

APPENDIX E

WALK QUALITY RESEARCH METHODOLOGY



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BUILDING THE DIGITAL TWIN AND INTEGRATING WALK-QUALITY

This work is linked to ‘Walk-Quality’ project. This initiative is led by Prof. Marcus White, Tianyi Yang, and Dave O’Reilly from Swinburne University of Technology, and Dr Nano Langenheim, Prof. Mark Stevens, Dr Robyn Scofield, Associate Prof. Steven Livesly and Dr Sachith Seneviratne from the University of Melbourne.

The project aims to enhance the ‘walk-quality’ of urban areas by developing a design platform that evaluates various factors influencing pedestrian experiences.

The project is funded by the Australian Research Council (ARC) Linkage Grant (LP190100089) and industry partners. The platform considers key urban design elements such as pedestrian accessibility, slope, thermal comfort, pedestrian risk, and pollution. By analysing these factors, the tool aims to improve urban environments for pedestrians, making walking safer, more convenient, and comfortable for everyone.

This cross-disciplinary study involves collaboration with partners from the University of Melbourne, the Transport Accident Commission (TAC), Glen Eira Council, engineering consultancy, Maribyrnong Council, and VicRoads. The research is conducted at Swinburne’s iHUB facility, which supports smarter urban planning, design, and management. For more detailed information, you can visit the project’s official website: [Walk-Quality.com](https://walk-quality.com)

We have built a 3D context model of entire municipal areas of suitable accuracy for assessing shading and over-shadowing impacts for different times of the year. Footpath and crossing data have been generated partially through use of machine learning and partially through manual GIS/CAD generation covering 17000 segments of footpaths and 6300 crossings (Figure 3).

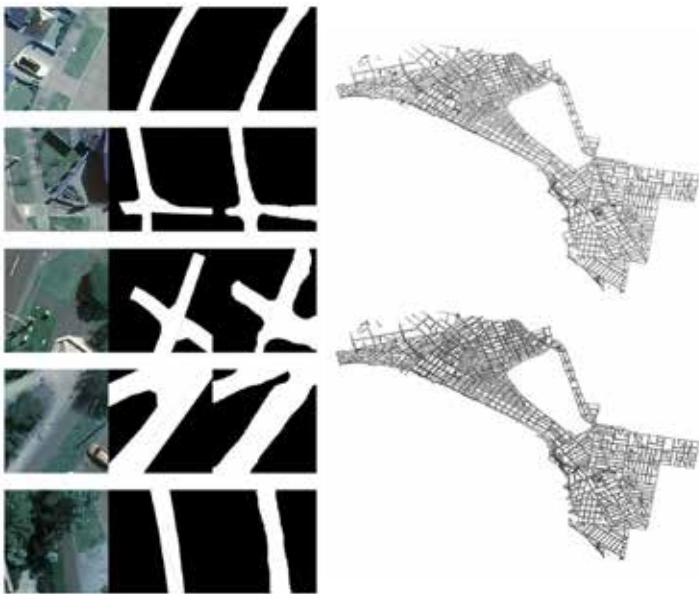


Figure 1: above, examples of the mask output from the best performing fine-tuning model. The model is pre-trained as the backbone of DINO-MCina self-supervised manner and then fine-tuned on footpath segmentation task training set with 1000 remote sensing images. Right, visualisation of the whole generated network with top right image of the ground truth footpath network, and bottom right showing the generated footpath network using our pipeline (Wanyan et al. 2023).

3D BUILT FORM MODEL FOR SHADOWS

The 3D built form model were generated from building extraction is done in three stages. Firstly, with Semantic Segmentation – recognising building pixels on an aerial image using deep neural networks (DNNs). Secondly, polygonization, by converting building pixel detections into polygons derived from Bing Maps imagery between 2014 and 2024 including Maxar, Airbus, and IGN imagery (available for download Bing Maps Global Building Footprints and use under ODbL).

The third stage of model development involved were estimating building heights by combining Open Street Map building height data, LiDAR data, and Bing Global Building height data derived from trained neural network to estimate height above ground using imagery paired with height measurements, with the average height of an overall building stored as a height attribute within a building polygon. We wrote a simple script to take the building height attribute and extrude the building outline polygon by that height attribute value to create a simple 3D building volume. Note that this model does not account for complex roof types or include the canopy of the building, so it should be used as a guide only. These 3D modelled buildings were used for shadow casting.

3D TREES MODELS FOR SHADOWS:

The process involved processed nearly 200,000 trees categorising species grouping and scaling for 3D model generation. Tree-shade shade maps were generated using 3D models with accurate height and canopy extent from geolocated trees (3D tree-form models) independently to the building shade. The trees-model was developed using the council (CoPP) GIS public tree point data, augmented with the Vicmap Vegetation imagery derived urban tree point data for location, height and canopy sizes. Newly planted small trees, which were not included in the CPP data or captured by Vicmap Vegetation imagery, are excluded from the model. The inclusion of trees within the private realm ensures a more comprehensive representation of those contributing to street shading.

The trees-model was processed in four stages. Firstly, to simplify, the GIS records of the 400 unique tree species planted across the municipality were categorised into six groups using a visual similarity approach. Each species was categorised as ‘conifer’, ‘deciduous’, ‘eucalypt’, ‘evergreen exotic’, ‘evergreen native’ or ‘palm’. Where no species data was available, trees were categorised as ‘undefined’. As no species data is available for the private realm trees, these trees were also categorised as ‘undefined’ (Figure 2).



Figure 2: Categorisation of species as either ‘conifer’, ‘deciduous’, ‘eucalypt’, ‘evergreen exotic’, ‘evergreen native’ or ‘palm’.

Secondly the categorisation was then used to assign which ‘3D tree-form model’ would pass to each of the 46,500 tree points as they were exported from the GIS environment to the 3D modelling environment. We used Autodesk Civil 3D™ Map import process and the query builder to generate blocks representing each tree point from the GIS data with the attribute for canopy width controlling x,y scale and the attribute for height controlling the block elevation (Figure 5).

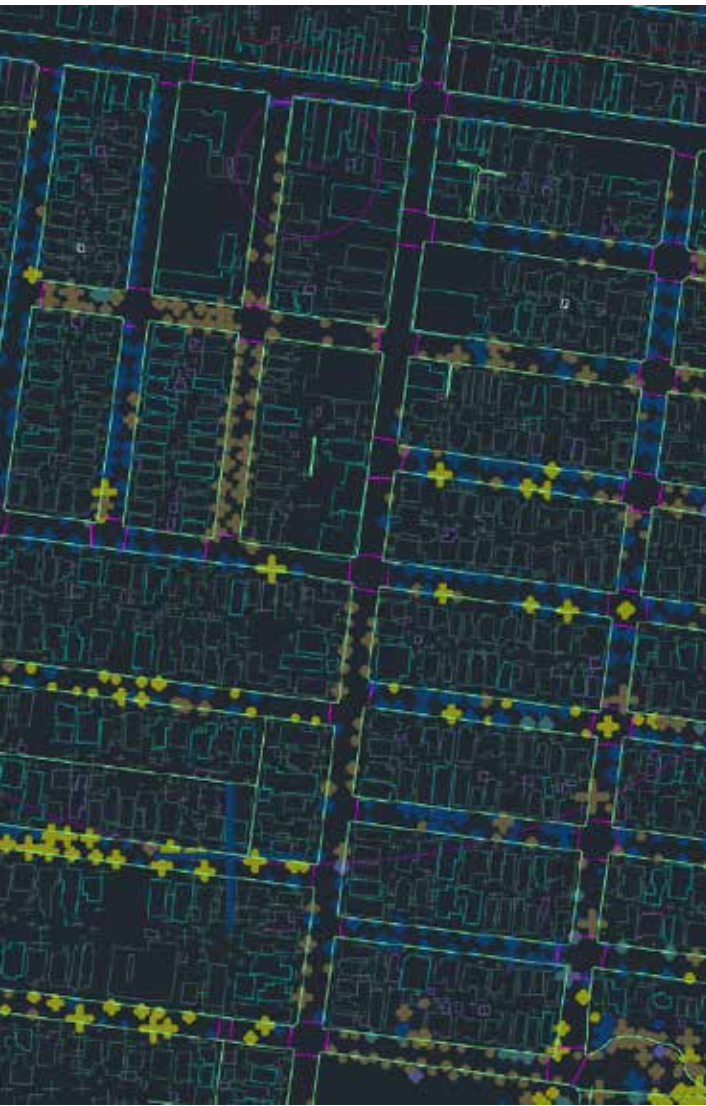


Figure 3: Screenshot of tree categorisation of nearly 200,00 trees, and 17000 segments of footpaths and 6300 crossings.

Thirdly, the 3D tree-form models were assigned to the point locations and coded to inherit the scaling properties of the AutoCAD blocks, while maintaining an average urban tree trunk height of 2.5m (scaling parameters are applied to the canopy section of the tree-form model). Scaled tree-point data was import as point from CIVIL3D with points coming in with block scale (X and Y) with height representing Z=canopy top height. Run script – read the Z value of the object and store as a Z height as a Z scale ‘multiplier’. Points for all trees (except palms) should be moved down in the Z direction by 2.5 metres with canopy scaled to fit into 1x1x1m box. Scale should be adjusted (trunk height of 2.5m) (assuming the canopy begins at 2.5m) (Figure 4).

The tree-form models were built with moderately high polygon-density to allow enough realism to produce both traditional design imagery for qualitative visual decision-making support and simultaneously shade quantification for different street configurations, different times of day, and at different times of year (Figure 5).

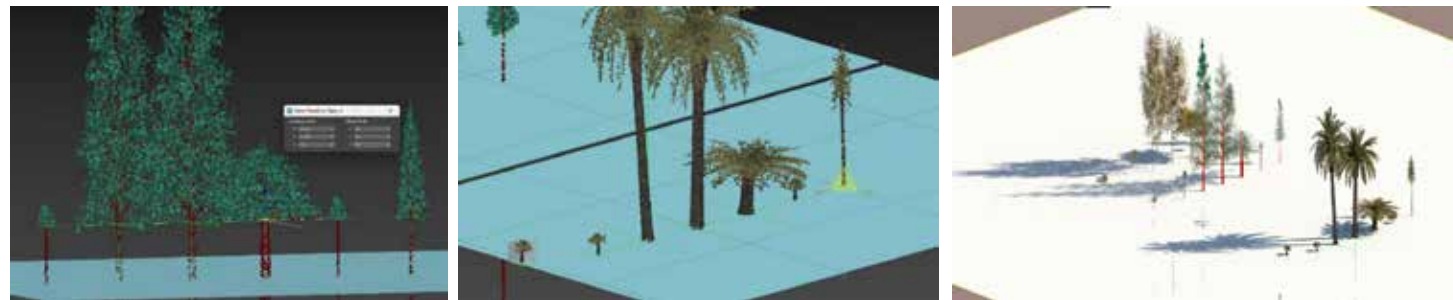


Figure 4: Tree models with canopy extents fit to 1x1x1 box upscaled based on canopy width and elevation data.

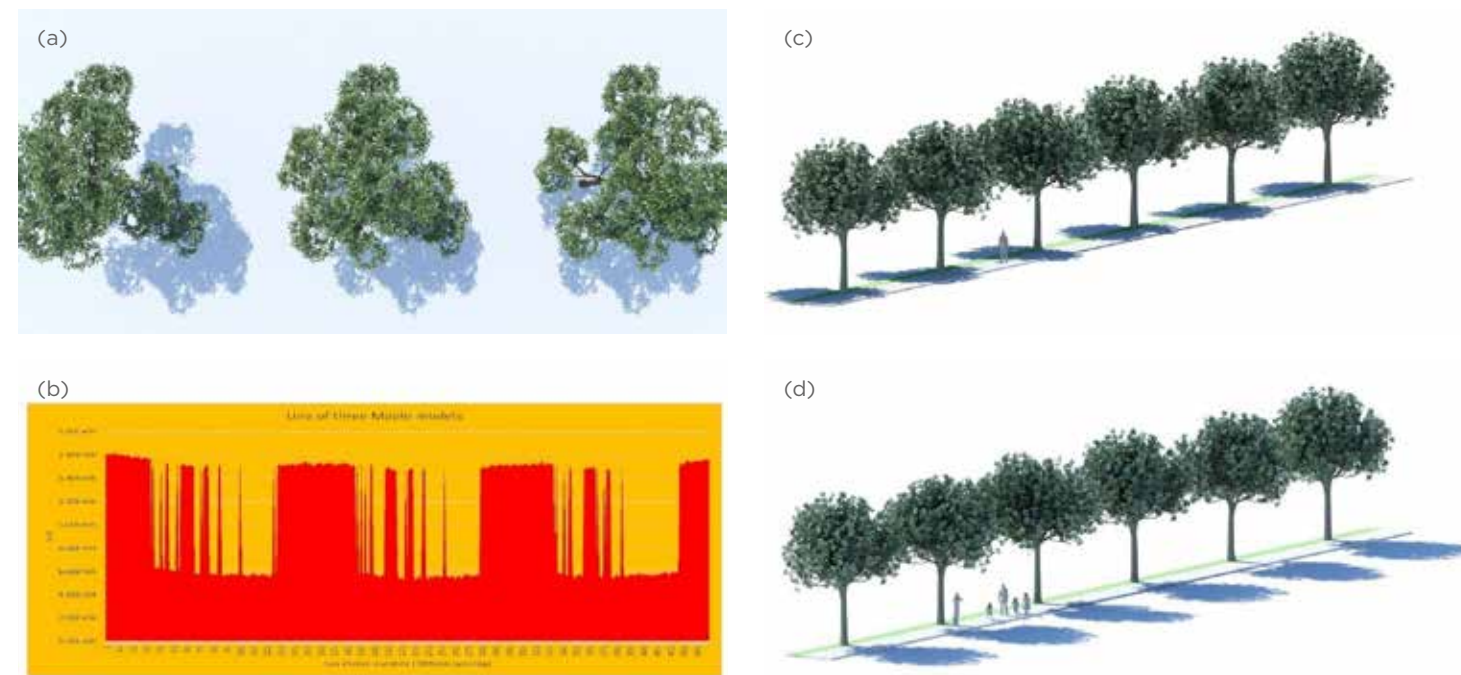


Figure 5: 3D Tree models (a) used to calculate time-based shadows measuring lux along footpaths (b). Shade can be assessed for different times of day, for example a north-south running street casting shadows on the footpath shading people at 12pm (c), or casting shade that misses the footpath and people walking at 3.30pm (d).

Fourthly, from this model, shade maps of tree planting scenarios at children’s head height (1.2 m) are ‘rendered out’, using a texture baking technique which captures shadows of objects in isolation, on a surface. The shade maps were rendered out at 1.6km by 1.6km at 8000x8000 pixels (each pixel =200mm) as ‘geo-tiles’ (geo-referenced to MGA2020/55).

The high-resolution tiles can be used for detailed analysis and also down-sized for merging with vector base footpaths for percentage shaded footpath calculations and visualisation (Figures 7, 8 and 9).



Figure 6 (above): Aerial perspective view of 3D building, tree and shade model.

Figure 7 (below): Down-scaled shadow map calculated for 3.30pm December 22.





Figure 8 (above): Down-scaled shadow map calculated for 3.30pm December 22 intersected with footpath vector data. Yellow footpath areas show footpath that is fully in shade, blue shows footpaths in shadow.

Figure 9 (below): Detailed plan view showing 3.30pm December 22 intersected with footpath vector data with yellow footpath areas show footpath that is fully in shade, blue shows footpaths in shadow, with dotted lines showing overhead powerline dataset.



INTEGRATING SHADE MAP WITH PEDESTRIAN CATCHMENTS

We've developed a tool (expanding upon our PedestrianCatch.com tool) that calculates walking access catchments, or 'ped-sheds,' while factoring in shade quality. This tool helps determine whether key destinations, such as air-conditioned buildings or well-vegetated community areas, are within a comfortable and safe ten-minute walk. Using a model that samples the shade maps produced in the earlier steps along footpaths, the tool evaluates tree shade coverage and sets a threshold for maximum direct sun exposure. This ensures that walking routes are not only accessible but also shaded enough to protect pedestrians, especially children, from excessive heat and UV radiation.

Walking catchments that integrate shading and pedestrian crossing wait times were generated for key destinations, measuring maximum direct sun exposure limits of 2, 4, 6, 8, and 10 minutes, as illustrated in Figure 10. Here, direct sunlight exposure acts as a limiting factor, influencing pedestrians to prioritise shaded pathways to minimise exposure to harsh sunlight. The resulting 10-minute walking catchment, which illustrates how far pedestrians can comfortably walk without significant sun exposure, is constrained primarily by the connectivity of the pedestrian network and street crossing points.

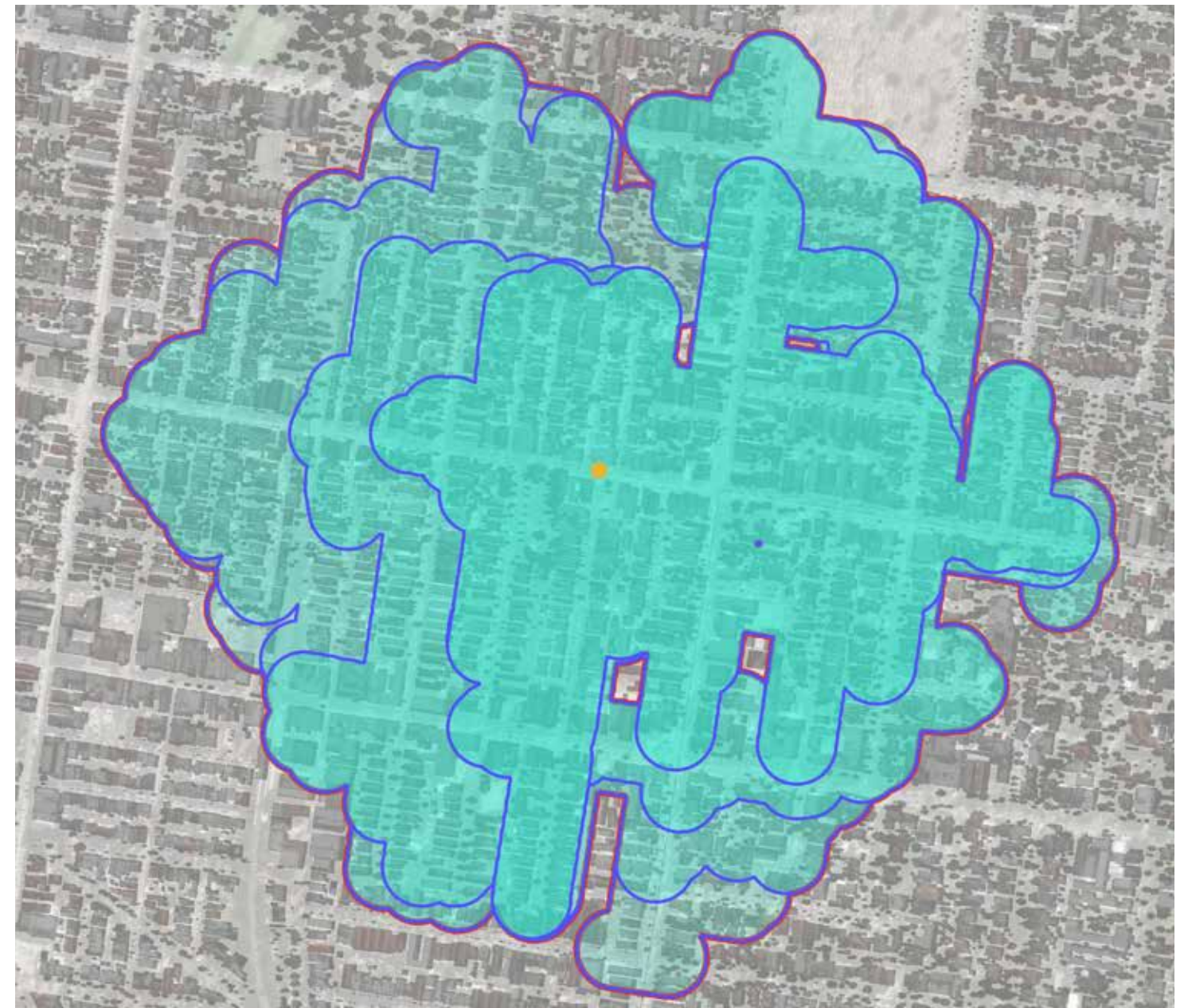


Figure 10: Pedestrian catchments for Inkerman Street on December 22nd at 3:30 pm. The shaded areas in light blue represent walking catchments with direct sun exposure limits of 2, 4, 6, and 8 minutes, while the red boundary outlines the full 10-minute exposure limit catchment (as though the entire walk is within shade).

TRAFFICKED ROUTES AND PRIORITY ROUTES

By simulating all possible pedestrian routes from key destinations under defined sun-exposure limits, we produced datasets indicating pedestrian route utilisation for each scenario. This analysis identifies street segments most frequently traversed by pedestrians, represented visually through colour-gradient mapping (Figure 11 and Figure 12). Routes with higher pedestrian density are represented by colours at the red and orange end of the spectrum, indicating priority streets that require shade improvements or infrastructure enhancements. Conversely, less-utilised street segments are shown in colours at the blue end of the spectrum. Analysing these patterns helps highlight routes significantly influenced by shading conditions, thereby informing targeted interventions such as tree planting, shade infrastructure, and other improvements to pedestrian amenities.

VISUALISING SHADE IMPACT - 'DIFFERENCES' LAYER

To clearly visualise the impact of shading on pedestrian route selection, we generated a comparative analysis between the 4-minute and 10-minute direct sun exposure scenarios for each destination. The differences between these scenarios were visualised using a gradient colour scale.

To clarify how these differences were calculated, explanatory diagrams (Figure 13, Figure 14 and Figure 15) demonstrate the method applied.

Figure 13 illustrates the resulting 10-minute walking catchment, representing how far pedestrians can comfortably walk without significant sun exposure. In this diagram, pedestrian route usage density is indicated by colour: the most frequently utilised pedestrian routes appear in red and orange, gradually transitioning through yellow, green, and blue along routes extending outward, reflecting progressively lower pedestrian density.

In contrast, Figure 14 illustrates the 4-minute direct sun exposure scenario. Here, pedestrians limit their direct sunlight exposure to a maximum of four minutes, prioritising shaded routes. Due to the limited availability of adequately shaded paths, pedestrian accessibility is notably reduced compared to the 10-minute scenario, impacting connecting pathways between both shaded and less-shaded areas.

Figure 15 shows a simplified example of the difference calculation method, highlighting hypothetical variations in pedestrian route usage between the 4-minute and 10-minute direct sun exposure scenarios. Route segments shown in red represent the greatest differences in pedestrian usage between scenarios, indicating street segments are strongly influenced by shading availability. Such differences can help target areas for strategic tree planting and urban shading improvements.



Figure 11 (above): Pedestrian route usage density for Inkerman Street with a maximum direct sun exposure limit of 4 minutes, simulated for December 22nd at 3:30 pm. The colour spectrum ranges from red, represent streets with higher pedestrian traffic density, through to dark blue, indicate routes with lower usage.



Figure 12 (above): Pedestrian route usage density for Inkerman Street with a maximum direct sun exposure limit of 10 minutes, simulated for December 22nd at 3:30 pm. The colour spectrum ranges from red, represent streets with higher pedestrian traffic density, through to dark blue, indicate routes with lower usage.

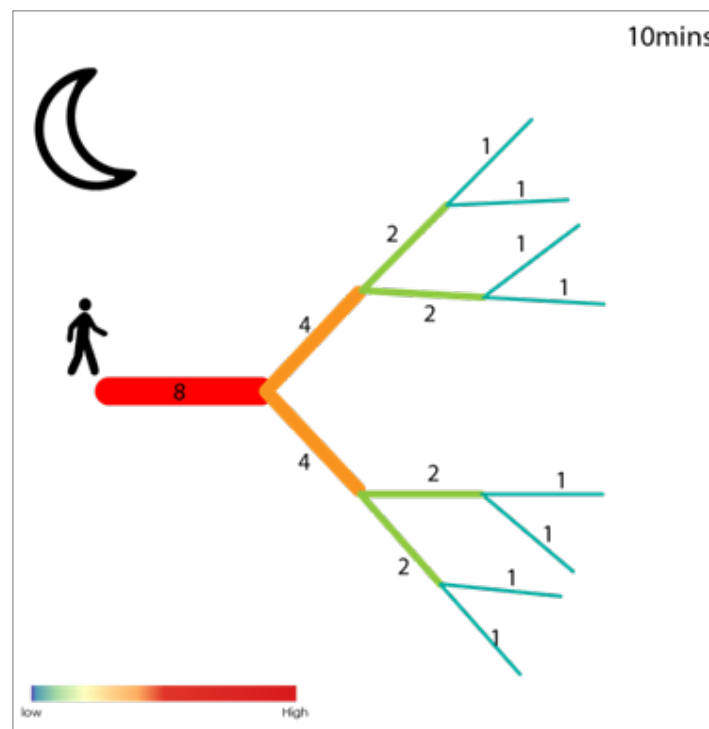


Figure 13 (above): Diagram illustrating the pedestrian route usage calculation for the 10-minute walking catchment scenario. Route segments are colour-coded by pedestrian density, with red and orange indicating the highest frequency of use, progressively transitioning to blue as pedestrian usage decreases along branching paths.

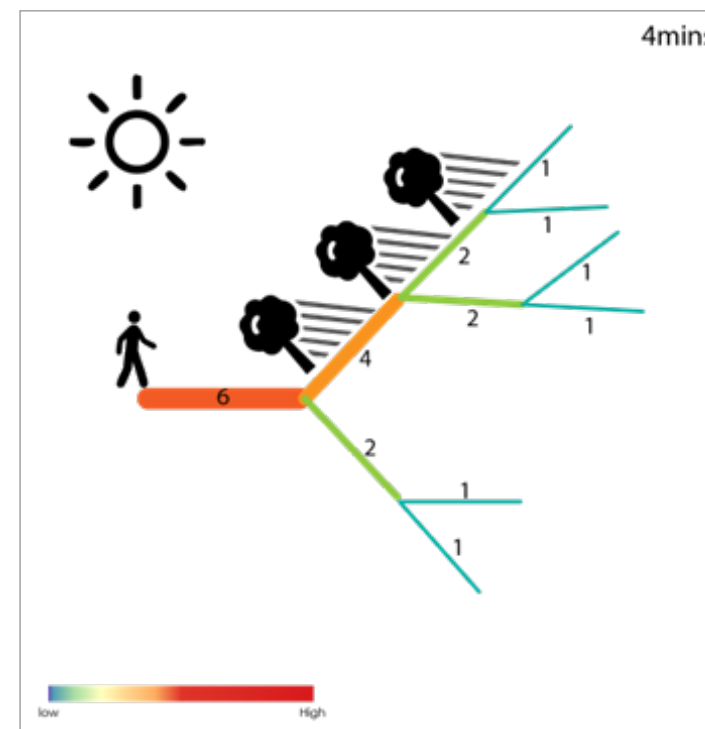


Figure 14 (above): Diagram illustrating pedestrian route usage calculation for the 4-minute direct sun exposure scenario. Route segments lacking sufficient shade (indicated by sun exposure symbols) become less accessible, leading pedestrians to prioritise shaded routes. This reduces the accessible pedestrian catchment area, impacting route density compared to the 10-minute scenario.

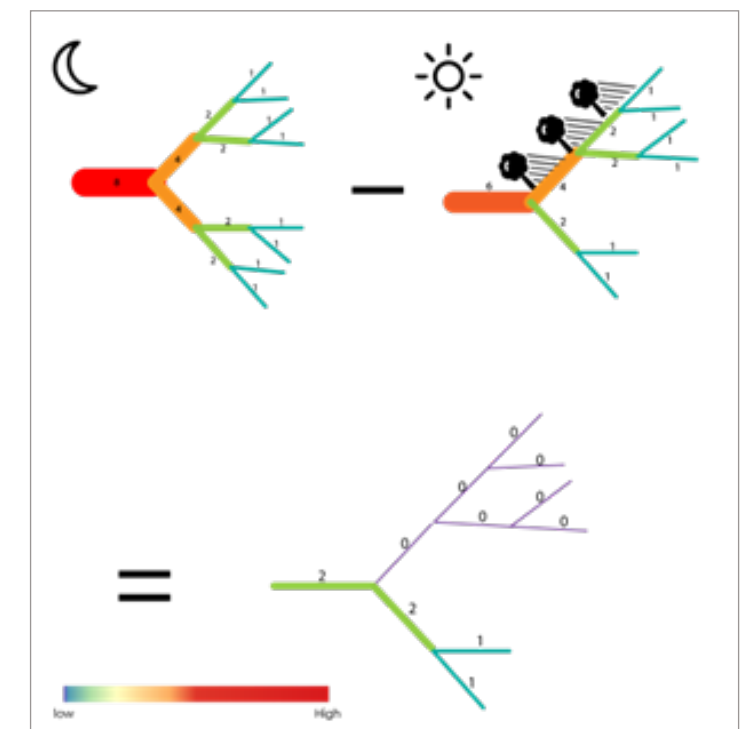


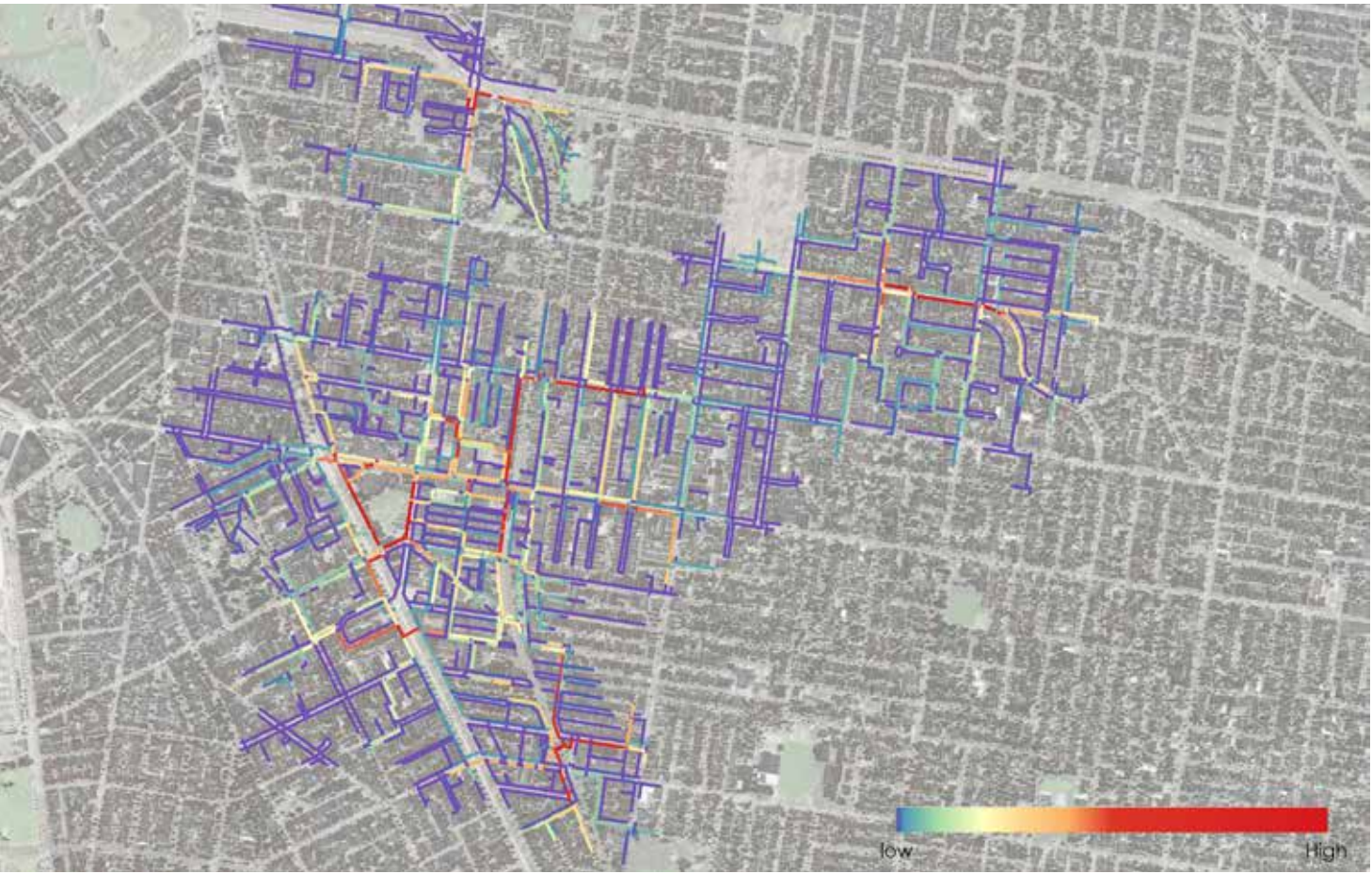
Figure 15 (above): Diagram illustrating the calculation of differences between pedestrian route usage under the 10-minute and 4-minute direct sun exposure scenarios. The upper diagrams show the route density for each scenario, and the lower diagram visualises the resulting differences.

Figure 16 illustrates an applied example of this calculation for Inkerman Street on December 22nd at 3:30 pm, specifically highlighting differences between the 4-minute and 10-minute scenarios. Finally, to provide a comprehensive view, differences calculated for all key destinations were combined into an overall visualisation, as shown in Figure 17. This visualisation identifies street segments consistently impacted by insufficient shading across multiple pedestrian catchments, guiding targeted urban interventions such as strategic tree planting and shade infrastructure enhancement.



Figure 16 (top): Visualisation of pedestrian route usage differences for Inkerman Street on December 22nd at 3:30 pm, comparing the 4-minute and 10-minute direct sun exposure scenarios. Route segments in red indicate areas with the highest difference in pedestrian activity between the scenarios, highlighting streets significantly impacted by insufficient shading and therefore prioritised for additional tree planting or shade infrastructure.

Figure 17 (bottom): Combined visualisation of pedestrian route usage differences across all key destinations, highlighting overall street segments most affected by insufficient shading between the 4-minute and 10-minute direct sun exposure scenarios.



APPENDIX F

**BACKGROUND DOCUMENT SUMMARIES,
CASE STUDIES & BEST PRACTICE**

KEY STRATEGIC DOCUMENTS

DOCUMENT REVIEW

A review of existing Council strategies and reports and similar projects in other locations was undertaken to inform the UFPP. These documents helped identify Councils aspirations for the functionality and hierarchy of streets and their various attributes.

For example, whether streets were identified as active travel corridors or potential bio-links, where the most substantial changes in residential density are forecast, and which streets have already been identified as being a priority for additional street tree planting. Some of the key implications from these documents have been summarised over the following pages.

Key documents that were reviewed in detail:

- Urban Forest Strategy, 2024 - 2040
- City of Port Phillip Housing Strategy, 2024 - 2039
- Places for People - Public Space Strategy, 2022 - 2032
- Public Space Strategy - Technical Report
- Integrated Transport Strategy, 2018-28
- Carlisle Street Activity Centre Structure Plan, 2009
- Council Plan & Budget, 2021 - 2031
- Parking Management Policy, 2020
- Nature Strip and Street Gardening Guidelines, 2022
- Urban Forest Strategy Background and Benchmarking Report
- Greening Port Phillip Street Tree Planting Program (2017-2022)

The following supporting documents were also considered:

- Greening Port Phillip - Various Documents
 - › An Urban Forest Approach, 2010
 - › Developing our new Urban Forest Strategy Testing the Draft Vision and Principles - Summary of Stage 1B Engagement (Draft 1, 26 September)
 - › Urban Forest Strategy Developing Evidence Based Targets. Information from Community Workshops
 - › Urban Forest Mid-Term Review and Report
 - › Urban Forest Strategy Stages 1, 1B, 2, & 2A Engagement Findings Report
 - › Urban Forest Strategy Strategic Directions: Inclusion of Community engagement feedback on the Vision and Principles
- Nature Strip Guidelines (2022). Analysis of phase one community engagement results

- Draft Public Space Strategy - Summary Engagement Report (2020)
- City of Port Phillip Housing Strategy Phase 3 - Feedback on the Draft Strategy Engagement Report
- Street Tree Planting Program (2017-2022)
- Permeability Baseline Assessment and Tool Development
- Permeability in the Private Realm
- Draft Public Space Strategy Summary Engagement Report
- South Melbourne Street Tree Planting
- City of Port Phillip Tree Ledger
- Protecting Vegetation in the Private Realm- Discussion Paper
- Cooling South Melbourne.
- Bothwell Street Biolink Plan, 2022
- Green Line Proposal (Green Line Alliance), 2022
- Inkerman Street Crash Statistics, 2023
- Inkerman Street Road Safety Audit, 2021
- Inkerman Street Project Impact Assessment, 2023
- Inkerman Street Safe Travel Corridor Report
- Inkerman Street Safety Improvement Project
- Elwood Foreshore Biodiversity Constraints Assessment, 2020
- Biodiversity Study and Action Plan - Background Research Discussion Paper, 2020
- Biodiversity Study and Action Plan - Implementation Plan, 2020

STRATEGIC CONTEXT MAPS

The strategic and policy aspiration for the study area have been summarised under three themes:

- placemaking, land use and development
- movement networks
- green and blue functions.

The UFPP examines how each category contributes to the broader goals of the project, considering factors such as density, sustainable transport, public realm activation, and the integration of green spaces. Through this integrated approach, the design solutions within the UFPP will be contextually appropriate and achievable.



URBAN FOREST STRATEGY, 2024-2040

The City of Port Phillip's Urban Forest Strategy (2024 to 2040) provides a comprehensive framework for the development and management of Port Phillip's urban forest. The urban forest encompasses all trees, shrubs, and groundcovers on both public and private land, including gardens, parks, green roofs, and industrial areas. The Urban Forest Strategy highlights the importance of greenery in enhancing quality of life, boosting biodiversity and habitat, reducing air pollution, mitigating heat and flood risks, reducing stormwater costs, and increasing property values. Urban vegetation also creates employment opportunities and can be an important way of reflecting the indigenous landscape of the place.

Developed with community input, the Urban Forest Strategy outlines a vision where vegetation and green spaces are healthy and abundant, biodiversity is valued and supported, and nature connects people.

The Strategy is structured around five guiding principles:

1. Prioritising tree retention and introducing resilient plant species to address climate vulnerabilities.
2. Fostering collaboration among Council, community, and industry partners to care for urban greenery.
3. Emphasising biodiversity and habitat creation.
4. Investing in integrated urban greening across various landscape types.
5. Valuing the urban forest as a long-term asset critical to community well-being and neighbourhood character.

The Strategy also identifies key challenges to a healthy urban forest, such as climate change, urban heat, invasive weeds and plant diseases, human population growth pressures, spatial constraints, and biodiversity loss.

The Strategy offers a comprehensive body of research that supports canopy targets, and details approaches to vegetation diversity, water management and sustainable use of maintenance resources.

This provides the framework within which the Urban Forest Precinct Plans will operate, by honing in to a more detailed, streetscape-scale proposal for improving the urban forest.

The core objectives of the Urban Forest Strategy are:

- Increased canopy cover on public and private land for a liveable, sustainable, equitable and vibrant city.
- A cooler and greener city, which is resilient to more severe weather and changes in rainfall.
- Our community is engaged, trees and plants are valued, and we build partnerships to green our urban environment across all land types.
- A well-managed forest, including healthy trees and tree quality, pest and disease management and succession planning for iconic species and locations.
- A biodiverse urban forest with diverse species, healthy ecosystems, and habitat.

The UFPP supports these objectives by providing details on how to implement increased trees and biodiversity outcomes.



CITY OF PORT PHILLIP HOUSING STRATEGY (2024-2039)

The City of Port Phillip Housing Strategy sets out a 15-year plan to guide housing growth while strengthening resilience, quality of life, and community diversity. It designates areas for substantial, moderate, incremental, and minimal change, aligning with broader Council strategies on transport, economic growth, and sustainability.

UFPP Considerations:

- Areas marked for substantial change, such as the Carlisle Street Major Activity Centre (MAC), present opportunities to integrate street tree planting and urban greening as part of the gradual changes.
- Property consolidation in areas of growth may allow for increased canopy cover through coordinated landscaping and open space initiatives.
- Streets experiencing minimal change provide stability for long-term tree planting and maintenance strategies.

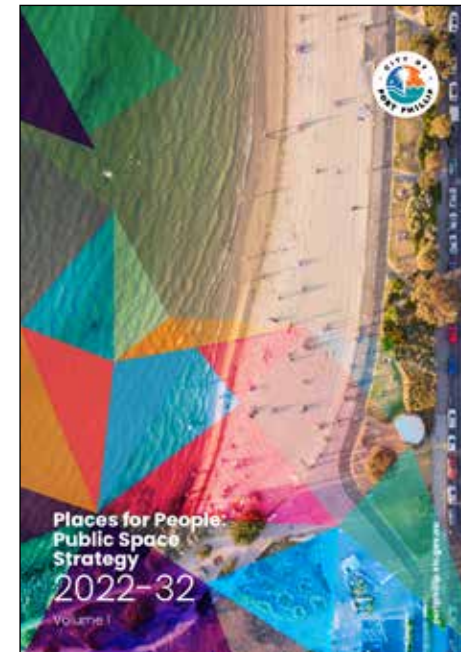


INTEGRATED TRANSPORT STRATEGY (2018-2028)

The Integrated Transport Strategy outlines a 10-year plan to improve transport connections within the City of Port Phillip. It prioritises sustainable and active transport, improves public transport access, and optimises infrastructure to accommodate population growth while preserving quality of life.

UFPP Considerations:

- Streets must balance canopy expansion with maintaining space for trams, buses, active transport and private vehicles.
- Opportunities exist to explore increased tree planting along transport routes identified in the Strategy to encourage cycling, walking and public transport usage across CoPP.
- Where land is not managed by Council such as state roads and rail, the UFPP will identify advocacy opportunities.
- The UFPP informs integrated transport planning by identifying streetscape interventions that enhance safety, shade, cooling, and overall user experience.

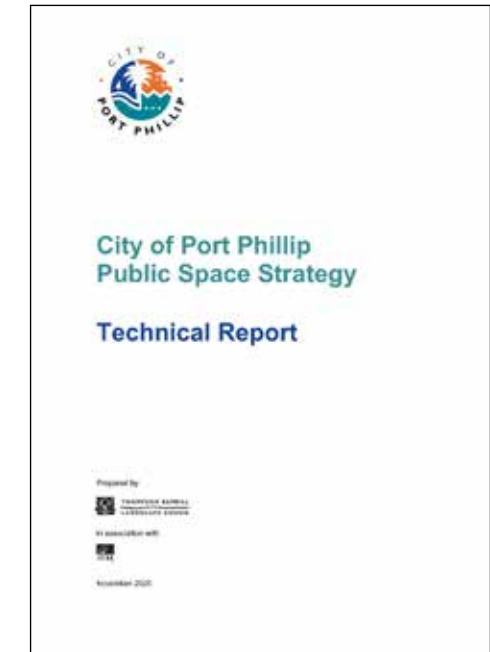


PLACES FOR PEOPLE - PUBLIC SPACE STRATEGY (2022-2032)

The Places for People – Public Space Strategy provides a vision for enhancing public spaces in Port Phillip. It establishes principles ensuring public spaces are equitable, abundant, versatile, and innovative.

UFPP Considerations

- Several streets, including those in the Alma Road and Chapel Street area, are identified for additional street trees to improve canopy cover and pedestrian experience.
- The strategy supports the integration of more tree planting within new public spaces, such as those being acquired by CoPP (e.g., 43 & 49 Pakington Street).
- Opportunities exist to partner with the Southern Metropolitan Cemeteries Trust for additional tree planting and biodiversity improvements.
- Initiatives like temporary street closures (e.g., Dickens Street) and carpark repurposing can provide space for tree canopy enhancements and urban greening.



PUBLIC SPACE STRATEGY - TECHNICAL REPORT (2020)

The Public Space Strategy – Technical Report informed the Public Space Strategy. It assessed current public space provision, identifies future needs, and details guidelines for the equitable and strategic management of open spaces.

UFPP Considerations

- The technical report assists with understanding the broader network of open spaces and how people use and move between them.
- Opportunities exist to uplift the canopy in existing open spaces, as identified in the Report, through targeted tree planting and design interventions.

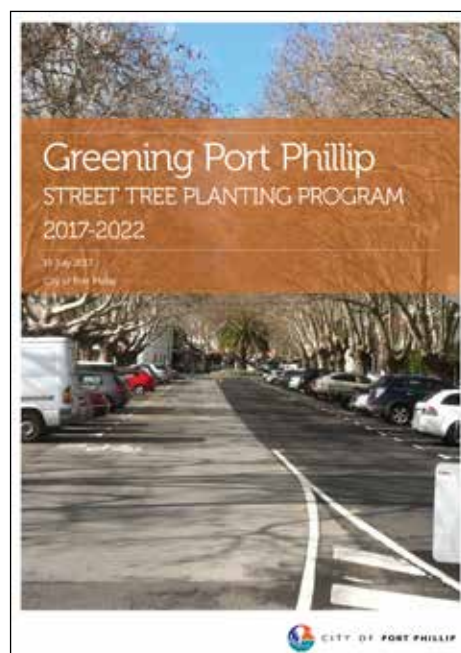


CARLISLE STREET ACTIVITY CENTRE STRUCTURE PLAN, (2009)

The Carlisle Street Activity Centre Structure Plan provides a framework for managing growth in response to economic and lifestyle trends. It aligns with the superceded Melbourne 2030 (now replaced by Plan Melbourne), focusing on increased residential density, a broader mix of activities, and improved public transport and walkability within the activity centre.

UFPP Considerations

- The Structure Plan proposes specific streets for new planting/greening, the UFPP should further support these recommendations.
- Areas that are identified for a greater pedestrian activity may need additional focus on providing shade.



GREENING PORT PHILLIP STREET TREE PLANTING PROGRAM (2017-2022)

The Greening Port Phillip Street Tree Planting Programme outlined a five-year plan to improve the City's urban forest through strategic tree planting. It supports the broader Greening Port Phillip vision by increasing canopy cover, reducing the Urban Heat Island effect, improving biodiversity, and enhancing public amenity.

UFPP Considerations

- The UFPP can support the Programme's goal of increasing canopy cover by integrating tree planting and green infrastructure into developments.
- This strategy provided a detailed tree species list which was used as the starting point for the UFPP species lists.

OTHER RESOURCES

CASE STUDIES

- City of Melbourne & The University of Melbourne. (2020) 'Streetscape biodiversity case study'. Available at: <https://cpb-ap-se2.wpmucdn.com/blogs.unimelb.edu.au/dist/c/359/files/2020/06/Streetscape-Biodiversity-Case-Study.pdf> (Accessed: 12 February 2025)

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