PLANNING SHADEWAYS IN BENDIGO: AN EXAMPLE OF DIGITAL PLANNING TO ADAPT TO EXTREME HEAT

Andrew Butt and Marco Amati
Centre for Urban Research, RMIT University, Melbourne

Abstract

Addressing extreme urban heat is rapidly becoming a core planning issue. For example, this year the Red Cross presented the UN with a guide for coping with extreme urban heat. Under climate change, green and 'grey' shade infrastructure has a vital role in protecting vulnerable populations and allowing the active use of public spaces. This concern has become particularly acute in Australia's inland cities where evidence of heat stress on people and urban vegetation is gaining broader community recognition. *Shadeways* is a digital solution designed for the city of Bendigo, Australia – a city where climate change, ageing and community disadvantage are evident. This paper describes the project's innovative approach to utilizing and triangulating geospatial data, community perspectives on urban greening and community shade mapping activities to develop a shade mapping and (walking) route comfort model for the city. The project addresses the challenge of providing up to date heat information for planning active travel on a mobile platform. In general, the project also supports initiatives to engage communities in strategies for urban greening and heat responses through localised temperature sensors. The research findings provide a guide for similar communities to replicate heat mapping in urban suburban and peri-urban areas, as well as demonstrating levels of community interest and capacity to utilize data and recognise shade benefits.

Key words: *Urban Heat, Green Infrastructure, Urban Analytics.*

Introduction

Urban heat management is an increasing planning issue internationally and in Australian cities. The intersection of climate change, population ageing, public health concerns and urban design for active transport coalesce in this issue – focusing in initiatives aimed at urban greening. It is also evident that community perspectives of the value of urban shade, urban greening and the amelioration of urban heat are contested, and in flux in many places.

Planning for enhanced green infrastructure needs both evidence of benefits and high levels of community support. Mapping the heat, comfort and shade in cities and neighborhoods offers the capacity to consider issues of public investment, planning regulation and to engage with communities about green infrastructure.

This paper explores these issues through the case study of the Shadeways Project, conducted in Bendigo, Victoria during 2017-2019[1]. The project utilized remote sensing, street level data collection and community engagement to consider how to both increasingly operationalize shade and green infrastructure as a strategic issue locally and at the city-scale, and also how to offer communities a perspective on the value and utility of shade in daily life. This program is coupled with a broader policy agenda of addressing heat and shade in Bendigo from local government, Bureau of Meteorology and community organizations.

The paper concludes with a set of considerations to guide the way that data and its analysis perform in process of public decision-making about shade infrastructure, and the challenges presented by an increasing variety of open data sources, including that collected and collated by broad processes of public, digital interaction.

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Shade as Urban Infrastructure

Interest has emerged in policy and public discourse focusing on urban shade infrastructure in Australian cities during a period that includes, globally, the warmest decade on record. Concern about the direct, indirect and cumulative impacts of heat and sunlight on human health have become a critical policy concern at the local level in the design of parks and schools (Dobbinson et al., 2009; Buller et al., 2017). However clear and meaningful infrastructure solutions in the public realm are often less advanced, and subject to tensions with other objectives in urban spaces, relating to design, natural habitat and risk management, for example.

High temperature events create varied impact within communities, however, it is broadly recognized that urban residents form the frontline of this threat (Estrada, Botzen et al. 2017), particularly in larger cities where these impacts are clearly evident through the amplification effects of an urban heat 'island' and of urban air pollution on temperature (Moriarty and Honnery 2015). Consequently, urban planners are recognizing the imperative to increase adaptation strategies for excess urban heat (Inayatullah 2011). This includes the clear recognition of urban heat impacts in public health planning for Australian state and local governments (DHHS, 2018). High temperatures and unsuitable public realms also result in reduced outdoor recreation activities, with consequences for chronic diseases and broader public health outcomes (Kjellstrom, Butler et al. 2010). Additionally, and particularly in Australia, the increased risk of exposure to UV radiation from low-shade urban environments is considered to contribute to the rate of skin cancer (Tracey, et al. 2010; Lefevre, de Bruin et al. 2015).

Natural or built shading is the oldest and most evident solution to urban heat and comforts in the public realm (Moll 1989), however, Australian cities exhibit many unequal and poorly-suited shade solutions in public and private realms. Different populations (for example older aged cohorts) may need, and utilise, more urban shade compared to others – different groups perceive outdoor thermal comfort differently. The urban context matters too, surfaces, built form, and of course local climate. The challenges of provision then relates to context of community and place, often resulting in poorly suited solutions (Boumaraf & Tacherift 2012). It is also evident that in Australian cities the distribution of *green* and of *shade* infrastructure is spatially and socio-economically uneven. Communities experiencing disadvantage are known to have poorer shade (and green) infrastructure quality and quantity (Anderson et al., 2012) and these reflect the broader issues of spatial inequality in urban design outcomes.

To explore these outcomes in a specific setting, the Shadeways project was developed in 2018, supported by a Commonwealth Government *Smart Cities and Suburbs* grant with application in urban Bendigo and investment from industry partners (www.shadeways.net). The concept of a 'shadeway', has been in use in the City of Brisbane since 2006 (Lyndal Plant, personal communication, 2019) as a corridor (particularly a walking route) through the urban environment with a relatively higher amount of natural and built shading, providing increased thermal comfort. In the Brisbane example, the City of Brisbane assigned two goals for its shadeways including an increase in shade from 35% (in 2010) to 50% (by 2031) for footpaths and bikeways in residential areas, the promotion of resident satisfaction with shade cover on footpaths in their suburb (Brisbane City Council, 2017).

Our conception of an effective *Shadeway* is multifaceted feature meeting the needs and the expectation of different population and user groups. It includes urban greening and the maintenance and preservation of tall trees (>10 m height) and the valorization of heritage shade infrastructure such as verandas. It also considers urban morphology: while Australian cities do not have citadels with narrow roadwidths to guarantee shade for most hours of the day, the laneway comprises a niche and serendipitous solution.

At the same time from local to National levels, governments that commission studies are being encouraged to share data (for example, https://data.vic.gov.au). We contend that the focus of planning should be on the design of the mobile interfaces that are used by people to access this data as well as the design of spaces and cities. In the context of Shadeways such a design should be based on various criteria, including community preferences for mobility and seasonal comfort in active transport. This suggests a people-place-information triad is necessary to gather the data required for planning and for the provision of meaningful insights for decision-makers (Fisher, Landry et al. 2007). The aim of this article is to highlight the frontiers of a pilot study to use modern technologies (a GIS-cloud platform) and understand the community expectation and policy-making possibilities of the Shadeways concept.

The Bendigo *Shadeways* Project

Shadeways Project involved key three areas of activity:

1. The development of an urban heat/thermal comfort mapping program;
2. Support for an enhanced network of localized temperature sensors; and,
3. A process of testing and research on issues of shade and active transport with community members

The outcomes of the project are ongoing, but include:

- Testing and synthesizing a series of heat comfort maps utilising a variety of available datasets from satellite/remote sensing sources, local government datasets and sources drawn from ground level observation;
- A prototype route mapping tool aimed at enabling heat/thermal comfort considerations for user-designing walking and cycling routes;
- Preliminary testing of attitudes, awareness and preferences for shade and green infrastructure in the setting of this small regional city.

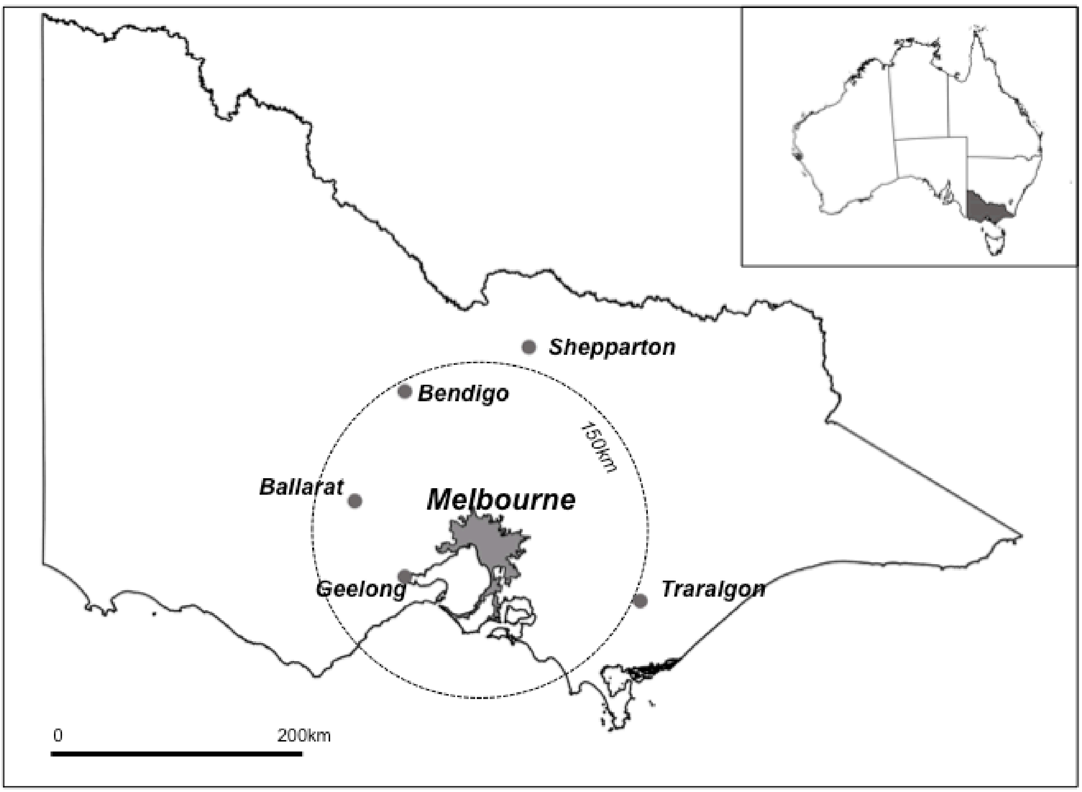
The context of the activity is significant. This relates not only the climate and community in a small, regional city, but also to the quality and availability of data, including GIS data, which is better than many small rural areas, but lacks the breadth and quality of many larger metropolitan areas. The process and contextual issues are outlined below.

The Context of Bendigo

Bendigo is a small to mid-sized Australian city with an urban population of just under 100,000 people (ABS, 2019). Bendigo is located 150 kilometres north west of metropolitan Melbourne and is experiencing population growth driven by various factors including metropolitan 'spill-over', regional (rural) population centralisation and broad economic restructure. Bendigo city features built heritage and urban landscapes drawn from a 19th century European imaginary that are superimposed onto a landscape of dry forest, intermittent waterways and abandoned gold mining sites. It has a relatively low rainfall (510 mm/year) and relatively high summer temperatures and a high annual proportion of clear, sunny days (BoM, 2019)

Despite a gold mining urban history, by the beginning of the 20th century gold became harder to extract, mining declined and the city stagnated. In 1901 the population was 39,400, declining until the 1950s. From the early 1970s the population began to grow due to industrial investment, the decentralisation of government functions and the establishment of higher education institutions.

Over the last twenty years population growth has been sustained, averaging over 1.5% per year, which is high in comparison to many urban areas, but it also exhibits an ageing population, and high levels of socio-economic disadvantage when compared to metropolitan Australia.



Map 1: Bendigo in the context of cities in Victoria, Australia

The urban morphology of the city is atypical for an Australian urban centre, and it is driven by three distinct patterns;

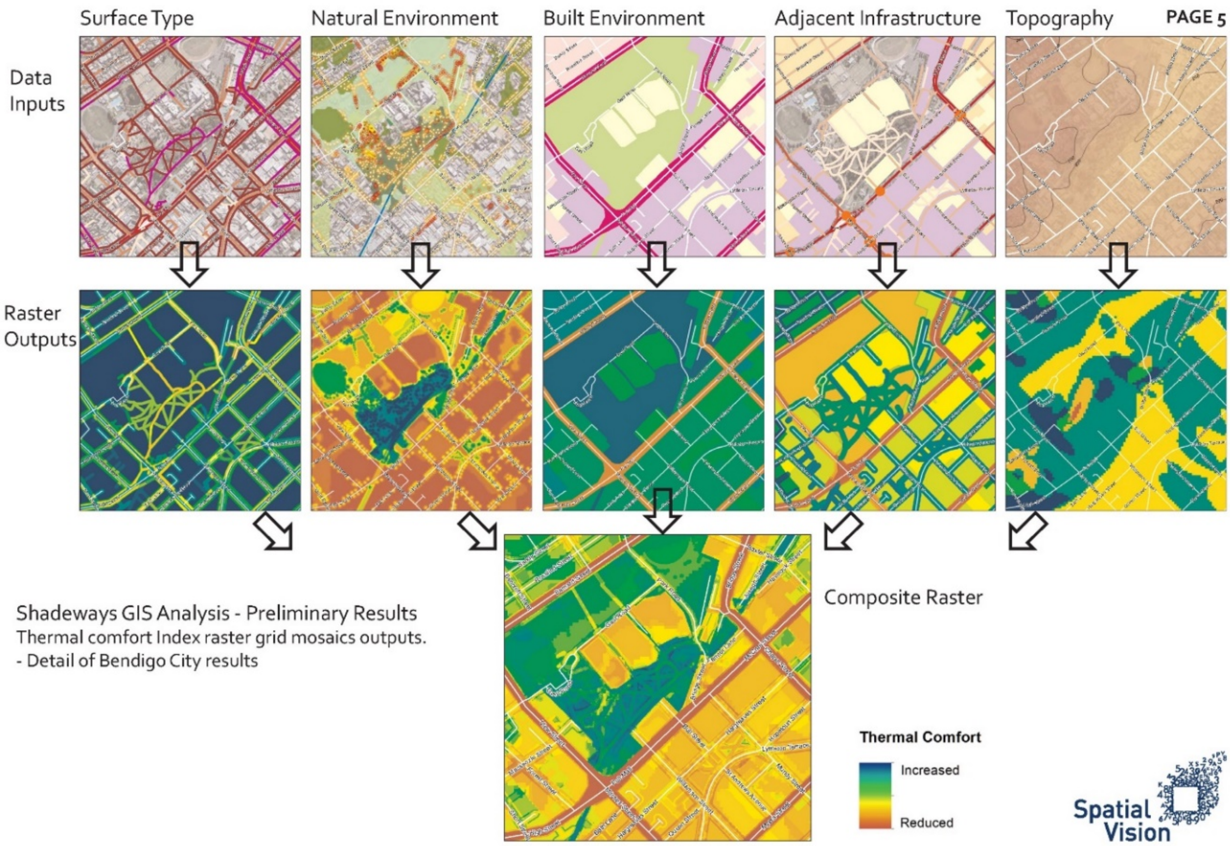
1. a formal, ordered Victorian era layout including wide, grid streets and formal urban plantings on streets and parks, in common with many Australian cities. The city centre also includes traditional areas of 'hard' shade in the form of verandahs, but only limited multi-storey development.
2. Beyond this a more scattered morphology following the gold mining activities and communities along the creeks and gullies which includes limited formal and structures streetscape planting, haphazard public open space provision and areas of unused (and often contaminated) former mining sites within the urban footprint that constrain development and are predominately in lower socio-economic suburban area
3. A car-based suburban form established since the mid 20th century which includes areas with and without formal pedestrian pathways and varied street planting including domestic and introduced species. Unlike metropolitan Australia, this suburban development includes many areas of informal road and pedestrian infrastructure, more consistent with peri-urban regions. The morphology of Bendigo is also substantially shaped by the forest (public land) that virtually encircles the urban area. In many places urban development is located hard up against extensive native vegetation and public land which serves as a recreational space. The city has a highly centralized employment pattern, low rates of active transport and few of the diseconomies of scale experienced in larger metropolitan regions that would typically lead to transport choices beyond the car. For many, reliance on active transport is challenging in summer months due to climate.

The distinctive social context and urban morphology of Bendigo matter in this project. An older population, a car-based transport preference and a sprawling, scattered urban form shape the experience of using the public realm. Similarly, the existing urban green infrastructure is subject to strong community opinions with the contest most typically framed between formal planting and indigenous vegetation and with urban planting and tree management often controversial (Jones, 2014).

Mapping Thermal Comfort – A Heat Vulnerability Index (HVI)

The explorative mapping process was an iterative activity which utilised several sources. Initial mapping utilised data available from the City of Greater Bendigo (CoGB) GIS dataset including road and footpath data to determine land use (especially road surfaces). This was combined with satellite imagery from Landsat and MODIS data to develop a Thermal Comfort Composite map which identified and scored areas of lower and higher relative heat and consequently scored heat comfort on the public road network in collaboration with the industry partner, Spatial Vision (see Figure 1).

Figure 1: Schematic of Data Inputs to the Thermal Comfort Index



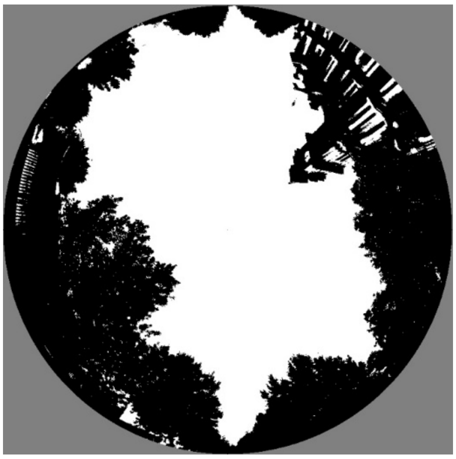
Temperature data derived from satellite thermal image are usually limited in spatial-temporal scales, for example, Landsat data is only available for morning surface temperature, while MODIS temperature data has low spatial resolution at 1000m but has available images at multiple times a day including morning and afternoon times. The resulting temperature dataset contains afternoon land surface temperature at 30m resolution (Figure 1). An assumed afternoon temperature was created using techniques adapted from previous studies (Hazaymeh & Hassan, 2015; Ping, Meng, & Su, 2018). This enabled the identification of likely 'hot' and 'cool' routes between key urban locations.

Figure 2. Calculating sky view factors along travel routes using Google Street View images

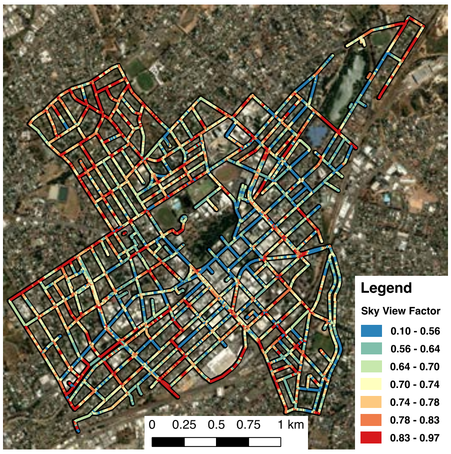
a. Example panorama image

b. Transformed fisheye image

c. Mean shifted image



d. Classified image

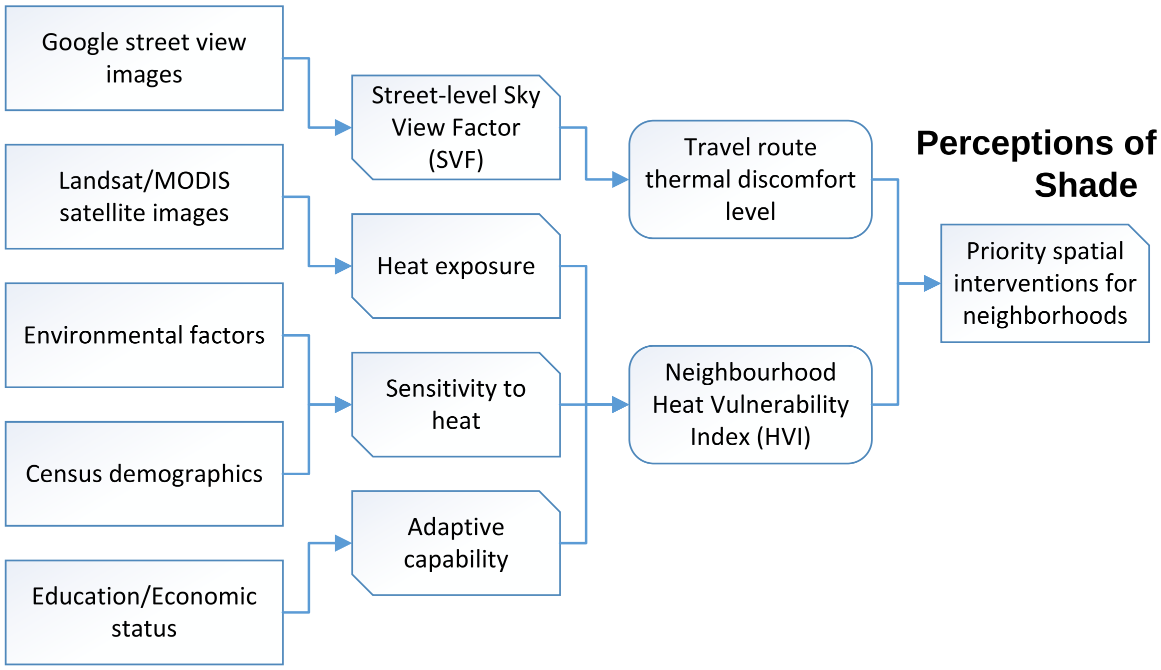


e. SVF map of Metropolitan Bendigo

The second stage involved creating a composite of these results with ABS Census data at meshblock level for indicators of socio-economic disadvantage and vulnerability – a Heat Vulnerability Index (HVI). This included measure of Heat Sensitivity (urban density, tree density) and Adaptive Capacity (prevalence of old and young people, levels of education and economic disadvantage). The purpose of this stage was to recognise the links between exposure, localised urban character and population type and also to establish those areas where improved shade was a critical issue for urban mobility.

Satellite data is unlikely to fully recognise the shade experience at street-level. Consequently a subsequent stage was undertaken to establish a 'sky view' factor. This utilised Google Street View imagery extracted at 10 metre intervals across the Bendigo street network. Once downloaded, the top half of each Street View panorama (Figure 2c) was transformed it into a 'fisheye' image (Figure 2.b), classified into 'shade' and 'sky' and the proportion of street-visible 'sky' calculated from a model proposed by Li et al. (2018).

Figure 3: ***Flowchart*** **of work program for HVI and Travel Route Mapping**



The Shadeways project involved two pilot activities seeking user input. Each was limited in scope, and intended to offer insight to approaches that have potential for application with a broader process of community research and aimed to:

1. understand likely pedestrian user perspectives and attitudes to concepts of urban shade and how this relates to habits in daily activities

2. test and 'ground truth' assumptions made about heat and comfort drawn from the various mapping processes undertaken as the core of the project

The form of engagement at this stage involved a series of focus groups and an activity using hand-held mobile devices in urban streets

The focus group process involved two stages:

1. Firstly a broad discussion of habits and perspectives on views and habits in relation to shade, walking and urban greening.

2. A second stage sought views on a series of prepared photographs of various intersections in Bendigo.

Focus Group - Discussions

Most participants showed habitual awareness of heat in daily (summer) activities. In each group, participants revealed regular behaviours that avoid hot weather, but also a desire to continue daily practices of walking, both for leisure/fitness and for daily activities (such as work or shopping).

I am conscious of the heat, particularly for gardening, like I'll put that off as an activity into the evening so… I garden a lot I feel like I'm always aware of the heat because I'm always thinking about it in relation to the plants

Walking the dog, you've got to do that early… before lunch

if there's an activity I want to go to whether it's work or something with my children, and it's too close not to walk…just have to walk, and just manage that in carrying water and hats and things

Conversely, participants also recognised the limits of coping through changes.

I like to walk, I, I prefer to park on the periphery and walk, but when it's hot, it… you've got to think all that through even clearer

I drive a bit too I must say, if it's a hot day, yeah, I just get in the car and drive

In relation to route choice, discussions were mixed. Some respondents described making clear choices to select routes, while others recognised limitations in this regard.

I've taken a few different like, side streets and bits that are like, off Google Maps, that I've just been able to kind of sus out on my way home, when I have a little bit of extra time to explore

…it's more comfortable isn't it, when you're cooler, so choose the shady routes. Unless you are running late

Sites such as a local reservoir were recognised for the comfort provided by shade

(The Reservoir) is attractive because you can run around and you're in shade most of the way around. Unless you do the boardwalk bit, but if you do the full circle there's very little sunshine

In relation to urban greening as shade infrastructure, responses were mixed. Participants typically understood the challenges and competing objectives of urban greening in the public realm. In this regard views were mixed about how urban street planting should be undertaken and managed. Discussion also involved question of native vs introduced species and their shade value.

that entry to Bendigo is so beautiful, years ago all the native gums down the middle… was just stunning

they provide an incredible amount of shade, [but], if we start doing more plantings for streets, you know so people can have shady areas, we're looking at a 20 year turnover

I love the bush tracks as well but they always, it's complicated because it's not, you see they're dryness in a way, so they, they always feel hotter

Discussion also involved consideration of the value of 'hard' versus 'green' infrastructure as a solution. Infrastructure variations (such as path surfaces) were also discussed

If you go to Mildura, it's shade, shade… all the car parks have them everywhere, Mildura's really onto it

you go out to Kangaroo Flat and all the parking in that area is all under shade

you look for that shade…shopping centres…you know that should be compulsory if they're going to build anymore of the damn things

we're now getting heat like Cairns used to get, and you go up there, and everything's under shade, and I'm talking about artificial shade - I don't care what the shade is… and that's the way it'll go

Some days you can handle the heat because the glare's not as strong

Focus Group - Route Preference

Participants were shown a selection of six (6) set of photographs taken in November 2018 at intersections in Bendigo (see examples below). The locations formed routes with options at various points and included an alignment along Bridge St and Lucan St, and a second route along Reservoir Rd and Harley St. Through the photo elicitation, respondents were asked to express a ranked preference for a route direction. The selection of sites was intended to offer examples of established deciduous plantings as well as native species, and older and newer streetscapes.

Outcomes of the route selection activity included:

- Preferences for older, established introduced species
- Preferences for green shading over 'hard' shade
- Recognition of ground surfaces, including perceptions of glare
- An understanding of the limited value of ornamental street planting (particularly *prunus* species)

From a methodological standpoint, the process of photo elicitation provided two outcomes:

- The concept of route choice and visualising aspects of preference has potential (with an increased dataset) to explore "machine reading" of features include shade, glare and shade quality (see also discussions on the use of Google Street View)
- Capacity for verification of the results of 'remote' thermal comfort mapping (aerial and street view). For example the perception of pedestrian experience in Lucan St (where shady footpaths are dominant) required recalibration of the thermal comfort mapping that was heavily influenced by the width of the asphalt road area.

Handheld Device Exercise

In February-March 2019 a pilot exercise in route selection and preferencing was undertaken using handheld mobile devices. Participants used a proprietary GIS software package (GISCloud). This was *not* a purpose built app as the exercise was designed to test the user experience of such an activity.

The users were asked to walk in the selected neighbourhoods on warm, sunny days and, when at intersections, photograph their preferred direction and answer a series of questions about why that route is preferred. Images and survey responses were geo-tagged and mapped.

From a methodological standpoint, the process of mobile review provided similar outcomes to the photo elicitation, albeit with an *in situ* activity:

- The concept of route choice and visualising
- Capacity for verification of the results of 'remote' thermal comfort mapping

The exercise also provided input to the route mapping app design.

Collectively, the participants recorded the data from 226 routes. Table 1 shows the descriptive statistics derived from the collected data. As shown in Table 3a, overall, 52.3% of the routes visited by participants suffered from either no or poor amount of shading. Also, 51% of respondents indicated that they would cycle or walk along a specific route if it has more shading. (The result implies the significance role of shadiness to promote physical activity among city residents. We also found that, overall, 44.2% of participants were not comfortable (disagree, somewhat disagree and strongly disagree) with the temperature of the visited routes. Moreover, the obtained results can provide a better picture about the traffic and directness of the visited routes. Collectively, 69% of the routes suffered from traffic fair, somewhat or heavy traffic. This study also applied cross-tabulation analysis to examine the traffic status of the routes and their related shadiness. This is key information for a stakeholder due to the fact that commuters may avoid specific routes despite having sufficient shadiness. This may have a negative impact on the rate of return of related infrastructures (e.g. sidewalks).

It was found that 53 of shaded areas (acceptable, good and excellent) located in the routes with somewhat and heavy traffic. This almost represents 24% of visited routes.

Table 1: Cross- tabulation results between shadiness and traffic of the routes.

		Assess the amount of shading					Total
		No shade	Poor shade	Acceptable shade	Good shade	Excellent shade	
Assess the amount of traffic	Heavy traffic	16	10	6	12	11	55
	Somewhat traffic	13	9	12	8	4	46
	Fair traffic	20	11	8	9	5	53
	Poor traffic	12	11	3	12	8	46
	No traffic	10	4	2	2	4	22
Total		71	45	31	43	32	222

Evidence, planning and mobilising community

In this project we present some preliminary results from the Shadeways project. While the results serve as a snapshot of the actions of a local government in the face of extreme heat, one of Australia's most significant urban challenges, we argue that the challenges we faced in this project are of wider significance for planning for green infrastructure and for shading in a changing climate. This includes the issues related to how local government and community engage in deliberations about strategy and costs in refitting urban areas for enhanced shade, as well as how these issues become visible in public discourse.

Data generated either through satellites and Google Street View (a tenuous and difficult to use data source, especially for replicable or publicly available uses) is not easily translated into meaningful information from a human point of view (Hoene at al. 2018). Our focus groups illustrate how subjective the sensations of heat are, and that although timely information may be desirable, it may not be possible to achieve this – even with the biggest data set.

In Bendigo the project relied on mixed sources of data, many of which are of varied quality, such as the footpath network GIS layer, and this needs work before a fully effective 'cool' route app can be developed. Other issues in this example relate to the particular nature of travel behaviours and drivers of change in a regional city, and the specific urban morphology of a post-mining landscape and streetscape However, this is a city seeking to innovate and increasingly move to a new era of open data and the use of a range of data sources to inform decision-making about public investment, while recognising the ongoing challenges of this task.

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