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Heat in the Streets:

Mapping the Lived Experience of Heat Stress of Climate-exposed Workers Towards Developing a Thriving and Resilient City

Final Report, November 2019

UTS

A. SUMMARY

This is a final report from the *Heat in the Streets: Mapping the Lived Experience of Heat Stress of Climate-exposed Workers Towards Developing a Thriving and Resilient City* project. The project was funded through a City of Sydney (CoS) Council Innovation Grant, and ran from 7 January 2019 to 30 September 2019. An interim progress report was provided to City of Sydney Council in May 2019 and the Project was completed in September. This final report outlines objectives, relevant literature, methodology, participant recruitment, production of the digital platform, findings from the surveys and interviews, analysis and recommendations.

Heat in the Streets is a feasibility study examining the heat stress of climate-exposed workers in the City of Sydney. Researchers tracked bike courier and municipal workers' pathways as they conducted their work on five selected hot days. Both qualitative and quantitative data was collected and analysed, via heat sensors, smartphones (GPS), surveys and in-person interviews.

The pilot project aimed to establish the feasibility of creating a real time data collection and story-telling smartphone platform, such as an app, to facilitate opportunities for urban interventions to mitigate urban heat effects. It project was completed by a research team based at the University of Technology Sydney (UTS), who seek to increase awareness of heat stress experienced by essential outdoor workers in the context of climate change. The UTS project team are:

- Associate Professor Nimish Biloria, Faculty of Design, Architecture and Building
- Professor James Goodman, Faculty of Arts and Social Sciences
- Dr Elizabeth Humphrys, Faculty of Arts and Social Sciences
- Freya Newman, Research Assistant, Faculty of Arts and Social Sciences
- Pejman Pakdel, Research Assistant, Faculty of Design, Architecture and Building
- Dr Francesca di Rimini, Research Assistant, Faculty of Arts and Social Sciences
- Associate Professor Leena Thomas, Faculty of Design, Architecture and Building

B. PROJECT OUTPUTS

The project has led to a series of briefing reports for both cohorts of workers and for other interested participants. An interim report was available in May 2019 and in July 2019 some of the key finding were used as the basis for a submission to the Victorian Government's Inquiry into On-Demand work, 'Heat Stress and On-Demand Work: The Experience of Food Delivery and courier cyclists'. A key output from the project has been the creation of an online platform for reporting heat stress. As this is a feasibility study, the URL for the project platform will be maintained for at least two years, to enable future development: https://heatinthestreets.online/

The final report will be published on a dedicated Heat and Work website, linked to the UTS Climate Justice Research Centre Website. Proposals for developing the project beyond the feasibility study were presented to the 2019 international 'Climathon'. In addition, a formal briefing on findings from the project was conducted with the Centre for Future Work and The Australia Institute, held on 28 October 2019 at Trades Hall in Sydney. Presentations from this event will be made available on the project webpage on the CJRC site. A summary report has been prepared for the Centre for Future Work, to be published on their website. An additional project workshop is to be organized later in 2019 for the City of Sydney and other interested participants.

C. LITERATURE SURVEY

The issue of climate change and workplace heat is of growing significance yet is under-researched (Kjellstrom et al., 2009). A 2013 literature review on heat stress, work and climate change, called for research to be prioritised, including 'social, economic, environmental and technical aspects' (Lundgren et al 2013). A further survey of the health impacts of workplace heat in 2014 found only 55 articles addressing the issue (Xiang et al 2014).

Since 2014 there has been a growing wave of international concern. The IPCC's Fourth Assessment Report in 2014 identified 'heat strain and heat stroke' under climate change as a major workplace issue. Noting that more than half of all non-household labour occurs outdoors, it highlighted agricultural and construction work, especially in tropical developing countries as 'among the most exposed' (IPCC 2014:731). In 2015 the World Health Organisation has issued an 'Atlas of health and climate', citing heat stress as an 'emerging' challenge (WHO 2015). Also in 2015 the International Labour Organisation called for 'assessments of increased or new OSH risks resulting from climate change' (ILO 2015:26).

In 2016 the UN released a major report on the issue, 'Climate Change and Labour: Impacts of Heat in the Workplace', which highlighted the rapid increase in daylight working hours lost due to over-heating, stressing threats to livelihood and health, concluding more research was 'urgently required' (UNDP 2016:26). Most recently, in July 2019, the ILO released a major report the impact of rising heat on 'decent work', 'Working on a Warming Planet', that directly linked the workplace to climate mitigation (ILO 2019).

Australia-based studies focused on heat stress, work and productivity, have found major threats for many classes of occupation (Zander et al., 2015). Climate heat is now recognised as posing 'immediate and pressing risks' for Australia (Stanley et al 2017). In 2011 Hanna et al addressed physiological impacts and policy responses, and pointed to the need for more qualitative work (Hanna et al 2011). Qualitative research on the issue remains relatively weak. An important exception is Xiang et al 2016 qualitative study in South Australia which found 30% of people working outdoors had experienced heat-related injuries (37% had experienced 'heat illness') (Xiang et al 2016). With no minimum national standard to address heat illness, the research found only 20% of employees stated that work would cease when the temperature exceeded 40°C. Half of those surveyed had concerns about extreme heat and strongly favoured training, regulation and workplace changes to address the problem (Xiang et al 2016).

Working conditions are an important factor in heat stress. A substantial body of public health, industrial relations and occupational health and safety research reveals direct connections between different working arrangements and health and safety outcomes for workers (see Quinlan 2013). There are wider concerns about livelihood and productivity, with agriculture most clearly affected (Gornall et al 2010; Kjellstrom et al 2016). Insecure and underpaid outdoor workers are likely to be much more vulnerable to heat stress than counterparts who have better employment conditions. One US study found heat-related fatality 20-times more likely for agri-industry than for other sectors (Jackson and Rosenberg 2010). Workers in these sectors are often self-employed or on piecework, and heat stress has livelihood impacts as well as health impacts.

There are also linkages between heat stress and the built environment, in terms of the ways in which cities are planned and constructed (Petkova et al 2014; Smith and Levermore 2009; Bulkeley et al 2016). Exposure to heat is heavily stratified both across workplaces and in social contexts (Harlan et al 2008). Reliance on home or work air conditioning and private transport can shape expectations for upper echelons; those unable to afford home cooling, who work in outdoor occupations and are dependent on public transport can be much more exposed, and at the same time more vulnerable. At the macro level, the emergence of satellite cites with large distances across suburbs only exacerbates exposure (Stone et al 2010). Urban planning is also significant at the 'micro' level such as access to water fountains and to shaded and cooled resting spaces, preferably with foliage (Norton et al 2015). Addressing such issues can be central to ensuring sociality in the city, enabling the city's connectivity and cultural vibrancy.

D. METHODOLOGY – MODELLING CITIZEN SCIENCE AND HEAT STRESS

The project has sought to create a participatory platform for gathering data on heat stress. This is conceptualised as a form of citizen science where participants find new ways of socialising the experience of heat stress, to enabling new ways of acting on it. It is inspired by the experience of citizen science projects in climate change, under the US National Climate Assessment for instance (Bäckstrand 2003). There is a wide range of initiatives to crowd-source local-level adaptation and mitigation initiatives, and to increase social engagement with climate issues. The 'crowd science' platform Zooniverse, said to be the world's largest, currently hosts more than a hundred projects, twelve centring on climate, mainly involving mass-scale observations. The MIT's 'Centre for Collective Intelligence' citizen science program has focused on crowd-sourcing engagement strategies for climate action; there are also online geo-spatial mappings of climate impacts, for instance the 'Climate Hot Map' by the Union of Concerned Scientists.

An important aspect across these projects would be to keep a focus on mediating scientific data and participant experiences (Hochachka et al 2012). To do this the project has to motivate participants, offering concrete benefits of participation; also, engagement must be accessible and simple, via electronic devices, based on common templates and interfaces. For this, researchers can draw on the existing extensive range of such materials supporting citizen science projects (hosted, for instance, at: citizenscience.org, citizensciencealliance.org, and citsci.org and the 'Commons Lab'; see Bonney et al 2014; Bates et al 2016).

The project seeks to enable a 'coupling' of qualitative workplace experiences with the broader science of climate heating, through geo-spatial digital representation (see Crain et al 2014). It produces new capacity to address what in large part is an individuated experience to raise awareness of climate risks; it targets those most directly affected; and advances knowledge about strategies to address the impacts. Most important perhaps, it offers strategies to initiate and to sustain self-generated data-gathering and deployment, considered vital for successful citizen science (Sauermann and Franzoni 2015).

This project complements Xiang et al's qualitative research on how people are experiencing heat stress in Australia workplaces and builds on initial findings from earlier work conducted by the investigators (see Newman and Humphrys 2019; also Rowlinson et al 2014). Newman and Humphrys' findings indicate that the level of workplace autonomy and organization, including unionisation, and the mode of employment, whether permanent, casual, contract, are key factors shaping the ability of outdoor workers to mitigate the impacts of heat stress in their day-to-day work.

For this reason, for this feasibility project we sought workers in two industries and types of employment:

1. Workers in ongoing work for a government body (council outdoor workers)
2. Gig workers who are working as subcontractors (bicycle delivery couriers).

We proposed that the mode of employment for workers in an industry, or a workplace, is likely to correlate with an employee's experience of heat stress. Workers who are able to alter the pace of work may be able to organise their working day to minimise heat stress; those who have to work to an externally-defined work schedule, that has no regard to heat stress, are likely to be most affected. In this context, the mode of employment may be critical. As we stated in our original proposal: ‘Couriers operate in the expanding informal labour sector, with minimal power to adjust individual and collective working conditions in response to heat. In comparison, Council’s outdoor workers receive more OH&S protections but nevertheless must weather the extremes of rising temperatures’.

In addition, we aimed to understand how urban planners in Sydney can design a more heat-sensitive and responsive urban environment, as part of making the streetscape more liveable in summer, and hence more likely to be accessed by the wider public. This, we suggested, was a key aspect of making the city more engaged and vibrant, a key objective of the City of Sydney. To address this we aimed to explore the perspectives of heat-exposed workers in the city on how planning could be improved. Heat stress is often exacerbated by absence of canopy cover, excessive built up areas with heat reflective materials such as glass facades and concrete paving, absence of shade provided by surrounding buildings, width of streets as well as traffic occupancy in certain urban zones of the city. These are issues of importance for everyone using the streets of the city: we posited that climate-exposed workers would lend special insights into these issues.

The project team resolved to collect both quantitative data (temperature, humidity and geographical movement) and qualitative information (time worked and physical responses to heat) from participants. Personal heat stress sensors were purchased; the project used Strava for GPS tracking for bicycle delivery riders, and survey and interview data for council workers; SurveyMonkey was used conduct the online surveys (see below).

(i) Participant recruitment

Council outdoor workers
CoS employees, as opposed to those working for contractors doing similar work, are likely to have a higher level of unionisation and workplace organisation, ongoing employment status with leave entitlements, greater OHS policy regulation of their work, and better general working conditions. Three teams of outdoor workers at the CoS were identified for possible participants: parks, waste, and civil infrastructure. Managers of these areas were asked if they wished to participate. Project staff visited CoS, to explain the project and answer questions. This meeting included a member of the CoS City Sustainability Team, and a CoS WHS Specialist. The Parks Maintenance Unit at the CoS then identified a group of six workers who were willing to participate in the study and one worker from roads maintenance (seven in all).

Bicycle courier riders
Delivery cyclists have very low levels of unionisation and workplace organisation, a precarious work status, less OHS and risk management oversight, and are most often employed as subcontractors to those who provide them with work (a form of work often called gig or piece work). An early scoping interview was held with a bicycle courier worker known to the project team which identified possibilities and challenges in recruiting bicycle couriers, and helped refine the survey and interview questions for this project. While initially the project sought to recruit food delivery workers we decided to extend the scope to include various types of cycle couriers employed under varying conditions and standards. Participants were recruited in person in the Sydney CBD at a known congregation point around the General Post Office at Martin Place, via a Facebook group for Sydney bike couriers, and through our contacts in relevant trade unions. A total of eight document delivery courier workers and three food delivery workers, were recruited for the study (eleven in all).

(ii) Data collection

The data collection stage of the project ran between January and April 2019. Between January and February 2019 participants were recruited, and scoping interviews were conducted to test and refine the data collection methods for the project. In February and March members of the UTS Project Team met with each participant to provide further details on the project, to set up heat monitors and the location monitors for the bike couriers, and to conduct brief intake interviews. Heat stress, location, and survey data was then collected from each participant on five selected hot days throughout March. Members of the Project Team then met with each participant again, to collect the heat sensors, and conduct a final exit interview.

(iii) Intake interviews

In-person intake interviews were conducted with project participants, by a member of the UTS research team. These interviews were recorded, and then later transcribed. See Findings (I).

Council outdoor workers
Members of the UTS Project Team met with the six CoS maintenance staff participants in February and explained the purpose of the project, and how the findings would be used. It was emphasised that data collected would be anonymised, and each participant was given an information sheet to read and a consent form to sign. Each participant was given a unique ID, which they would use to complete the surveys throughout the research period. Participants were also given a heat stress sensor to carry during working hours throughout the research period, and a basic information sheet to fill out. Then, members of the UTS Project Team interviewed all six participants about their experience of heat stress at work in a semi-structured group interview. The roads maintenance worker was interviewed separately.

Bicycle courier riders
Members of the UTS Project Team met with bike courier riders individually in late February, 2019. Each participant was given an information and consent form, and briefed on the general purpose of the study and how to use the heat sensor and Strava. Each participant was given a unique ID, which they would use to complete the surveys throughout the research period. Participants were also given a heat stress sensor to carry during working hours throughout the research period, as well as a unique login to the Strava location tracking app.

(iv) Survey

A brief survey was created using a mobile phone based Survey Monkey, that participants could easily respond-to. Participants were sent an SMS the evening before each block of days, asking to carry their heat stress sensors with them on these days. Bike courier riders were also asked to login to Strava on these days. Around midday on each day, both groups of participants were sent a text message prompting them to complete the short 5 minute survey (link included), if they were working, had been working, or would be working that day. Survey questions related to their experience of heat stress on that day.

(v) Exit interview

Face-to-face exit interviews were conducted with all project participants by a member of the UTS research team. These interviews were recorded, and then later transcribed. See Findings.

For the council outdoor workers, two researchers met with the City of Sydney Parks employees and had an extensive group discussion about the research project and the issues arising from addressing heat stress in their workplace. This was recorded and transcribed. One researcher also met with the participant from roads maintenance and recorded an interview, which was transcribed.

For the courier and delivery riders, one to two members of the project team met with each participant individually, between mid and late March 2019. Exit interviews asked about participants' experience in the study, as well as any further reflections or comments they had to make about the experience of heat stress and work. Some of these interviews were brief, others were quite extensive. All the interviews were transcribed.

E. PRODUCTION OF A DIGITAL PLATFORM

A prototype Digital Platform was created for indexing, analysing and visualising both quantitative and qualitative data sets collected during the term of the project. The data relating to heat stress measurement as well as geo-location were collected in addition to the survey and interviews. The role of the dashboard was to aggregate the collected datasets and visualise all associated parameters relating to the experiences of each participant. These parameters included Temperature and Humidity to derive the Heat Index (a measure of how hot it really feels when relative humidity is factored in with the air temperature, https://climate.ncsu.edu/climate/heat_index_climatology), Speed at the point of the collected measurement and the Distance covered by the participant at the point of the acquired reading. Besides this, salient features of the interviews in terms of the perception and experience of urban heat, and ways in which people cope with it are also displayed. This adds a qualitative dimension to the quantitative datasets and enables comparison of on-ground environmental conditions with the lived experience of the participant.

(i) Hardware and Software for Data-gathering

Heat stress data for each participant (bike couriers as well as council workers) was collected using a temperature and humidity data logger: Minnow Sensor 1.0 (Figure 1). Minnow 1.0 offers accurate and repeatable logging for temperature and humidity. Temperature is measured to an accuracy of +/- 0.3C over the range 5-60°C; humidity is measured to an accuracy of +/- 2.0% over the 20-80% humidity range.

Figure 1 Minnow Sensor 1.0 used in the field study

Both temperature and humidity were logged at a user-configurable logging rate (set to a reading rate of 1 minute in the case of this study) set via a PC application program: Sensonics. Raw data relating to temperature and humidity was registered in the Sensonics platform (Figure 2) where they are automatically converted to CSV file format for ease of transferring to a custom Mongo database through a custom program written in Node.js.

Geolocation data was captured for Bike courier riders (owing to their mobile nature) using Strava. Strava is a free social fitness application primarily used for tracking dynamic fitness activities such as cycling and running using GPS data using mobile networks on mobile phones. Bicycle Courier participants were asked to download the Strava application and log in using accounts specifically created for this study. Each participant's recorded log can be mapped onto the city using OpenStreetMap (Figure 3). These data sets are downloaded directly from respective Strava accounts of each of the participants as GPX files. Using a custom program written in Node.js, we transfered these geolocation and associated datasets to our custom Mongo database.

Figure 2 A screenshot of the Senonics software page, which extracts raw sensor data from the Minnow sensors and converts it to a CSV file format

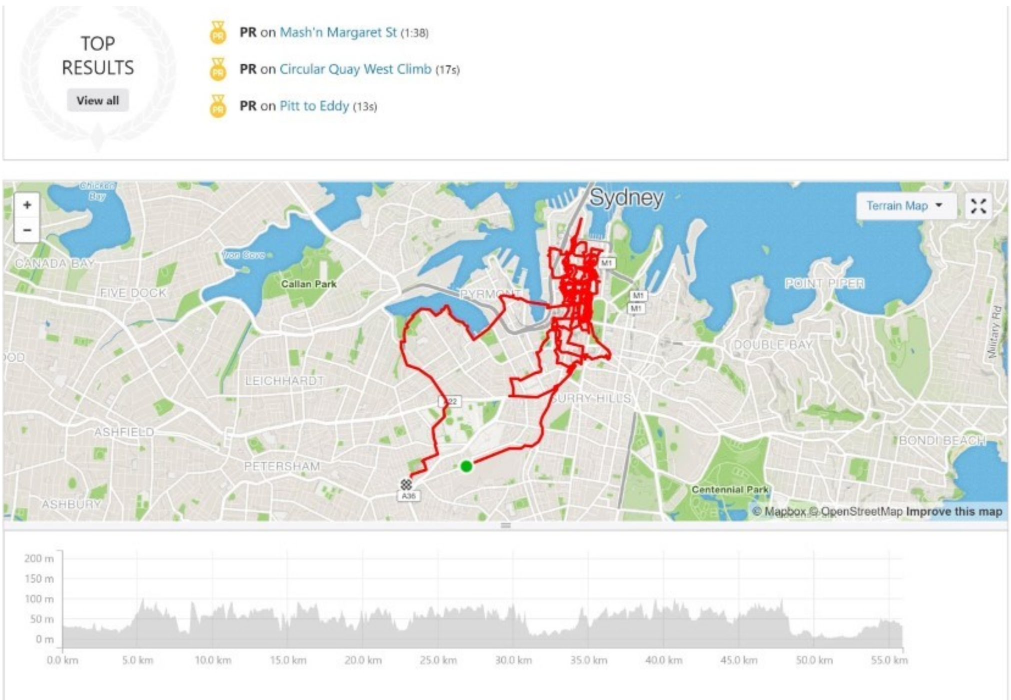

Figure 3 A screenshot of Strava website showcasing geolocation and associated time segment (point to point) data plotted on OpenStreetMap

(ii) Data filtering and correlation

An algorithm to calculate matching entries of data between Strava's geolocation data and Minnow sensor's data has been developed. In this algorithm, first, the data of each collection with respect to date and participant id. The matching sets of temporal, heat stress and spatial data are stored in the custom database (Figure 4).

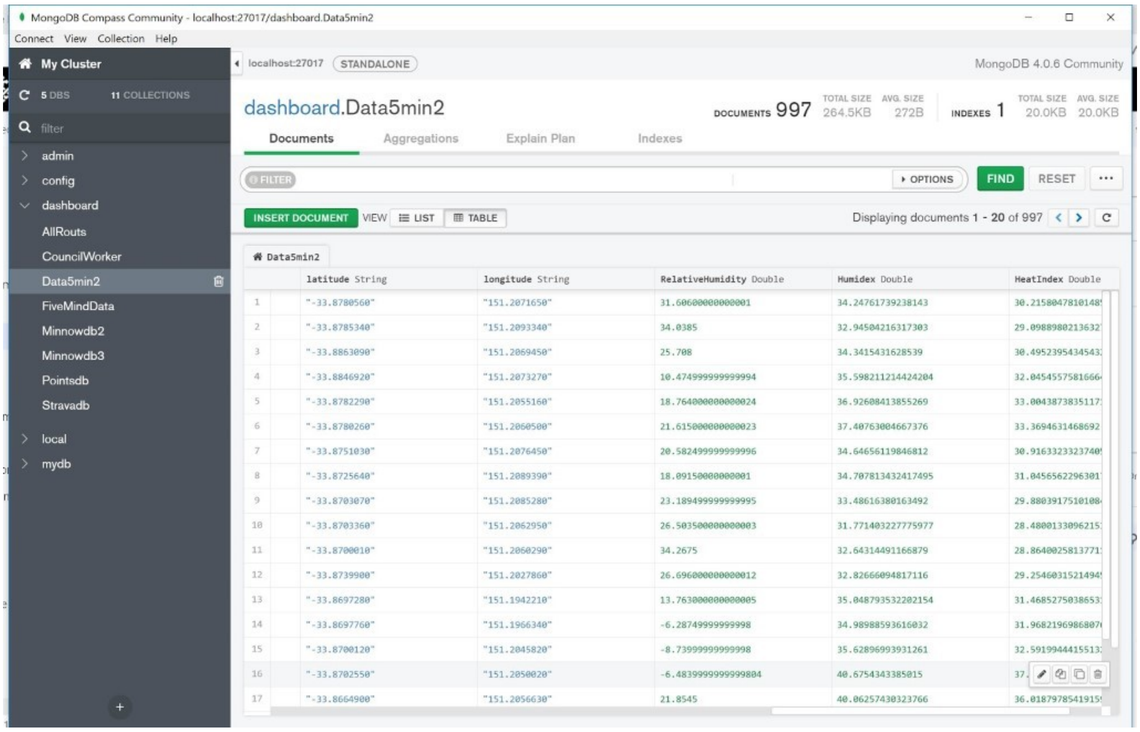

Figure 4 A screenshot of MongoDB database which hosts Sensor data and Strava data and geolocation data organised by time and participant

(iii) Data Visualization in the Digital Dashboard

The digital dashboard visualises the correlated datasets in two distinct sections (Figure 5) with an operating menu bar towards the top of the dashboard front end.

The menu bar (Figure 6) allows intuitive navigation and selection of the following:

- Selection of participant type: Bicycle Couriers or Council Workers
- Selection of the Heat Index caution level based data visualisation
- Selection of individual participant and the day for which the data has been recorded

After selecting criteria the Filter button needs to be clicked in order to display relevant data. Besides this, a Download option is also provided in order to extract the chosen selection-based data in an excel sheet.

The primary visualisation section below the menu bar is divided into two halves: the left half displays a geospatial mapping of the filtered and correlated datasets. The matching data is plotted in the Dashboard's geospatial visualisation section using OpenMaps. The visualisation is in the form of Heat Index plots at an interval of 5 minutes on the route taken per bike courier. The colour variation in these plots reflect environmental caution levels (Figure 7).

The right half of the screen is a direct automatic feed from the survey that had been completed on the day, both with quantitative responses and with open-ended comments. This is a very important aspect of the visualisation, as this can be completed in the absence of Strava data or Heat sensor data, direct from a mobile phone. As discussed below, the survey can be linked to phone's geo-location data, feeding the time and place the survey was completed onto the platform.

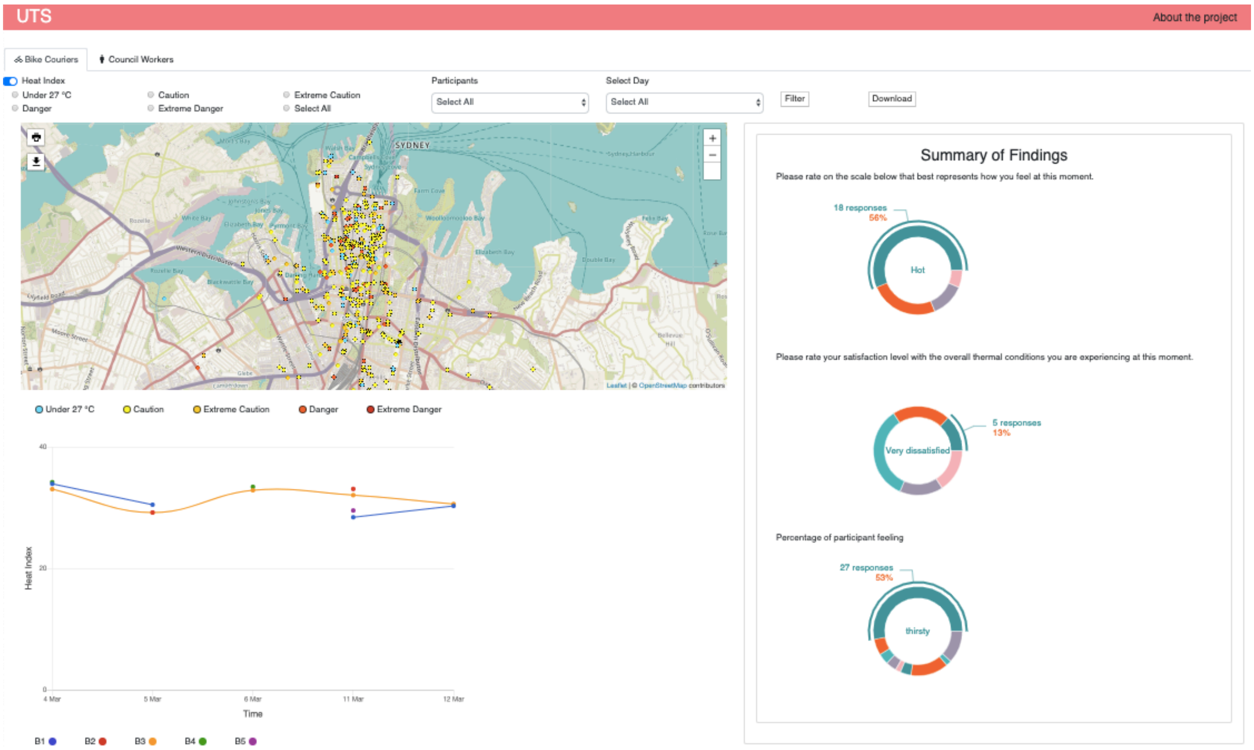

Figure 5 Screenshot of the Dashboard Frontend with the Menu bar on top and two distinct Left and right data visualisation sections.

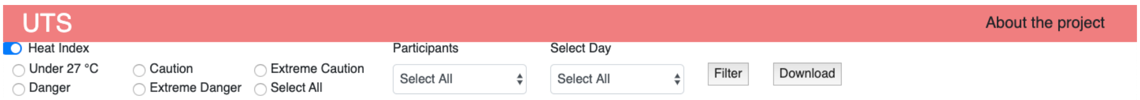

Figure 6 Screenshot of the Menu Bar of the Dashboard.

A provision to see the plotted heat stress data in full screen is also made available in dashboard. Below this section is a visualisation of the Heat Index value per participant which is plotted in relation to the day of the selected data. Each plotted Heat Index point can be clicked to reveal a Google Street View of the location in order to get an idea of the 3-dimensional quality of the urban space. This helps in determining the degree of green shading, the height of buildings which could shade the streets, usual traffic conditions and the land use at that particular location (Figure 8).

The Council worker tab also operates on a similar visual basis, however, owing to the fact that this group tends to work within an allocated area for a long stretch of time, we did not opt for the geolocation based OpenMap display for this category of workers. Instead, two interactive plots on display the Heat Index range on respective days per participant and clicking on any participant data opens up an interactive visual mapping the progression of the Heat Index Reading as compared with the actual Temperature changes for the chosen day.

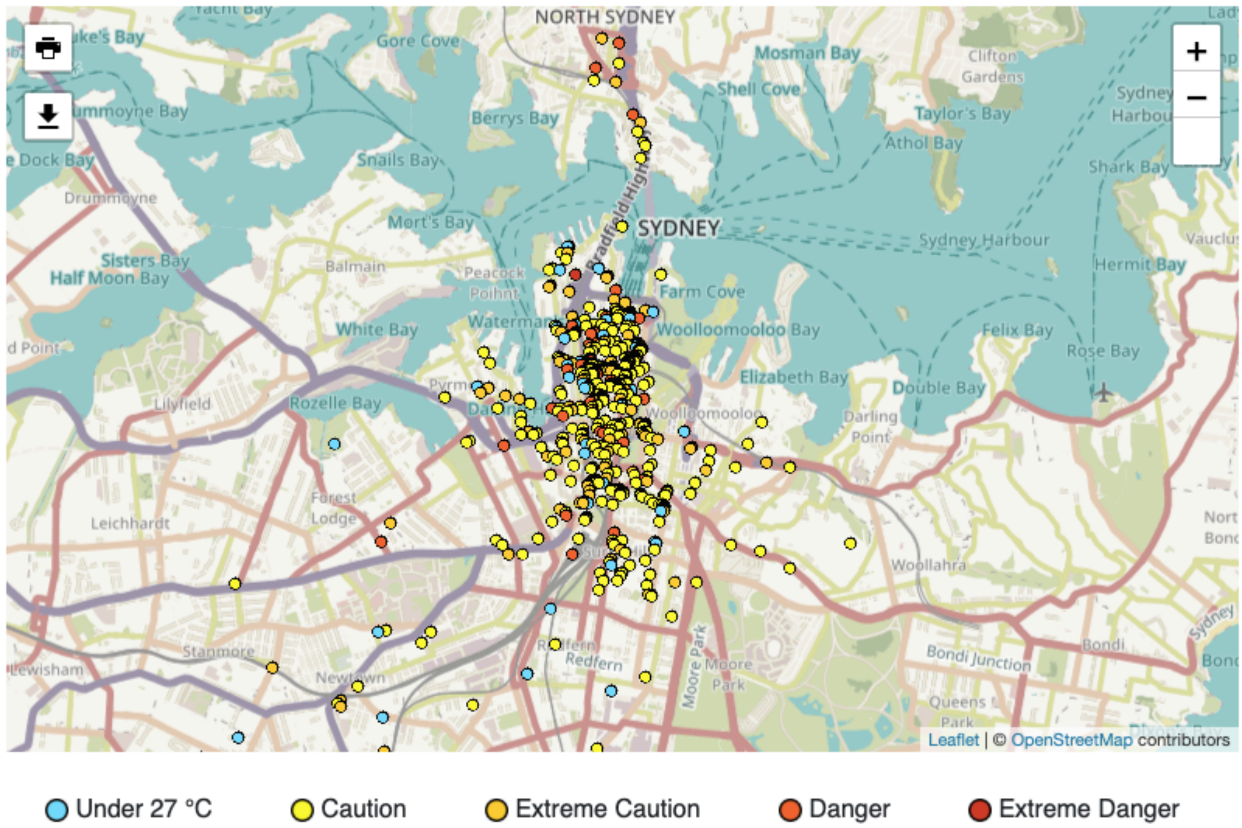

Figure 7 Screenshot showcasing Heat Index visualization on geolocated datasets of all participants on a given day and time interval

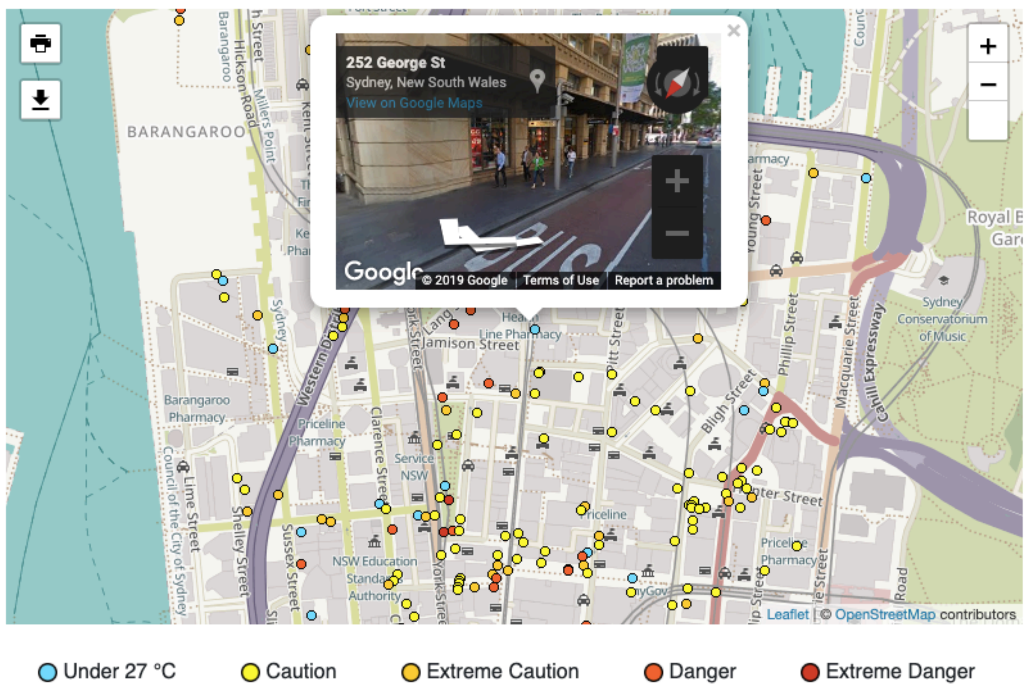

Figure 8 Screenshot showcasing Google Street View corresponding to the selected Heat Stress Point

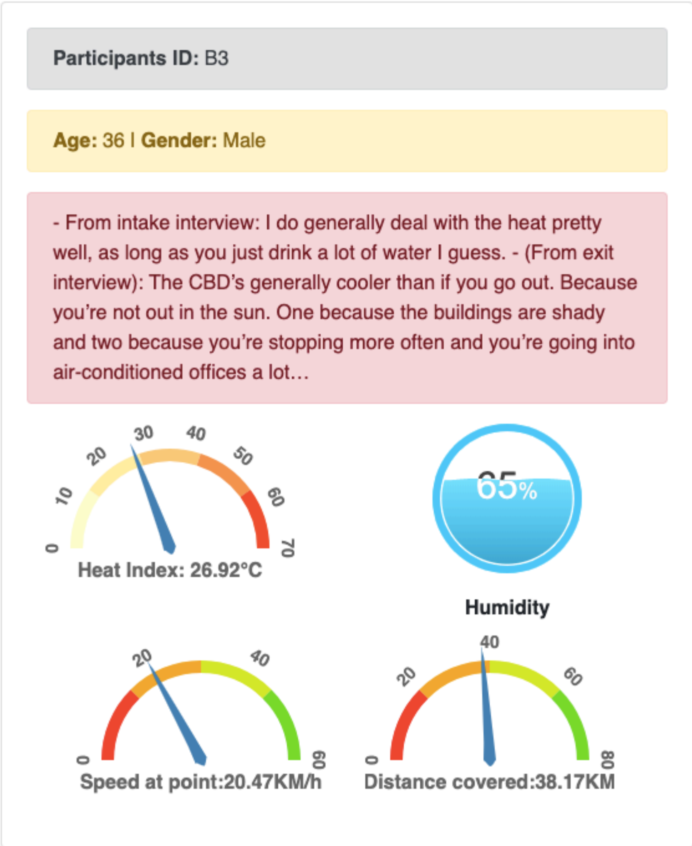

Figure 9 Screenshot of the right data visualisation panel showcasing qualitative and quantitative datasets of a participant

The right side of the pane has two purposes: In the home page view, the right side of the dashboard pane acts as a 'Summary of Findings' information graphic section which outlines qualitative feedback pertaining to experienced responses to thermal condition, physiological response and overall perception of temperature conditions during the term of the experiment. This data is collated from the survey forms and is based on the responses provided by actual participants in the study.

The selection of a participant from the menu bar (for both Bike and Courier workers) transforms the visual display on the right pane and showcases data relevant to the chosen participant. This includes Participant ID, Survey data (both quantitative and qualitative), excerpts from any interview conducted with the participant, Heat Index measurement and humidity measurement (Figure 9).

A mixture of anonymous qualitative and quantitative data for each the participant can be viewed, or several participants can be grouped together. The system architecture diagram presented below (Figure 10) outlines the entire technical development process of the digital platform.

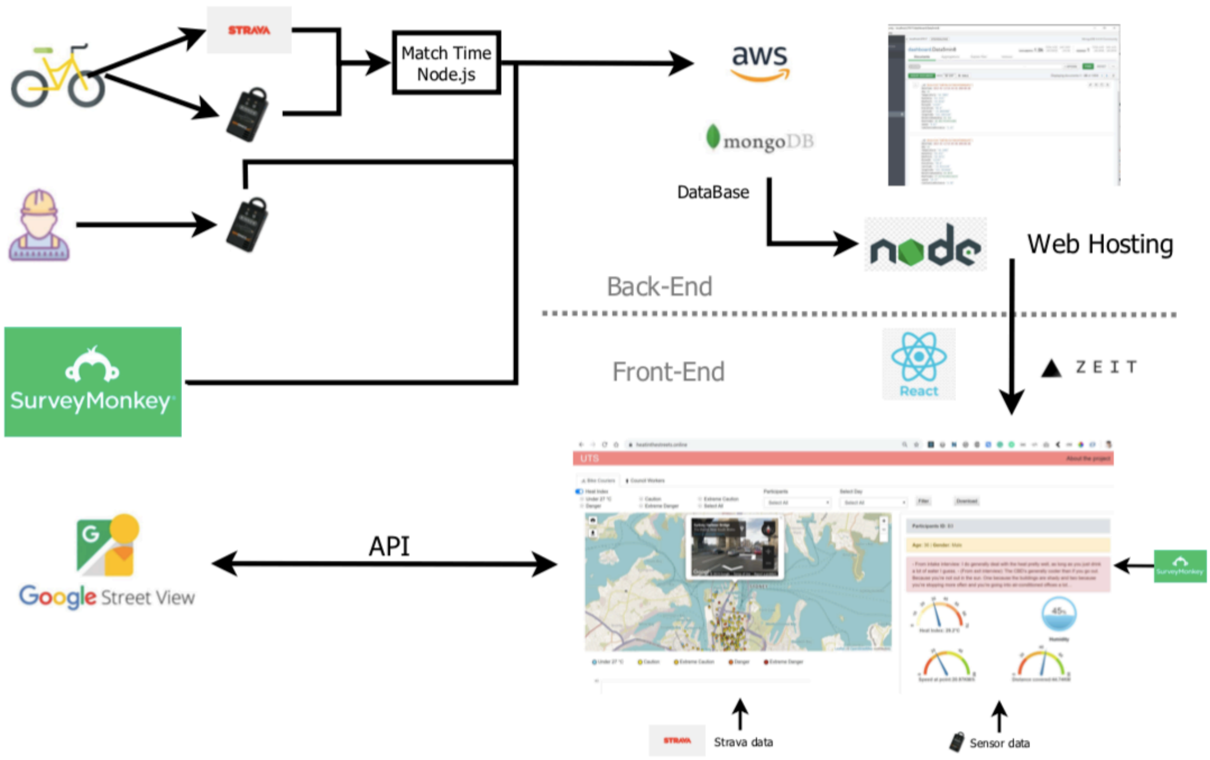

Figure 10 System Architecture of the entire Digital Platform

F. PROJECT FINDINGS

(i) Findings from the Survey

The findings from the survey demonstrate the importance of heat stress in these workplaces and underline the contrast between the two sets of workers. These are reported separately here, with the quantitative findings first, followed by some of the qualitative responses. Each participant was asked to fill in the survey during a particularly hot day, and as noted, most completed it at the end of the day. The results are expressed as a percentage of overall reports on that issue across the returned surveys.

Quantitative data
Participants were asked to click on any statement that described how they felt at work on the day concerned. As outlined in the Appendix, the heat stress was having a surprisingly similar impact on both cyclists and Council workers. About half of all respondents stated they were hot at work, with three-quarters saying they were thirsty. A quarter to a third of both cyclists and council workers were 'extra tired', were finding it difficult to concentrate, and had trouble completing tasks. A small number felt 'faint or dizzy'.

There is a clear difference on how the two groups sought to deal with the heat stress.
For the cyclists, about two-fifths had taken extra breaks and a quarter had otherwise changed the way they did their work. Three quarters had rehydrated more often, 10% had taken on lighter duties and only 4% had stopped work. Among the Council workers only a fifth had taken extra breaks while two fifths had otherwise changed the way did their work or where they worked. Almost all of the Council workers had rehydrated more often; 15% had undertaken lighter duties and 9% had stopped work. Council workers were more likely to change their work schedule in response to the

heat; courier workers were much more likely to take breaks, but council workers were more likely to take-on lighter duties.

These responses reflect the contrasting nature of the work-flow for couriers as against council workers. Flexibility in work scheduling allows council workers to re-allocate the most physically exerting tasks. Couriers may be able to take more breaks, between deliveries for instance, but are not able to take-on lighter tasks and generally. These differences in work scheduling and work intensity between the two groups of workers are discussed in more detail in the interview analysis.

Open-ended responses
The open-ended comments, both from couriers and council workers, give a strong sense of the emotional impact of heat stress through the day. This is recounted with a mixture of stoicism and humour, and concern for the impact on those around them. In this respect, heat stress was seen to be internalised as a personal burden and responsibility.

All the participants were asked if there was anything else that they wanted to share about heat stress at work. Responses from cycle couriers included:

- 'I suppose what makes me more uncomfortable is the layers I have to wear etc. it's harder too concentrate if I'm uncomfortable'
- 'Humid weather wearing me down as time goes by'
- 'It's been a really warm and humid day to work on a push bike'
- 'Changes to intensity and mode of work cause me to incur costs and lose earnings as I am in a sham contract'
- 'It was a very hot day, using sun cream every 3h'
- 'Staying indoors in order to cope with the heat'
- 'Not really wasn't that hot'
- 'I am fine with low 30's. I get more heat stress high 30's low 40's'
- 'Worked a different area so much easier heatwise today'
- 'It stormed in the afternoon and cooled down completely'
- 'I don't enjoy today's combination of heat and humidity. Hard to swear when the air is so moist'
- 'Felt extremely overheated'
- 'There was a constant gentle breeze which kept me cool.'
- 'Pretty relaxed short shift'
- 'Only working short shifts this week, unrelated to heat though-just a quiet week for me. Finished by 2.30pm roughly. Last half hour was commuting home in the sun and 30c'
- 'There was a broken fountain in Alexandria outside the IGA on Botany. Water on the Paddington hill on Oxford street would be good.'

Responses from Council workers on this theme included:

- 'Very hot and humid'
- 'Not in ute, driving truck with poor A/C'
- 'Hedging large hedges most of the day creates a hot personal environment due to how close the machinery is to your body and the extra safety gear worn'
- 'Lack of any breeze and bushfire smoke haze made it uncomfortable to work today'
- 'Very humid day felt from early morning'
- 'There is no way to cool down'
- '20 min drive to the depot in the A/C was a great way to relieve myself from such a muggy afternoon'

- ‘Temperature was around 35 degrees, estimate it felt like around 40 degrees. Very hot and somewhat uncomfortable. Makes any labour task harder to physically do and reduces the speed at which you work’

Cyclists who reported feeling they had been relatively hot or humid on their last shift were asked to explain how this affected them:
- ‘Tiring, drank lots of water’
- ‘Less efficient at work’
- ‘Wasn’t that bad’
- ‘Was humid but not too hot. Basically in the CBD all day though so plenty of shade and air con available’
- ‘I was hot and bothered and tired. Too humid for my liking’
- ‘I was dehydrated and exhausted and it caused me to be a little emotionally on edge and just kind of “over it”’
- ‘I was dehydrated and needed to drink a lot of water. It’s not as present to work when you are so hot.’
- ‘Slower and less efficient’
- ‘Yelled a lot at inanimate objects’

Council workers who had stated they were particularly hot or humid were also asked how the had affected them, and responded as follows: :
- ‘Longer to complete tasks, irritable and uncomfortable’
- ‘Losing fluids faster than able to replenish, didn't stop from discomfort so mentally felt stronger’
- ‘Sweating, feeling hot, wanting to get out of direct sun when appropriate’
- ‘Second day of heat so was a bit slower today found it harder to concentrate and get tasks completed’
- ‘Besides the discomfort, irritability, sweating and subsequent body odour that's the low end of the scale at its worst the shakes, legs start to feel like jelly and headaches’
- ‘Quickly realised that I was getting less friendly the hotter I became. Also I feel as my work was slowed down as some cramping became apparent in my late afternoon’
- ‘Effects me once I stop moving for a long period (over 30min) as fatigue sets in, and it's hard to feel hydrated for a few hrs after that’

The Council workers were asked at which locations they felt the hottest during their shift. Answers included Rushcutters bay, Reg Bartley Oval, Gowrie Street, McEvoy Street, Isabella Hills Reserves, Waterloo oval, Solander Park, Kepos Street, Maddison Street, and jobs that were beside main roads.

(ii) Findings from the Interviews

Initial data demonstrates the well-established nexus between outside temperature/ humidity and work effort in producing heat stress. There are evident differences in the physical exertion required, and the exposure to heat involved in a particular form of work. Workers in continuously highly-exerting exposed work, e.g. in asphalting on public footpaths and roads, stressed the need to pace the work and enable time for relief. Workers in highly heat-exposed work, operating dangerous machinery in public spaces, stressed the risks involved and the need to avoid the hottest part of the day. Workers involved as couriers, delivering parcels or food, took a wide variety of issues consideration to minimise heat stress, from seeking-out shaded streets, to delaying or rescheduling deliveries to avoid the heat.

Workplace relations
Contractual arrangements are critical in shaping how work effort can be managed. One courier

summarised the situation succinctly: ‘‘the main way in which they force work out of us is by paying us effectively below award or below minimum wage, which induces people to work stupidly hard, which means they can’t regulate their taking of jobs during peak heat periods’. Workers undertaking monitored piecework at the hottest time of the day, such as for food delivery and some parcel delivery workers, generally fare the worst. Workers with a daily piecework allocation that could be scheduled or arranged during the working day were in a better position. Hourly-paid workers were more able to vary the intensity of their work as income did not hinge on the pace of work. Workers in continuing employment, organised into teams with the autonomy to organise the working week fared much better.

Document couriers have more autonomy than food delivery workers as there can be some delay in document delivery, unlike for food. Some piecework document delivery workers are given their quota of deliveries at the start of the day and adopt various techniques to minimise effort, delays and discomfort on hot days. Others deliver on demand and are less able to plan their day. Following successful efforts by the trade union, most couriers are hourly paid and consequently are under less pressure. By necessity food delivery workers work more slowly on a hot day and suffer as a result: one stated ‘Normal days, if I work three or four hours I’m okay. But on hot day, one or two is too much’. For these piecework couriers the focus is on making enough deliveries: ‘you don’t care, you’re sweating, you don’t take drinks when you should, you don’t rest when you should, you just don’t stop. You just do it. So it’s a totally different mentality’.

One piecework document delivery worker was earning $800 a week for 400 kilometers, just $20 an hour for a 40 hour week. One food delivery ‘contractor’ is stoic and angry: ‘You suck it, you push through it, you fall off the bike, you sleep off the sunburn, you get back on it. Or, you suck it until it turns 9pm and then it’s just hot instead of also burning, and go home at 1am when the drunks are finished eating and sleep until as early as you can wake up till lunchtime to roll on food again’.

For contracted workers there is a disincentive for employers to take responsibility for the working conditions of contractors: to do so would indicate the contractors are in an ongoing working relationship and should in fact be designated as employees. The document courier workers had in large part been able to shift from a piecework system by making this argument. Food delivery contractors are not contracted per job but are permitted to ‘bid’ for a timeslot depending on their track record, and then are required to make any deliveries they are allocated in that time period. Ranking of contractors and the allocation of work by time (rather than by number of deliveries) suggest ongoing employment, and are under challenge. Remarkably, food delivery workers are required to pay for their own uniform emblazoned with the company logo. One rider calculated that the food delivery companies appeared to be aiming for a $15 per hour rate of pay (well below the minimum wage).

All of these aspects exacerbate vulnerability to heat stress. One cyclist encountered several ‘absolutely exhausted’ food delivery workers on the road one late afternoon in a heat wave. He recalled one rider in particular, who had collapsed by the side of the road but wanted to keep going to avoid being demoted on the company app, stating ‘they’re tracking me’. Many of these riders are highly vulnerable: up to fifty percent of cyclist were international students (with university careers services recommending the work as a source of employment). He had attended two funerals for students who had been killed while delivering food. Insurance and work cover can be a major challenge: several food delivery workers stated they had been discouraged from making insurance claims as this would threaten their ability to bid for desirable slots in the delivery company’s mobile app.

Council workers in parks and roads workers noted that localised knowledge of how different areas of the city were likely to be affected by heat over the day, coupled with their own initiative in light of weather forecasts, influenced scheduling of tasks over the day and week. Scheduling work to avoid the hottest part of the day was easier with a series of different activities over a two-week cycle, as opposed to situations where a single task had to be completed to a fixed deadline. As one council worker put it: 'the good thing about our work is that we're the ones out in the field, we're the ones determining what we actually need to do, so we can play with what we actually have to do at the time… so there's a bit of autonomy'. The contrast with food delivery workers, for whom the lunchtime peaks in work intensity directly coincide with the heat stress peak, is important.

Ultimately, though, the work had to be done regardless of the impact, as one council worker put it: 'there's days you've gotta suck it up, there's days when you've just gotta put up and do it'. . It is hard for council workers to stop work, as one joked, 'There's not really a job in bright yellow, or bright orange, where you can stop work. People know straight away…It attracts too much attention [laughs].

But clearly no one fares well when there is a heat wave that lasts more than a few days, as exerting tasks can become more exhausting after successive days of high temperatures (and sleepless nights). That said, personal adaptation and acclimatisation to heat stress is clearly important: newly-arrived workers are particularly vulnerable, in terms of capacity to adapt and protect themselves. Demonstrating this, an interesting minority of very long-term messenger and delivery riders find hot days and hard schedules invigorating (though these are outliers).

The emotional toll of the heat can be important: one council worker said 'I think that's my hardest part: even though you know you're overheating, you've still got to try to remain somewhat professional'. For them there is strong public accountability, with complaints from the public relayed directly to workers: 'If that work doesn't get completed there will be a call, it goes down the line and comes back to us, please explain…' Fatigue at the end of long hot days was also noted, particularly in relation to driver safety: many of the Council staff interviewed drive an hour or so each way from and to the outskirts of the city not well connected by public transport.

Urban infrastructure

Beyond acclimatisation and adaptation to heat, most courier riders developed a tacit knowledge of the city and immediate locale in relation to availability of water, shade, breeze and quiet spots, but many suggested these could be improved. Where workers had a degree of autonomy over scheduling and choice of routes, it was clear they were taking advantage of the available infrastructure of the city to mitigate the impacts of heat. Reported strategies included choosing to work in the CBD where streets were shaded by the tall buildings in the middle of the day, or finding refuge in air-conditioned lobbies, cycling along tree-lined streets, or relegating strenuous or inclined routes to cooler parts of the day. Other key factors in choice of routes related to knowledge of dedicated bicycle paths, congestion and traffic at different times of the day.

Through the interviews there were several suggestions about how the council could minimise heat stress – providing access to cold water was critical, with many cyclists complaining at the lack of working bubblers, and some calling for a map of public water access across the city. Council workers called for hydralytes to deal with humidity, non-polyester clothing and shade roofing for ride-on machines; couriers called for more street shading, both on streets and in rest areas, with one suggesting water misters in specified public areas (and there were numerous issues unrelated to heat, such as a call to educate drivers, simplify rules for cycleways, ensure google maps is accurate and use slip-proof paint for cycleways).

Further, as regards urban planning, the decision to cease vehicle deliveries in the City during the construction of the light rail was widely welcomed, not just as it reduced city traffic, but also as it supported the couriers in establishing a temporary delivery hub at Goulburn Street. One described the arrangement as a 'beautiful accident', comparing it with similar successful experiments in other cities. He and others were hoping the arrangement would become permanent and looked forward to working with the council to create a new permanent hub, with proper facilities (water, showers, etc).

Social organisation
One important finding is that exposed workers have a strong density of social infrastructure and organisation. For council workers this is built into the informal structures of the workplace: there is evidence of strong team-based mutual support among the parks and road workers. This in large part reflects the specialised and highly localised knowledge that comes with their work, and appears to have formed organically (rather than intentionally) from the work allocation process. There is also strong evidence that courier and delivery workers are able to create their own networks of support: they strongly identify with their peers and have created structures to communicate with each other (often via social media platforms). They at the end of a working day at informally designated places that offer shade and water; some couriers in particular parts of the city have a shared cultural background, others identify with the local union; some are part of globally-networked sub-cultures, moving across cities and even competing in the 'Cycle Messenger World Championships', the courier Olympics.

Social links can create strong identification: 'it's a good crew, we all hang out on the weekends', and to some extent can provide support for new cyclists. As one courier stated: 'shared social organisation seems to come out of shared highly alienated work experiences'. One response to this has been through the Transport Workers Union, which has been active among cycle couriers, pursuing legal test cases on behalf of couriers, to force companies to employ couriers as employees rather than as contractors. They had also work closely with the Delivery Riders Alliance and at the time of the research were developing a Delivery Riders Charter.

G. DIFFICULTIES, LIMITATIONS AND POSSIBILITIES

The project was designed to give an indication of what kinds of experiences of heat stress are common among outdoor workers. As a pilot study, its additional purpose was to test-out a methodology for data collection and for visualisation. We believe these two objectives have been achieved, though there were several difficulties along the way.

Certainly, there had to be some creative adaptation in the course of the research process. Timing for data gathering is central: the project has to proceed during the hotter months. Due to various delays the data was collected on hot days later in the year (February and March) rather than during January when the 2019 heat waves happened to occur. Despite this, the results showed serious problems for outdoor work, even for moderately hot spells where maximum temperatures mainly ranged from 28 to 35° C. For subsequent projects it would be critical to gather data during the hottest part of the year.

Recruitment of research participants was challenging. Researchers established contact with bicycle couriers by approaching them 'cold' at various gathering points in the city. Most responded positively and helped the research team find other participants through their social networks. Social media was also important as a recruiting tool, with workers contacted via various emails to dedicated social media sites for courier and food delivery workers. Council workers were self-nominated following a general 'call' for participation from their manager: again, this approach was developed during the research process, along with shopping tokens for courier participants to compensate them for their time in participating in the project (which was welcomed but not a deciding factor for most).

Data-gathering itself was complex, with a layering of heat stress measurements, survey responses and geo-location data. For this project we were deliberately ambitious, to see what could be feasible. The participants were generally well-disposed to this, and proved to be highly engaged and interested to participate and learn of the results, and contribute further if the opportunity arose. Allocating a heat stress monitor to each research participant although an expensive option (at about $100 per sensor, though they can be re-used), offers the ability to understand the unique activity patterns of different users in different zones of a workplace. Participants had no difficulty carrying the sensors with them, though some accidentally switched off or reset the Minnow devices, causing loss of data. Cost-effective and simple heat sensor based products that can be attached to one's smartphone are constantly being developed, and such devices may serve to get realistic "on-ground" information

Workers had to have permission from their employer (in this case the City of Sydney) to bring the heat stress sensor into the workplace; couriers were defined as contractors and as self-employed workers, and hence were able give their own consent. In other contexts, gaining consent from employers may not be feasible. Further, in cases where a group of workers work in similar conditions, it may not be necessary for every research participant to carry a heat sensor as, for instance, one member of a group could carry it. Additionally, locally-available temperature and humidity measurements, for instance from the Bureau of Meteorology or City of Sydney smart poles or a customised network of fixed sensors, could be used to enrich the platform.

Our efforts to incorporate geo-locational data for the couriers required us to establish separate Strava accounts for each research participant. This was laborious and would be difficult to achieve for a larger sample. Some couriers reported that Strava drained their mobile phone batteries, though others were already tracking their level of activity and other aspects via Strava, carrying spare batteries. Individualised geo-location data, though may not be necessary if research subjects are not mobile and their location is known (as was the case for City of Sydney workers). An individual could be asked to report experiences of heat stress, in any context, and could simply assign their location via their mobile phone.

While heat index measures and geolocation help to ground-truth and visualise experiences at key locations in the city, the survey was the critical data source, which could record individual experiences on heat stress, potentially in any context. The survey link was sent directly to research participants' mobile phones on a hot day; they could access and complete the survey from the phone in a matter of minutes. In practice the overwhelming majority of participants reported that they undertook the survey at the end of the day, as they had little time to engage with it during their working hours.

Most important, survey results were directly uploaded to the platform, and linked (through user ID) with both the journeys and heat stress estimates. This offers an important and very simple-to-use mechanism, centred on a mobile phone to report heat stress experiences, and potentially could be applied in any social context. While the present pilot did not integrate the online survey administration component as part of the digital platform, it could be integrated in a future development of the platform.

In the future potentially interested participants could register their interest online to receive the survey and associated heat stress data on hot days, to gather their experiences onto the visualisation platform.

H. ANALYSIS, PRACTICAL APPLICATIONS AND FURTHER RESEARCH

The project aimed to combine workplace citizen science with the pattern-finding power of data visualisation, to create a model for establishing human stories in the heat data. The project team is now aiming to establish partnerships with governmental agencies, especially in urban areas, concerned to develop a response to growing climate heat. We also are interested in pursuing the workplace applications of the project, and will seek to work with relevant trade union and research organisations.

The insights from this project are centred on workplace heat stress and on wider experiences of heat stress in the city. The digital platform developed in this study could be used for either of these: it is fully scalable and is able to represent data for a much larger sample set. Real-time streaming of captured data can be visualized as a live dashboard, freely available to view by the City of Sydney and residents of Sydney. The platforms could be enriched through a mobile application version built on the same footprint of the platform wherein survey forms, note taking and commenting as well as geolocation are combined into one seamless package. It would also be possible to integrate real time temperature and heat stress data at fixed points within the city — be they through smart poles/bus stops etc. A network of such sensors would allow for the development of a temporal understanding of key places of interests — public parks, public spaces, bus stops and other areas where citizens are exposed to the vagaries of climate.

The data demonstrates the well-established nexus between outside temperature and humidity and work effort in producing heat stress. The capacity to minimise exertion during the hotter times of the day, and allocate work requiring more effort to the cooler days/times can be critical. The analysis suggests the importance of workplace autonomy in determining the pace and type of work, and thus in shaping the experience of heat stress. Heat stress is thus linked to employment arrangements - and in part is a product of the category of employment. Addressing heat stress points to increasing worker autonomy, including stronger social organisation among exposed workers. The data also highlights the impact of urban design on heat stress, whether as a constraining factor exacerbating exposure, or as an enabling factor where public space can offer refuge from the heat, allowing social interaction.

Further development

The project points to various avenues for further development, across workplaces, public spaces and other contexts. Whether participation is focused or more generalised, the platform could enable participants to mutually recognize both shared problems and common solutions. A focused study could see participants carry heat sensors, and respond with data alongside their location, providing feedback on their experience. Alternatively, wider forms of public engagement are possible with everyday citizens who would engage with the platform by tagging themselves at a particular location and particular time using the app, and leaving real time survey feedback. This could work well alongside the fixed sensors described above, especially if they were deployed as a network across the city.

Website-based data visualisation can socialize what is largely an individuated experience, and offer a platform for participating citizens and organisations to develop shared strategies. By creating a way to aggregate the experience of growing workplace heat, and how to address it, the platform could also stimulate public debate about climate and heat. The benefit, over time, would be to highlight and potentially politicise experiences to achieve safer public spaces and workplaces where livelihood and health are not endangered by climactic heat.

At the next stage of development it will be important to move beyond visualisation, incorporate aspects of data analytics, pattern recognition and problem solving. These will need to be integrated with the modes of data gathering, to enable compatibility across interfaces (see Isaac 2014). Here, issues of simplicity, intuitiveness, coherence, reciprocity, usefulness and collective reflection can become central (the 'OpenLab' model, see Hemment et al 2011).

A successor project could also focus attention on questions of public policy and climate heat, at a range of levels, from immediate workplace adaptation to health and livelihood protections, and wider requirements for global emissions reduction. For workplaces, the project could for instance relate to worker training for monitoring and adaptation, employer responsibilities and legal obligations, regulatory and enforcement models, public health initiatives and industry-specific emission-reduction initiatives. For urban designers the platform could enable informed decision-making on heat stress mitigation strategies in the built environment. This would be useful whenever the City or stakeholder needs to gain detailed feedback for a particular cohort or a specific area of urban development. There could be comparisons with parallel projects — the use of citizen science and policy change in this way is increasingly commonplace, especially in Europe (Haklay 2015).

Overall we see great potential for this platform, and the broad approaches that have been developed in this feasibility study, and hope to collaborate with others in further developing this initiative.

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APPENDIX

Survey Findings

(i) Cycle couriers

Main temperature felt at work	
Hot	50.77%
Warm	21.54%
Slightly warm	12%
Neutral	8%
Slightly cool	7.69%
Cool	0%
Cold	0%

Experience of heat stress symptoms at work	
Thirsty	72.46%
extra tired	29.39%
finding it difficult to concentrate	23.54%
feeling faint or dizzy	11.69%
feeling sick	2%
having trouble completing tasks	19.69%
feeling overheated	25.08%
wearing extra protective clothing	33.39%
none of the above	19.69%

Actions taken to address heat stress at work	
taken extra breaks	39.08%
changed the way you work	25.23%
changed where you work	3.85%
rehydrate more often	72.46%
eat or drink something special	35.23%
undertaken lighter duties	9.69%
stopped work	3.85%
none of the above	11.85%

(ii) Outdoor Council Workers

Main temperature felt at work	
Hot	52.72%
Warm	37.72%

Slightly warm	0%
Neutral	4.5%
Slightly cool	5%
Cool	0%
Cold	0%

Experience of heat stress symptoms at work	
thirsty	80.91%
extra tired	33.18%
finding it difficult to concentrate	28.64%
feeling faint or dizzy	5%
feeling sick	0%
having trouble completing tasks	34.09%
feeling overheated	18.64%
wearing extra protective clothing	38.18%
none of the above	9.55%

Actions taken to address heat stress at work	
taken extra breaks	10.00%
changed the way you work	38.18%
changed where you work	33.18%
rehydrate more often	86.37%
eat or drink something special	28.18%
undertaken lighter duties	14.55%
stopped work	9.09%
none of the above	4.55%

Extract of Bureau of Meteorology Daily Weather Observations for Sydney, New South Wales during March 4-12 2019

Most observations from Observatory Hill, but some from Fort Denison and Sydney Airport. http://www.bom.gov.au/climate/dwo/201903/html/IDCJDW2124.201903.shtml

Date	Day	Temps		Rain	Evap	Sun	Max wind gust			9 am						3 pm					
		Min	Max				Dir	Spd	Time	Temp	RH	Cld	Dir	Spd	MSLP	Temp	RH	Cld	Dir	Spd	MSLP
		°C	°C	mm	mm	hours	km/h		local	°C	%	8th	km/h		hPa	°C	%	8th	km/h		hPa
4	Mo	21.8	28.2	0	8.8	9.9	NE	48	19:34	25.6	59	1	NNE	17	1022.1	27.7	54	2	ENE	28	1019.0
5	Tu	21.9	28.6	0	10.2	8.7	NNE	48	16:48	24.5	63	3	NNE	6	1017.8	27.5	56	4	ENE	22	1012.7
6	We	22.2	35.6	0	7.2	4.8	SW	59	13:26	27.7	44	3	WNW	6	1008.7	26.3	50	7	S	19	1008.2
7	Th	18.0	23.9	1.4	8.6	1.3	SSW	43	09:42	18.5	59	7	SW	20	1022.7	21.5	48	7	SE	19	1023.3
8	Fr	18.4	27.2	0	3.0	9.4	NE	46	16:37	23.9	56	5	N	11	1021.7	26.8	53	3	NE	28	1018.2
9	Sa	21.2	24.3	0	7.6	0.7	SSW	46	07:32	21.2	70	8	SSW	24	1017.8	23.0	72	8	S	13	1017.3
10	Su	19.9	27.9	0.8	3.2	8.0	NNE	35	16:42	21.4	82	7	W	9	1016.1	27.3	61	3	ENE	22	1009.8
11	Mo	21.4	28.3	0	6.2	9.3	SSW	37	05:44	24.7	64	3	SW	22	1010.9	27.1	53	2	ESE	22	1009.0
12	Tu	21.0	34.6	0	5.8	10.5	SSE	61	20:37	24.5	67	0	W	15	1008.1	31.9	32	2	E	20	1004.1