WHY ARE PEOPLE *STILL* NOT WALKING? THE NEED FOR A MICRO-SCALED MULTI-CRITERIA SPATIO-TEMPORAL DESIGN APPROACH TO IMPROVE WALK-QUALITY

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ABSTRACT:

Walking is essential for the health and well-being of communities as well as meeting environmental challenges of the 21st Century. There have been significant research contributions in recent decades to understanding factors that can influence the likelihood of citizens choosing active travel modes, with great advances in understanding the built environment, particularly macro-scaled urban factors such as land-use mix, population density, and street patterns. So why are people *still* not walking? And is there anything we can do to try to change this? To answer these questions, this paper explores walking environment assessment approaches using a trans-disciplinary narrative approach, touching on multiple critical disciplinary knowledge areas. We find that while much of the research into the built environment's influence on walking has made positive contributions in helping identify areas of cities that discourage active travel, the capacity to improve these areas has been limited. While macro-scaled factors commonly considered in 'walkability' analysis are highly influential to mode choice, unless working on green-field development, these factors may require re-zoning private land, substantial demolition and renewal, and may be financially or politically infeasible and thus extremely difficult to change. There is a need to augment macro-scaled analysis with micro-scaled tools, and to establish multi-criterion spatio-temporal design decision support approaches drawing from emerging technologies to make informed, integrated and effective urban design changes. These methods applied at precinct and streetscape levels have the potential to make feasible improvements to the 'walk-quality' of the built environment and contribute to facilitating active travel.

1 INTRODUCTION

1.1 Declining active commuting: A public health challenge affecting Australians and costing $billions

As Australian cities evolve and grow, it is important to provide inclusive, comfortable walking access to public transport, shops, healthy food, parks and recreation facilities (Thomson et al., 2017). Designing better walking environments with proximity (pedestrian accessibility) to key destinations has social equity benefits for older adults, women and children. Better walking environments promote autonomous mobility for older people and members of the disability community, greatly improving their independence, mental health and well-being (Rosso et al., 2011). Active transport use has multiple benefits for both individuals and the populace. At the individual level, the selection of active transport contributes to daily physical activity and helps individuals reach recommended physical activity targets. The health benefits of reaching these targets are substantial, including reducing cardiovascular disease, reducing obesity risk, and reductions in mental health issues (Giles-Corti et al., 2011). At a populace level, these health issues represent substantial costs. For example, physical inactivity is a grossly under-rated risk factor for heart disease which is estimated to cost the Nation's health budget several billion dollars annually (Shilton, 2016; Tolley, 2011). In addition, traffic congestion in Australian cities is also estimated to cost over $16bn through lost productivity (Shilton, 2016). Despite these benefits, over 50% of short trips under 1km in Australian suburbs, are by car (Charting Transport, 2014).
There is a clear and urgent need to shift citizen transport mode choice from both health and economic perspectives.
So why are people *still* not walking? And is there anything we can do to try to change this?

In this paper, we will first focus on describing the importance of walking in communities, illustrating the paradigmatic shift towards consideration of factors that influence the choice of citizens to walk. We then discuss prevailing evaluation approaches, particularly the walkability index, problems we face between micro and macro scale studies, and key challenges for creating urban environments that promote more active mobility. We then examine emerging technologies that show potential for application and integration into walk-quality modelling.

2 REMOVING BARRIERS TO WALKING

2.1 Method

To answer this question, this paper explores the topic using a trans-disciplinary narrative approach as described by Montouri (2013), touching on critical disciplinary knowledge areas, including architecture, landscape architecture, planning, transport safety and epidemiology, urban forestry, computer science, and geospatial science.

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2.2 The significance of walking

Walking used to be the predominant transport mode used by humans prior to the development of an industrialised society. Today, although alternative modes are used for long range transportation, walking is still the way we 'finish the last step' and is considered the most efficient method for short distance movement. In recent decades, research on the connection between walking and physical as well as mental health has encouraged governments and citizens to place more importance on walking behaviour, such that people are not just using walking as a requirement for transit, but they do so as a way to keep fit and relaxed. Over the last fifty years, a considerable amount of research has been conducted to enhance the understanding of the design agenda for vehicular transportation modes and space. However, active transport research is a more recent addition, predominantly occurring over the last twenty-five years, and though it has made up a small proportion of transport research, it has amassed a growing body of evidence on the numerous co-benefits of active travel. 'Only in the postmodernist planning era has the walking environment been identified as a critical component of efficient, accessible, equitable, sustainable and liveable communities' (Hutabarat Lo, 2011). Amongst all the relevant research and practice, some key advantages of enhancing the built environment for walking are:

1. Health: in recent decades, researchers began to find correlations between walking behaviour and individual health, amassing substantial evidence towards the end of the last century. Morris (2012), concluded that walking is important to maintain health, which is relevant to increasing endurance (stamina), weight control, blood circulation, cardiac output and mental health, and many have engaged with this topic in an urban environment (Aschwanden, 2014; Frank et al., 2005; Giles-Corti & Donovan, 2002; Stevenson et al., 2016).

2. Energy consumption: Counter to the 'sprawling' car-centric urban planning and transportation thinking of the previous century, urban development that is conducive to walking and less 'car dependant' can contribute to the reduction of energy consumption and carbon emissions (Newman & Kenworthy, 1989; Roseland, 1997).

3. Happiness: The term 'happy' is difficult to define and can be understood from many perspectives, and this research domain is currenttly emerging. However, studies on this topic suggest strong connections between happiness and walking, particularly for women and older adults (Adamson & Parker, 2006; Rasciute & Downward, 2010, p. 201).

4. Mobility choices: Walking as a 'genetically programmed' behaviour is a movement method that humans are naturally able to perform. It is the last step for almost all displacement, and we must be aware of its flexibility (Cervero & Kockelman, 1997; Duncan et al., 2016).

5. Economy: The prosperity of a space is usually derived from a variety of social activities with sufficient pedestrians to enrich vitality. A more 'walkable' street is often considered to be located in areas with higher 'choices' of pathways to reach destinations that bring more retail opportunities and boost the local economy (Enström & Netzell, 2008; Narvaez et al., 2012). Other researchers have used qualitative research methods and found that highly walkable environments have a positive influence for the local economy (Cortright, 2009; Litman, 2003).

6. Social capital: Car-centric planning of the previous century, where private vehicles are the primary mode of transport have resulted in dispersed populations who are more isolated, with communications with other communities significantly reduced. Walking and the built environment that enhance walking behaviour augment the possibilities of communication for different groups and therefore enhance socio capital and stability (Cerin et al., 2009; Leyden, 2003).

3 FACTORS IMPACTING ACTIVE TRAVEL CHOICE

There are several factors that reduce the likelihood of people undertaking active journeys. According to the research from Giles-Corti and Donovan (2005; 2002), the key factors affecting likelihood of people walking can be catagorised as *individual* factors, *social* factors and *physical environmental* characteristics.

3.1.1 Individual factors

Individual factors refer to personal attitudes and demographic differentiation, including age, gender, education levels, marital status, ethnicity, socioeconomic status (Yarlagadda & Srinivasan, 2008). While demographic factors have limited potential for change, it may be possible to assert some influence over personal attitudes towards walking through education and active lifestyle campaigns. For example, the 'Life. Be in it', advertising campaign by the Victorian State Government (1975-1981), while achieving a high level of penetration into the population's consciousness, these campaigns alone have not stopped the continuing reduction in physical activity (Fullagar, 2002).

3.1.2 Social factors

Social factors refer to connections with social activities, which include: club membership, frequency of participation in physical activity with groups of significant others, and frequency of a significant others doing physical activity with respondent (Kelly et al., 2017). In Australia, hundreds of millions of dollars are spent each year to fund sports clubs and social recreation groups, for example Australian Government's 2021–22 Budget allocated $245.8 million (Australian Government Department of Health and Aged Care, 2021). Despite this substantial sustained investment, physical activity levels have continued to decline. And while these social factors are highly important to mode choice, they generally sit outside of the potential influence of planners, architects, landscape architects and urban designers.

3.1.3 Physical environmental

Finally, ***physical environmental*** factors can be understood as the functional environment, appeal of the environment, overall spatial access to built facilities and overall spatial access to natural facilities.

4 PHYSICAL ENVIRONMENTAL FACTORS – MEASURMENT AND POTENTIAL IMPACT

4.1.1 Walking and 'good city form'

Architects, planners and urban designers have been interested in patterns and layouts of cities along with the movement of people in various forms for centuries. From Roman grids and Haussmann's boulevards designed to move infantry soldiers quickly through cities (Kostof, 1991), modernists who desired safe walking paths separated from all vehicular traffic (White & Langenheim, 2020), to the postmodernist and new urbanists desiring 'traditional neighbourhood' layouts for improved walking environments. Architectural theories about the spatial arrangement and significant features that influence the overall walking qualities of built environment have been explored extensively, particularly over the last fifty years. Lynch described the performance dimensions of cities in general and by extension, pedestrian spaces (Lynch, 1984; Lo, 2009). He described dimensions as sense, vitality, fit, access and control, and efficiency and justice as additional criteria for evaluating 'good' walking spaces. While much of this work has been highly influential, the evidence provided was anecdotal and theoretical.

4.1.2 'Walkability' - Density, Diversity and Design

With a desire for a more quantitative approach to understanding the relationship between the built environment and citizens choosing active travel, researchers have sought geospatial and statistical modelling methods to analyse and measure various factors influencing travel mode choice. 'Density, diversity and design' (the three 'D's), is a classic concept used to analyse walking environments. Stemming from research in the early 1990s, Cervero and Kockleman (1997) found that population density, land use diversity and street connectivity (design), in general, can encourage active travel significantly. The overall walking condition offered by the built environment was later simplified to these main factors and was commonly referred to as 'walkability' from the late 1990s (Ngram, 2022). Continuing in the same vein, Frank et al. (2005) found that the development of policy that promotes increased levels of land-use mix, street connectivity, retail area and residential density as interventions can encourage active travel significantly and have lasting public health benefits. Frank et al., (2010) proposed a simplified version from previous studies formulating the "walkability index" by reducing the tens of factors to just four evenly weighted measures:

$$Walkability = \text{Net residential density} + (2 \times \text{Street Connectivity}) + \text{Land-use mix} + \text{Retail Floor area.}$$

This research has made a further contribution based on Cervero and Kockelman's work by acknowledging certain built environment variables that are not included in the original intensity and walking-quality factors, such as land use mix, can influence mode choice. Their conclusion is backed by correlating statistical evidence of in American cities, but can potentially be implemented in other similar contexts worldwide.

More recent versions of walkability indexes are taking advantage of advanced digital techniques and attempting to integrate with the design process more closely. Rakha and Reinhart developed an urban walkability analysis workflow using a Rhino 3D™ Grasshopper™ tool called UMI (2012). They introduced the integration of their form-based modelling tool with a walkability calculator. They tested the approach with urban form alternatives, applying genetic algorithms to optimize designs through the allocation of land use. The final simulation results suggest a series of 'optimal' solutions according to the walkability index calculation. Since then, other researchers have used form-based coding and static walkability assessment. Cichocka (2015), who's toolbox generates urban massing and suggests building uses to reach the best 'walk score'. Nourian (2015) proposed an urban walkability assessment model based on specific walkability features: distance and topography, and Indraprastha and Dwi Pranata Putra (2019) introduced the concept of 'informed walkable city model' by using a multi-objective optimisation method to generate urban forms accordingly.

Each of these 'walkability index' toolsets have simplified the influential built environment factors down to three or four main factors. The ease of accessing relevant data for these factors and the large-scale applicability of these index tools lend themselves to analysing regional or municipality-scaled areas. Not only are walkability index tools helpful in identifying problem areas in existing cities but can be applied to large greenfield developments such as new towns or fringe subdivisions.

4.1.3 Space Syntax

Space Syntax is a set of theories and methods for modelling and analysing cities, building on the work of Hillier and his colleagues over the past four decades (Hillier & Hanson, 1984, 1984; Hillier, 1996). The theory describes the logic of society through spatial systems and the configuration of space. Space Syntax uses graph-based measurements, including intersection integration/depth mapping, axial mapping, and visual graph analysis (visual connectivity), each showing how well a place is connected and integrated into the street network. Like Walkability Index modelling, Space Syntax is relatively easily applied at macro-scale using readily available street network data from sources such as Open Street Map, and also lends itself to analysing existing urban conditions or being applied to new, greenfield development.

4.1.4 Agent-based Modelling (ABM) and pedestrian simulation

In the last two decades, agent-based modelling has become an emerging simulation technique with applications in many disciplines. Comprising of actions and interactions between autonomous agents, ABM makes it possible to form and describe a complex system. A typical ABM requires using 'mobile cells', which result in an entire range of actions and interaction effects relevant to dynamic environments (Batty, 2016). Hence, in many domains, multi-criteria decision-making, emergent phenomena and adaptive mechanisms can be further tested.

In urban design and planning domains, the applications of ABM are frequently used for walking behaviour modelling and crowd pedestrian simulation. In 1997, Allen was the first to demonstrate how bifurcate behaviours can be generated via randomisation of nonlinear structures at the micro-level in urban scenarios (Batty, 2016). Thereafter, ABMs have been used in dynamic environment simulation and urban policymaking (Huang, 2019), including fire egress and building evacuation (Marzouk & Al Daour, 2018), favourable walking route optimisation (Pizarro et al., 2022; Xu et al., 2021), crowd behaviours and interaction simulations in both indoor and outdoor environment (Crooks et al., 2015; Huang et al., 2017; Khodabandelu & Park, 2021)
While ABM has continuing challenges in the verification of results due to the extreme complexity of human behaviour, it has the advantage of allowing a more complex understanding of human movement to be integrated. ABM has the potential to integrate multiple fine-grain micro-scaled physical environment factors that may influence walking behaviours.

5 MESO AND MICRO-SCALED 'WALK-QUALITY'

As discussed above, over the last 30 years, the prevailing research about the physical environment to determine how friendly an area is for walking, or 'walkability', has focused on creating scoring indexes using macro-scale measures derived from *intersection density*, *residential density*, and *land use mix* or *diversity*. These *walkability index* tools are highly valuable for comparative analysis between cities, identifying problem areas in existing suburbs or influencing greenfield development, taking advantage of the readily available macro-level data, and the comparative ease of analysis using desktop GIS applications.

In contrast, micro-level design factors that contribute to walking quality (Cervero & Kockelman, 1997), have rarely been included in modelling. Micro-scaled 'walk-quality' factors such as footpath continuity, universal access characteristics, path directness, safety at road crossings, heavy or high-speed traffic, pedestrian separation from traffic and landscape quality, which also significantly impact on mode choice, have been largely excluded due to the time, cost and difficulty associated with data collection and analysis (Park et al., 2015).

For urban designers and policymakers, the significance of this research gap has been exacerbated by the impractical reality of implementing macro-scaled (precinct-wide) measures when compared to altering micro-level factors, particularly in existing urban areas (Rodríguez et al., 2006). For example, the cost-benefit of modifying micro-level streetscapes by increasing tree coverage, ensuring continuity of footpaths and introducing traffic calming measures is far higher than increasing street intersection densities or changing land-use in existing urban areas. An array of meso and micro-scaled physical factors impact journey mode choice. In addition to macro scaled, and meso-scaled factors such as commute times, street network connectivity (NRC, 2005), traffic volumes and wait times of street crossings, and the severity of route inclines (White & Kimm, 2018) can influence travel modes. Furthermore, multiple forms of pollution, and thermal stress (Giles-Corti et al., 2016) also contribute to the choice to walk. Urban designers need to consider not only where key destinations and community facilities such as schools and transit nodes are situated at a neighbourhood's street layout (Giles-Corti et al., 2011) but also how elements of city streetscape design may act as barriers to active journeys. However, tools that support the design process for urban decision-makers to prioritise walking infrastructure spending are currently lacking.

6 A NEED FOR A MULTI-CRITERIA SPATIO-TEMPORAL DESIGN APPROACH TO IMPROVE WALK-QUALITY

The discussion above indicates that we need to address micro-scaled elements within meso-scaled precinct-level investigations, especially when working with the existing urban fabric in the Australian context. There are many key factors that have potential to influence active travel choice but are yet to draw upon suitable analysis and design methods for integrating into urban design decision making.

There is a growing array of emerging technologies and new (big) data sources that may have potential to contribute to the previously unobtainable micro-scaled modelling aimed addressing streetscape level urban design walking choice factors. We see great potential to explore new approaches that include Urban accessibility and topography, Pedestrian risk, Human Thermal Comfort, and Air pollution. These technologies including agent-based modelling (ABM), computational botany, highly efficient proxy-object GPU rendering and city-scaled shadow modelling, mutli-factorial pedestrian risk modelling, artificial intelligence and machine learning with semantic segmentation, as well as remote sensing and the internet of things (IoT).

6.1.1 Pedestrian network accessibility

One key meso-scaled factor that impacts walking is proximity (pedestrian accessibility) to services or features of interest. The likelihood of residents walking instead of driving is greatly increased if there are parks, shops and particularly public transport nodes located within a short walking distance from their homes (Clifton & Dill, 2005; Ellaway et al., 2005; Giles-Corti et al., 2005; Sugiyama et al., 2012). Giles-Corti's considers three main factors: Distance, Attractiveness and Size, concluding that all three factors have a substantial impact on walking, but distance is the most influential of the three. Koohsari et al.'s study (2016) also support this conclusion with case studies in Australia suggesting that while perceptual qualities are very important, they are less influential than proximity which is the predominant factor that influences the choice to walk to public open spaces.

How do we calculate pedestrian accessibility? Significant improvements in computer power mean that sophisticated pedestrian modelling that would have been computationally unfeasible ten years ago, is now possible and slowly becoming available to urban designers. Until recently, modelling access to services such as schools and transport nodes was limited (Sander et al., 2010), to 'Euclidean buffers' (circular catchments), which are an as-the-crow-flies distance from services being the most common approach (Andersen & Landex, 2009). The approach of drawing a circle of 800m radius to represent 10 minutes' walk at 1.3 m/s (Pushkarev & Zupan, 1975) to approximate a pedestrian catchment for a chosen node is still widely used in planning practice. This is despite criticism of inaccuracy, overestimation of catchment areas incomplete accounting of street networks and barriers such as rivers or railroad tracks (Sander et al., 2010). The approach also fails to consider physical environmental aspects that influence walking such as gradients, perceived safety, and climatic conditions (Giles-Corti et al., 2011), or allow 'what if' scenario testing. Development of proprietary GIS software with additional network accessibility (ESRI™ Arc Map with Network-Analyst™ plugin) has dramatically improved accessibility catchment modelling (Andersen & Landex, 2009) with vector distance based Service Area Approach or 'ped-sheds'. This method can produce accurate accessibility analysis but can be prohibitively expensive and require high-end GIS software and specialist staff (Badland et al., 2013).

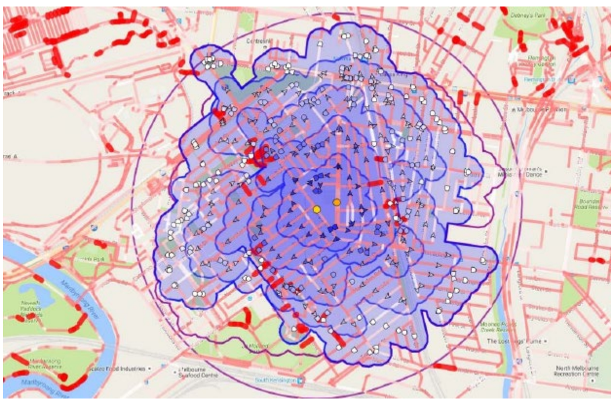

Figure 1: Screen grab of pedestriancatch.com tool used to analyse access to Kensington Primary School.

In response to these limitations, the ped-shed modelling tool www.PedestrianCatch.com was developed to analyse pedestrian catchment areas using simple agent-based modelling (White, 2007; Badland et al., 2013; White & Kimm, 2018). Pedestrian access is calculated in the tool using large numbers of intelligent agents to measure the pedestrian catchments for a central node. The agents (output shown in **Figure 1**) make basic decisions in moving away from the central node (eg. a school), at walking speed, interacting with the streets, traffic, and crossings, measuring and mapping all the possible journeys that can be walked in a specified time (eg. 10-minutes). The analysis, an animated isochrone with catchment area analytics output, is suitable for comparative scenario studies and for stakeholder engagement as it highlights pedestrian access barriers and allows users to propose and rapidly test design options or interventions. Although the PedededestrianCatch.com tool has proven useful in urban design research and practice with over 22,500 uses (White, 2022), the tool is currently limited to the single network accessibility factor. The tool does, however, provide an extensible platform to build upon and allow integration of other crucial physical factors impeding active journeys. At this stage, crucial factors we have identified as having potential for integration are terrain, pedestrian risk, human thermal comfort and air quality.

6.1.2 Urban topography

Urban topography (slope of terrain) is a built environment factor that can significantly impact pedestrian accessibility, particularly for people with mobility impairment, older adults and children. Common scenarios, such as parents pushing prams, children riding bikes or grandparents walking grandchildren to school, are all negatively impacted by steep gradients. Although there have been significant developments of technology for analysing topography, such as ESRIs Aspect-Slope Raster Function (2017), or the more user-friendly hillmapper.com (slope map of San Francisco), these tools are not currently integrated into pedestrian accessibility modelling applications. There is a growing need for urban designers to have access to tools to model accessibility in their community, assess gradients to identify topographical barriers and to then design solutions that transition to more inclusive urban environments.

There is potential to develop a method to integrate urban topography by integration of openly accessible elevation data such as NASA's SRTM elevation and terrain data. Street segments could be measured for steepness by sampling points along the pathways against elevation values to calculate the gradient (rise/run) for each section of the street. Steep streets can be excluded from the street network based on a user-specified gradient threshold, e.g., gradients over 1:14 may be too steep to traverse. A prototype of this concept is shown in **Figure 1**.

6.1.3 Pedestrian risk, safety, and perceptions of safety

Pedestrian risk and the safety of a journey is a critical factor in journey mode selection. Pedestrians and cyclists account for 13% and 4% of road traffic deaths, respectively (WHO, 2015) and child pedestrian injury (aged 0-14 years) ranks highly as a major cause of premature mortality in Australia (ABS, 2016). As such, parental concern about traffic safety has been identified as a barrier to children undertaking active journeys in Australia and globally (Control & Prevention, 2005). In addition to actual risk, perceived risk is also a vital factor to consider for encouraging active travel (Timperio et al., 2006). Understanding these risks as well as perceived risks and providing a means to examine the urban design and road networks to address these risks is a key step to creating opportunities for active and safe journeys.

With the recent advances in capability of machine learning, there is potential to build on previous risk rating systems such as those developed by Logan et al. (2013), which combines five traffic factors that contribute to the risk of injury whilst a pedestrian namely, 1) the speed limit at the crossing point, 2) the traffic volume (vehicles per hour) at the crossing, 3) the width of the road to be crossed, 4) the number of conflict points encountered during the crossing, and 5) the type of crossing facility provided (i.e. traffic signal, school crossing, or zebra crossing).

By using computer vision (artificial intelligence extracting meaningful data from visual inputs such as photos), remote sensing data including satellite aerial photography or 'street view' images can be analysed using machine learning alongside geo-spatially located accident data, there is potential for more nuanced built environment elements to be part of assessing risks. By generating risk-maps at meso and micro scale, a system could be developed to allow assessment of pedestrian risk across entire journeys, as well as allow local governments to test and implement safety improvements while also gaining a better understanding of how pedestrian risk impacts on the desirability of making active journeys.

6.1.4 Human thermal comfort and UV

Human thermal comfort (HTC) and Ultraviolet (UV) exposure are essential factors impacting transport mode selection and yet there is a paucity of research assessing the role these factors play. It is often recognised in walkability assessments that amenities such as shading can increase the walkability of an area (Millington et al., 2009) but these factors are generally difficult to quantify and are rarely considered in isolation from other streetscape aesthetic properties. Poor HTC can make active transport both difficult and undesirable (Buys & Miller, 2011). UV exposure is also a critical issue to consider in designing for active journeys. Shading from a tree canopy can provide a sun protection factor (SPF) of 2, with denser canopies providing between 5 and 15 (Grant et al., 2002). This is particularly important in Australia which has one of the highest incidences of skin cancer in the world (Fransen et al., 2012). Assessing the impact of shade provided by trees and the design of urban tree-scapes for active travel has developed significantly in the past decade (Berry et al., 2013; White & Langenheim, 2014, 2018). Continuing in this vein, heat mapping for cycling has recently been explored by the City of Bendigo with Amati, and the City of Melbourne. The digital 3D modelling of tree-scapes and their shade has also seen significant efficiency improvements – it is now feasible to digitally simulate meso-scaled urban precinct scenarios integrating micro-scaled geometrically accurate trees modelling (White & Langenheim, 2014) (see **Figure 2**). Therefore, the incorporation of such modelling into an active journey toolset is highly desirable due to the potential impact of both UV exposure and HTC have on improving walk-quality.

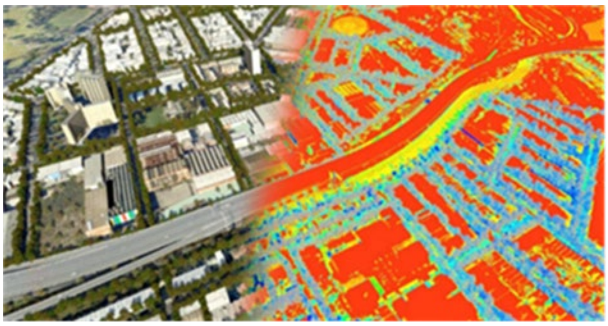

Figure 2: 3D digital model solar impact study using algorithmic botany modelling.

By developing a better understanding of existing microclimates of streets, as well as likely implications of modified streetscape designs that may, for example, provide increased levels of shade, heat maps of thermal discomfort zones could be integrated with pedestrian accessibility modelling to analyse potential increases in thermally comfortable pedestrian catchments. This kind of modelling would be ideal for strategic improvement of walk-quality around areas with populations vulnerable to UV exposure and heat, such as near schools

6.1.5 Air Quality

Air pollution is acknowledged as an environmental amenity which can make areas less walkable (Marshall et al., 2009) but currently, there is no metric established to determine the exact impact of these pollutants on the desirability of making an active journey. High densities of vehicular traffic lead to increased emissions including particulate matter ($PM_{2.5}$ and PM_{10}) and can increase the likelihood of respiratory disease when undertaking active journeys (Giles-Corti et al., 2016) and reduce walking comfort. To date, no implementable design tools are available for urban design decision makers to map out less polluted routes for walking. Understanding the impact of pollution and allowing what-if design scenarios to strategically improve air quality is key to improving walk-quality and encouraging active journeys.

Recently, there has been an explosion of IoT sensors becoming more readily available and being installed by many local councils. Networks of IoT sensors can be deployed to collect observations over a variety of days, street locations, and weather conditions. These observations may be combined with monthly wind roses, and MET profiles, based on road network (road length and orientation, traffic densities and fleet profiles), to produce temporal air pollution maps of common pollutants for different hours of the day, and different days of the week. Again, this meso-micro scaled air quality modelling could be combined with pedestrian accessibility models to understand and improve human experience and desirability of active journeys.

7 DISCUSSION AND CONCLUSION

There is an urgent need to shift citizen transport mode choice to sustainable active transport from both health and economic perspectives. So why are people *still* not walking? As we have outlined through this paper, the answer to this question is complex. There are many individual and social factors that inform walking behaviour but are difficult to influence. While much research into the built environment's influence on walking and associated analysis tools have made positive contributions in helping identify areas of cities that discourage active travel, the capacity to use this analysis improve these areas has been limited due to the difficulty to change macro-scaled urban planning in existing cities and suburbs. Unless working on green-field development, the macro-scaled factors commonly considered in 'walkability' analysis may require re-zoning private land, substantial demolition, and urban fabric renewal, and may be financially or politically infeasible and thus extremely difficult to change. There is a clear need to augment this macro-scaled analysis with micro-scaled tools, and to establish multi-criterion spatio-temporal design decision support approaches drawing from emerging technologies that can be used by built environment professionals to make more informed, integrated and effective urban design decisions. If these new technologies and design methods are applied at the streetscape level design and re-design, they have the potential to make more feasible and 'implementable' improvements to the 'walk-quality' of the built environment and may contribute to facilitating active travel.

'God, grant me the serenity to accept the things I cannot change [such as land use mix and population density], courage to change the things I can [micro-scaled design features such as strategically planted street trees, better footpath design, traffic calming and speed restrictions], and wisdom [and modelling tools] to know the difference', Reinhold Niebuhr, The Serenity Prayer (1943).

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