to minimize heat-related human health risks in minibus taxis and taxi ranks.

References

Barrett, J. 2003. Organizing in the Informal Economy: A Case Study of the Minibus Taxi Industry in South Africa. https://www.ilo.org/publications/organizing-informal-economy-case-study-minibus-taxi-industry-south-africa

Basu, R., Feng, W.-Y., Ostro, B.D. 2008. Characterizing temperature and mortality in nine California counties. *Epidemiology*, *19*, 138–145.

Bayomi, N., Fernandez, J. E. 2023. Quantification of heat vulnerability using system dynamics. Frontiers in Built Environment, 9. https://doi.org/10.3389/fbuil.2023.1025480

Bega S. 2021. South Africa unprepared for intense heatwaves of the next 20 years. Mail & Guardian. https://mg.co.za/the-green-guardian/2021-10-29-south-africa-unprepared-for-intense-heatwaves-of-the-next-20-years/

Booysen, M. J., Andersen, S. J., Zeeman, A. S. 2013. Informal public transport in Sub-Saharan Africa as a vessel for novel Intelligent Transport Systems. 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), 767–772. https://doi.org/10.1109/ITSC.2013.6728324

Boudreaux, K. 2006. Series policy comment No. 3 Enterprise Africa. Taxing Alternatives. Poverty alleviation and the South African taxi / minibus industry. www.mercatus.org/enterpriseafrica

CDC. 2020. Protecting vulnerable groups from extreme heat. https://www.cdc.gov/disasters/extremeheat/specificgroups.html

Choi, E. Y., Lee, H., & Chang, V. W. 2023. Cumulative exposure to extreme heat and trajectories of cognitive decline among older adults in the USA. Journal of Epidemiology and Community Health, 77(11), 728–735. https://doi.org/10.1136/jech-2023-220675

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Competition Commission South Africa. 2021. Land-based public passenger transport sector. https://one.oecd.org/document/DAF/COMP/WP2/WD(2022)18/en/pdf#:~:text=The%20land%2Dbased%20public%20passenger,intercity%20buses)%20and%20commuter%20rail.

Darlington, A. 2023. ERS Driver Safety Series: Unique Challenges on South African Roads – Taxis. https://excelrs.co.za/ers-driver-safety-series-unique-challenges-on-south-african-roads-taxis/

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., & Jay, O. 2021. Hot weather and heat extremes: health risks. In The Lancet (Vol. 398, Issue 10301, pp. 698–708). Elsevier B.V. https://doi.org/10.1016/S0140-6736(21)01208-3

Engelbrecht, F., Adegoke, J., Bopape, M. J., Naidoo, M., Garland, R., Thatcher, M., McGregor, J., Katzfey, J., Werner, M., Ichoku, C., & Gatebe, C. 2015. Projections of rapidly rising surface temperatures over Africa under low mitigation. Environmental Research Letters, 10(8). https://doi.org/10.1088/1748-9326/10/8/085004

Fraser, A.M. & Chester, M. V., 2017, 'Transit system design and vulnerability of riders to heat', *Journal of Transport and Health*, 4, 216–225.

Geneva, I.I., Cuzzo, B, Fazili, T, Javaid, W. Normal Body Temperature: A Systematic Review, *Open Forum Infectious Diseases*, Volume 6, Issue 4, April 2019, ofz032, https://doi.org/10.1093/ofid/ofz032

Ghani, S., Mahgoub, A. O., Bakochristou, F., & ElBialy, E. A. 2021. Assessment of thermal comfort indices in an open air-conditioned stadium in hot and arid environment. Journal of Building Engineering, 40. https://doi.org/10.1016/j.jobe.2021.102378

Glaser, J., Lemery, J., Rajagopalan, B., Diaz, H. F., García-Trabanino, R., Taduri, G., Madero, M., Amarasinghe, M., Abraham, G., Anutrakulchai, S., Jha, V., Stenvinkel, P., Roncal-Jimenez, C., Lanaspa, M. A., Correa-Rotter, R., Sheikh-Hamad, D., Burdmann, E. A., Andres-Hernando, A., Milagres, T., ... Johnson, R. J. 2016. Climate change and the emergent epidemic of CKD from heat stress in rural communities: The case for heat stress nephropathy. Clinical Journal of the American Society of Nephrology, 11(8), 1472–1483. https://doi.org/10.2215/CJN.13841215

Govender, K. K. 2014. African Journal of Business Management Public transport service quality in South Africa: A case study of bus and minibus services in Johannesburg. 8(10), 317–326. https://doi.org/10.5897/AJBM2014.7416

Havenith, G., Fiala, D. 2016. Thermal indices and thermophysiological modeling for heat stress. Comprehensive Physiology, 6(1), 255–302. https://doi.org/10.1002/cphy.c140051

Hondula, D. M. et al. 2021. Novel metrics for relating personal heat exposure to social risk factors and outdoor ambient temperature. Environ. Int. 146, 106271.

iButton Link Technologies, 2024, *Description of Thermochron iButton DS1921G-F5#*.

International Station Meteorological Climate Summary. 2024. Historical Weather : Durban, South Africa. 2024. https://www.washingtonpost.com/wp-srv/weather/longterm/historical/data/durban_south_africa.htm

IPCC, 2012, Special report of the Intergovernmental Panel on Climate Change managing the risks of extreme events and disasters to advance climate change adaptation. https://www.ipcc.ch/report/managing-the-risks-of-extreme-events-and-disasters-to-advance-climate-change-adaptation/

Jansen, F. 2023. Heatwave continues for the week. SA People News. https://www.sapeople.com/weather/heatwave-continues-for-the-week/

Jansen, F. 2024. Durban is getting hit with a heatwave this week. SA People News. https://www.sapeople.com/weather/durban-is-getting-hit-with-a-heatwave-this-week/

Jurgilevich, A, Käyhkö, J, Räsänen, A, Pörsti, S, Lagström, H, Käyhkö, J, Juhola, S. 2023Factors influencing vulnerability to climate change-related health impacts in cities – A conceptual framework, Environment International, 173, 107837, https://doi.org/10.1016/j.envint.2023.107837.

Khan, A.A., 2019, *Heat related illnesses: Review of an ongoing challenge*, *Saudi Medical Journal*, 40(12), 1195–1201.

Kim, Y., Shin, Y., Cho, H. 2021. Influencing factors on thermal comfort and biosignals of occupant-a review. J Mech Sci Technol 35, 4201–4224. https://doi.org/10.1007/s12206-021-0832-5

Kottek, M., Grieser, J., Rudolf, B., Rubel, F., 2006, 'World Map of the Köppen-Geiger climate classification updated', *Meteorologische Zeitschrift*, 15, 259–263.

Kenny, G. P., Tetzlaff, E. J., Journeay, W. S., Henderson, S. B., & O'Connor, F. K. 2024. Indoor overheating: A review of vulnerabilities, causes, and strategies to prevent adverse human health outcomes during extreme heat events. In Temperature. Taylor and Francis Ltd. https://doi.org/10.1080/23328940.2024.2361223

Kruger, A., Sekele, S. 2013, Trends in extreme temperature indices in South Africa: 1962–2009. *International Journal of Climatology,* 33**,** 661-676.

Kruger, A. C., Shongwe, S. 2004. Temperature trends in South Africa: 1960-2003. International Journal of Climatology, 24(15), 1929–1945. https://doi.org/10.1002/joc.1096

Kgwedi, R., Krygsman, S. 2017. Mini-bus taxis as providers of scheduled, park & ride services: a concept for Stellenbosch. 36th Southern African Transport Conference, 10-13 July 2017. https://www.satc.org.za/archive17/assets/2b_kgwedi.pdf

Liezl Human, & Ella Morrison. 2023. How the taxi industry works in the Western Cape. GroundUp.

Maure, G., Pinto, I., Ndebele-Murisa, M., Muthige, M., Lennard, C., Nikulin, G., Dosio, A., Meque, A. 2018. The southern African climate under 1.5 °c and 2 °c of global warming as simulated by CORDEX regional climate models. Environmental Research Letters, 13(6). https://doi.org/10.1088/1748-9326/aab190

Mbokodo, I., Bopape, M. J., Chikoore, H., Engelbrecht, F., Nethengwe, N. 2020. Heatwaves in the future warmer climate of South Africa. Atmosphere, 11(7). https://doi.org/10.3390/atmos11070712

Mbokodo, I. L., Bopape, M. J. M., Ndarana, T., Mbatha, S. M. S., Muofhe, T. P., Singo, M. V., Xulu, N. G., Mohomi, T., Ayisi, K. K., Chikoore, H. 2023. Heatwave Variability and Structure in South Africa during Summer Drought. Climate, 11(2). https://doi.org/10.3390/cli11020038

Meadows, M. E. 2006. Global change and southern Africa. Geographical Research, 44(2), 135–145. https://doi.org/10.1111/j.1745-5871.2006.00375.x

National Government Handbook – South Africa, 2021, *eThekwini Metropolitan Municipality (ETH)*. https://cdn.lgseta.co.za/resources/YES_MEDIA_Local_Government_Handbook_2021_PDF_Version.pdf

McLaren, C., Null, J. & Quinn, J., 2005, Heat stress from enclosed vehicles: Moderate ambient temperatures cause significant temperature rise in enclosed vehicles, *Pediatrics*, 116(1).

Mncube, Z., Adelabu, S., Adagbasa, E., 2023, 'Is eThekwini metropolitan municipality (EMM) experiencing light pollution?: A remote sensing analysis of nighttime data of EMM, South Africa', *Spatial Information Research*, 31(2), 211–223.

Masson, V., Lemonsu, A., Hidalgo, J., Voogt, J., 2020. Urban climates and climate change. Annual Review of Environment and Resources, 45, pp.411-444.

Nakayoshi, M, Kanda, M, Shi, R, de Dear R. 2015. Outdoor thermal physiology along human pathways: a study using a wearable measurement system. Int J Biometeorol, 59: 503-515. 10.1007/s00484-014-0864-y

NIEHS. 2020. Effects of heat. Accessed 12 January 2021. https://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/heat/index.cfm

Ninan, G., Gunasekaran, K., Jayakaran, J.J., Johnson, J., Abhilash, K.P., Pichamuthu, K. Iyadurai, R., 2020, 'Heat-related illness—Clinical profile and predictors of outcome from a healthcare center in South India', *Journal of Family Medicine and Primary Care*, 9(8), 4210.

Noah M. 2002. An investigation into the environmental impact of the taxi industry in Butterworth, University of Natal, 21st Annual South African Transport Conference, Conference. https://repository.up.ac.za/bitstream/handle/2263/7888/090.pdf?sequence=1&isAllowed=y

Notley, S. R., Meade, R. D., D'Souza, A. W., Friesen, B. J., Kenny, G. P. 2018. Heat Loss Is Impaired in Older Men on the Day after Prolonged Work in the Heat. Medicine and Science in Sports and Exercise, 50(9), 1859–1867. https://doi.org/10.1249/MSS.0000000000001643

Obradovich, N., Migliorini, R., Mednick, S. C., Fowler, J. H. 2017. Nighttime temperature and human sleep loss in a changing climate. https://www.science.org

Périard, J. D., Eijsvogels, T. M. H., Daanen, H. A. M. 2021. Exercise under heat stress: Thermoregulation, hydration, performance implications, and mitigation strategies. In Physiological Reviews, Vol. 101(4), 1873–1979). https://doi.org/10.1152/physrev.00038.2020

Perkins-Kirkpatrick, S. E., Lewis, S. C. 2020. Increasing trends in regional heatwaves. Nature Communications, 11(1). https://doi.org/10.1038/s41467-020-16970-7

Presbitero, A., Melnikov, V. R., Krzhizhanovskaya, V. V., Sloot, P. M. A. 2021. A unifying model to estimate the effect of heat stress in the human innate immunity during physical activities. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-96191-0

Ramukumba, Tendani S., & Mathikhi, Makwena S. 2016. Health assessment of taxi drivers in the city of Tshwane. Curationis, 39(1), 1-7. https://dx.doi.org/10.4102/curationis.v39i1.1671

Russo, S., Marchese, A. F., Sillmann, J., Immé, G. 2016. When will unusual heat waves become normal in a warming Africa? In Environmental Research Letters (Vol. 11, Issue 5). Institute of Physics Publishing. https://doi.org/10.1088/1748-9326/11/5/054016

SAWS. (2020). Heatwave hits parts of KZN. SABC News. https://www.sabcnews.com/sabcnews/heatwave-hits-parts-of-kzn/

Schlader, Z. J., Colburn, D., Hostler, D. 2017. Heat Strain Is Exacerbated on the Second of Consecutive Days of Fire Suppression. Medicine and Science in Sports and Exercise, 49(5), 999–1005. https://doi.org/10.1249/MSS.0000000000001191

Scholes, R., Engelbrecht, F. 2021. Climate impacts in southern Africa during the 21st Century. https://www.globalcarbonproject.org/carbonbudget/20

Seong, K., Jiao, J., Mandalapu, A. 2023. Hourly Associations between Heat Index and Heat-Related Emergency Medical Service (EMS) Calls in Austin-Travis County, Texas. International Journal of Environmental Research and Public Health, 20(19). https://doi.org/10.3390/ijerph20196853

Simion, M, Socaciu, L, Unguresan, P. 2016. Factors which Influence the Thermal Comfort Inside of Vehicles, Energy Procedia, Volume 85, 472-480. https://doi.org/10.1016/j.egypro.2015.12.229.

South African Weather Services. (2024). Weather Questions. www.weathersa.co.za.

StatsSA. 2020. National Households Travel Survey 2020 Statistical release P0320. www.statssa.gov.za,info@statssa.gov.za.

Steadman, R.G. 1979. The assessment of sultriness part I: A temperature-humidity index based on human physiology and clothing science. *J. Appl. Meteorol. 18*, 861–873.

TETA. 2020. Taxi Chamber.www.teta.org.za

Thornton, P. K., Ericksen, P. J., Herrero, M., Challinor, A. J. 2014. Climate variability and vulnerability to climate change: A review. In Global Change Biology (Vol. 20, Issue 11, pp. 3313–3328). https://doi.org/10.1111/gcb.12581

eThekwini Municipality. (2022). Title: Durban Climate Change Strategy. https://www.durban.gov.za/storage/Documents/Climate/DCCS_Strategy.pdf

Trisos, C. H., Adelekan, I. O., Totin, E., & Ayanlade, A. 2022. Africa. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Climate Change 2022 – Impacts, Adaptation and Vulnerability, 1285–1456. https://doi.org/10.1017/9781009325844.011

United Nations. 2018. Urbanization and migration. https://www.un.org/en/development/desa/population/events/pdf/expert/28/EGM_Joseph_Teye_ppt.pdf

United Nations, 2024. Climate Change. https://unfccc.int/process-and-meetings/the-paris-agreement#:~:text=With%20the%20Paris%20Agreement%2C%20countries,and%20support%20provided%20or%20received.WHO. 2020. Heatwaves. Accessed 13 January 2021. https://www.who.int/health-topics/heatwaves#tab=tab_1

WHO, 2024, *Heat and health*, *WHO (World Health Organization)*. https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

Wright, C. Y., Kapwata, T., du Preez, D. J., Wernecke, B., Garland, R. M., Nkosi, V., Landman, W. A., Dyson, L., Norval, M. 2021. Major climate change-induced risks to human health in South Africa. Environmental Research, 196. https://doi.org/10.1016/j.envres.2021.110973

Yılmaz, M., Kara, Y., Toros, H. 2024. Analysis of the summer thermal comfort indices in İstanbul. Int J Biometeorol 68, 1327–1342. https://doi.org/10.1007/s00484-024-02669-7

Vargas Zeppetello, L.R., Raftery, A.E., Battisti, D.S. 2022. Probabilistic projections of increased heat stress driven by climate change. Commun Earth Environ 3, 183. https://doi.org/10.1038/s43247-022-00524-4

Zanobetti, A.; Schwartz, J. 2008. Temperature and mortality in nine US cities. *Epidemiology*, *19*, 563–570.

Zhou, I, Lai, D, Chen, O. 2019. Experimental investigation of thermal comfort in a passenger car under driving conditions, Building and Environment, Volume 149, 2019, Pages 109-119, https://doi.org/10.1016/j.buildenv.2018.12.022.

Supplementary Material

Checklist

Rank Observation Checklist_Durban

Record ID	________________________
Type of Taxi Rank	○ Low Use Rank (Taxi rank where there are predominantly low passenger volumes. are generally located in suburban areas) ○ Medium Use Rank (Taxi rank where there are moderate passenger volumes. These ranks are predominantly located in suburban areas such as Shopping Centres and Community Centres) ○ High Use Rank (Taxi rank servicing locations. They are predominantly located at major attractions such as City and Town CBD's, Sporting Venues, Entertainment Precincts, Hotels, Clubs and Major Office Centres. Often a high use rank is provided close to bus stop infrastructure.)
How many destinations does the rank service?	________________________
What is the average queuing time at the rank?	________________________
What are the pick times at the rank?	________________________
How many taxis use the facility at any given time, given observations?	________________________
Does the rank have a commuter waiting area?	○ Yes ○ No
Does the waiting area have shade?	○ Yes ○ No
Does the rank have custom designed shelters?	○ Yes ○ No
Are taxi rank shelters sufficient to accommodate the required number of waiting commuters?	○ Yes ○ No
Does the taxi rank have pedestrian infrastructure including links to pedestrian crossings?	○ Yes ○ No
Does the rank have seating?	○ Yes ○ No
Does the rank have rubbish bins?	○ Yes ○ No
Does the rank have queuing rails?	○ Yes ○ No

Does the taxi rank have vendors' stalls/shops?	○ Yes ○ No
Do the vendors have shelter	○ Yes ○ No
Does the rank have running water for drinking?	○ Yes ○ No
Does the rank have restrooms / toilet facilities?	○ Yes ○ No
Are entry and exit points clearly identifiable?	○ Yes ○ No
Are there any trees that provide shade?	○ Yes ○ No
How many trees can you see in the taxi rank area	________________________
How tall are the trees?	☐ Under roof height ☐ Roof height ☐ Above roof height
Leaves of the trees	☐ Deciduous ☐ Evergreen
Rank grounds - % Grass/Greening	________________________
Rank grounds - % bare sand	________________________
Rank grounds - % concrete	________________________
Rank grounds - % paving	________________________
Rank grounds - % tar	________________________
Is space available to provide a roofed area for queuing passengers to protect them from the weather?	○ Yes ○ No

Questionnaire

Taxi Driver Questionnaire Durban Be2f02

Record ID	______________________
Unique Questionnaire Identity Number	______________________
Are you:	◯ Male ◯ Female ◯ Other
How old are you?	______________________
Have you ever been told that you have:	◯ Heart attack or coronary heart disease ◯ Rheumatic heart disease or other heart problem ◯ Stroke ◯ Cancer ◯ High blood cholesterol ◯ Diabetes/elevated blood sugar ◯ High blood pressure ◯ Kidney failure ◯ Mental health problems like depression,anxiety, stress ◯ None of the above
How many hours a day do you spend inside a taxi?	______________________
When you are driving or travelling in the taxi, do you feel hot:	◯ Never ◯ Sometimes ◯ Always
Have you ever experienced any of the following symptoms when you feel hot while driving/sitting in the taxi?	☐ Sweating ☐ Heat cramps ☐ Headaches ☐ A faster heartbeat ☐ Nausea / vomiting ☐ Heat rash / pimples or blisters on skin ☐ Heat exhaustion / feeling tired or weak ☐ Dizziness or confusion ☐ Difficulties breathing ☐ Fainting ☐ Irritability ☐ None of the above ☐ Other - open-ended
Are these symptoms worse in the morning or in the afternoon?	☐ Morning ☐ Afternoon
When you feel hot, do you do something to try and feel cooler?	◯ Yes ◯ No

What do you do to try and feel cooler when you feel hot in the taxi? You can mention as many ways of coping as you like.	☐ Drink water ☐ Drink cold drink / fizzy drinks ☐ Drink an energy drink ☐ Take off an item of clothing ☐ Fan yourself (eg with your hand, a paper) ☐ Open a window ☐ None of the above ☐ Other: open-ended
Other - Heat coping mechanism	__________________________________
Do you use the air conditioner in the taxi:	○ Never ○ Sometimes ○ Always
Do you use the fan setting in the taxi:	○ Never ○ Sometimes ○ Always
How many hours a day do you spend inside the taxi rank?	__________________________________
Do you feel it is more hot inside the taxi rank or outside?	○ Inside ○ Outside
Have you ever experienced any of the following symptoms when you feel hot while in the taxi rank:	☐ Sweating ☐ Heat cramps ☐ Headaches ☐ A faster heartbeat ☐ Nausea / vomiting ☐ Heat rash / pimples or blisters on skin ☐ Heat exhaustion / feeling tired or weak ☐ Dizziness or confusion ☐ Difficulties breathing ☐ Fainting ☐ Irritability ☐ None of the above ☐ Other - open-ended
What do you think can be done to make taxi ranks cooler and more comfortable when it is hot?	__________________________________
Telephone number	__________________________________

Supplementary Table

Table S1. Results of the taxi rank observation checklist.

Total number of taxi ranks (N= 12)	Frequency	
Question	**Number (n)**	**Percentage (%)**
What is the type of the taxi rank?		
Low Use Rank	6	50
Medium Use Rank	1	8
High Use Rank	5	42
How many destinations does the rank service?		
1 destination	10	83
2 destinations	1	8
7 destinations	1	8
What are the pick times at the rank?		
06:00-17:00	1	8
06:00-19:00	2	16
06:00-20:00	1	8
06:00-20:00 & 16:00-19:00	2	16
07:00-17:00	1	8
07:00-18:00	1	8
07:00-20:00	1	8
08:00-18:00	2	16
08:00-19:00	1	8
How many taxis use the facility at any given time, given observations?		
0-10 taxis	1	8
11-20 taxis	6	50
21-30 taxis	1	8
31-40 taxis	3	25
41-50 taxis	0	0
51-60 taxis	1	8
Does the rank have a commuter waiting area?		
Yes	6	50
No	6	50
Does the waiting area have shade?		
Yes	4	33
No	1	8
Missing data	7	58
Does the rank have custom designed shelters?		
Yes	3	25
No	9	75
Are taxi rank shelters sufficient to accommodate the required number of waiting commuters?		
Yes	3	25
No	9	75
Does the taxi rank have pedestrian infrastructure including links to pedestrian crossings?		
Yes	5	42
No	7	58

Does the rank have seating?		
Yes	0	0
No	12	100
Does the rank have rubbish bins?		
Yes	4	33
No	8	67
Does rank have queuing rails?		
Yes	4	33
No	7	58
Missing data	1	8
Does the rank have vendors' stalls/shops?		
Yes	6	50
No	6	50
Do the vendors' stalls/shops have shelter?		
Yes	3	25
No	3	25
Missing data	6	50
Does the rank have running water for drinking?		
Yes	0	0
No	12	100
Does the rank have restrooms/toilet facilities?		
Yes	5	42
No	7	58
Are entry and exit points clearly identifiable?		
Yes	7	58
No	5	42
Are there any trees that provide shade?		
Yes	6	6
No	1	1
How many trees can you see in the taxi rank area?		
0-5 trees	9	75
6-10 trees	2	17
11-15 trees	1	8
What is the height of the trees?		
Under roof height	0	0
Roof height	3	25
Above roof height	8	75
What is the leaf type of the trees?		
Deciduous leaves	0	0
Evergreen leaves	10	83
What is the percentage of the grass/greening on the rank grounds?		
0-20 % Grass/greening	3	25
21-40 % Grass/greening	3	25
41-60 % Grass/greening	1	8
0-20 % Bare/sand	1	8
0-20 % Concrete	1	8
61-80 % Concrete	1	8
0-20 % Paving	7	58
21-40 % Tar	1	8
41-60 % Tar	1	8
61-80 % Tar	8	67
81-100 % Tar	1	8

Is there space available to provide a roofed area for queuing passengers to protect them from the weather?		
Yes	6	92
No	1	8