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Allowing Users to Benefit from Tree Shading: Using a Smartphone App to Allow Adaptive Route Planning during Extreme Heat

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Abstract: This paper presents the outcomes from a joint research project that aims to develop a smartphone application/online platform to model the most thermally comfortable active transport route to a planned destination using heat information and tree shading (Shadeway). Here, we provide a summary of our systematic review of academic literature and applications from the Google Play and Apple App Store, to identify current knowledge about personal adaptation strategies when navigating travel in cities during high temperatures. The review identifies that there is a lack of attention regarding the use of smartphone applications to address urban thermal comfort for active transport by government and private industry. We then present the initial results of original research from three community focus groups and an online survey that elicited participants' opinions about Shadeways in the City of Greater Bendigo (CoGB), Australia. The results clearly show the need for better management of Shadeways in CoGB. For example, 52.3% of the routes traveled by participants suffer from either no or poor levels of shading, and 53 of the shaded areas were located along routes that also experience heavy traffic, which can have an adverse effect on perceptions and actual safety. It is expected that this study will contribute to improve understanding of the methods used to identify adaptation strategies to increasingly extreme temperatures.

Keywords: urban heat; Shadeway; tree shading; build shading; smartphone apps; route mapping; thermal comfort

1. Introduction

As the world endures the warmest decade on record, there is widespread concern about the direct, indirect, and cumulative effect of high temperature on human physical health and even mental health. High temperature reduces opportunities for outdoor recreational activities, which may contribute to an increase in chronic diseases [1]. Excessive temperature may also contribute to a greater risk of exposure to ultraviolet (UV) radiation and thereby raise the incidence rate of skin cancer [2]. Moreover, a review of 35 articles showed that excess heat may contribute to a wide range of mental health issues such as bipolar disorder, dementia and depression [3].

It is recognized that urban residents, and especially those who walk or cycle for transport, constitute a growing population under this threat [4] as the proportion of global urban dwellers increases [5].

City dwellers experience higher temperatures compared to non-urban residents due to the amplification effect of the urban heat island and air pollution on air temperature [6,7]. In Australia, major cities accommodate 71% of the population which has led to a greater number of people experiencing heat exposure (stress) in comparison to other countries [8]. In Australia, heatwaves account for more deaths than other natural disasters [9]. Moreover, the Australian Medical Association has named heat as a "silent killer" [9]. As a result, Australian cities have started various measures to enhance adaptation to excess heat [10]. Among such measures, urban planners and policy makers have focused on traditional strategies such as natural (e.g., urban trees) or built shading (e.g., eaves, awnings, pergolas and louvres) to overcoming localised heat [11].

In this paper, we consider the concept of 'Shadeways', which was introduced in Australia by the City of Brisbane in 2006 [12,13]. Shadeways are sidewalks or pathways through the city that have a relatively higher amount of natural and built (artificial) shading that provide thermal comfort for active travelers. The City of Brisbane originally developed shadeways as a metric, i.e., the ratio of shaded to unshaded streets. However, in our project, we expand the notion of Shadeways so it can be applied as a multifaceted feature of the urban environment. This is essential because Shadeways affect a variety of stakeholders, each with different views about the required location, type and quality of shade, as well as other considerations e.g., sightlines and safety for both pathway and road users at crossing points and other interfaces.

To respond to diverse needs and preferences within the smart city concept, we integrated information and communication technology (ICT) to provide a digital platform to: (1) assist people to navigate to their destinations based on the desired shade as per their identified criteria; and (2) help pedestrians and cyclists communicate their assessments of Shadeways attributes by updating information daily on platforms that can be shared with each other and stakeholders. A review of available digital platforms shows that our approach is valuable, as previous efforts have widely focused on transportation efficiency and security [14–16]. For example, public transport smart cards simplify travelling for users, while behind-the-scenes, the cards provide valuable data for route planning. Ride-sharing applications (apps) also have transformed urban movement patterns [17]. Yet, there is great scope to extend the use of these technologies; specifically, there is very little evidence showing that cities are using such practices to improve the efficient use of Shadeways, which can eventually lead to increased adaptation to excess heat in urban areas.

Moreover, obviously, in the new normal (Covid-19 situation) the role of smart technologies for managing Shadeways is more important than ever. The vast majority of the world's population do not have access to outdoor/public exercise equipment or gyms, and those that do might be concerned about using these facilities due to this unprecedented situation. Concern about facilities has been associated with public transport. As a result, walking and cycling will be a strong option for daily exercise and travel. Accordingly, relevant apps and platforms could make these activities easier and more comfortable. Moreover, the Covid-19 global financial crisis might provide opportunities for design projects that support urban resilience or greening as part of an economic recovery program, or restrict new initiatives dues to budgetary constraints, which emphasises the need to make optimal use of existing infrastructure.

Given the above background, the objective of this article is twofold. The first objective is to provide a review of digital platforms (apps or websites) that improve the accessibility of urban residents to shaded routes or places (Shadeways). In particular, we focus on smartphone apps or platforms (webpages) that help pedestrians and cyclists navigate to shaded routes for active travel. We address this objective by conducting a systematic review of articles and the apps in Google Play and App store. Subsequently, this article presents the results obtained from exploring the shading condition of routes with the help of volunteers in the City of Greater Bendigo (CoGB), Australia, as the case study. This project is a work in progress to develop a platform for pedestrians and cyclists of Bendigo to navigate shaded transport routes. We believe that our approach to collecting, monitoring and measuring shading can underpin evidence-informed Shadeway implementation. Overall, these activities will lead to a people-place-information triad for gathering relevant data and providing meaningful insights for decision-makers [18].

This article consists of five main sections. The following section presents the different classification of Shadeways. Subsequently, apps using existing technologies, within Google Play Store and Apple App Store, related to route mapping and adapting to excess heat apps were identified and reviewed, followed by the results of a systematic review of peer-review journals and conference articles is then provided. The article then presents the results obtained from exploring Shadeways by the help of volunteers in the City of Greater Bendigo, Australia, as the case study. The last section will provide the conclusions of this study.

2. Classification of Shadeways

For this study, we define Shadeways as sidewalks or pathways, within public spaces of cities, that have relatively higher levels of natural or built (artificial) shading which provides greater thermal comfort for pedestrians and cyclists in comparison to its surrounding areas. Natural Shadeways can be implemented by planting urban trees at a density that provides consistent cover. This type of shading is widely available in suburban or low-density zones of cities due to the availability of space for tree planting. It is documented that areas shaded by trees can be cooler than non-shaded areas by 0.1 °C–5.6 °C, taking into account specific climatic and environmental factors of particular regions [19]. Built Shadeways, on the other hand, are provided through the street canopy, including buildings or roofs on both sides of pedestrian routes [20]. This is broadly available in the commercial parts of cities, particularly central business districts (CBD), often influenced by historical development trends and the challenges of developing natural shading. It is noteworthy that, Shadeways also can be created through an amalgam of street and tree canopies. Figure 1 shows images of different categories of Shadeways.

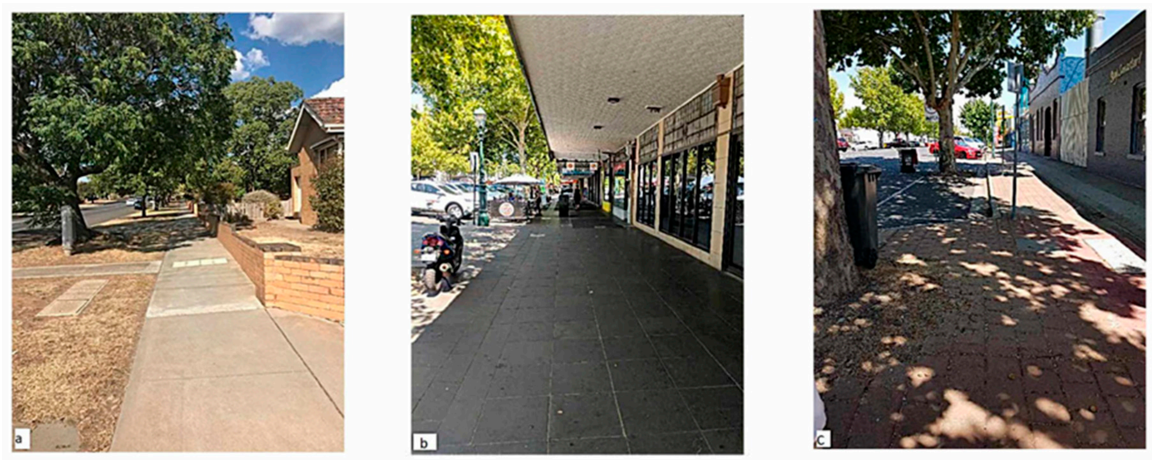

Figure 1. Images of natural (**a**), built (**b**) and amalgam Shadeways (**c**).

3. Systematic Review of Smartphone Apps and Scholarly Literature

This study applied a systematic approach to identify smartphone apps that contribute to navigation and use of shaded routes or specific routes based on thermal comfort by pedestrians and cyclists, and locate relevant scholarly literature that reported on related research projects. Accordingly, we searched: (1) the dominant stores for smartphone apps including Google Play Store (Android smartphone platform) and Apple App Store (iOS smartphone platform); and (2) scholarly electronic databases including, Scopus, Web of Science, Wiley online library, directory of open access journals (DOAJ), ScienceDirect as well as through newspaper articles and patents. Figure 2 illustrates the systematic approach to find suitable literature and apps for this study.

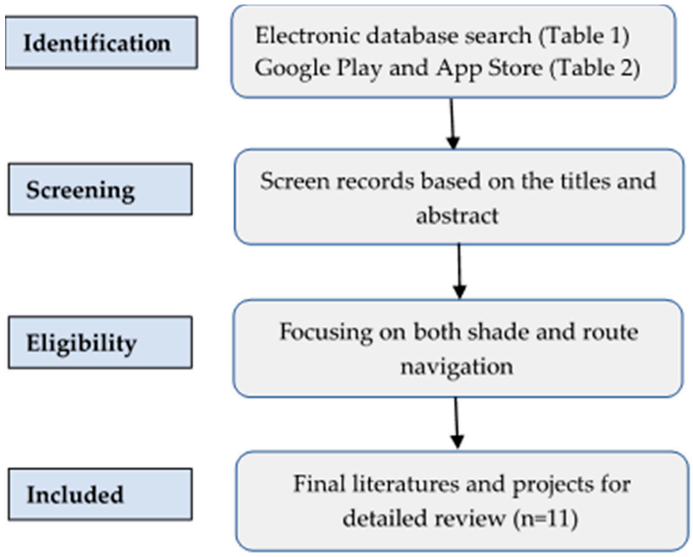

Figure 2. The steps adopted in the systematic review process.

Designing an efficient search strategy to find suitable apps was challenging because Google Play and App Stores only facilitated browsing of applications using single terminology or existing classifications, rather than enabling multiple terminologies and logical operations (such as AND or OR). We thus extended this search by using Google Search Engine to find other relevant apps or relevant projects. As a benefit, this broader approach also allows researchers to find potential apps that are only available in specific regions [21]. Table 1 shows the criteria used to find the relevant smartphone apps.

Table 1. Criteria used to search Google Play Store and App Store.

Key words used to find the apps in Google Play and App Store	1. "walkability" 2. "walking route planner" 3. "walking route tracker" 4. "Pedestrian"
Apps categories	Health and Fitness; Get Outside; Weather; Maps and Navigation; Travel
Browsing time	1 April 2019–1 July 2020

The U.S Department of Labor represents the earliest effort (August 2011) at developing a smartphone app about heat thermal comfort [22]. This app targets workers, and its purpose is to determine necessary protective measures using the risk level of the heat index. The app also provides users with precautionary and safety measures such as advice for drinking fluids, taking rest breaks and adjusting work operations. Although this app focuses on thermal comfort, it is not a navigation app for travelling based on thermal comfort. We also could not find any further reporting about the possible outcomes of this project.

The "Parasol Navigation" platform in Boston enables users to distinguish between sunny and shady routes [23]. This platform only covers a relatively small region between Charles River Esplanade and South Station in Boston (about 1.5 miles/2.5 km). However, we were unable to access the final version of this platform, which was developed based on the high-resolution elevation model. This technology allows the platform developer to simulate sun/shade using the position of the sun for a given date and time to illuminate the elevation grid. This project also used Dijkstra's algorithm to compute the shortest path given this custom cost (sun and shade).

Our browsing also revealed two additional apps on Google Play and Apple App Store. The first app, "Walkonomics Navigation and Maps" is only available on the Google Play Store and a selection of specific cities. It provides a rating for routes based on various criteria such as safety, illness, beauty and rate of crime. App development is still in early stages. The second app, "Walkspan", is only available for iOS phones within Manhattan, New York. This app has a very similar function to the Walkonomics, and is also in early stages of development. Neither of these apps have features to allow pedestrians and cyclists to find routes based on thermal comfort. It is noteworthy that Google Play Store and Apple App Store have many weather apps that provide various weather observations. These apps however are not able to guide commuters to specific routes based on their desired temperature. The review shows that thermal comfort measurement has not been popularized and well valued.

Google browsing revealed a digital platform that helps residents of Paris to navigate to cool spots (islands) within the urban fabric. The digital platform provides a thematic map of parks in Paris based on the amount of shade in each one, as well as the location of key cooling infrastructures, such as misters and water fountains [24].

Locating scholarly literature was equally difficult. There were a multiplicity of words, phrases and terminology used within and between academic disciplines. Based on the initial search, we screened the articles' abstracts to check whether the publications provided the details of smartphone apps related to the thermal comfort of urban residents. The screening revealed only nine articles that reported on projects that fit the search criteria, which we selected for detailed review. Table 2 presents the criteria used to find the relevant academic literature.

Table 2. Criteria used to select publications for review in this research.

Combination of keywords used to find publications for review	1. "smartphone apps" AND "pedestrian" 2. "smartphone apps" AND "shadow" 3. "smartphone apps AND thermal comfort" 4. "smart technology AND thermal comforts" 5. "smartphone apps" AND walkability" 6. "smart technology AND walkability" 7. "smart technology AND "pedestrian"
Document type Peer-review status	Journal articles, conference proceedings, book chapters Only peer-reviewed documents
Language Publication date range	English 2007–April 2019

In one of the scholarly papers, Bandini, et al. [25] present the details of the "LONGEVICITY" project initiated in Milan, Italy. The aim of the project is to decrease the social exclusion of elderly people by enhancing their walkability in urban areas. The project is based on the "General Theory of Walkabality" [26] and related indicators: (a) the presence of services within a walkable distance; (b) level of comfort and safety experienced by people while walking; (c) attractiveness of the urban areas, in terms of architectural design and social context. However, the article did not specify whether "level of comfort" includes thermal comfort.

In contrast to previous projects and research articles, Monreal, et al. [27] focused on shading as a route quality parameter for pedestrians. They developed a smartphone app based on the Android Platform and Open Street Map (OSM) data. This app estimates the amount of shading along the routes using a combination of the direction of the sidewalk, sun position and tree density. However, we were not able to find the final version of this smartphone app on the Google Play Store. Likewise, Novack, et al. [28] proposed a framework based on the OSM data to incorporate greenness, sociability, and quietness in a customized routing mapping system. This system allows users to find a route through the desired level of greenness, sociability, and quietness. A similar effort also was conducted by White, et al. [29] and White and Langenheim [30] who introduced "PedCatch", an animated pedestrian catchment modelling tool. This tool is an agent-based catchment analysis model that combines data about the business of roads or intersections, with high-quality 3D proxy-object tree modelling and flexible 3D precinct modelling. An initial version of this tool is available on a WebGIS platform at http://pedcatch.com/. Finally, Oliveira Júnior, et al. [31] presented Aurora, a smartphone app based on the Android platform. Users can manually insert thermal comfort data into the app while such data are used to create maps of spatial variability of thermal comfort indices. This app adopts inverse distance weighted (IDW) techniques to interpolate thermal comfort data for creating thermal comfort indices maps. A version (1.0.1) of this app is available on Google Play. Table 3 details the specifications of the literature and apps selected for review.

Table 3. Specifications of literature and apps selected for detailed review.

Source or Location	Digital Platform	Function	Reference
U.S Department of Labor	Smartphone app	Assisting workers to determine necessary protective measures in relation to temperature. Targeting workers and its purpose was to determine necessary protective measures using the	[22]
LONGEVICITY, Milan, Italy	Webpage	Decreasing the social exclusion of elderly people by enhancing their walkability in urban areas.	[25]
Paris	Webpage	Providing a thematic map of parks in Paris based on the amount of shade	[24]
Vienna, Austria	Smartphone app (Android)	Identifying route quality by focusing on shade available for pedestrians.	[27]
Germany	Webpage	Incorporating greenness, sociability, and quietness in a customized routing mapping system.	[28]
PedCatch	Webpage	Combining data about busy roads with proxy-object tree modelling in an agent-based catchment analysis model. An agent-based catchment analysis model that combines data about busy roads with proxy-object tree modelling	[29,30]
Parasol Navigation, Boston	Webpage	Allowing users to distinguish between sunny and shady routes	[23]
Aurora	Smartphone app (Android)	Providing maps of spatial variability of thermal comfort indices	[31]
Walkonomics Navigation and Maps	Smartphone app (Android)	Providing a rating for routes based on various criteria	Google Play Store
Walkspan	Smartphone app (Apple)	Providing a rating for routes based on various criteria	App Store

4. Future Shadeways

4.1. Concept of Our Project

As part of our digital platform development, we integrate active travel networks with environmental data to communicate possible routes—essentially, a digitally enabled Shadeway. The prototype we report on below, and the resultant digital platform will provide a multimodal navigation environment involving temperature, existing road network, green space and tree Shadeways. As the prototype shows, temperature and tree shade variables act as facilitating or impeding measures for active travel navigation and route planning. It models the most thermally comfortable route to a planned destination on the road network that meets the needs of different groups of travelers.

The digital platform has the potential to be integrated into popular mobile mapping and navigation systems to allow users to add of hotspot information to existing digital platforms and behaviors. It also allows governments and their agencies to communicate the benefits of urban greening and to promote safe active transport, as well as directing users to urban environments that exhibit desirable qualities such as shade and greening. Consequently, the outcomes are not only based on individual trips and data accumulated over many people and over time, but also have the potential to generate policy and planning approaches that integrates user feedback and further develop community advocacy for urban greening initiatives.

4.2. Study Area

This project was conducted within the regional city of Bendigo, Victoria, Australia in March 2019 (Figure 3). According to the Koppen–Geiger classification, CoGB is a Cfb type, which refers to a temperate climate, with wet cool winters and hot dry summers (there are regularly days above 35 degrees Celsius) [32]. In 2018, Bendigo accommodated a population of 116,045 [33]. It is a progressive city with a diversified manufacturing base, growing health industry and precinct, and other service sectors. The local government council has a strong set of policies that support digital futures in the face of climate change. Planning, budgeting and implementation are already underway for creating more sustainable development. However, this is a slow process. Significantly, the council has strong partnerships with four universities, working with each on different projects to ensure a strong and current evidence base for future policy development and identification of priority actions.

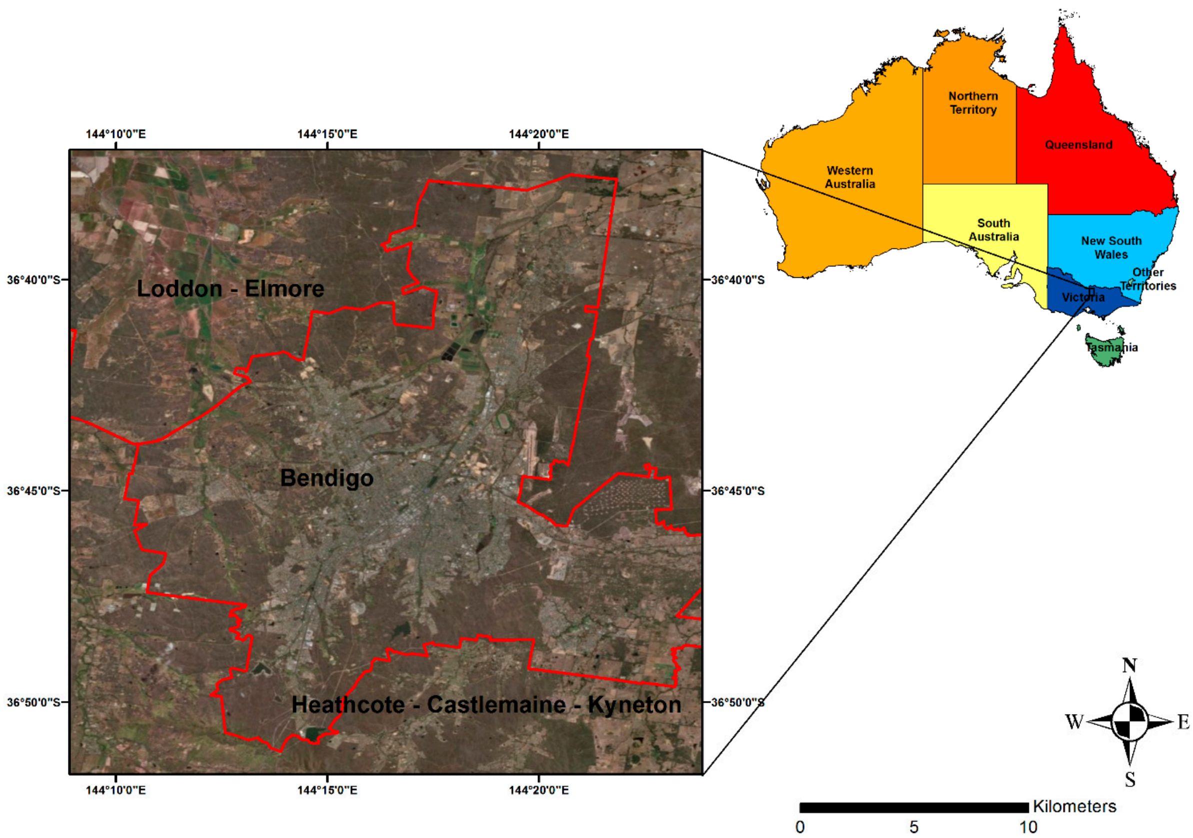

Figure 3. Location of Bendigo in Australia.

Table 4 provides a breakdown of the age cohort in 20 year increments [33]. The average age is 42. Children and young people aged 0–14 comprise 18.5% of the population and those aged 65 and over comprise 19.2% which, together, accounts for substantial cohort of the population who are generally more susceptible to heat, and potentially more reliant on alternative and active transport. Together, the character of the city, its policy focus and its climate, makes an ideal case study site for this project.

Table 4. The breakdown of the population of City of Greater Bendigo.

Age	Number	%
0–19 Years	37,678	24.61
20–39 Years	35,004	22.86
40–59 Years	40,760	26.62
60–79 Years	32,074	20.95
80+	7591	4.96
Total	153,107	100.00

4.3. Understanding Shading from a Citizen User Perspective

Our project initially involved two pilot activities that sought user input. These were limited in scope but offer insight into potential approaches at a larger scale. The first pilot activity included three community focus groups conducted in December 2018. One was undertaken with an existing community walking group, comprising older-aged participants, during a regular walking activity at Kennington Reservoir, which is located 3 km south-east of the Bendigo central business district. This is a popular place for bushwalking, fishing and having a picnic. A second was undertaken at La Trobe University (3 km south-west of the city centre), with a mixed audience of (generally active) walkers and cyclists drawn from the community via a broad invitation to local groups interested in walking, cycling and urban greening A third group of mostly older participants was held at Elmore Community Health (a small town north of Bendigo city). The aim of this participant selection was to draw views of a range of user types but to particularly focus on those who may be considered most vulnerable to urban heat in their daily activities

The second activity involved a limited user group undertaking site-based testing of the concept of route selection; tests were conducted at various intersections in central Bendigo during February/March 2019. The testing group invited participants, including CoGB staff, La Trobe University students and interested community members; due to software licensing limitations it was not opened to a broader audience. The participants used a proprietary geographic information system (GIS) software (GISCloud) with a mobile questionnaire to text their experiences while at specific locations. On specific warm sunny days, the users were asked to walk in their neighbourhoods and, when at intersections, select and photograph a preferred direction and answer a series of questions about their choice. Questions were asked to help the team understand how users adapt to heat in the city and especially how this affects their routing. These questions were designed to understand how to improve the digital platform. Responses were geo-tagged and mapped.

A total of 17 people recorded the temperature, shadiness, directness and traffic along their daily walking routes based on the Likert scale questionnaire. The questions included: (1) Are you comfortable with the temperature at this location with regard to the shading? (2) If this route was more shaded would you cycle or walk along it more often? (3) Please assess the traffic on the route; (4) Please assess the directness of the route; and (5) Please assess the shadiness of the route. We also asked the participants to capture an image of their desired route and upload it to the platform. Questions were selected based on the outcomes from the focus discussions held in the first pilot, especially those answers relating to discretionary travel such as taking side streets. The survey was designed to further explore these choices by asking respondents how their route choice in such a scenario could depend on the shading in a street.

4.4. Results and Discussion

4.4.1. Focus Groups

Most participants showed habitual awareness of heat in their daily (summer) activities. Most participants revealed that they already practice behaviours that avoid hot weather, but that they continue daily practices of walking, for recreation and daily activities (such as work or shopping). For example:

> *"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, 9."*

> *"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, some participants identified the limits to this:

> *"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, opinions were mixed. While some respondents described making clear choices others saw limitations presented by the urban environment.

> *"Sites such as Kennington Reservoir were recognised for the comfort provided by shade (Kennington Res) 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."*

> *"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".*

In relation to urban greening as shade infrastructure, responses were mixed. Participants typically understood the challenges and competing objectives for urban greening in the public realm. In this regard views were mixed about how urban street planting should be undertaken and managed.

> *"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 either or their dryness in a way, so they, they always feel hotter."*

The relative value of 'hard' shade infrastructure (verandahs) versus urban planting, along with the impacts of other variations in the public realm (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."*

> *"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."*

A deeper understanding of participants' opinions was achieved by conducting a "word frequency query" and "text search query" on the collected opinions. These are useful results to identify the dominant concept and themes. Figure 4 shows the results of the word cloud (the most 50 frequent words) and tree cloud. As shown, "shade", "heat" and "walk" were the main focus of the participants' opinions. This study also conducted two "word tree" analyses based on the words "heat" and "shade".

The results again confirm the significance of the shade to allow people to continue their daily life despite the hot weather.

Figure 4. Word cloud and word tree visualization derived from the participants' opinions.

In general, the implications of this qualitative data gathering alerted us to the following ideas. 1. Certain walking and active travel options are non-discretionary and are strongly dependent on daily habits. For example, walking the dog or exercising. To enable these movements, users will currently change their schedules. The ability for users to select the time for their activity based on app information gives them greater flexibility to plan their movement so it is more comfortable, and is a promotional feature of the app. 2. Helping individuals to shift mode of transport away from the car is difficult, complex and determined by a range of factors [34], and it is also beyond the scope of this project. 3. Aesthetics and perceptions of heat are critically important in deciding on active travel. It is possible to map the amounts of shade and even whether shade is derived from native or deciduous trees. Shade under these trees will be different, i.e., more or less dappled and users are sensitive to this.

4.4.2. Results from the Handheld Device

To further test the implications of point (3), we designed a mobile survey to further explore and identify some of the factors that might affect users' choice of route once they decided to walk. We also wanted to examine whether a digital feedback tool could be used as part of the app. Collectively, the participants surveyed 226 pathways. This study then conducted descriptive and cross-tabulation analysis on the collected survey to identify statistically significant relationships. Table 5 (a–d) illustrate the results of descriptive statistics. In general, Table 5 (a) indicates that CoGB's level of shading is moderately acceptable. Respondents reported 46.9% of the pathways provide acceptable, good and excellent level of shading. In contrast, 52.3% of pathways suffered from no or a poor level of shading.

Table 5. Descriptive statistics derived from geographic information system (GIS) platform.

(a) Assessment of Shadiness of the Route		**Frequency**	**Percent**
Responses	No shade	72	31.9
	Poor shade	46	20.4
	Acceptable shade	31	13.7
	Good shade	43	19.0
	Excellent shade	32	14.2
	Missing	2	0.9
	Total	226	100.0
(b) If this Route was More Shaded would You Cycle or Walk along it More Often		**Frequency**	**Percent**
Responses	No Answer	86	38.1
	No	24	10.6
	Yes	116	51.3
	Total	226	100.0
(c) Am I Comfortable with the Temperature at This Location?		**Frequency**	**Percent**
Responses	Strongly disagree	45	19.9
	Somewhat disagree	26	11.5
	Disagree	29	12.8
	Neither agree nor disagree	11	4.9
	Agree	45	19.9
	Somewhat agree	54	23.9
	Strongly agree	16	7.1
	Total	226	100
(d) Assessment the Traffic of the Route		**Frequency**	**Percent**
Responses	Heavy traffic	56	24.8
	Somewhat traffic	46	20.4
	Fair traffic	54	23.9
	Poor traffic	46	20.4
	No traffic	22	9.7
	Missing	2	0.9
	Total	226	100.0

As shown in Table 5 (b), 51% of respondents would walk or cycle along a specific route, if that route had greater levels of shading. This result confirms the findings of past studies about the importance of shade to promote an active mode of transport (e.g., walking and cycling) among urban residents. For example, Lusk, et al. [35] conducted a survey in Boston, U.S. about the impact of tree shading on thermal comfort and cooling of cyclists (number of participants = 836; 49.3% of the participants were cyclists). The results clearly showed that cyclists feel cooler once they use routes with tree shade. A similar result also was reported by Klemm, et al. [36] in the Netherlands.

Our study also found 44% of respondents were not comfortable with the temperature of the visited pathways (Table 5 (c)). Finally, Table 5 (d) revealed a significant amount of traffic across or along visited pathways. In total, participants reported that 69% of visited pathways were located in areas with fair, somewhat, or heavy traffic. This result allowed the project to conduct a cross-tabulation analysis between the level of shading and the related amount of traffic in the visited pathways (Figure 5). This shows that routes chosen by our participants, which are shady, are also used by cars. The reason for this is space. The major routes tend to be wide enough to accommodate heavy traffic while also allowing for trees to be planted. Moreover, it was found that a total of 53 pathways (that provide acceptable, good and excellent shade) are located along the streets/roads assessed as having somewhat heavy traffic. This could be useful information for urban planners and policy-makers. Pedestrians and cyclists might avoid shady routes if there is a high level of traffic, thus indicating a need to identify and potentially plan for greater shade on less busy transport routes.

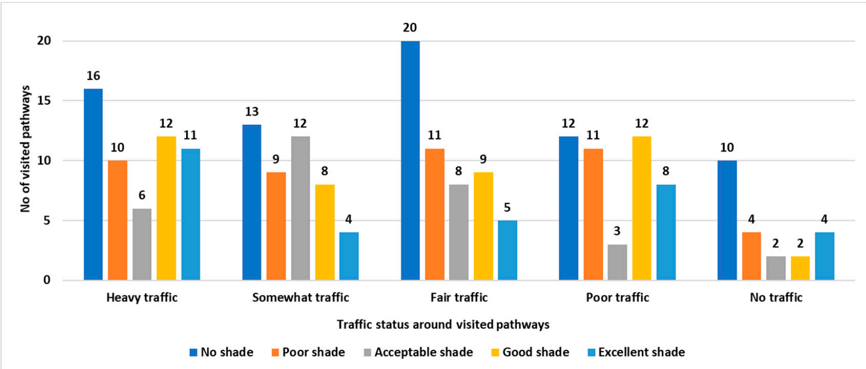

Figure 5. Cross-tabulation shows the relationship between shadiness and traffic of visited pathways.

Figure 6 shows an example of the images that volunteers captured from the routes, which illustrates the level of shade at particular points in the city. The images were geotagged to be used for processing in further stages of the project.

Figure 6. Images captured by the volunteers from the visited routes.

5. Conclusions

The world is bracing for hotter days on record and it is documented that urban dwellers could suffer heat more than their rural peers. As a result, cities have started significant efforts to promote and implement strategies of resilience and adaptability. Among these efforts, enhancing the use of existing cool spots (islands) in cities has gained significant attention from researchers and practitioners.

To achieve this purpose, smartphone apps can offer unique capabilities. Indeed, our app specifies pathways through the city that have a relatively higher amount of natural and built (artificial) shading that provide thermal comfort for commuters.

However, our study showed a significant lack of attention to the use of these technologies in enhancing the use of Shadeways. The systematic review of the apps on Google Play and App Store, and the literature review revealed only 11 projects. We focused on the projects, smartphone apps, or online platforms that can navigate pedestrians or bicycle riders to travel through Shadeways from the origin to the destination. Unfortunately, we also found that none of the projects were developed further or had been halted.

While we used all the possible strategies to find the target apps or platforms, it is likely that we have overlooked projects. We believe this limitation could be more obvious in the case of browsing apps in Google Play and App Store. This mostly stems from this issue that there is not enough information about the functionality of the apps on their webpages. Despite these limitations, our study clearly showed the lack of attention to develop apps or platforms for managing Shadeways.

This is despite the positive impact of these apps or platforms for enhancing the mental and physical health of the community. Obviously, this is critical in the new normal life (Covid-19 situation) in which active transport becomes an increasingly important alternative to private transport, especially if people are wary of public transport. Moreover, with the forecast of the financial crisis across the globe, it could be expected that many people might seek to reduce their transport costs at the same time that urban resilience or design projects could be halted due to strict budgets or extended to boost the economy. In the current conditions, these apps or platforms can facilitate optimal use of existing shaded areas or help to identify areas for future works.

In this article, we introduced a project within the City of Greater Bendigo that aims to develop a platform or mobile apps that allow residents to travel through urban Shadeways. As the initial steps to conduct this project, we held three community focus groups and conducted an online survey to collect residents' opinions about Shadeways in their cities. The findings revealed how different technologies of surveying and mapping could perform to improve the condition of Shadeways in CoGB, and to improve the responsiveness and relevance of digital solutions.

In this era of enlightened transparency, there is an assumption of a citizenry of tech-able and interested/engaged people with access to data, but also the capacity (and willingness) to contribute useful spatial data. This project demonstrates that, as tantalising as new technologies might be for shaping urban environments and our understanding of them, the complexity of data choices, the paucity of reliable, decontextualized information, and varied community perception often make such projects more, rather than less, complex. Drawing out decisions still relies on notions of welfare and political judgments of capacity.

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