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Notes to the Appendices

These Appendices must be read together with the thesis and two videos, the four parts form the PhD submission.

Sample drawings are used in the A4 thesis, the A3 format allows for enlargements, the original drawings are in A3.

- Appendix A contains extracts from the Society of Society of Automotive Engineers (SAE) Taxonomy for the levels of vehicle automation.
- Appendices B to E contain A3 annotated drawings.
- Appendix C contains reductions of an A0 size drawing and part enlargements of the same drawing re-composed in A3 format for clarity.

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Appendix A. Society of Automotive Engineers Taxonomy: Levels of Vehicle Automation

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1. SCOPE

This document describes [motor] vehicle driving automation systems that perform part or all of the dynamic driving task (DDT) on a sustained basis. It provides a taxonomy with detailed definitions for six levels of driving automation, ranging from no driving automation (Level 0) to full driving automation (Level 5), in the context of [motor] vehicles (hereafter also referred to as “vehicle” or “vehicles”) and their operation on roadways:

Level 0: No Driving Automation

Level 1: Driver Assistance

Level 2: Partial Driving Automation

Level 3: Conditional Driving Automation

Level 4: High Driving Automation

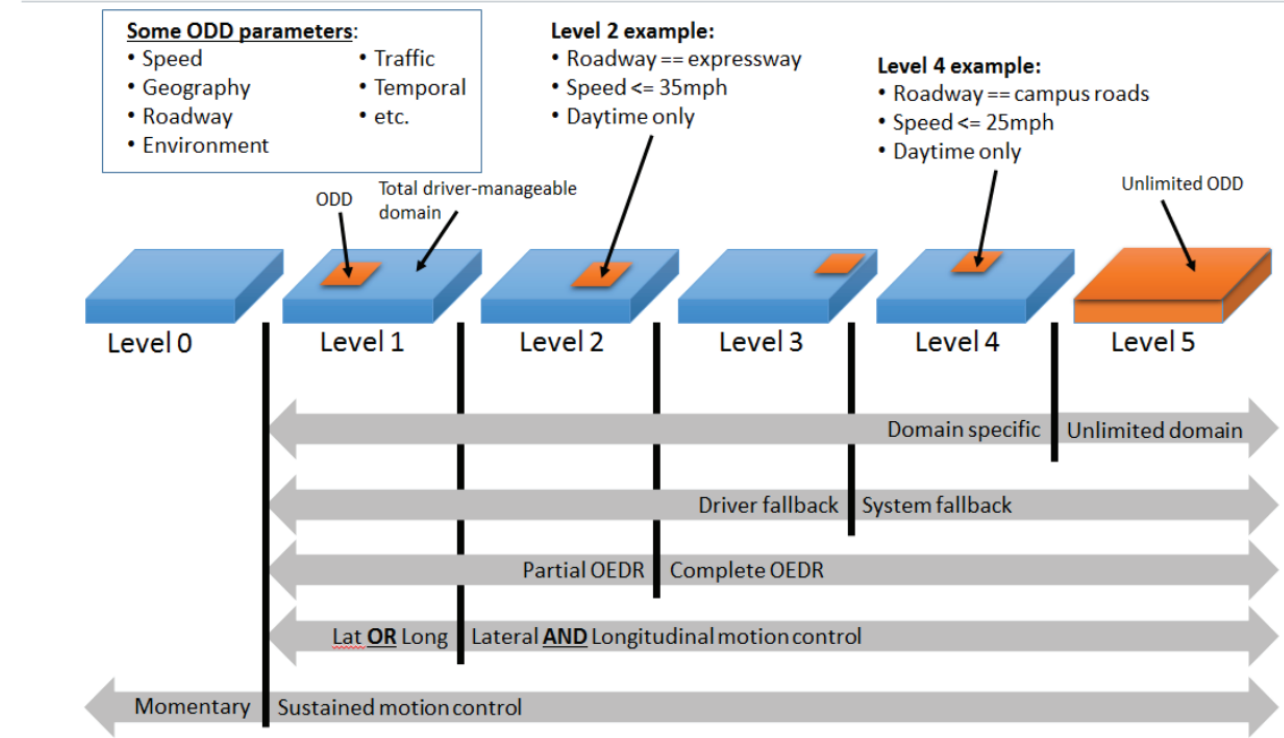
Level 5: Full Driving Automation

These level definitions, along with additional supporting terms and definitions provided herein, can be used to describe the full range of driving automation features equipped on [motor] vehicles in a functionally consistent and coherent manner. “On-road” refers to publicly accessible roadways (including parking areas and private campuses that permit public access) that collectively serve all road users, including cyclists, pedestrians, and users of vehicles with and without driving automation features.

The levels apply to the driving automation feature(s) that are engaged in any given instance of on-road operation of an equipped vehicle. As such, although a given vehicle may be equipped with a driving automation system that is capable of delivering multiple driving automation features that perform at different levels, the level of driving automation exhibited in any given instance is determined by the feature(s) that are engaged.

This document also refers to three primary actors in driving: the (human) user, the driving automation system, and other vehicle systems and components. These other vehicle systems and components (or the vehicle in general terms) do not include the driving automation system in this model, even though as a practical matter a driving automation system may actually share hardware and software components with other vehicle systems, such as a processing module(s) or operating code.

The levels of driving automation are defined by reference to the specific role played by each of the three primary actors in performance of the DDT and/or DDT fallback. “Role” in this context refers to the expected role of a given primary actor, based on the design of the driving automation system in question and not necessarily to the actual performance of a given primary actor. For example, a driver who fails to monitor the roadway during engagement of a Level 1 adaptive cruise control (ACC) system still has the role of driver, even while s/he is neglecting it.



App. Fig. 1. The SAE diagram of the operational design domain (ODD) relative to driving automation.

Level 5 - Full Driving Automation	<p><i>Driver/dispatcher</i> (while the ADS is not engaged):</p> <ul style="list-style-type: none"> Verifies <i>operational</i> readiness of the ADS-equipped vehicle ⁽¹⁾ Determines whether to engage the ADS Becomes a <i>passenger</i> when the ADS is engaged only if physically present in the vehicle <p><i>Passenger/dispatcher</i> (while the ADS is engaged):</p> <ul style="list-style-type: none"> Need not perform the DDT or DDT fallback Need not determine whether and how to achieve a <i>minimal risk condition</i> May request that the ADS disengage and may achieve a <i>minimal risk condition</i> after it is disengaged May become the <i>driver</i> after a requested disengagement 	<p>ADS (while not engaged):</p> <ul style="list-style-type: none"> Permits engagement of the ADS under all <i>driver-manageable</i> on-road conditions <p>ADS (while engaged):</p> <ul style="list-style-type: none"> Performs the entire DDT Performs DDT fallback and transitions automatically to a <i>minimal risk condition</i> when: <ul style="list-style-type: none"> A DDT performance-relevant system failure occurs or A user requests that it achieve a <i>minimal risk condition</i> Disengages, if appropriate, only after: <ul style="list-style-type: none"> It achieves a <i>minimal risk condition</i> or A driver is performing the DDT May delay a user-requested disengagement
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App. Fig. 2. The SAE Level 5 Full Driving Automation classification.

Active safety systems, such as electronic stability control (ESC) and automatic emergency braking (AEB), and certain types of driver assistance systems, such as lane keeping assistance (LKA), are excluded from the scope of this driving automation taxonomy because they do not perform part or all of the DDT on a sustained basis, but rather provide momentary intervention during potentially hazardous situations. Due to the momentary nature of the actions of active safety systems, their intervention does not change or eliminate the role of the driver in performing part or all of the DDT, and thus are not considered to be driving automation, even though they perform automated functions. In addition, systems that inform, alert, or warn the driver about hazards in the driving environment are also outside the scope of this driving automation taxonomy, as they neither automate part or all of the DDT, nor change the driver's role in performance of the DDT (see 8.13).

It should be noted, however, that crash avoidance features, including intervention-type active safety systems, may be included in vehicles equipped with driving automation systems at any level. For automated driving system (ADS) features (i.e., Levels 3 to 5) that perform the complete DDT, crash mitigation and avoidance capability is part of ADS functionality (see also 8.13).

P29 Table 2 Roles of human user and driving automation by level of driving automation

6. SIGNIFICANCE OF OPERATIONAL DESIGN DOMAIN (ODD)

Conceptually, the role of a driving automation system vis-à-vis a user in performance of part or all of the DDT is orthogonal to the specific conditions under which it performs that role. For example, a specific implementation of adaptive cruise control may be intended to operate only at high speeds, only at low speeds, or at all speeds. For simplicity, however, this taxonomy collapses these two axes into a single set of levels of driving automation. Levels 1 through 4 expressly contemplate ODD limitations. In contrast, Level 5 (like Level 0) does not have ODD limitations (subject to the discussion in 8.8). Accordingly, accurately describing a feature (other than at Levels 0 and 5) requires identifying both its level of driving automation and its operational design domain (ODD). As provided in the definitions above, this combination of level of driving automation and ODD is called a usage specification, and a given feature satisfies a given usage specification. Because of the wide range of possible ODDs, a wide range of possible features may exist at each level (e.g., Level 4 includes parking, high-speed, low-speed, geo-fenced, etc.). For this reason, this taxonomy provides less detail about the ODD attributes that may define a given feature than about the respective roles of a driving automation system and its user.

ODD is especially important to understanding why a given ADS is not Level 5 merely because it operates an ADS-dedicated vehicle. Unlike a Level 5 ADS, a Level 3 or 4 ADS has a limited ODD. Geographic, speed, environmental or other ODD restrictions on an ADS-DV may reflect technological limitations of its ADS, or they may reflect vehicle design limitations

P34 7.1.1 Autonomous

This term has been used for a long time in the robotics and artificial intelligence research communities to signify systems that have the ability and authority to make decisions independently and self-sufficiently. Over time, this usage was casually broadened to not only encompass decision making, but to represent the entire system functionality, thereby becoming synonymous with automated. This usage obscures the question of whether a so-called “autonomous vehicle” depends on communication and/or cooperation with outside entities for important functionality (such as data acquisition and collection). Some driving automation systems may indeed be autonomous if they perform all of their functions independently and self-sufficiently, but if they depend on communication and/or cooperation with outside entities, they should be considered cooperative rather than autonomous. Some vernacular usages associate autonomous specifically with full driving automation (Level 5), while other usages apply it to all levels of driving automation, and some state legislation has defined it to correspond approximately to any ADS at or above Level 3 (or to any vehicle equipped with such an ADS).

Additionally, in jurisprudence, autonomy refers to the capacity for self-governance. In this sense, also, “autonomous” is a misnomer as applied to automated driving technology, because even the most advanced ADSs are not “self-governing.” Rather, ADSs operate based on algorithms and otherwise obey the commands of users.

For these reasons, this document does not use the popular term “autonomous” to describe driving automation.

7.2 Automated or Autonomous Vehicle

This document recommends against using terms that make vehicles, rather than driving, the object of automation, because doing so tends to lead to confusion between vehicles that can be operated by a (human) driver or by an ADS and ADS-DVs, which are designed to be operated exclusively by an ADS. It also fails to distinguish other forms of vehicular automation that do not involve automating part or all of the DDT. Moreover, a given vehicle may be equipped with a driving automation system that is capable of delivering multiple driving automation features that operate at different levels; thus, the level of driving automation exhibited in any given instance is determined by the feature(s) engaged. As such, the recommended usage for describing a vehicle with driving automation capability is “Level [1 or 2] driving automation system-equipped vehicle” or “Level [3, 4, or 5] ADS-equipped vehicle.” The recommended usage for describing a vehicle with an engaged system (versus one that is merely available) is “Level [1 or 2] driving automation system-engaged vehicle” or “Level [3, 4, or 5] ADS-operated vehicle.”

Appendix B. Symposium speakers list

SYMPOSIUM 1 – Communications for the future CAREV vehicle in the urban context.

1. Dr Jon Goodbun
2. Dr Artur Mausbach
3. Andrew Collison – design strategist at Land Rover UK

SYMPOSIUM 2 – Transfiguration or chaos

1. Dr Adam Kaasa

Dr Adam Kaasa is a Senior Tutor (Research) in the RCA School of Architecture. He is Programme Lead MRes RCA: Architecture Pathway and Liaison Tutor Critical & Historical Studies. Adam's work moves between urban theory, facilitation and performance. As an interdisciplinary scholar he specialises in the intersection of culture, history and inequality in the city, foregrounding the role of architecture and design. <https://www.rca.ac.uk/more/staff/dr-adam-kaasa/>

2. Despina Papadopoulos

Despina Papadopoulos is a researcher and designer whose work is concerned with the move towards disembodiment and the taming of materiality, the me-not-me of machine - body assemblages and the space where embodied cognition meets machine learning. Her pioneering work in wearable technology and e-textiles has resulted in collaborations with a wide range of organisations, such as Ralph Lauren Innovation, Lubrizol Material Sciences, Nivea Research, and NCR, and it forms the basis of her practice led - PhD research at the Royal College of Art, supported by a National Productivity and Investment Fund AHRC scholarship. She has taught at NYU's Interactive Telecommunications Program for 14 years and is a founding faculty member of SVA's Design for Social Innovation MFA. <https://pixelpetty.com/>, <http://principled-design.com/>

3. Dr Chris Thorpe

Dr Chris Thorpe is Acting Head of Program intelligent Mobility, RCA School of Design. He also the Director of Intelligent Design Associates Limited, established in 2011, which is a strategic interdisciplinary 3D design studio focussed on the commercial ethical - technical design space. Chris's practice and research interests span sustainable products and system design, as well as the paradigm of new technology and its relevance to human culture, experience and value. <https://www.rca.ac.uk/more/staff/dr-chris-thorpe/>

4. Kam Rehal

Kam Rehal is Senior Lecturer and Programme Leader of Graphic and Digital Design at the School of Design, University of Greenwich, and a PhD candidate at the RCA School of Communication. His research interrogates emerging perspectives of place encountered within the current social and political context and questions the role and responsibility of the subjective researcher within local communities. Prior to his academic appointment, he led the graphic design team of the Natural History Museum and was senior designer at Imperial War Museums. More recently, he designed, co-edited and contributed works to the flash fiction collection 'Story Cities: A City Guide for the Imagination' – engaging the physical printed book to facilitate reading as a narrative spatial practice.

SYMPOSIUM 3 – Synthetic chatter or lifesaving semiotics

1. Greg Frey

Greg Frey is an environmental activist based in the UK. He has helped organise and participated in Extinction Rebellion and Insulate Britain protests, and he is currently supporting Just Stop Oil. He has written about democracy, climate and protest for The Trouble, Novara Media and other outlets.

2. Dr Susan Young

Susan Young is currently exploring the therapeutic potential of animation in relation to psychological trauma at the Royal College of Art through a practice-based research degree. Her films, title sequences, music videos and commercials have been screened extensively at international film festivals and on television, and she has regularly been called on to judge films in competitions at animation festivals worldwide. <https://www.rca.ac.uk/students/susan-young/>

3. Kam Rehal

SYMPOSIUM 4 – Mobility metamorphosis

1. Professor Dale Harrow – <https://www.rca.ac.uk/more/staff/professor-dale-harrow/>
2. Dr Artur Mausbach
3. Dr Jon Goodbun
4. Daniel Sjöholm – Einride – <https://www.rca.ac.uk/students/daniel-sjoholm/>
5. Casey Hyun – Incheon National University – <https://good-design.org/ambassadors/casey-hyun/>
6. Laura Ferrarello – RCA1.2 – <https://www.researchgate.net/profile/Laura-Ferrarello>
7. Orla Fahey – RCA – <https://research-biennale.rca.ac.uk/projects/how-can-design-improve-the-safety-of-the-vulnerable-road-user-in-london>
8. Stephanie Sherman – <https://stephaniesherman.info/>
9. Julian Siravo – Autonomy – <https://www.rca.ac.uk/students/julian-siravo/>
10. Tatseng Chiam – Tandem – <https://zincvc.medium.com/how-tandem-is-working-towards-ending-transport-poverty-e872d93b5c10>
11. Professor Roberto Rocco – TU Delft – <https://robertorocco.com/>
12. Dr Luke Harmer – Loughborough University – <https://www.lboro.ac.uk/schools/design-creative-arts/people/luke-harmer/>
13. Dr Katia Canova – Quapa USP – <https://researchid.co/katia.canova>
14. Robin Severs – RCA – <https://www.rca.ac.uk/students/robin-severs/>
15. Lizete Druka – Volvo – <https://cargocollective.com/lizetedruka/About-Lizete-Druka>
16. Professor Antti Ahlava – <https://research.aalto.fi/en/persons/antti-ahlava>
17. Dan Phillips – RCA – <https://www.rca.ac.uk/more/staff/dan-phillips/>
18. Dr Robert Phillips – RCA – <https://www.rca.ac.uk/more/staff/dr-rob-phillips/>
19. Charles Morgan – RCA – <https://www.researchgate.net/profile/Charles-Morgan-11>
20. Niel Brooker – BMW Designworks – <https://www.bmwgroupdesignworks.com/people/neil-brooker/>

SYMPOSIUM 5 – Beyond justice

1. Gareth Collins

Gareth is the director for urban design at Transport for NSW, a landscape architect and an urban designer. He has worked for transport authorities in Australia and Scotland and in private practice in the UK. He is a Fellow of the Australian Institute of Landscape Architects and a Recognised Urban Design Practitioner.

2. Dr Timea Nochtá (she/her)

Timea is a Lecturer (Assistant Professor) at the Institute of Local Government Studies at the University of Birmingham. Her research focuses on networks and governance in urban policy and implementation relating to technological change, especially decarbonisation and digitalisation. She has an interdisciplinary background rooted in architecture and public policy, with additional training in urban geography. Her recent work includes studies on the governance of sustainability transitions in energy and transport as well as digitalisation and digital twins in smart cities. Online CV: <https://www.birmingham.ac.uk/staff/profiles/gov/nochta-timea.aspx>

3. Dan Phillips – RCA – <https://www.rca.ac.uk/more/staff/dan-phillips/>

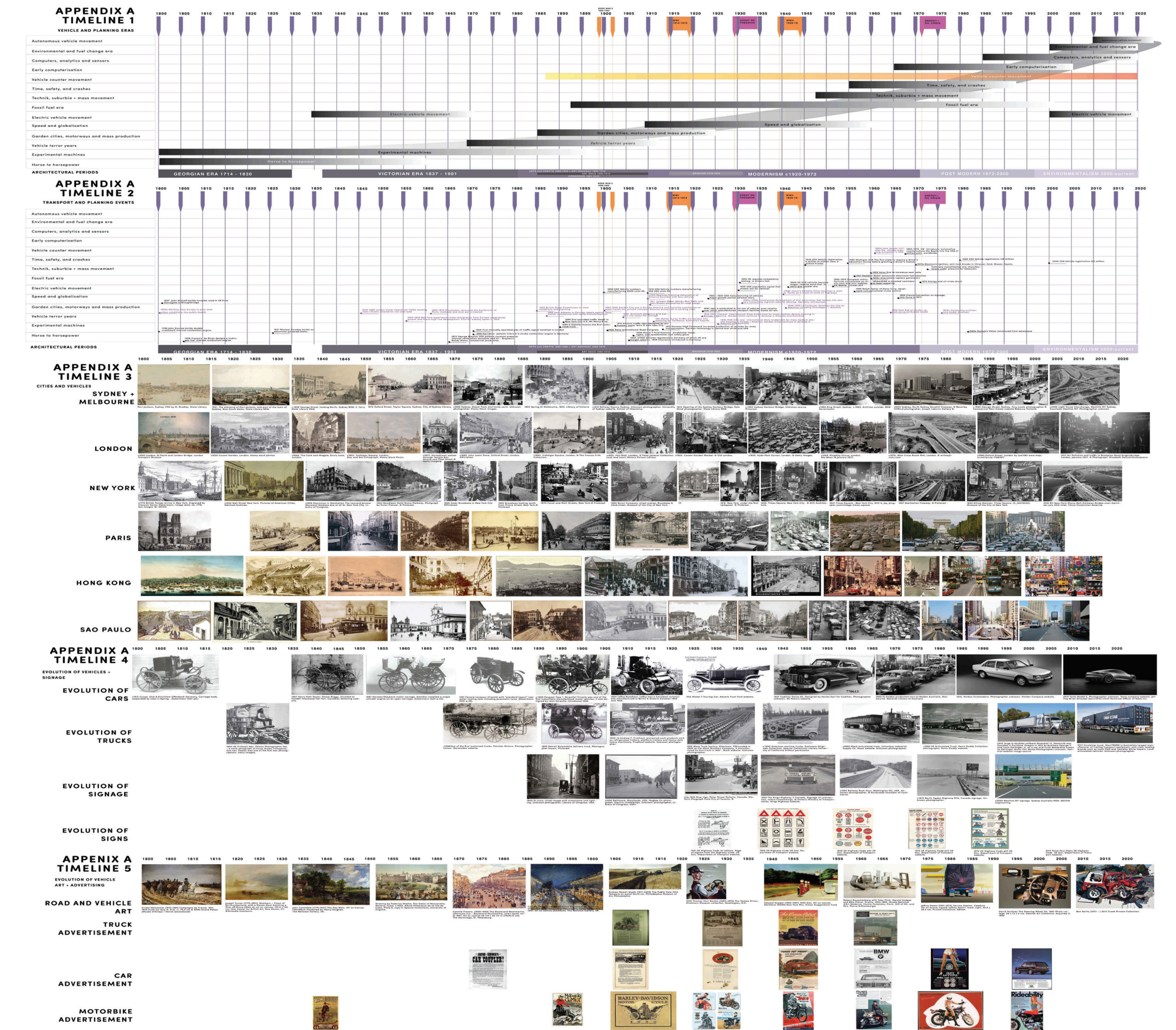
Dan Phillips is a Senior Research Fellow at the Royal College of Art. He is a designer and engineer with 30 years of experience in developing innovative environments, products and services. <https://www.rca.ac.uk/more/staff/dr-rob-phillips/>

Appendix C. Vehicles, the city and semiotics - a visual taxonomy

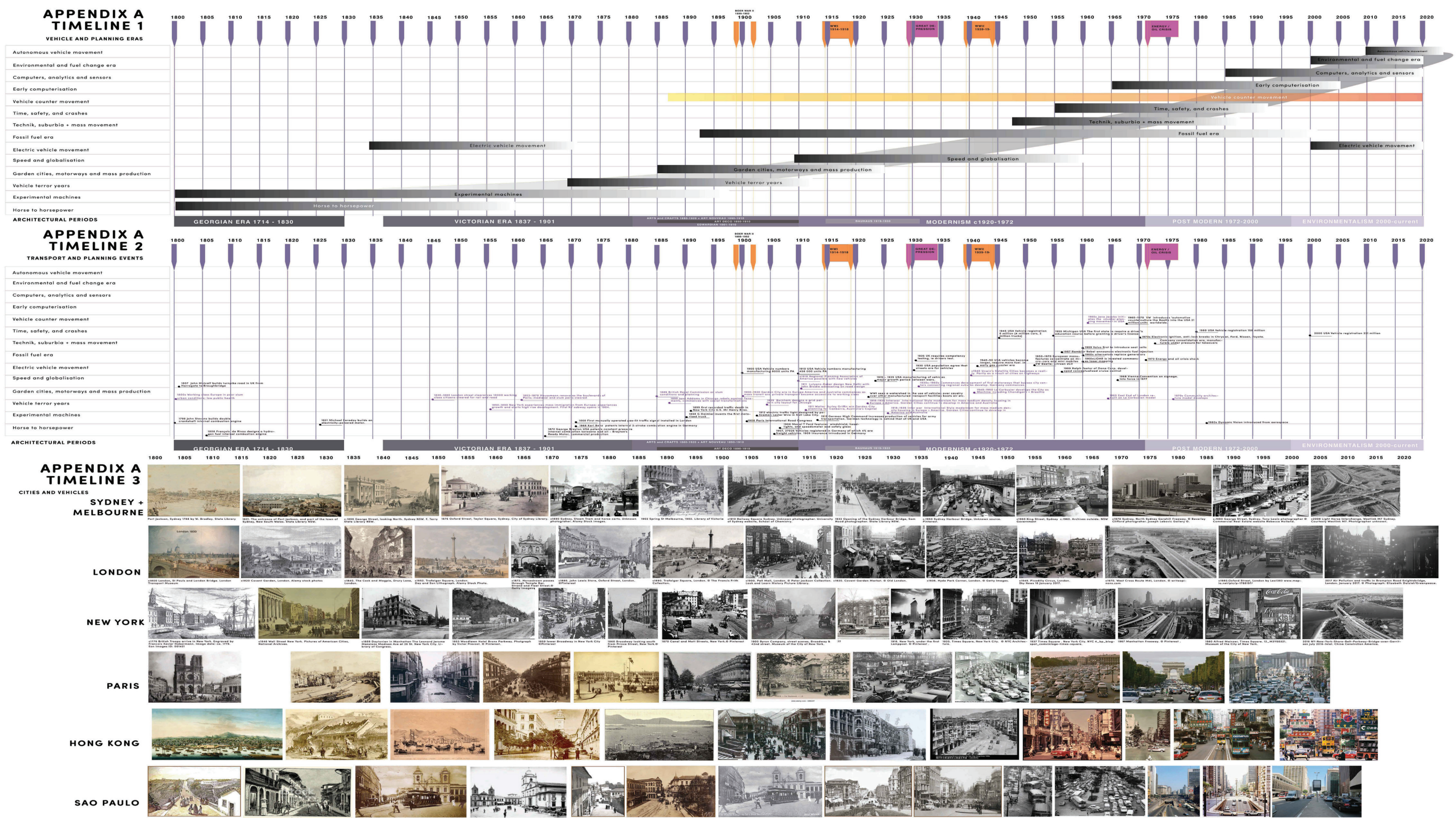
The taxonomy of vehicles and the city is a visual chronology of the relationship between vehicles, vehicle technology, city aesthetics, semiotics and art from 1800 to 2000.

- 'Timeline 1 - Vehicle and planning eras' explores the evolution of major technological developments, such as the transition from cart to motorised vehicle, computerisation and AVs.
- 'Timeline 2 - Transport and planning events' chronologically maps major planning evolution and vehicle interactions.
- 'Timeline 3 - Cities and vehicles' shows the photographic taxonomy of the cities of Sydney and Melbourne, London, Paris, Hong Kong and Sao Paolo, which reveals the reach of vehicle globalisation from early in the twentieth century. The photographs span approximately 30-year intervals as a visual depiction of the evolution of vehicles and the city.
- 'Timeline 4 - Evolution of vehicles + signage' illustrates photographic taxonomy of vehicle development, which is often depicted alone. Here, the photographic taxonomy of vehicles is seen together with city photographs showing the aesthetic fashions, trends and aesthetic influence of car and truck evolution in cities as a composite along with semiotic developments.
- 'Timeline 5 - Evolution of vehicle art + advertising' explores the evolving relationship between art, vehicles and the city through paintings and advertisements of vehicles as a commercial phenomenon.

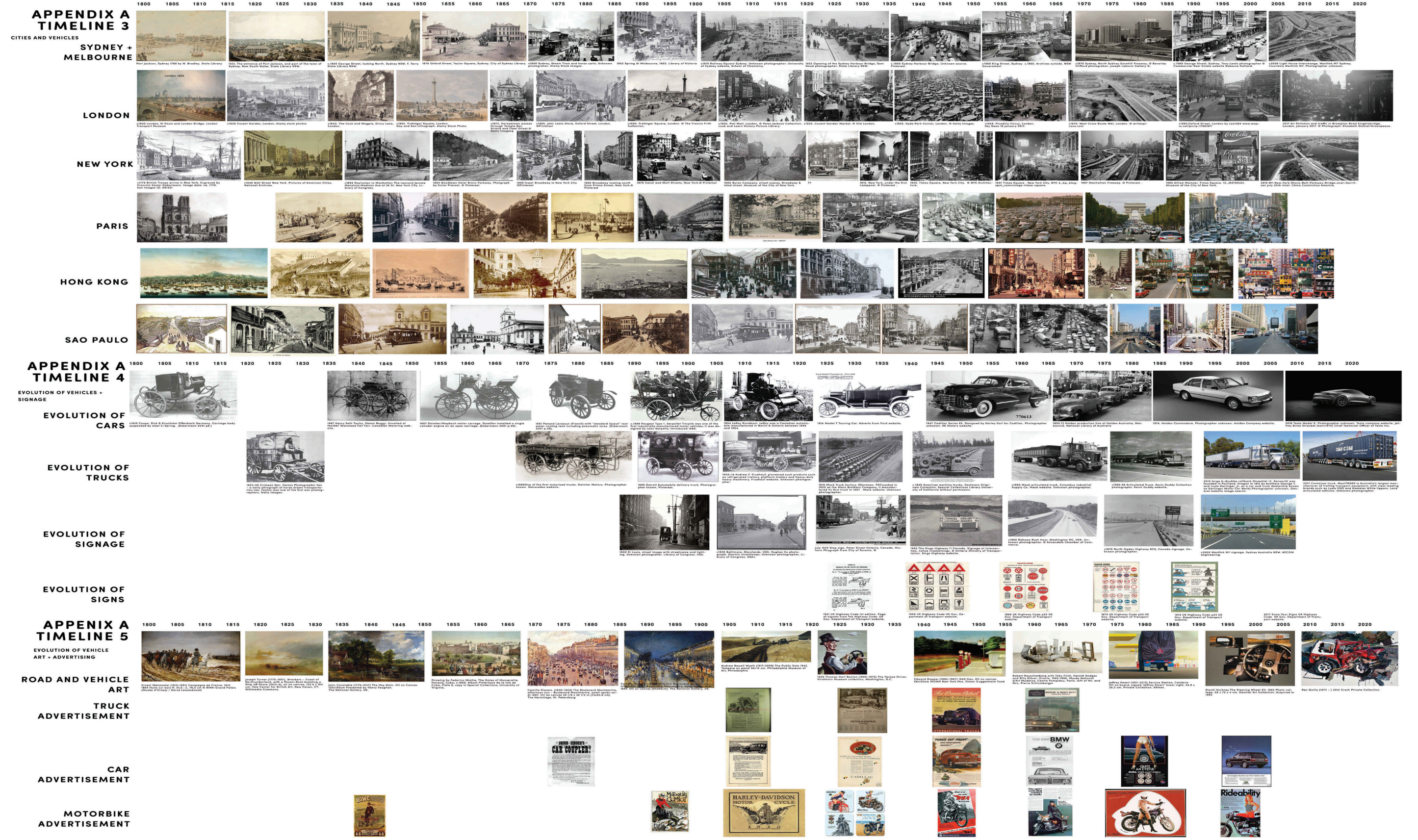
This taxonomy is a visual tool to understand the evolution of vehicles, the city and semiotics as an aesthetic contribution - that is, to provide a holistic appreciation of a selected view of the evolution of the combined effects. It was used throughout the research as part of the Capra-Luisi framework to appreciate systemic evolution.



App. Fig. 3. The chronology of vehicles, the city and semiotics - a visual taxonomy (original A0 drawing).



App. Fig. 4. Details of Timelines 1, 2 and 3 on the chronology of vehicles, the city and semiotics – a visual taxonomy.



App. Fig. 5. Details of Timelines 1, 2 and 3 on the chronology of vehicles, the city and semiotics – a visual taxonomy.

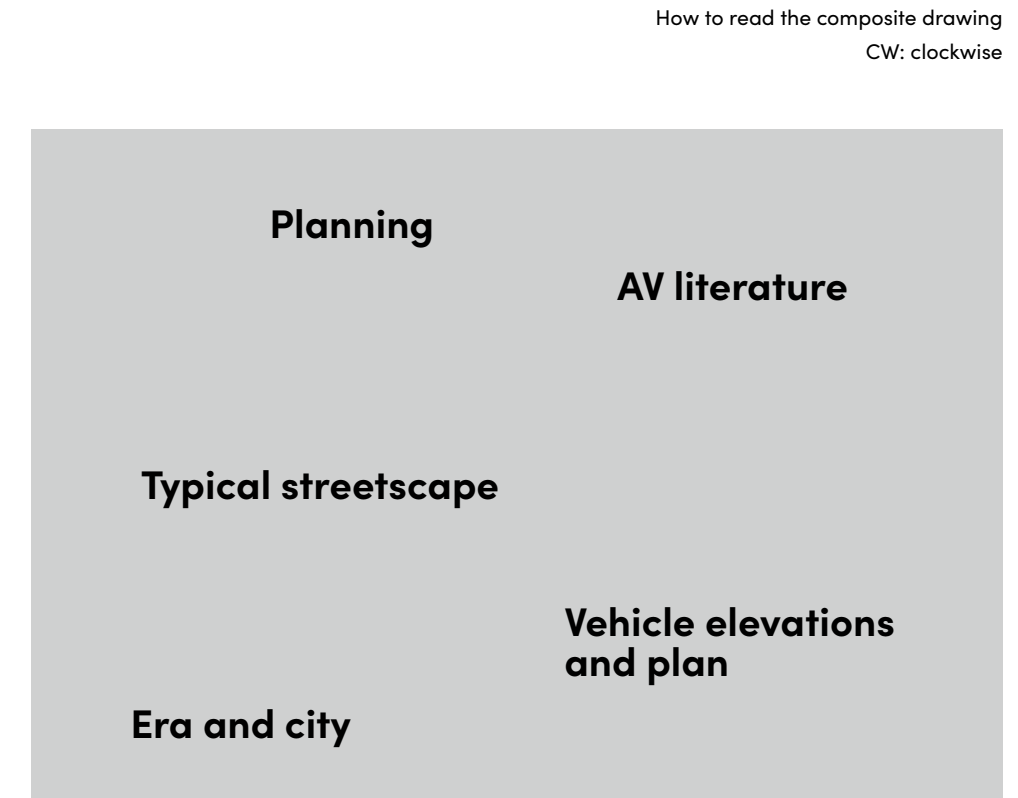
Appendix D. Composite taxonomy of the cities, vehicles, semiotics and AV film

The aesthetic taxonomy drawings provide a visual comparative analysis of the aesthetics. These hand drawings are selected composites forming a visual synthesis. They categorise aesthetic eras showing the evolution of the city, the vehicle, people, semiotics and AV literature published in the associated period. The hand drawing methods of Francis Ching and Barrie Biermann are referenced in the drawing style.

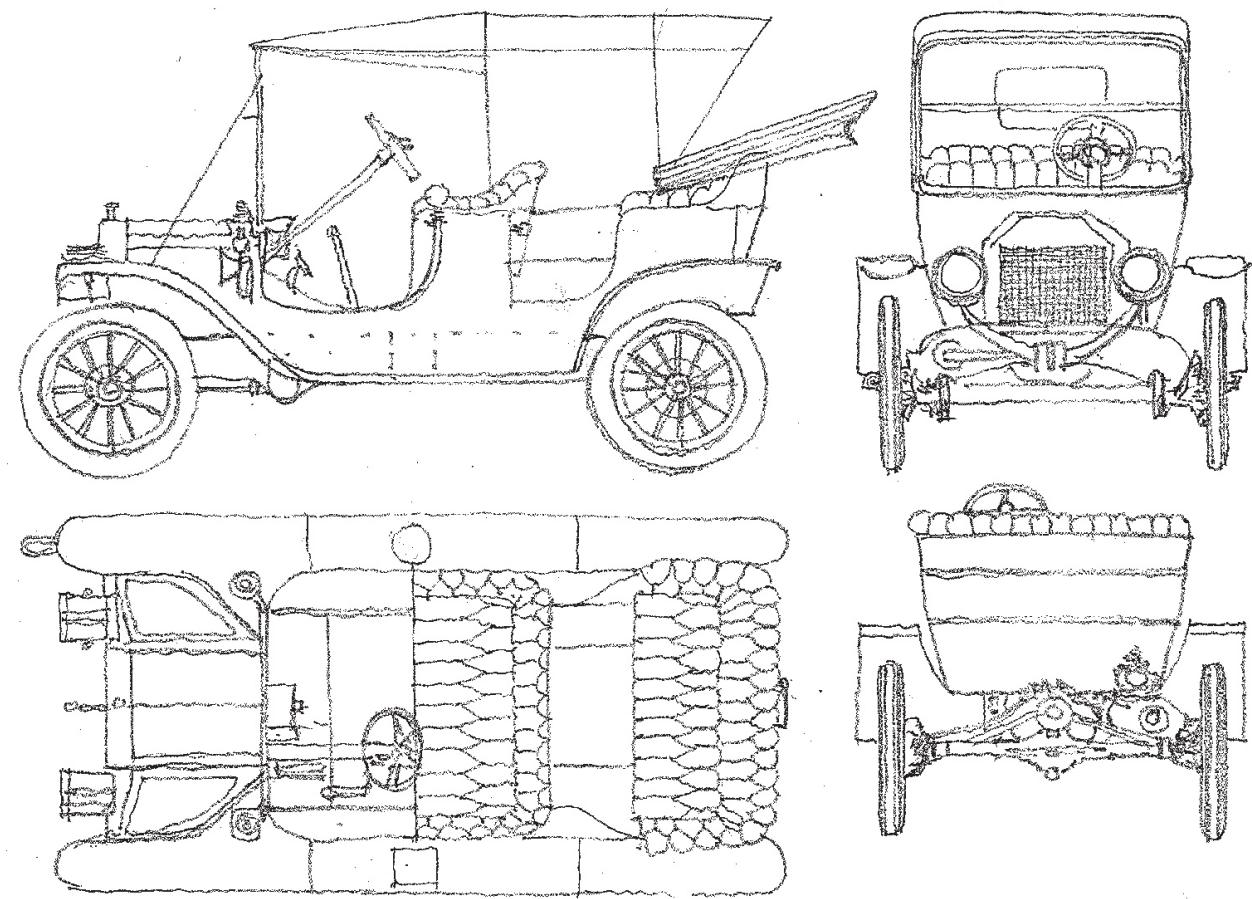
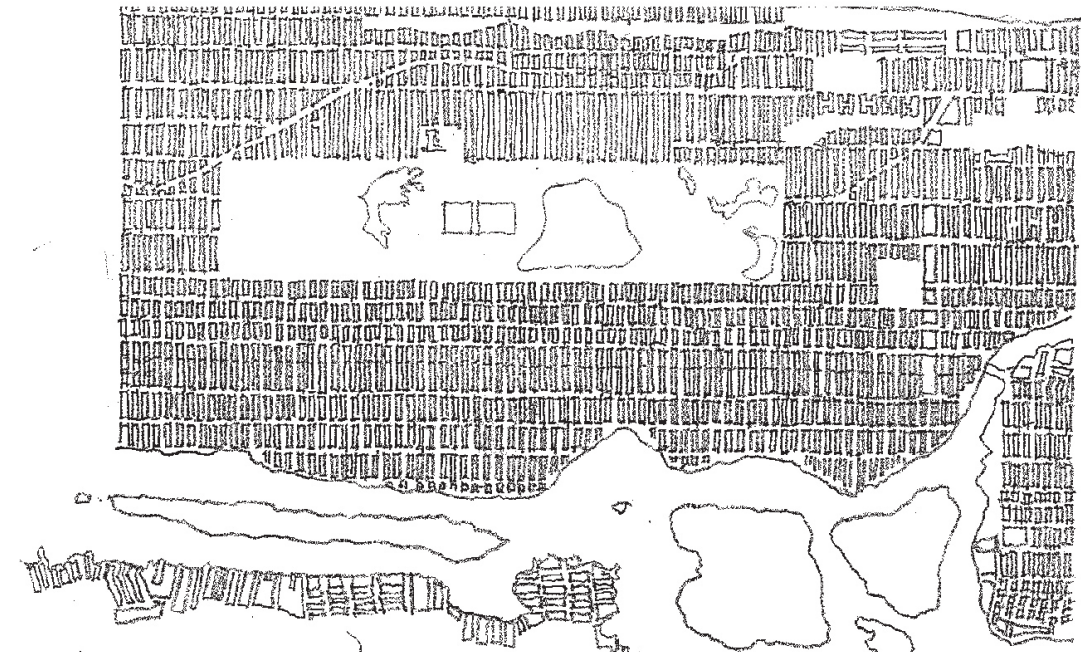
The composite taxonomy drawings explore the aesthetic patterns that exist among vehicles, cities and people. The patterns establish similarities and differences in the linguistic/stylistic conventions of the period as a trend in globalisation. Additionally, they assist in identifying specific periods across multiple research disciplines, including planning, AV literature, typical streetscapes and vehicle design, as a systemic approach.

The trends in architecture, vehicle design and planning demonstrate architectural and design influences that spread across the world as part of globalisation.

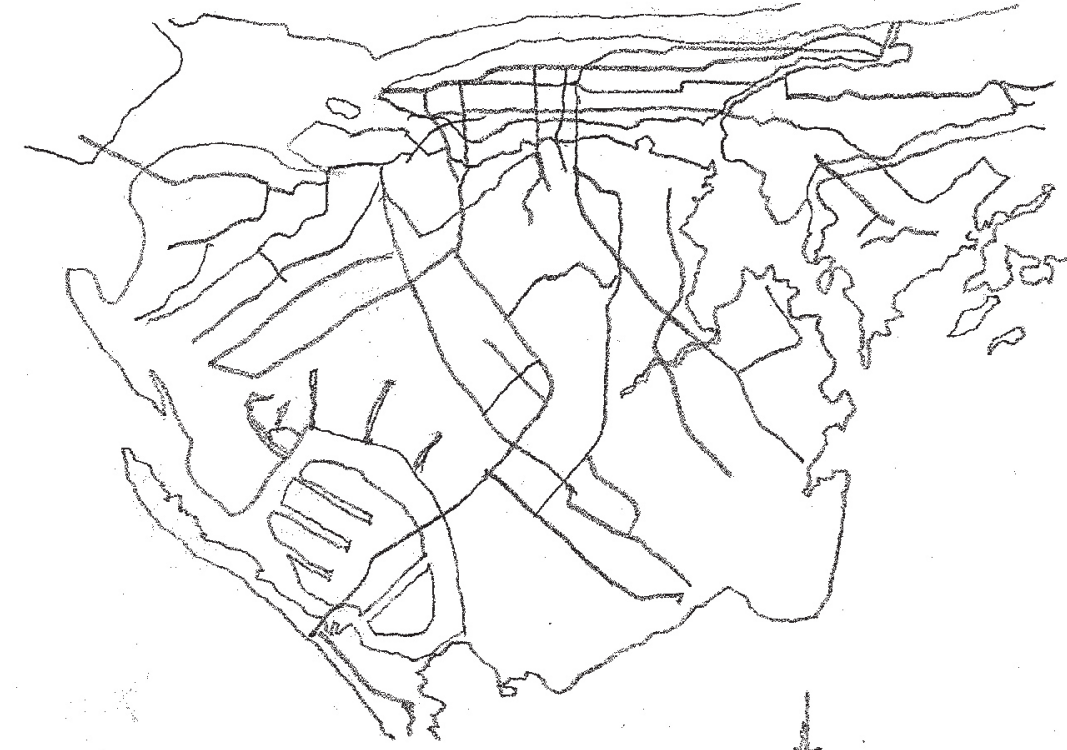
Stop motion animations (AV literature) have facilitated a new interest in the depiction of AV. There is a noticeable similarity in the architecture of the 1930s and vehicle designs of the era for example.



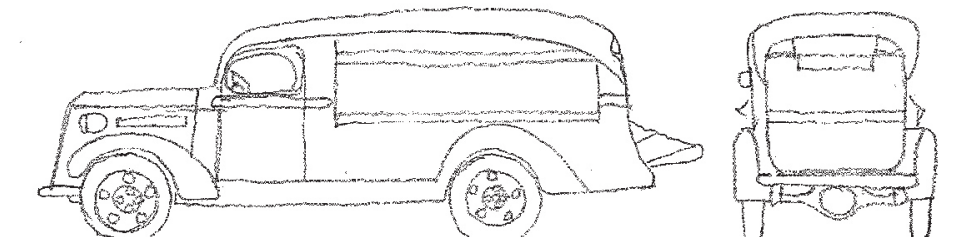
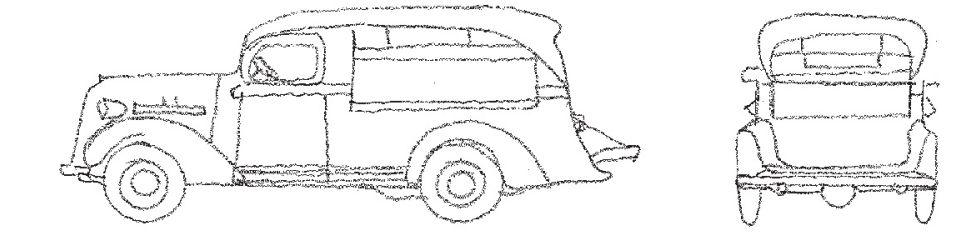
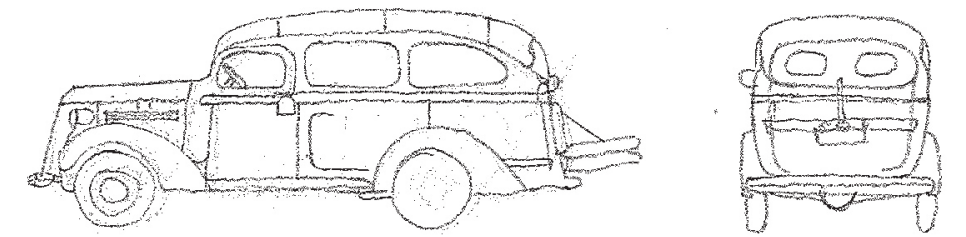
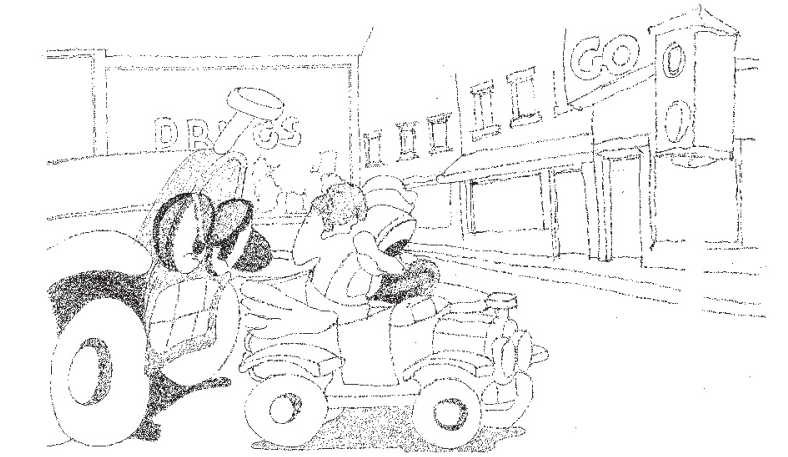
App. Fig. 6. Composite drawing of the aesthetic taxonomy of vehicles and the city – Sydney c. 1870.
CW: 1867 Map of Sydney and surrounds from National Library of Australia. Antoine Galland. 1840. 'Contes Arabes, Les Mille et Une Nuits'. Paris.
Various Coach drawn by 6 horses. F Terry. 1858. 'George Street, Sydney Looking north c 1855) State Library NSW.

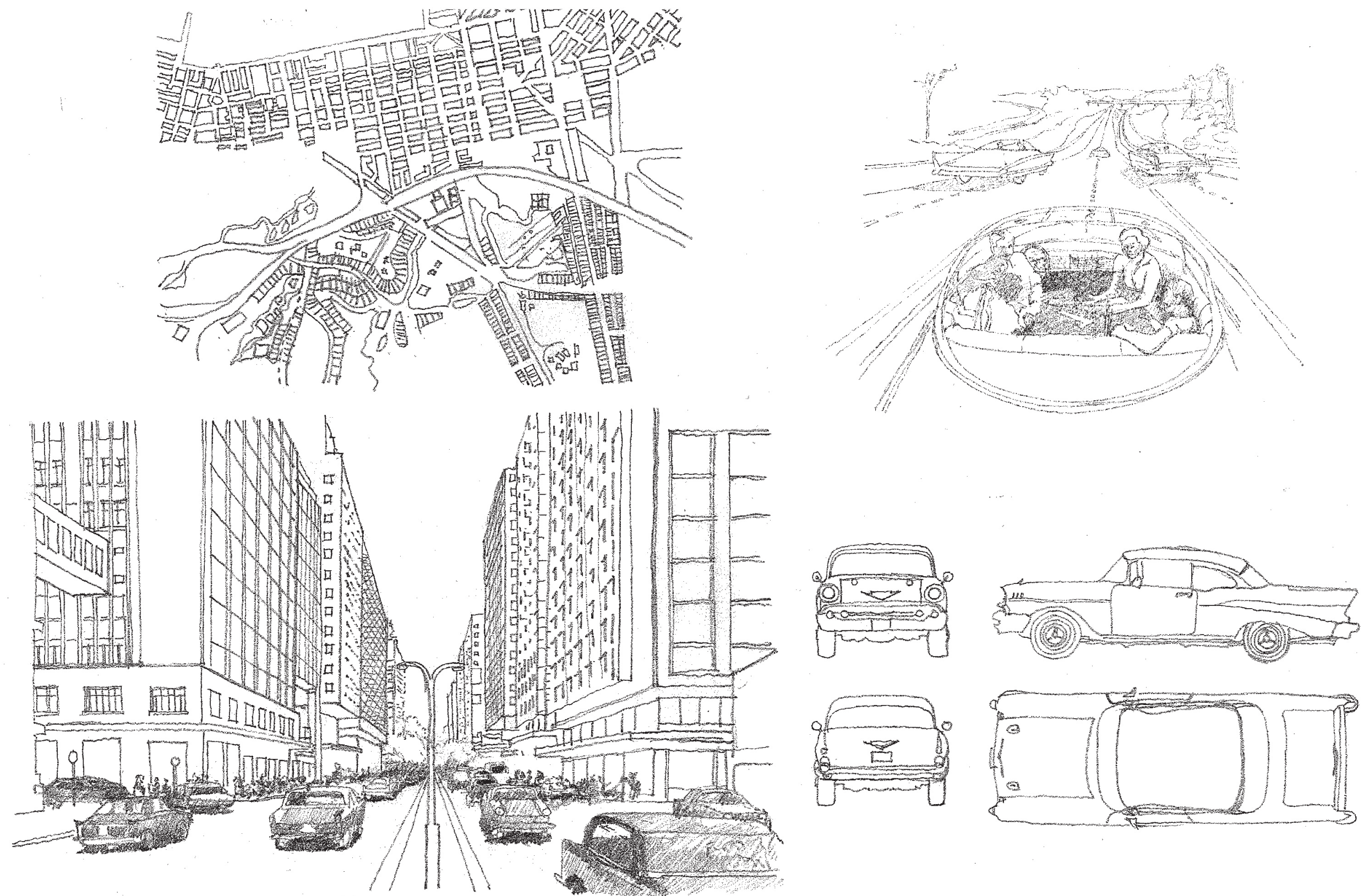


App. Fig. 7. Composite drawing of the aesthetic taxonomy of vehicles and the city – New York c. 1900.
 CW: A 1938 map of Manhattan, New York LETTS North Web. Technical drawing of Ford Model T. 1903. 'George Street, Sydney Looking north c 1855)
 State Library NSW. Model T Ford outside a New York apartment block.

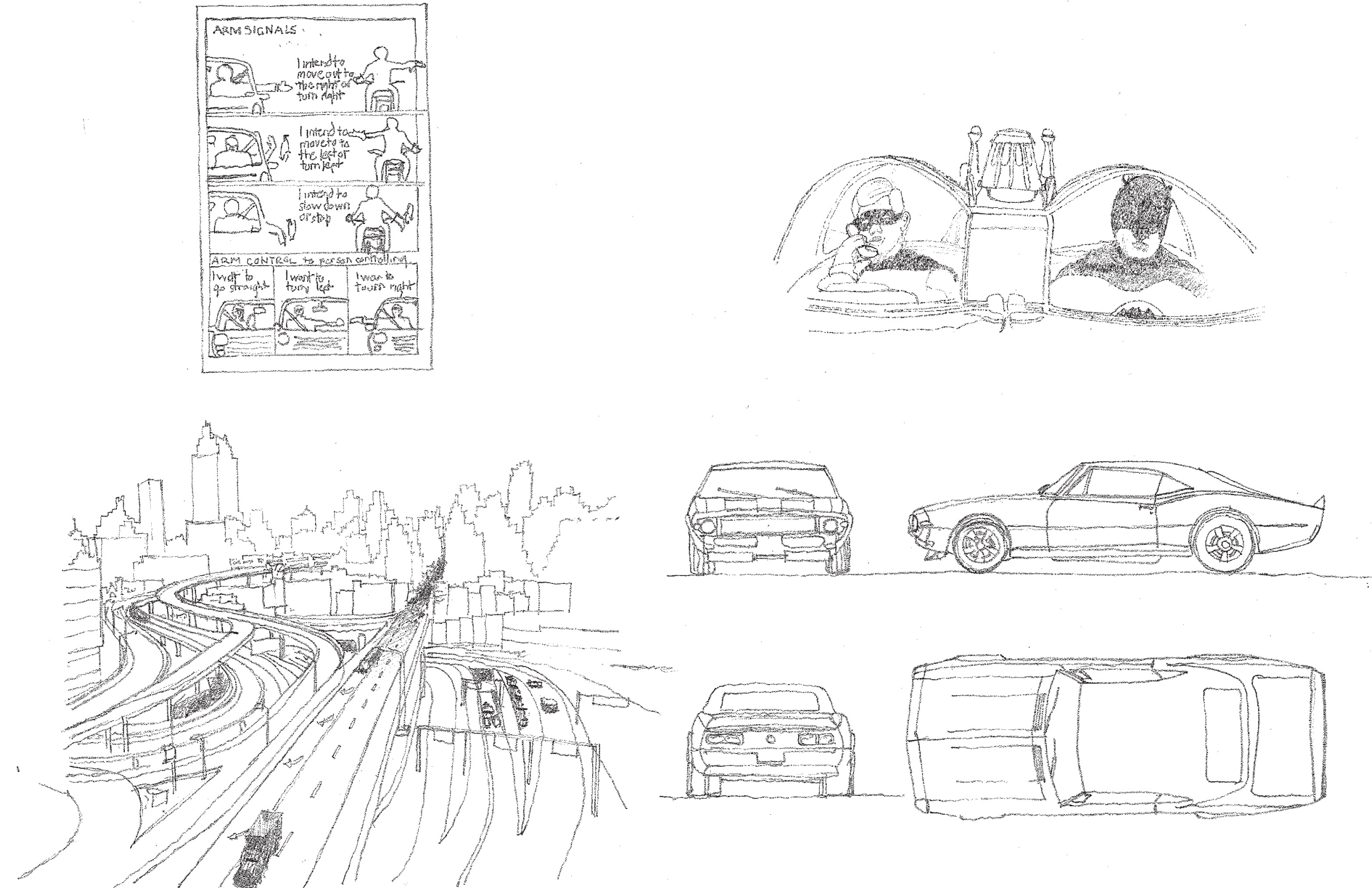


App. Fig. 8. Composite drawing of the aesthetic taxonomy of vehicles and the city – New York c. 1930.
 CW: In 1920, the Board of Transportation of the City of New York proposed additional rapid transit and proposed vehicle tunnels. Ub Iwerks. 1930. 'The New Car'. Ub Iwerks. An autonomous vehicle in one of the first stop motion animations. A 1938 Chevrolet Carryall Suburban, Half - Ton Canopy Express and Ton Canopy Express. Times Square with Chevy advert in 1938.

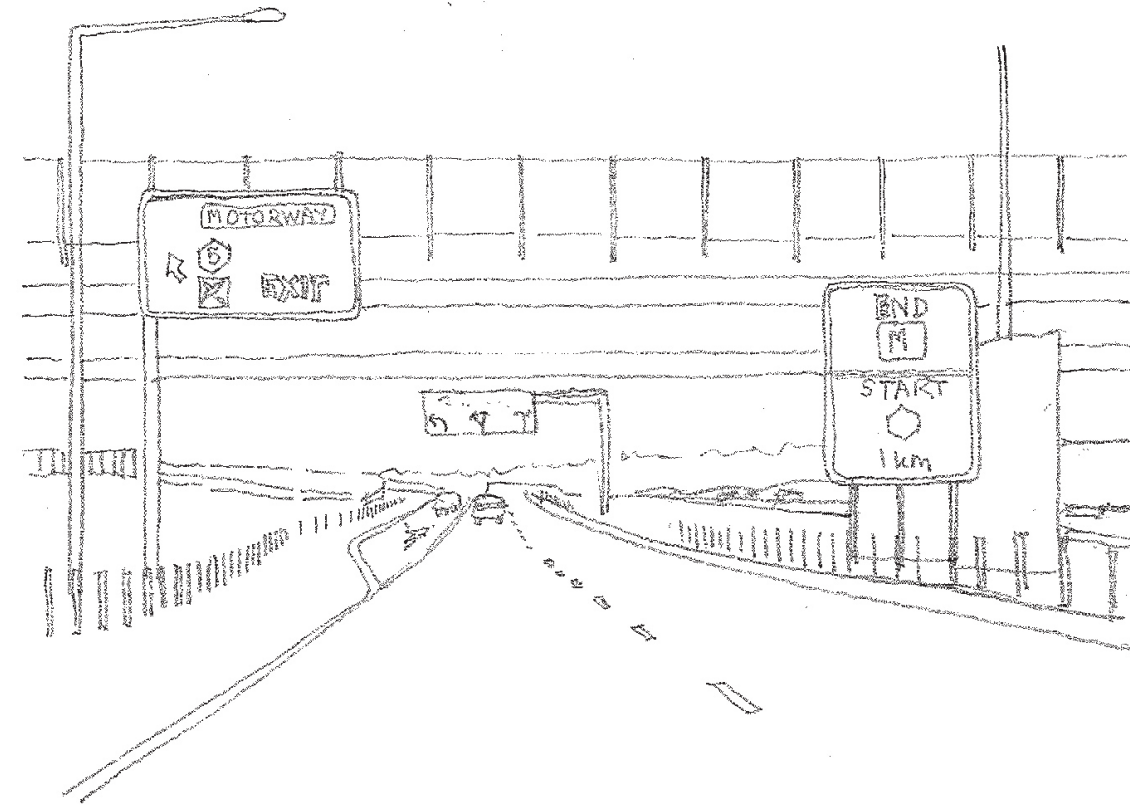




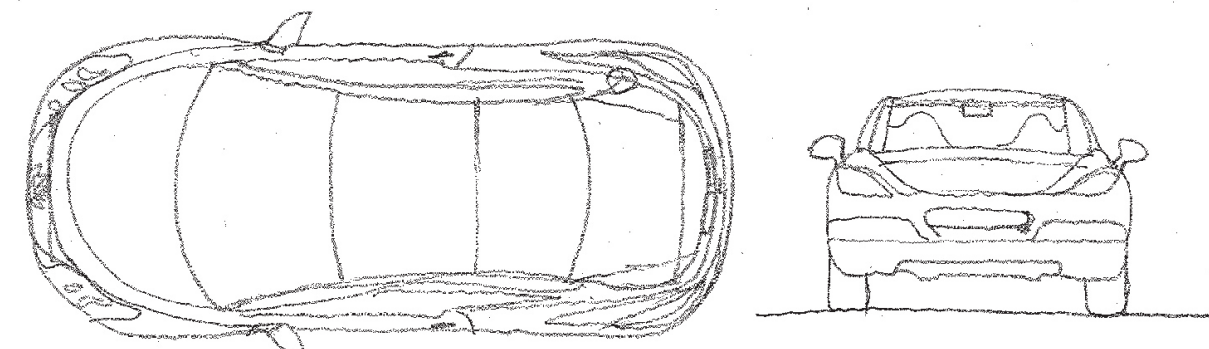
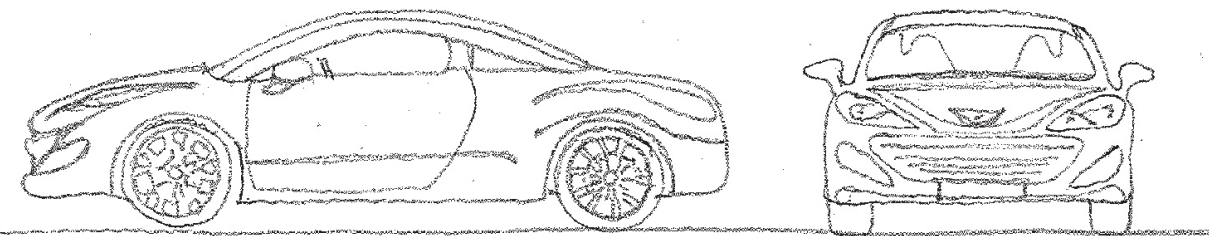
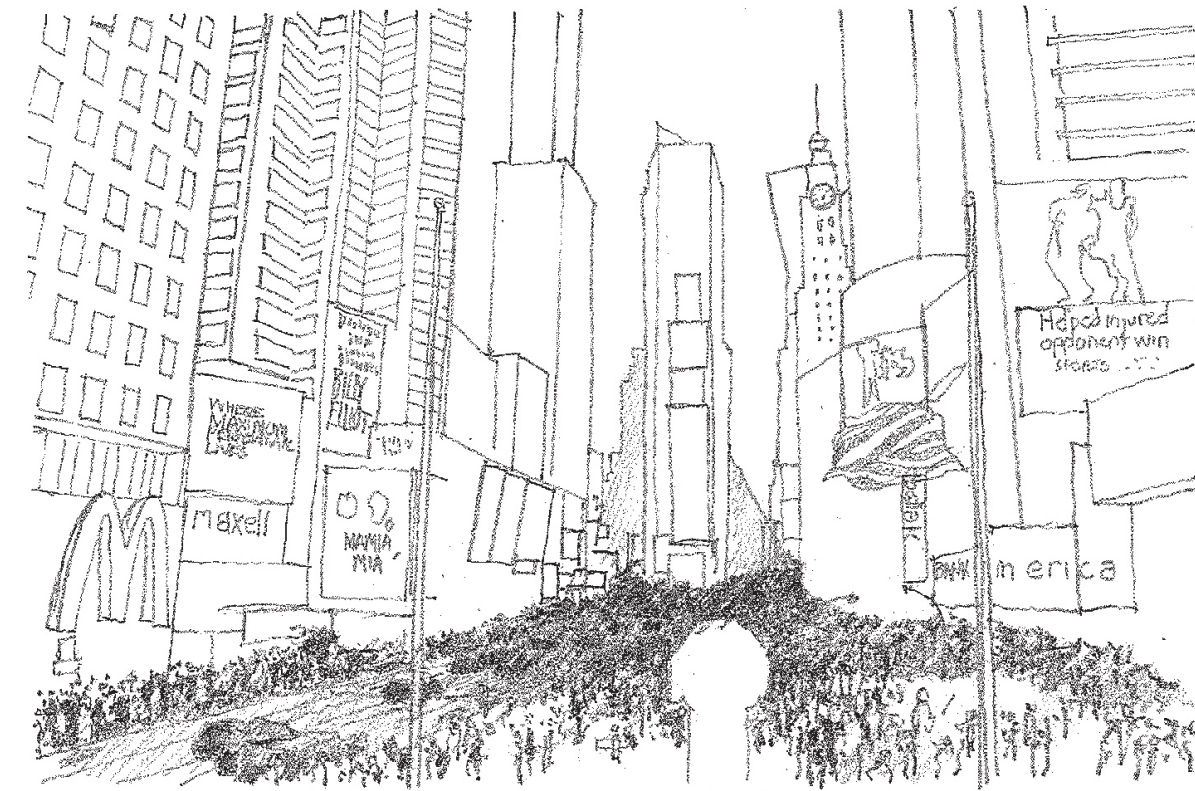
App. Fig. 9. Composite drawing of the aesthetic taxonomy of vehicles and city Hong Kong 1950s.
 CW: A 1957 map of Hong Kong. Vintage illustration from an advertisement by H. Miller of a family of four playing a board game while their futuristic electric car automatically drives itself. Technical drawings of the 1957 Chevrolet Bel Air coupe. Batgung-fiona St, Hong Kong, 1960.



App. Fig. 10. Composite drawing of the aesthetic taxonomy of vehicles and the city - Manhattan, 1970s.
 CW: The 974 Highway Code p35. Batman and Robin's Batmobile, an autonomous vehicle the Lincoln Futura-based Batmobile as seen in the 1960s Batman TV series. Batman: The Movie (1966). A 1970 Chevrolet Camaro Z28: retro series. The 1970 Manhattan Freeway - the New York skyline with new viaduct overpasses into the heart of the city.



Intentionally blank.



App. Fig. 11. Composite drawing of the aesthetic taxonomy of vehicles and the city – New York, 2000s.
 CW: The Newark south motorway, New York, 2000. Aladdin and his flying carpet, Disney's Aladdin, 1997. Times Square, Manhattan, New York. The Audi TT 2000, a popular luxury vehicle.

Appendix E. CAREV communications unit

Purpose

During Symposium 1, there was early discussion about the semiotics of AVs/CAVs/CAREVs, indicating insufficient data. The purpose of developing a communications unit for AVs/CAVs/CAREVs is to investigate methods for culturally appropriate communications between humans in the public realm and AVs.

Selected literature review

Currently, the standard indicator light, as prescribed under the UN vehicle prescriptions, is the only system being considered for use in AVs'. This comment references general current vehicle designs, which show little development of semiotic systems. In 2020, Hyundai developed a concept Mobis prototype with the ability to digitise communications. In 2019, Fiat Centoventi developed a digitised panel for communication, but the Centoventi communications unit has shown a mixed and inconsistent approach to vehicle safety and advertising.

Cultural and social history

In Disney's highly awarded animated feature film Aladdin (1992), the most developed semiotic systems of Aladdin's carpet are at its corners. There is also evidence of anthropomorphised AVs in Ub Iwerks's 'The New Car' (1930s) and Herbie from The Love Bug (1969).

Prototype – design, specification and manufacture

Integrating a communications unit with a vehicle is a major design exercise. This design investigation was an early prototype experiment to facilitate digitised semiotics on a vehicle. The specification design considered the basic premise that the unit should be on the corner of the vehicle (as required under the UN vehicle prescriptions). The corner positions would provide actors in the public realm with views of at least two unit sides on the vehicle; one of the two would act as redundancy and also cross-check of communications affording panoramic views at the corner. The semiotic displayed on the unit would have to consider the overall road aesthetics as well as the individual aesthetics of the specific vehicle. Vehicle manufacturers are constantly redesigning indicator lights to suit specific brand types. The specifications for the experimental prototype of the communications unit included the following:

- A digitised panel would accept dynamic input instructions.
- The corner location means that the panel would need to be able to bend or be designed to stretch around the corner of a CAREV.
- It would need to be visible during the day and at night in Australian conditions.
- Computer and vehicle energy sources would power the unit (12V DC).
- The design would need to be neat and safe for use as a teaching and experimental design unit.
- The unit would need to be large enough to be seen from a distance of 50 m, as per the Australian standard (AS) for vehicle signs and semiotics; this was established to be a unit at least 200 mm high and about 600 mm long (300 mm × 2 around the corner).

Display hardware

In consultation with a specialist lighting manufacturing engineer, it was agreed that an OLED mat provides flexibility and reliability for a vehicle corner location. The flexible LED mat would allow shaping around corners as well as gallery/exhibition displays. It would comprise LED units that maintain current international candela illumination. The mat would be approximately 200 mm high to allow for AS-standard words to be seen at a distance of 50 m. The display would be about 800 mm long, allowing for the corner and approximately 300 mm of display at the front and side. The LED mat would have to be magnetised should vehicle testing be required; the magnet would also provide a temporary attachment method.

Geometry of the vehicle indicator/break lights

Reference is made to the history of indicator and brake lights in which the history of the geometric position of the indicator systems can be found. Communication systems such as indicator and brake lights, depend on high visibility, and the geometric history of the communication elements is critical to understanding the intention of the vehicle direction (and speed). The legislated positions of indicator lights are considered culturally accepted locations; humans expect to see these critical direction-indicating systems in the established locations on all vehicles, from trucks to motorcycles. Cultural acceptance is an important factor in developing novel designs. The four locations (as a minimum) allow for 360-degree viewing of the communications unit, with at least two of the elements being visible to actors anywhere around the vehicle.



App. Fig. 12. Photograph of the completed flexible LED communications unit.

The image shows the test display sitting on a desk in 2019, shortly after manufacture and testing were completed, located on a desk. The computer interface and transformer are not shown.

Prototype manufacturer

'The company BCS Online specialises in developing and servicing various electronic and software products, with expertise spanning industrial electronics, automotive systems, telecommunications, security devices, instrumentation and medical devices. BCS Online develops products, assigning all intellectual property, including designs, to the client. This process includes full documentation handover and support, providing full ownership and access to the source code, original schematics and PCB files, design description documents, specifications and test reports. Each project commences with a feasibility investigation to determine its technical complexity, scope, risks, and time frame. This investigation includes detailed analysis and documentation of the system's requirements, culminating in the design specification to be implemented. 'In the current research work, the prototyping included the production of one semaphore with a wireless interface. Although the full operational firmware would not be implemented at the prototype stage, a subset of the communication was enveloped to demonstrate a minimum of 12 semaphore gestures.

Details of the prototype construction

The prototype process was exploratory, and the discussions set the following general objectives:

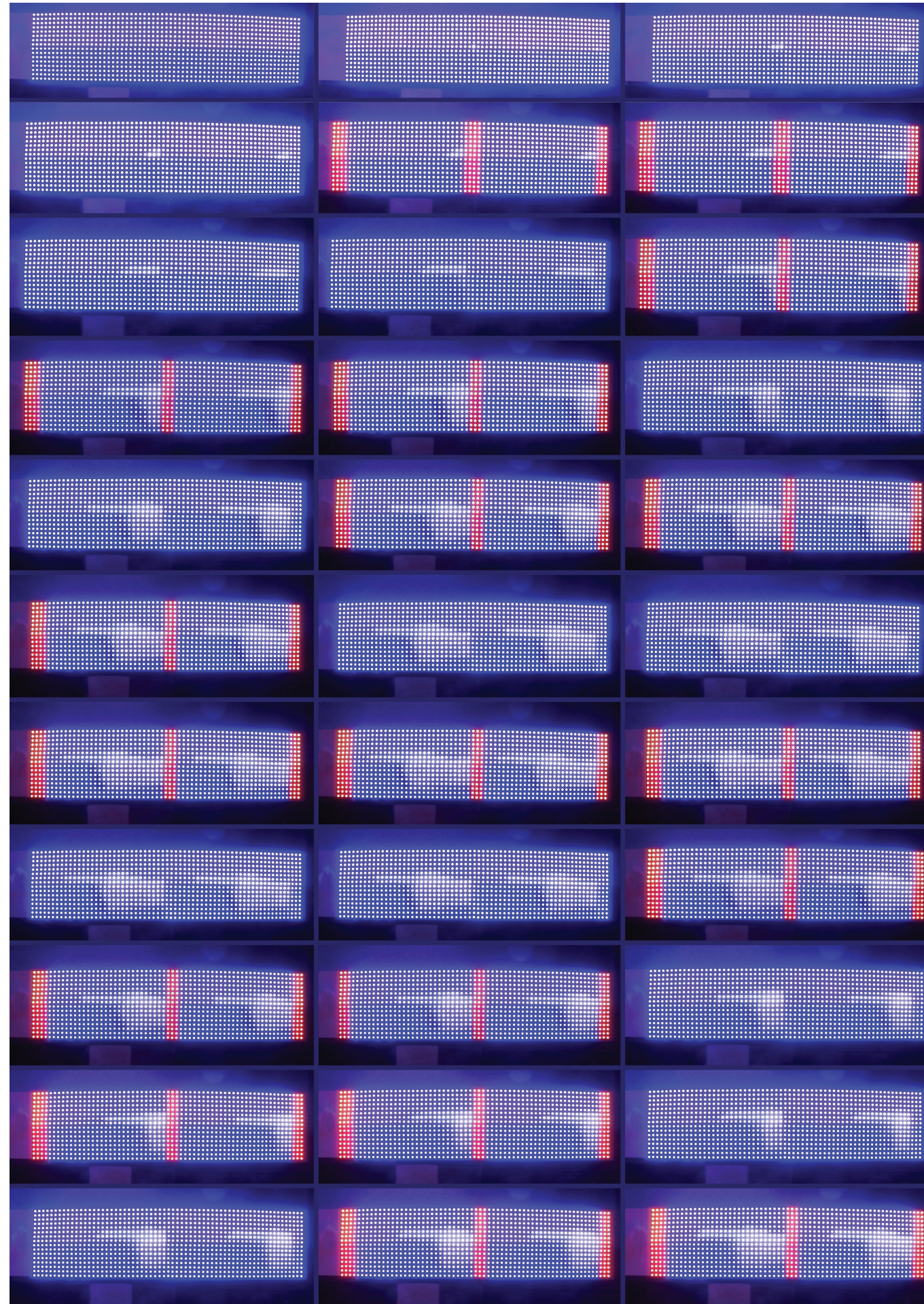
1. The communications unit will be flexible to allow it to be shaped to suit a variety of test vehicles.
2. The overall shape of the unit must accommodate a 90-degree soft bend.
3. The unit dimension will be at least 180 mm deep to accommodate 147-mm symbols on a 70% contrast background, which is the AS for vision-impaired word recognition. This AS is a sliding scale, but a size of 147 mm allows for partially impaired vision viewing at a distance of 50 m. The AS contains other detailed font shape, kerning and leading and scale information.
4. The unit must be able to be temporarily affixed to a vehicle (magnetic).
5. The shape of the communications unit will be sculptural to allow it to be displayed in non-vehicle applications as well as on vehicles.
6. The unit will likely be constructed of RGBW OLED lamps with enough resolution to allow for words and symbols, but it will not have computer monitor resolution.
7. The unit will have a rear-fixed short-term rechargeable battery for energy, a controller for Bluetooth wi-fi connectivity, and magnetic connectors.
8. The communications unit will be robust enough for vehicle testing and for transport to London by air
9. The software used to control the semiotics will be a standard industry bitmap-type graphic interface with off-the-shelf industry software for use on a laptop
10. The interface will allow a maximum of 12 semaphores, which may be updated through the software interface
11. The prototype unit will be bright enough to meet AS for indicator lights and will also be controllable.

Critical assessment

The communication unit's design and manufacture took 16 months, from specification writing through various forms of review, to commissioning. The software interface appears to be more complex than originally envisaged. However, it will be able to perform the task at hand. Developing an OLED panel rather than the selected mat option likely would have resulted in better outcomes. However, it would not have been possible to develop a flexible OLED panel with current resources. As a pixelated flexible daylight LED panel, the prototype will be able to demonstrate the principles of vehicle-to-human communications. It could be associated with digital technologies, including auditory and haptic interventions.

In the final testing and commissioning of the unit, the software interface was found to be overly crude and could not accept the continuous flow of detailed instructions from a computer. In daylight, the semaphores were not visible. As a teaching facility, the prototype had few applications, and the unit's limitations were regarded as hampering its potential expansion as a educational device.

The hand signals from the Auslan interpreter were filmed and digitised, and then, they were converted onto the LED panel translation software using Adobe Premiere Pro. This translation was a challenging and time-consuming process, as it required learning basic software LED instructions (similar to DOS). Four signal types were converted for use and filmed on the communications unit. The semaphore films and stills of the films were satisfactory for presenting a conceptual discussion in Symposium 3; refer to the discussion in Chapter 3.



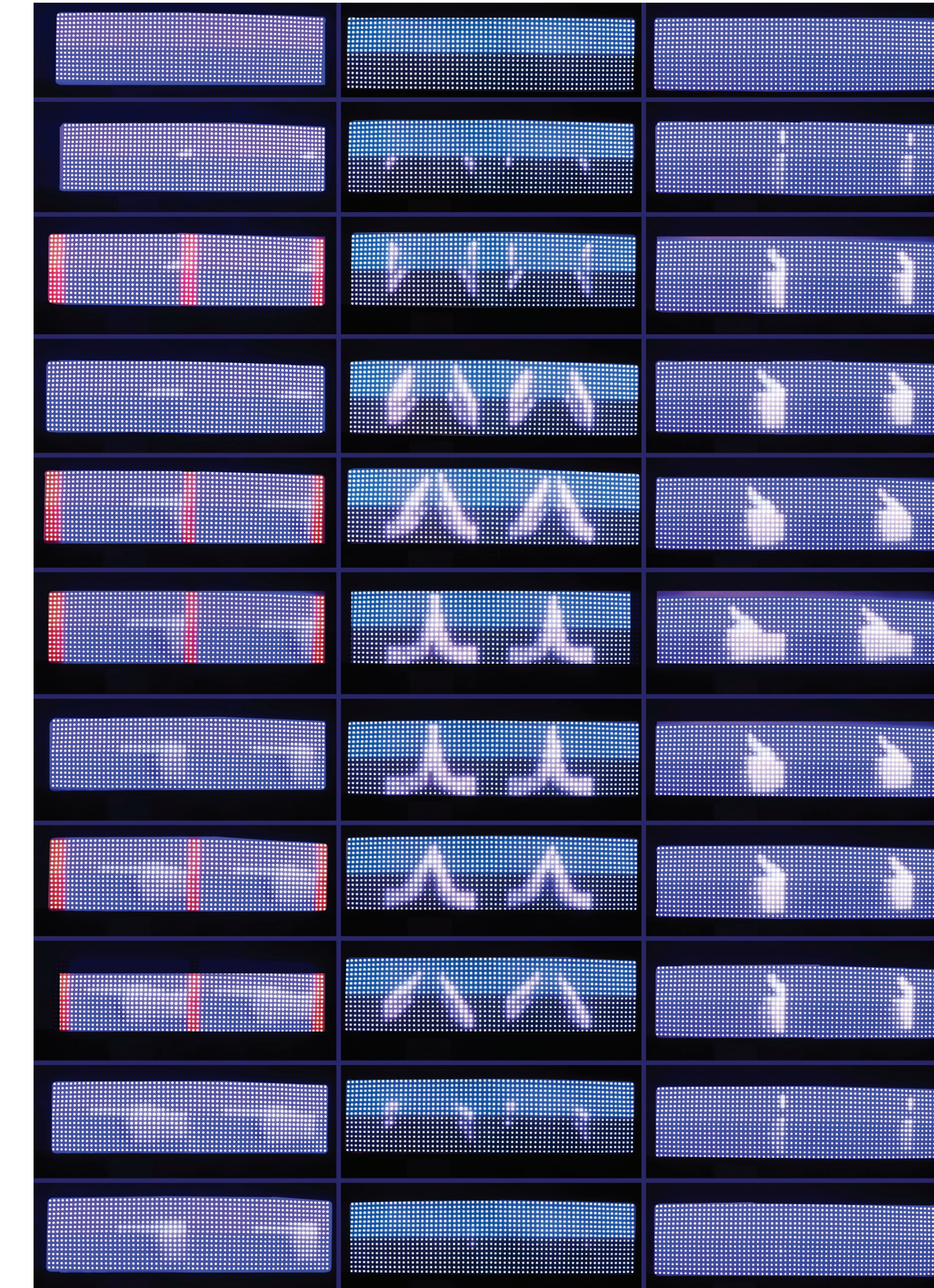
App. Fig. 13. Semaphore of turning left. The hand signal indicates left, with orange flashing side panels.



App. Fig. 14. Semaphore of 'OK'. This hand signal advises the viewer that it is OK to proceed.



App. Fig. 15. Semaphore of 'thank you'. The hand signal is a courtesy signal' or 'This is a courtesy signal.



App. Fig. 16. Mosaic of a combined summary of the semaphores tested on the communications unit.

Appendix F. Spatial investigation

Appendix F.1 Vehicle ergonomic study for CAREVs

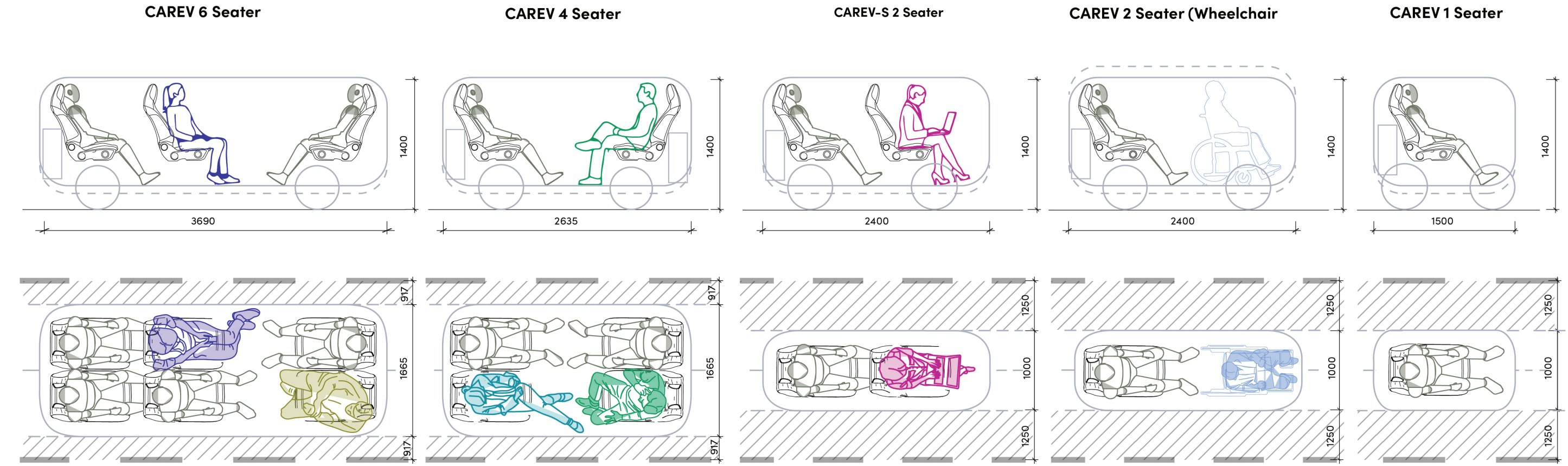
This study investigated a diversity of human forms seated in a CAREV. The ergonomic study included universal access for a diversity of user types, including babies, children, teenagers, adults, and aged and disabled cohorts, to ensure the system is just and inclusive of all people. Seating was a study limitation, as road transportation is safely undertaken while seated.

- Existing vehicle dimensions (four- and six-seat vehicles and trucks) were provided, with volumetric and dimensional analysis. The seating arrangements referenced five typical vehicle dimensions with optional storage space.
- The renewable energy battery storage and the space for the engines were approximated in this study.
- CAREVs with no human driver seating were arranged in one-, two-, four-² and six seat configurations.

The following is a summary of the dimensions used in the study:

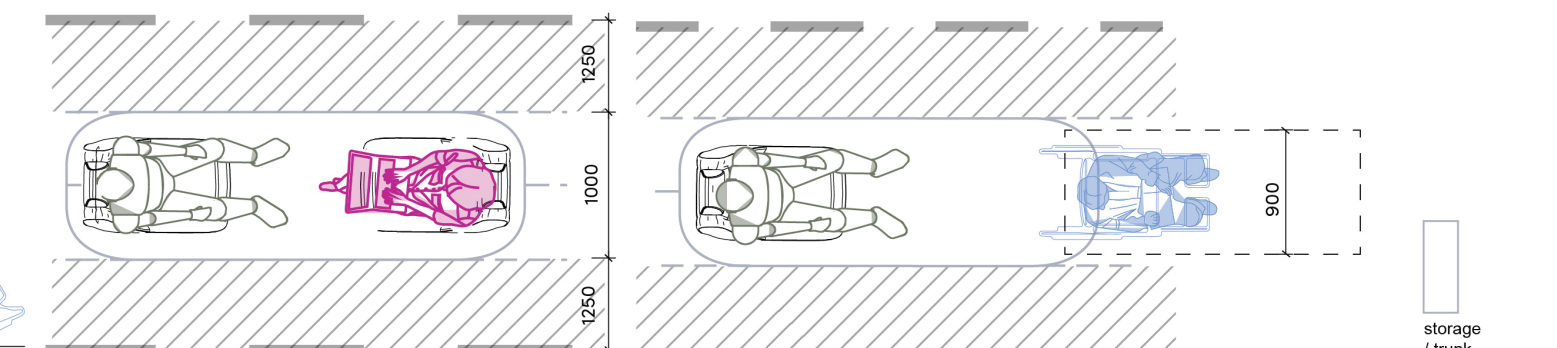
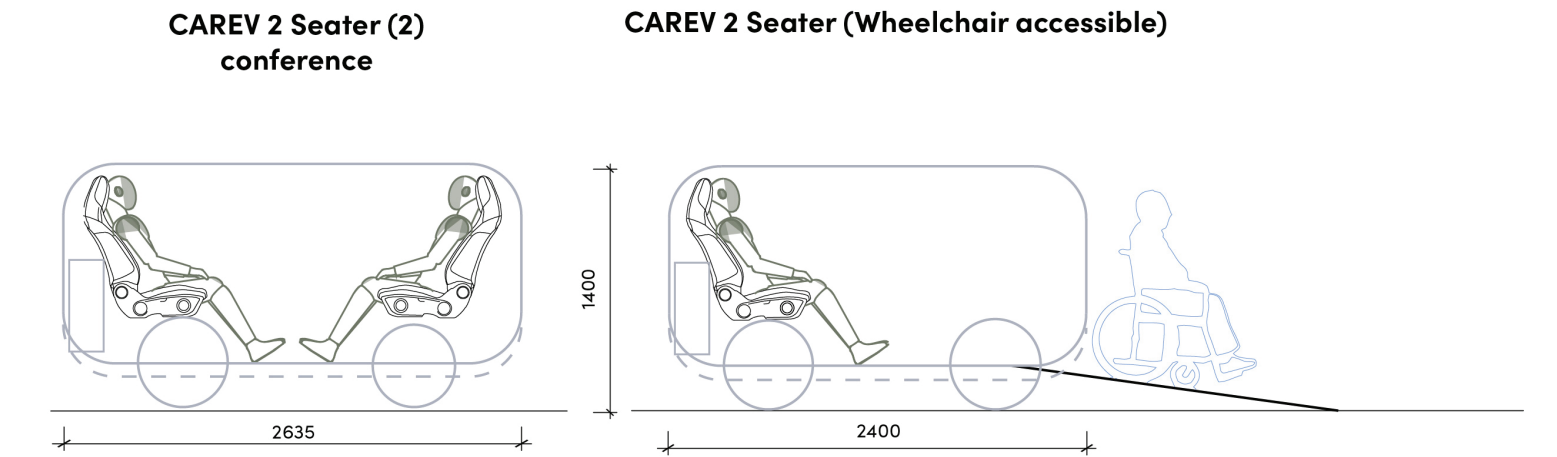
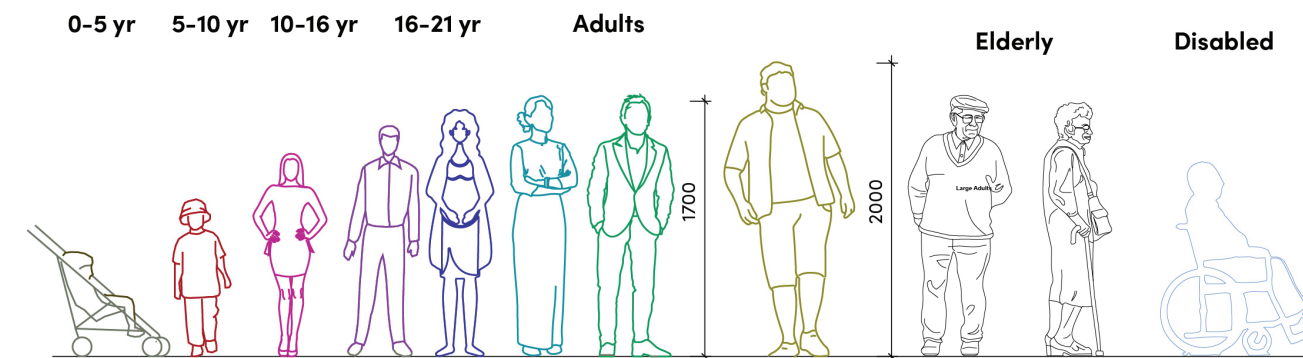
TYPE OF VEHICLE	LENGTH mm	WIDTH mm
CAV 6 - seater	3690	1400
CAV 4 - seater conference	2635	1400
CAV 2 - seater forward facing	2400	1000
CAV 2 - seater conference	2635	1000
CAV 1 - seater	1500	1000

The study was focussed on smaller passenger vehicles. However, the modelling included vehicles such as buses, container trucks, freight vehicles and cranes into the CAREV transport system.



Chassis, engines, wheels, battery - the basic equipment of an electric vehicle. From Naste and Charlton, WIRED, 2021.

Universal models used in this study



CAREV Ergonomic Study

Scale 1:40

App. Fig. 17. Ergonomic and vehicle size study for CAREV spatial study plans and sections.

Appendix F.2 Lane widths: narrower vehicles and existing lane configuration study

Broadly an international standard for motorways lane widths (and roads generally) in this study are 3500mm, wide.

This study investigated narrow vehicle dimensions (CAREV-S) with one- and two-seat configurations that are able to fit within standard lanes. This approach was aimed at retaining and adaptively reusing existing infrastructure. The two-seat CAREV-S configurations allow for tandem or conference seating arrangements internally. A comparative analysis of existing vehicle sizes is given below.

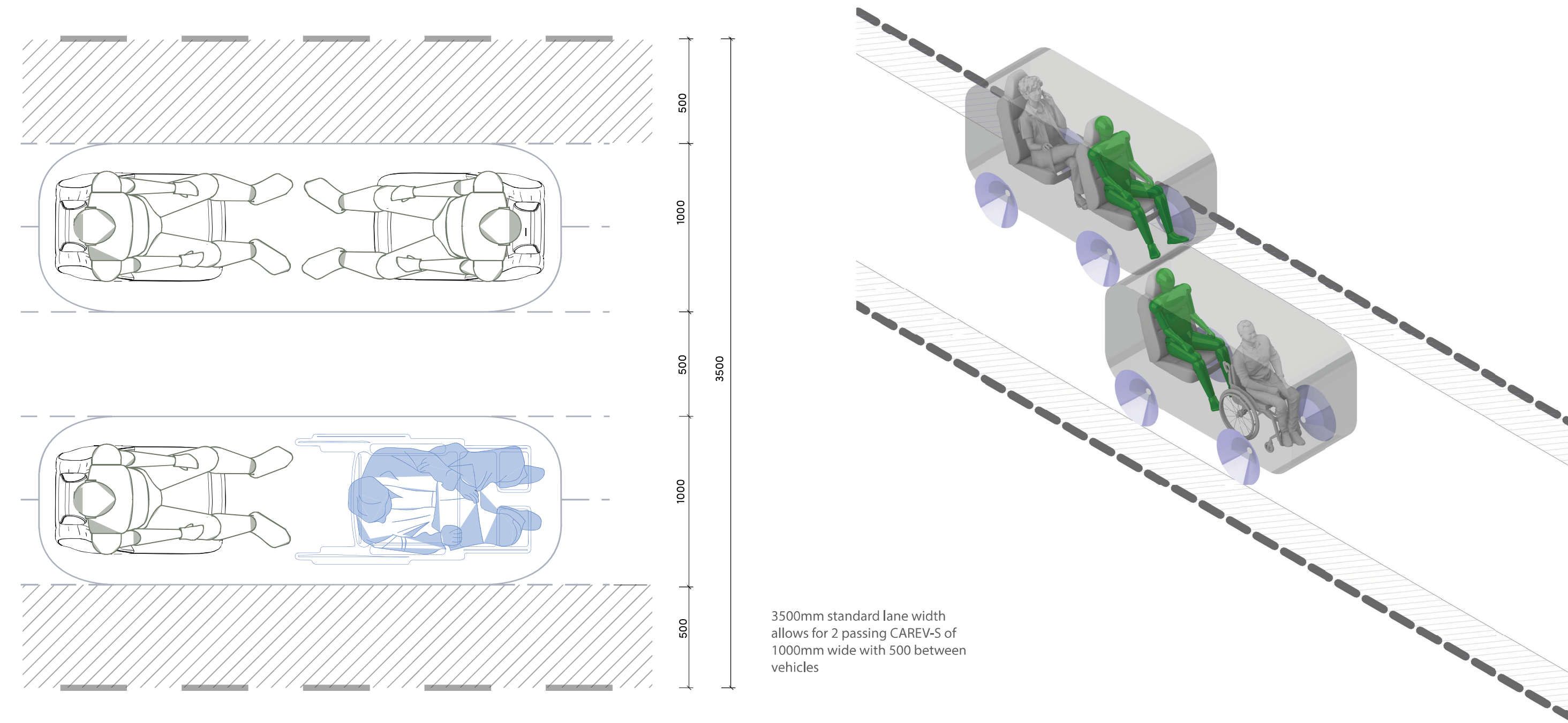
DESCRIPTION	EXISTING VEHICLES 2 - seater		ERGONOMIC STUDY	
	RENAULT TWIZY	MERCEDES SMART	CAREV-S 2 - seater	CAREV 4 - seater
Length	2338mm	2695mm	2635mm	2635mm
Width	1234mm	1663mm	1000mm	1400mm
Height	1686mm	1555mm	1400mm	1400mm

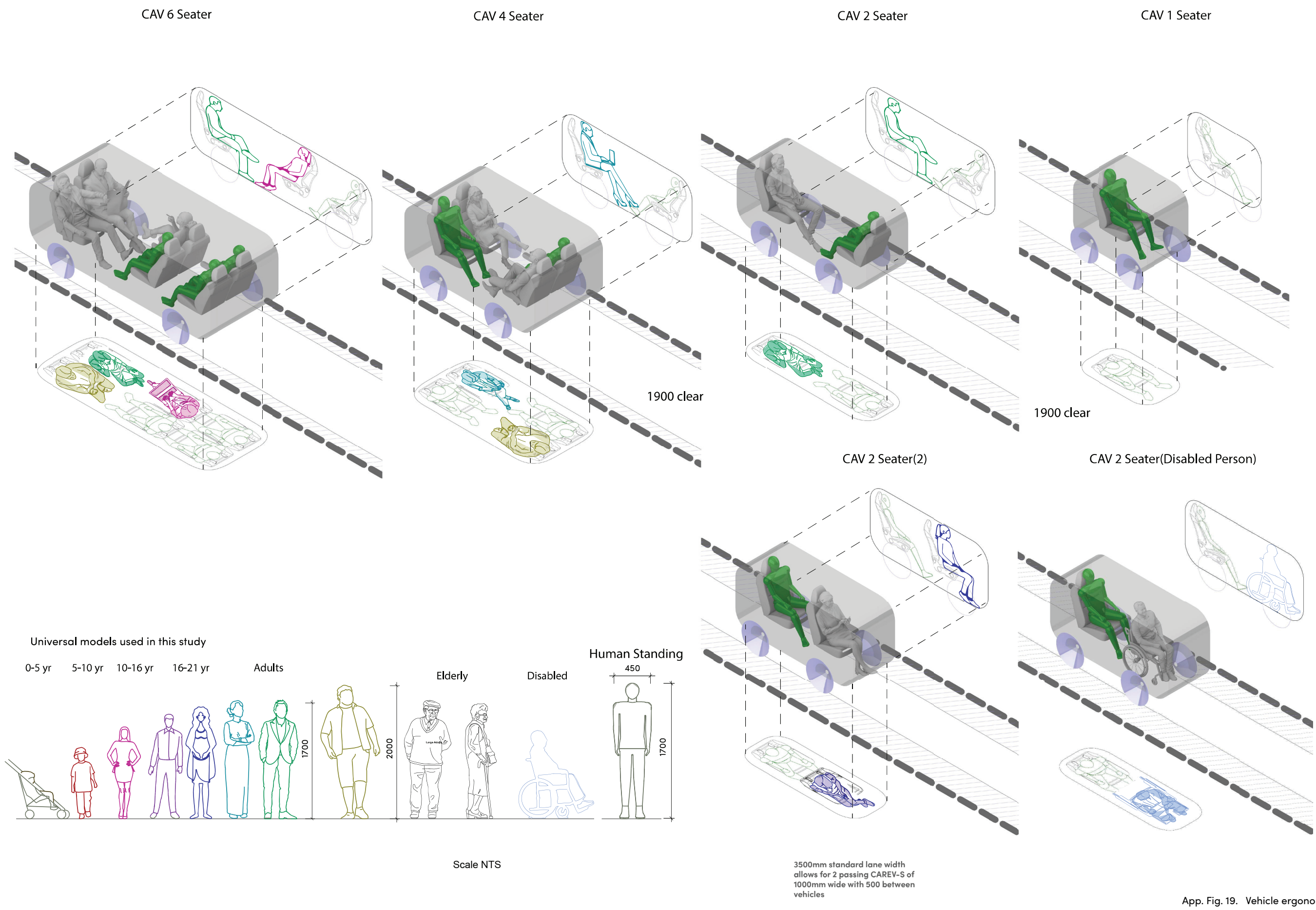
As a comparison, the two-seater Renault Twizy dimensions are 1234 mm with people seated alongside each other, facing forward. This dimensional comparison suggests that a 1,000-mm-wide CAREV-S could realistically fit within a standard lane and that two such vehicles could bypass each other.

As a result of the reduction in vehicle width, narrowing of lane widths would also be possible.

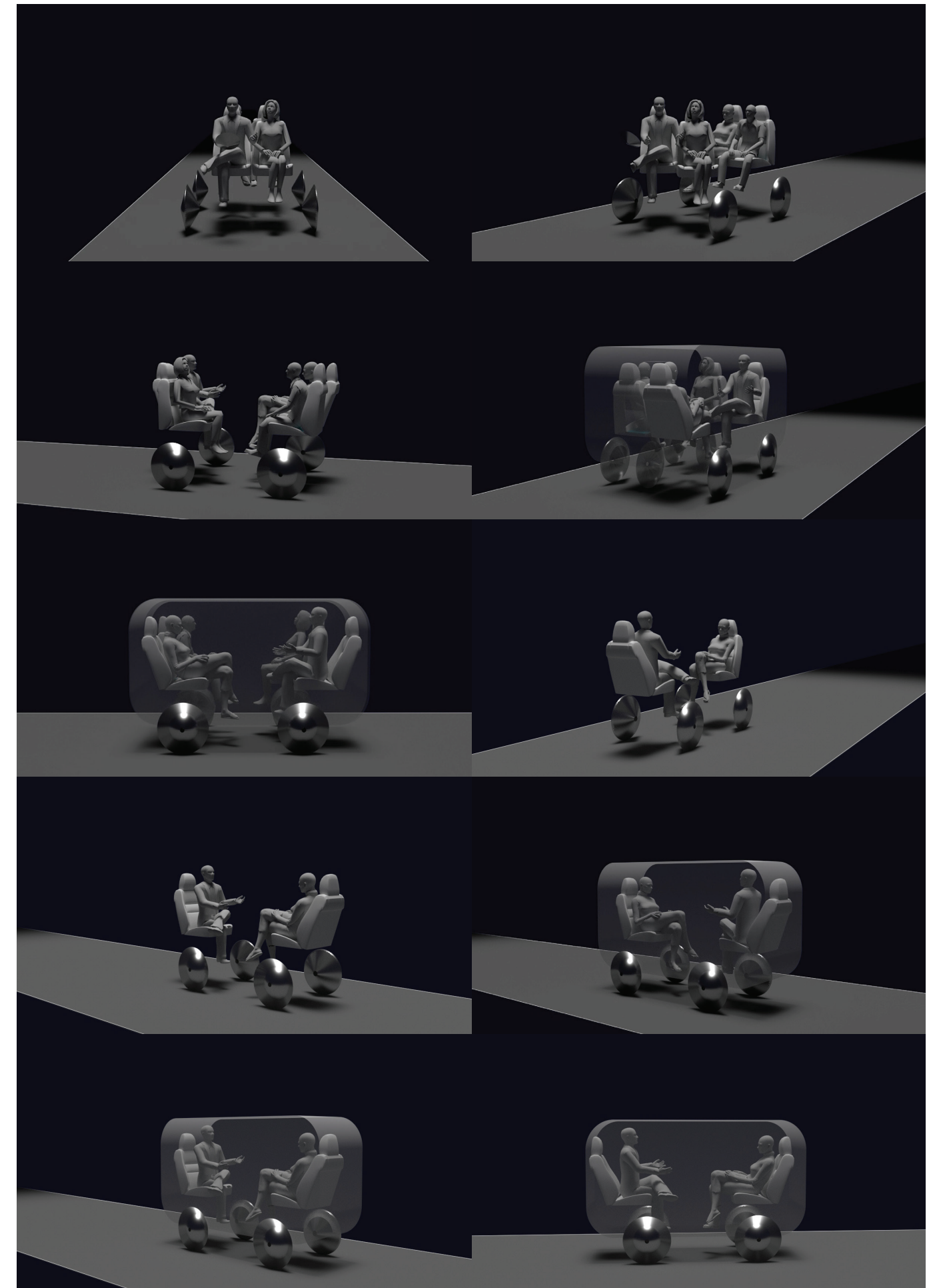
An AV drift space of 500 mm on either side of the vehicles is a generous allocation. Drift space dimensions need to be tested once CAREV technology is available, or the technology should be designed to ensure a 500 mm vehicle passing safety width accuracy for this study.

The ergonomic study was developed into a 3D spatial investigation to better understand the relationship of the CAREV-S seating arrangement, spatial layout and the lane widths. An animation was also developed to assist with conceptualising the CAREV-S ergonomic reformation.





App. Fig. 19. Vehicle ergonomic 3D spatial study.



App. Fig. 20. Vehicle ergonomic 3D study - mosaic of animated frames CAREV-S.

This mosaic of animated film can be seen in Video 2, the animation shows how the conference seating arrangement of a 2 seat vehicle has spatial benefits while maintaining internal spatial comfort. The benefits for the city, as a method to allow vehicles to pass each other using existing lane widths are part of the spatial investigation.

Appendix F.3 Case study – Surry Hills, Sydney, Australia

Surry Hills is the home of Studio Colin Polwarth, which may be affected by CAREVs in the future. It has a typical nineteenth-century Edwardian/Victorian planned gridded layout for an inner city suburb in Australia. The planning and design can be traced to similar British town planning models. Surry Hills is located alongside the CBD. Historically, the urban workforce chose to live close to the heart of the CBD. The road layout has transformed over the decades from the horse and cart era to the motorised era.

'The road network – that is, the underlying structure – of the planning form of Surry Hills has (in this study) five major road types, as follows:

1. Class A motorway
2. Arterial road
3. Feeder routes (no parking)
4. Local arterial road
5. Local road

The study area was selected to include the five road types and the associated urban forms, including activity precincts such as schools, high streets, administration and health care facilities, recreation premises, and inter-modal links to rail and light rail.

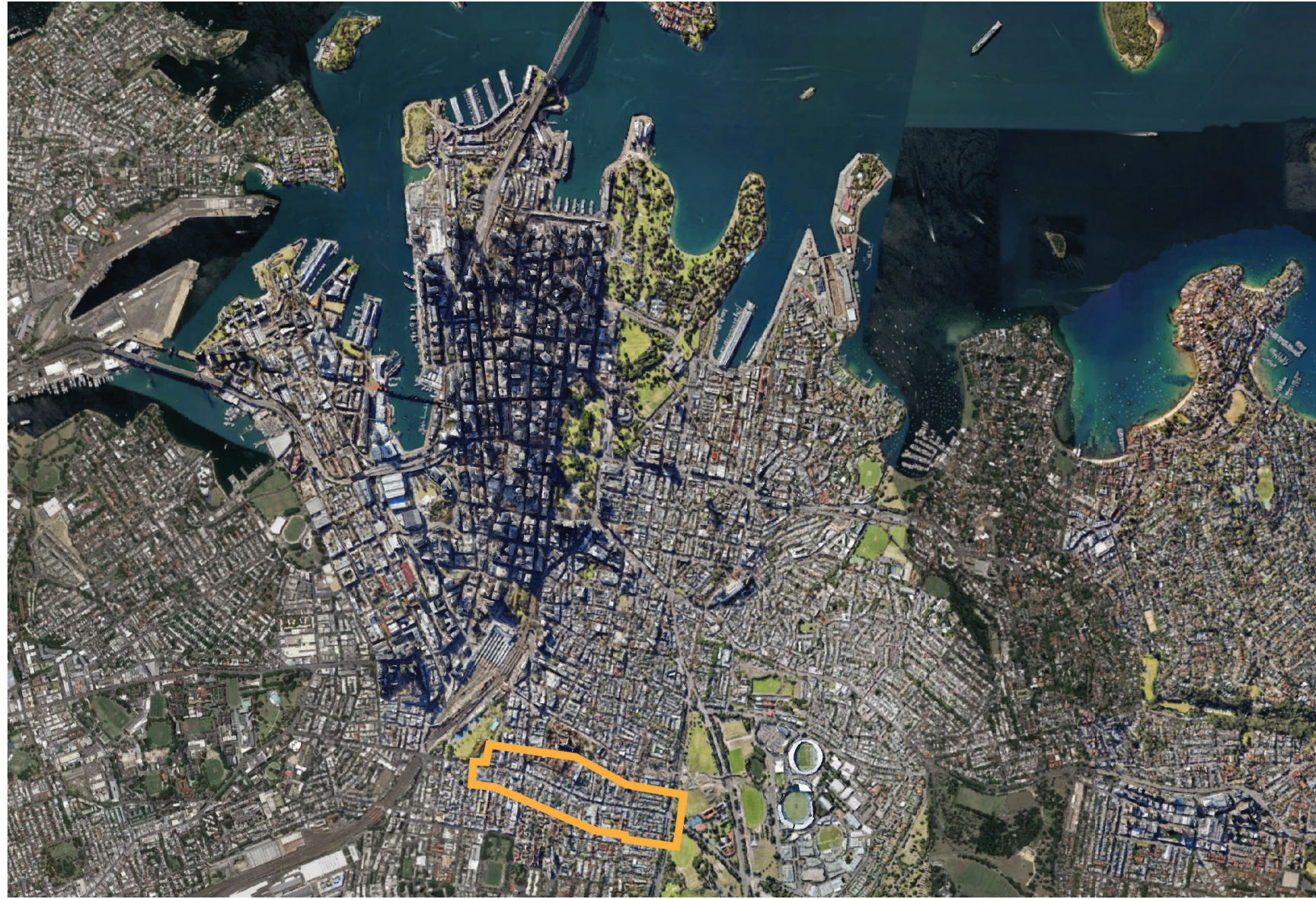
The study area of approximately 307 hectares was the maximum area UHI and road capacity that the parametric modelling could manage using desktop computers. It was also sufficiently large for use in the study' or 'It also represented a substantial area for research purposes.

The following diagram locates the study area in the context of the city's CBD with photographs. The network analysis drawing identifies the urban structure defined by the road network. The aerial night photography assists in showing the road network when illuminated.



App. Fig. 21. Night time aerial photograph over the spatial study case area, Surry Hills, Sydney, 2023.

Aerial view over Surry Hills looking northeast towards the Sydney CBD at night. The nighttime filing allows the viewer to gain a deeper appreciation of the road network. It has similar features to an animated figure-ground illustration.



Motorway, Eastern Distributor Surry Hills, 2020



Arterial, Cleveland Street Surry Hills, 2020



Feeder Route, Elizabeth Street, Surry Hills, 2020

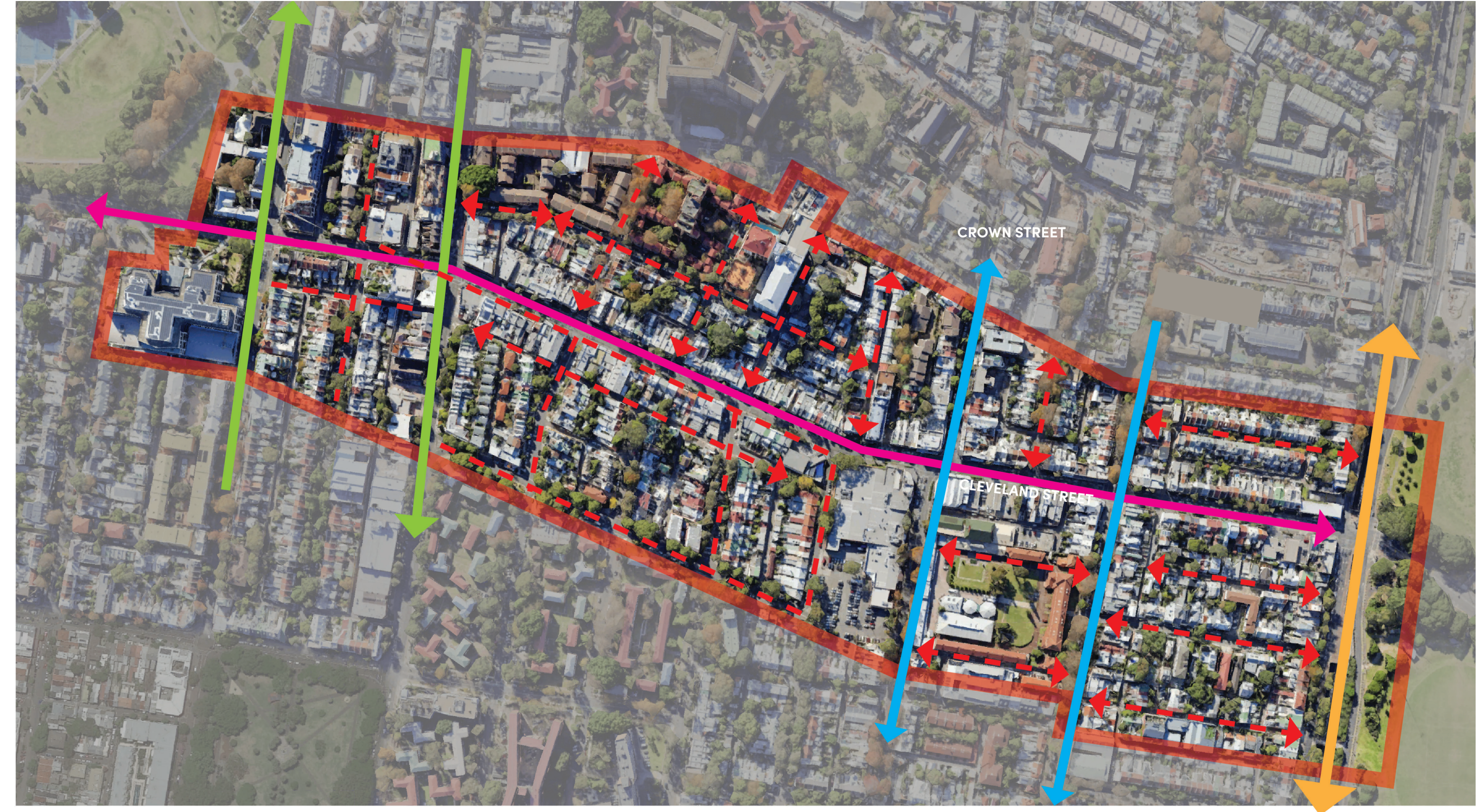


Local Arterial, Bourke Street, Surry Hills, 2020



Local Road, Goodlet Street, Surry Hills, 2020

App. Fig. 22. The CAREV case study location, and photographs of Surry Hills, Sydney.



LEGEND

- Motorway
- Arterial
- Feeder route
- Local arterial
- - - Local road

App. Fig. 23. The road network of the case study area, Surry Hills, Sydney, for CAREV-Ss.

Appendix F.4 Road capacity study with existing vehicle size

The following drawings are parametric models and calculations of road capacities. The existing road typology study provided baseline metrics (control study) for the five road types. The five road types are typical of those seen in the road network in Surry Hills, but form part of a wider road network system. The baseline metrics were used to compare case study metrics. The current study refers to the drawing, which depicts the road typology capacity for standard four-seat, human-driven vehicles. The model assessed the roads' maximum capacity as well as peak and normal operation.

Table depicting the maximum capacity for existing human - driven vehicles in a variety of road typologies.

Vehicle / road capacity calculations used in this study: speed, area and percentages of spaces.¹

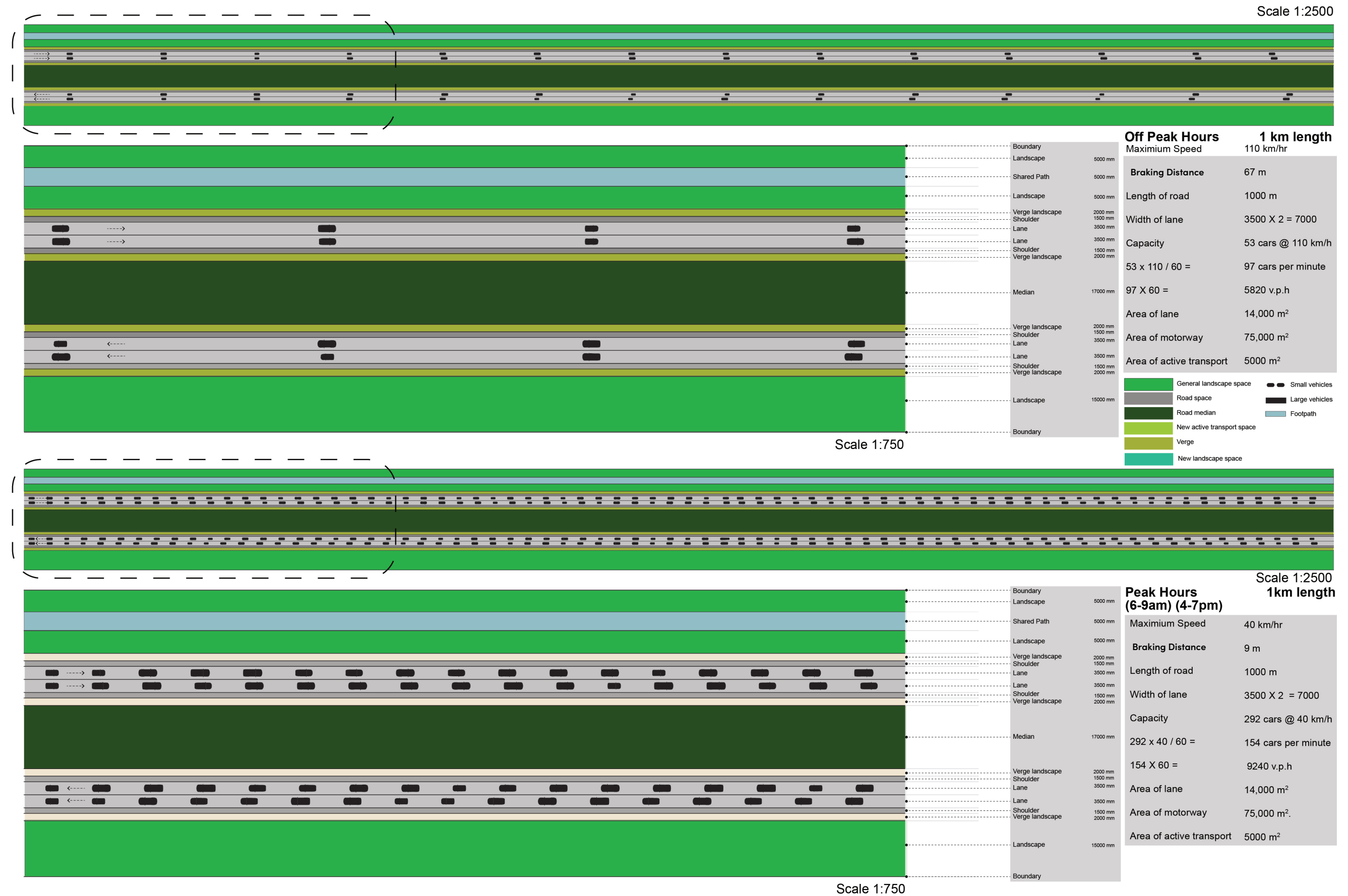
TYOLOGY	TIME / SPEED	MAX CAPACITY vph	AREAS m2	ACTIVE TRANSPORT AREA	%	ENVIRO AREA	%	PARKING
EXISTING								
Motorway	peak 40kph	5820	75000	5000	6.7	50000	66.7	0
	normal 110kph	9240						
Arterial	peak 40kph	7920	34800	6400	18.4	7000	20.1	0
	normal 60kph	11640						
Feeder route	50kph	10620	24300	6400	26.3	0	0.0	372
Local arterial	40kph	11640	27200	6400	23.5	0	0.0	372
Local road	40kph	6400	20800	6400	30.8	0	0.0	372

Summary: The maximum capacity metrics approximate current conditons.

¹ Notable metrics in this study and the following:

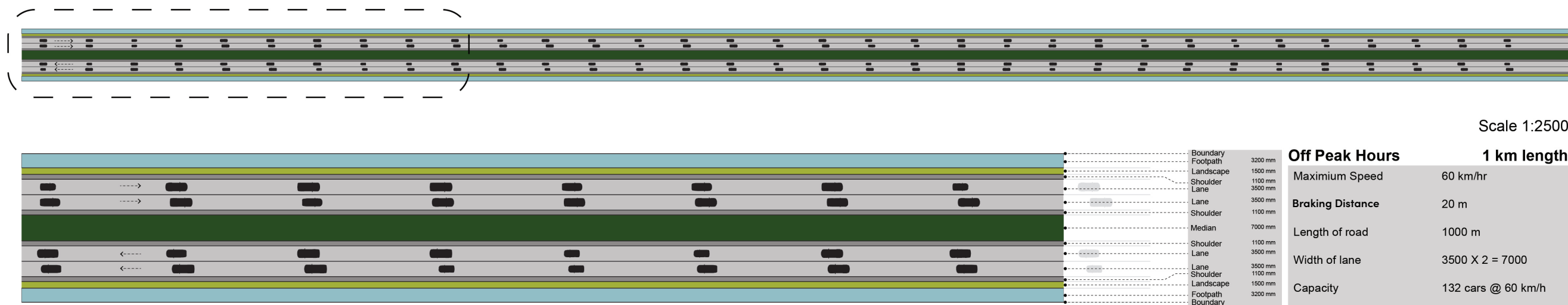
- In this study, arterial roads and feeder routes have higher capacities than motorways. This is not representative of reality, as arterial roads have traffic lights, which slow throughput.
- Active transport areas are 7% approximate range for motorways, but 18-30% for all other roads
- Motorways have 66% of the area available for landscape (environmental) mainly due to larger footprint, road geometry and large infrastructure required, e.g. major cross drainage and civil works. Arterial roads have 20% for all other roads, the metrics do not allow landscape space.
- The study is based on typical contemporary fossil-fuelled vehicles of 2400mm width and 5200 mm long.
- Braking distance is the distance required by driving regulations, an assumed human reaction time to incidents, and the acceleration and deceleration between vehicles at normal operating speeds.
- Capacities are theoretical, based on streamlined flows of traffic. That is the study does not represent all factors, such as slowing due to driver reactions times and intersections.
- The key differences in infrastructure required for various road typologies contribute to significant differences in corridor footprints, e.g. major cross drainage, waterway crossings, road geometry and major/minor traffic intersections.
- Traffic congestion is excluded in the modelling, as it has dynamic implications that affect capacity and alternate route option selection (i.e. human intervention).
- Lane changes, overtaking and reactions and on-route decision - making at interchanges and interactions could impact theoretical capacities; therefore, they are not represented in the study.
- Traffic network simulation modelling technology is expected to be integrated with synthetic intelligence to help increase traffic management and regulation to maintain optimum flow and capacity.
- The model on the lane capacity per kilometer does not include network performance considerations.

Motorway - existing with human drivers



App. Fig. 24. Spatial study – standard vehicles with human drivers on existing motorway capacity.

Arterial - existing with human drivers



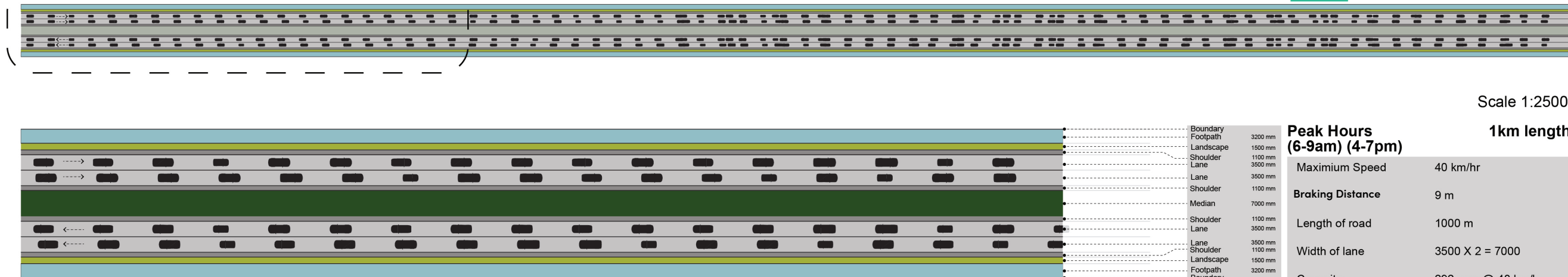
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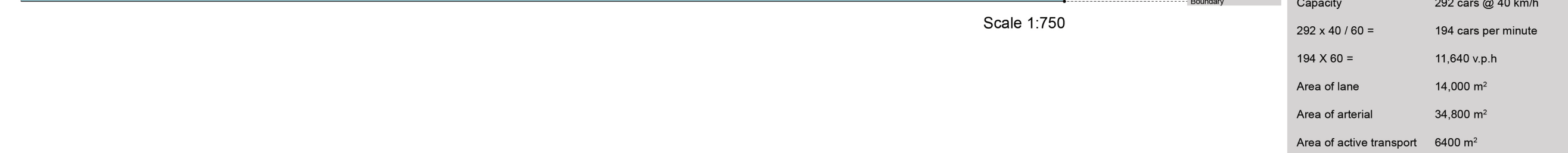
Scale 1:750

Off Peak Hours		1 km length	
Maximum Speed	60 km/hr		
Braking Distance	20 m		
Length of road	1000 m		
Width of lane	3500 X 2 = 7000		
Capacity	132 cars @ 60 km/h		
	$132 \times 60 / 60 =$	132 cars per minute	
	$132 \times 60 =$	7920 v.p.h	
Area of lane	14,000 m ²		
Area of arterial	34,800 m ²		
Area of active transport	6400 m ²		

General landscape space	Small vehicles
Road space	Large vehicles
Road median	Footpath
New active transport space	
Verge	
New landscape space	



Scale 1:2500

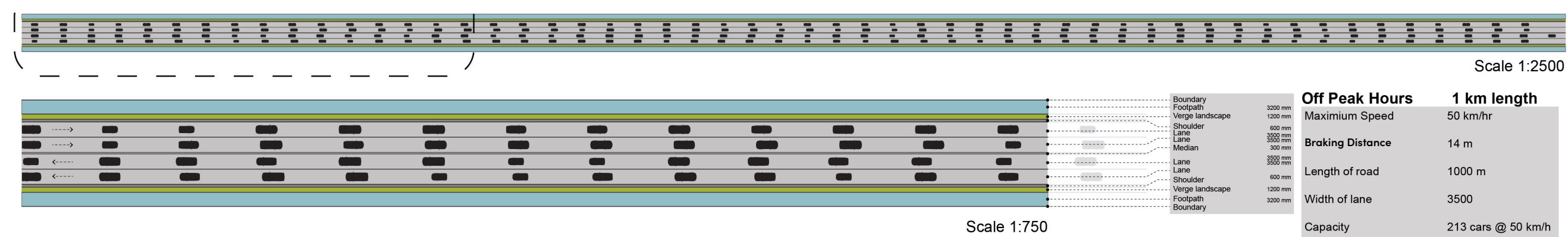


Scale 1:750

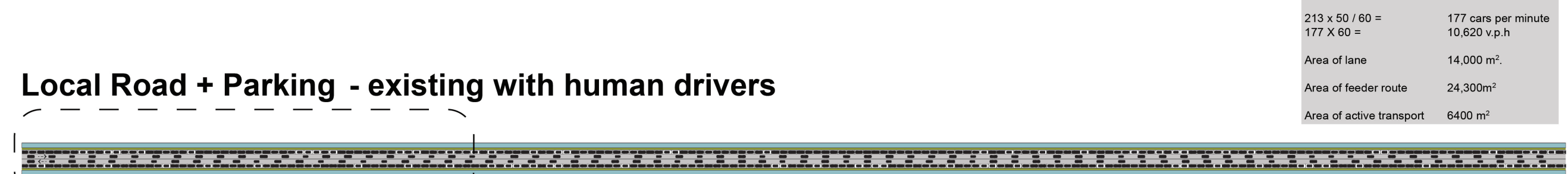
Peak Hours (6-9am) (4-7pm)		1km length	
Maximum Speed	40 km/hr		
Braking Distance	9 m		
Length of road	1000 m		
Width of lane	3500 X 2 = 7000		
Capacity	292 cars @ 40 km/h		
	$292 \times 40 / 60 =$	194 cars per minute	
	$194 \times 60 =$	11,640 v.p.h	
Area of lane	14,000 m ²		
Area of arterial	34,800 m ²		
Area of active transport	6400 m ²		

App. Fig. 25. Spatial study – standard human-driven vehicles on existing arterial.

Feeder Route - existing with human drivers



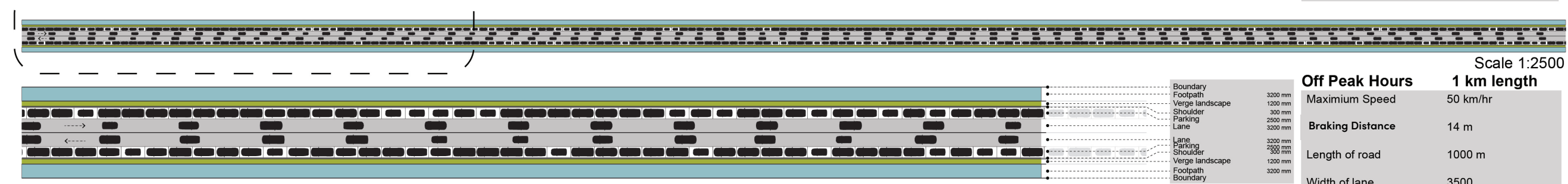
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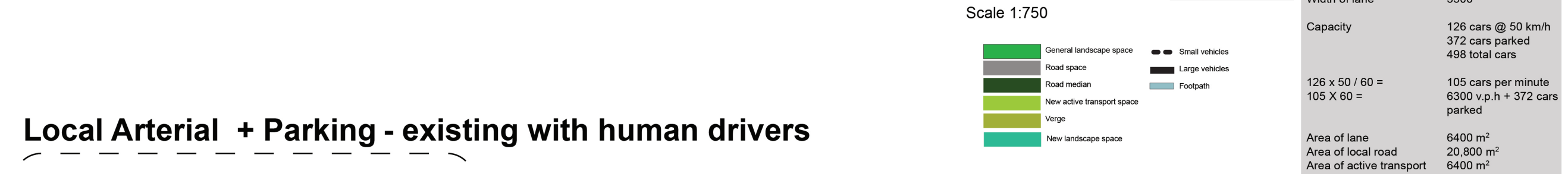
Scale 1:750

Off Peak Hours		1 km length	
Maximum Speed	50 km/hr		
Braking Distance	14 m		
Length of road	1000 m		
Width of lane	3500		
Capacity	213 cars @ 50 km/h		
	$213 \times 50 / 60 =$	177 cars per minute	
	$177 \times 60 =$	10,620 v.p.h	
Area of lane	14,000 m ²		
Area of feeder route	24,300 m ²		
Area of active transport	6400 m ²		

Local Road + Parking - existing with human drivers



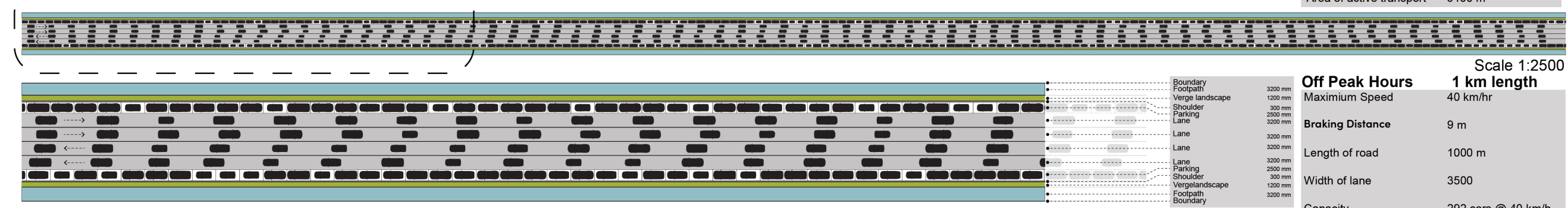
Scale 1:2500



Scale 1:750

Off Peak Hours		1 km length	
Maximum Speed	50 km/hr		
Braking Distance	14 m		
Length of road	1000 m		
Width of lane	3500		
Capacity	126 cars @ 50 km/h		
	$126 \times 50 / 60 =$	105 cars per minute	
	$105 \times 60 =$	6300 v.p.h + 372 cars parked	
Area of lane	6400 m ²		
Area of local road	20,800 m ²		
Area of active transport	6400 m ²		

Local Arterial + Parking - existing with human drivers



Scale 1:2500

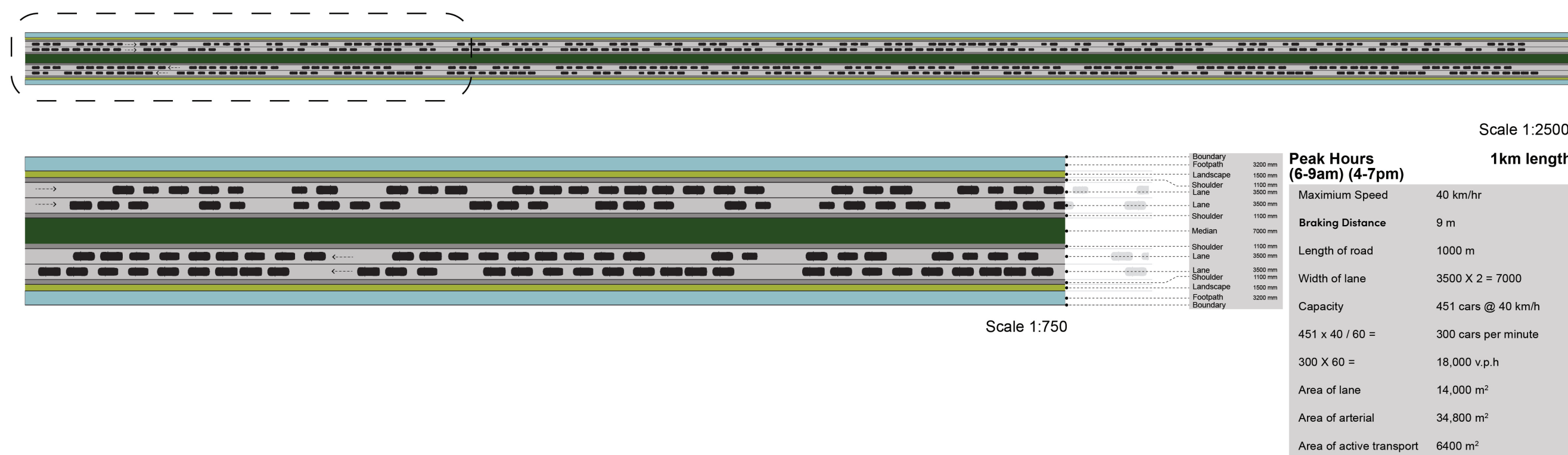
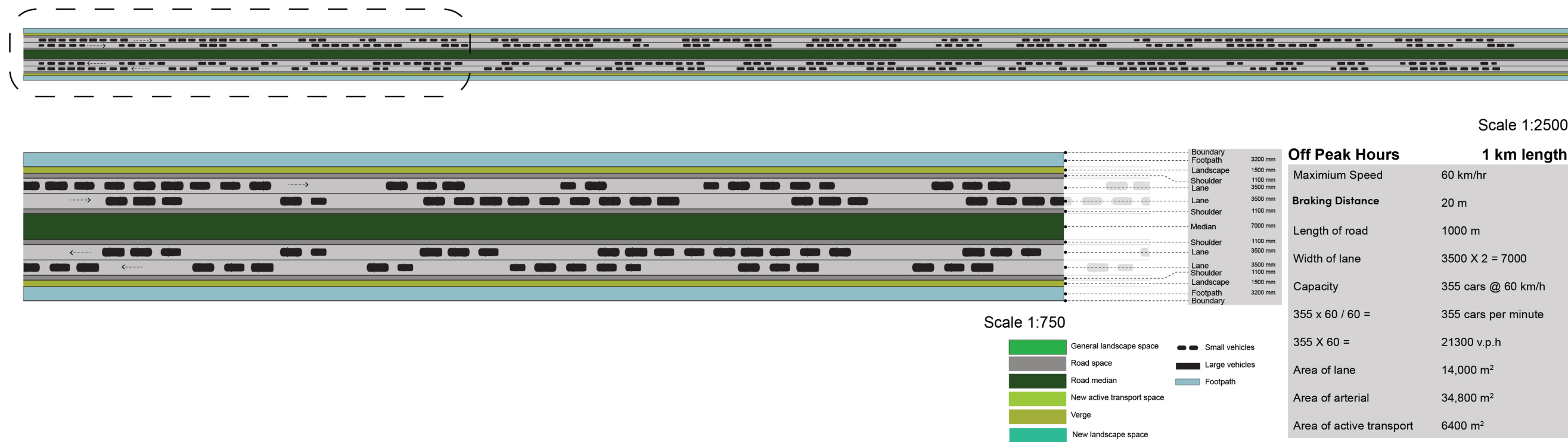


Scale 1:750

Off Peak Hours		1 km length	
Maximum Speed	40 km/hr		
Braking Distance	9 m		
Length of road	1000 m		
Width of lane	3500		
Capacity	292 cars @ 40 km/h		
	$292 \times 40 / 60 =$	194 cars per minute	
	$194 \times 60 =$	11,640 v.p.h + 372 cars parked	
Area of lane	12,800 m ²		
Area of local arterial	27,200 m ²		
Area of active transport	6400 m ²		

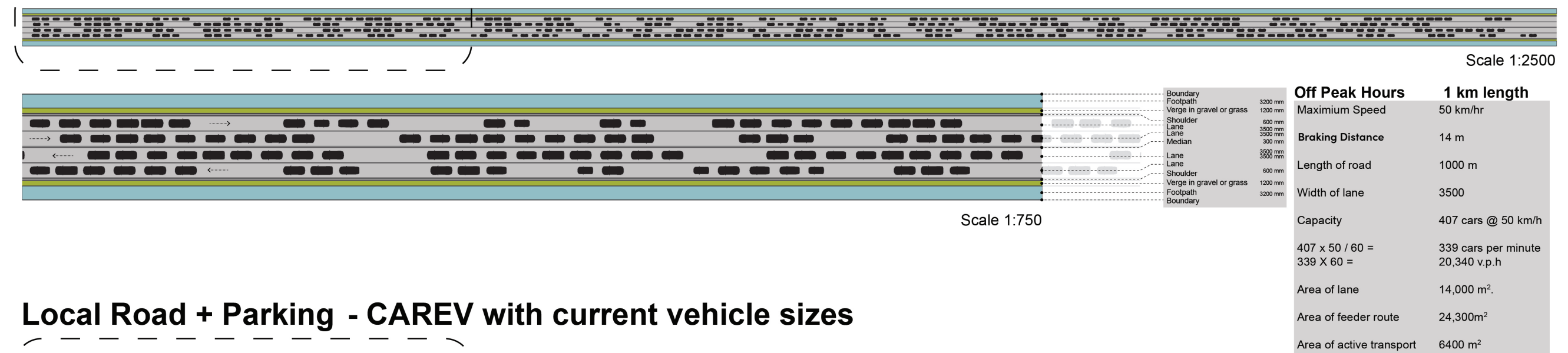
App. Fig. 26. Spatial study – standard human-driven vehicles on feeder route, local road and local arterial.

Arterial - CAREV with current vehicle sizes

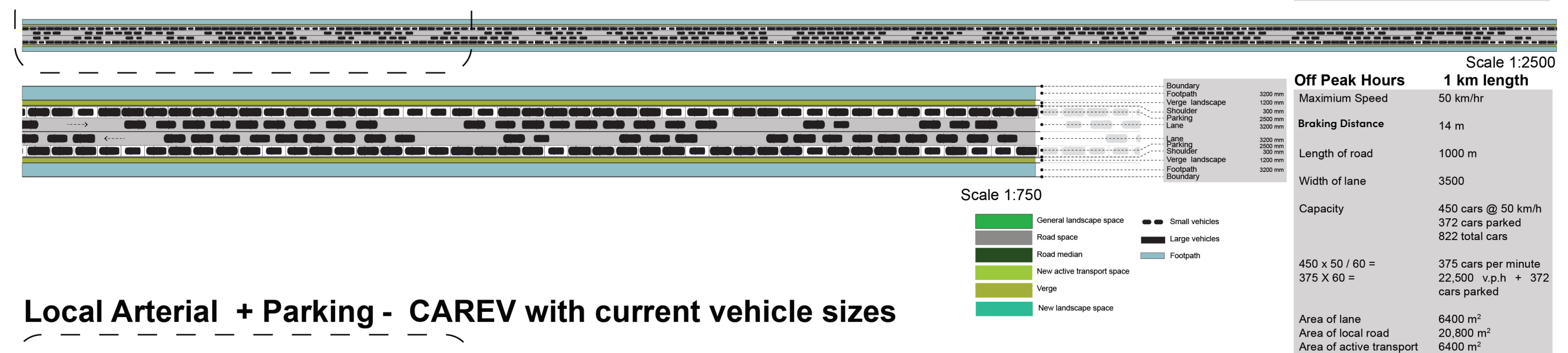


App. Fig. 28. Spatial study – CAREV standard vehicle size on arterial study.

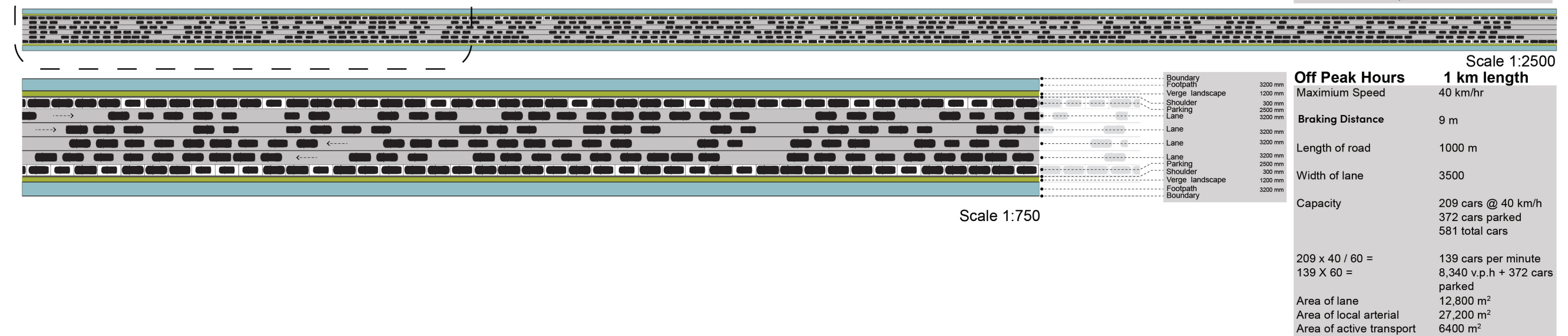
Feeder Route - CAREV with current vehicle sizes



Local Road + Parking - CAREV with current vehicle sizes



Local Arterial + Parking - CAREV with current vehicle sizes



App. Fig. 29. Spatial study – CAREV standard vehicle size on feeder route, local road, local arterial study.

Appendix F.6 Road capacity study with CAREV-S

This CAREV-S (narrow format) and mixed CAREV study 'aimed to maintain...and adjust the criteria the existing five road typologies and adjusting the criteria, as follows:

- Vehicle sizes were reduced: 63% of vehicles had one seat, 7% two seats (CAREV-S) and the remaining 30% four seats. These figures are consistent with current average use patterns in Australia.
- The lane width (3200 mm) was reduced for larger CAREVs, and two 1750 mm tango lanes were added as a CAV does not require the same lane space as a human - driven vehicle.

The study investigated how many additional lanes could be added when using CAREV-Ss (CAREV technology and smaller vehicle types).

The research explored three options that could arise from the use of smaller vehicles , as follows:

- Maximising parking
- Maximising active transport pathways
- Maximising environmental (landscape) space

Table of CAREV-S spatial study - maximum capacity.

Comparative analysis of parking, environmental area and active transport options.

TPOLOGY	TIME / SPEED	Human driven Vehicle CAPACITY vph	CAREV driven Vph	CAREV -S CAPACITY Vph	AREAS m2	ACTIVE TRANS-PORT AREA	%	ENVIRO AREA	%	PARK
EXISTING										
Motorway	peak 40kph	5820	17700	51280	75000	5000	6.7	50000	66.7	0
	normal 110kph	9240	20460	108900						
Arterial	peak 40kph	7920	21300	51280	34800	6400	18.4	7000	20.1	0
	normal 60kph	11640	18000	54240						
Feeder route	50kph	10620	20340	45400	24300	6400	26.3	0	0.0	372
Local arterial	40kph	11640	22500	60540	27200	6400	23.5	0	0.0	372
Local road	40kph	6400	8320	33540	20800	6400	30.8	0	0.0	372

Notes'

Overall, the road capacity could significantly increase with the use of smaller vehicles with CAREV technology, as follows:

- CAREV-S technology in this study could increase the road capacity throughput.
- The maximized capacity of motorways could increase by $\pm 600\%$ to $\pm 1000\%$ depending on the arrangement of small vehicle platooning and braking distances and the vehicle types.
- The capacity of arterials could increase by $\pm 300\%$ to $\pm 680\%$ depending on the arrangement of small vehicle platooning.

1 The CAREV-S and road typology studies could provide opportunities to achieve the following:

- Road capacity could be increased. This would will result in existing roads not having to be widened to accommodate the technology. This would be an adaptive re-use of the existing road space
- The approach to adaptive reuse could extend the life of existing road networks and infrastructure
- The study accepted that for motorways and feeder routes, larger vehicle types (up to 2400 mm wide; which is consistent with container and freight width requirements, would be required. The CAREV technology allows for narrower lanes, as the technology has more accurate navigation than human - driven drift space
- The remainder of the existing lane configurations would be reconfigured with line markings to suit the smaller vehicles (CAREV-S). This is a simplified assumption that no engineering required to pavement infrastructure and other features are required for CAREV-S.
- Smaller vehicles could increase the road capacity, and the number of people being transported, reducing seat waste.
- The CAREV-S technology allows for platooning and swarmings which would lead to significant capacity improvements
- CAREV-Ss emit less pollution, carbon dioxide and noxious gases and make less noise than fossil-fuelled vehicles. Therefore, they have multiple environmental benefits
- Where required, roads currently suffering from a lack of parking space could benefit from increased parking capacity with smaller vehicles
- Roads currently suffering from congestion could be relieved with CAREV-S technology and smaller vehicles using swarming and platooning
- Where roads are required to maintain parking levels, smaller vehicles would allow for a 20%-30% increase in landscape area. These areas could contribute to reducing heat island effects
- Where roads require additional active transport routes (dedicated), one side of the road could be changed to an active transport route. This strategy has been used in Sydney, specifically on Bourke Street, which is in the study area. However in the Sydney study, there was a reduction in vehicle parking as the vehicle sizes did not change.

Table of the comparative analysis of the parking, environmental area and active transport options.

TPOLOGY	TIME SPEED	CAPACITY vph	AREAS m2	ACT T AREA	%	ENVIRO	%	PARKING
EXISTING								
Motorway								None
Arterial								None
Feeder route	50kph	10620	24300	6400	26.3	0	0.0	372
Local arterial	40kph	11640	27200	6400	23.5	0	0.0	372
Local road	40kph	6400	20800	6400	30.8	0	0.0	372

PARKING MAX								
CAV Motorway	peak 40kph	58200	75000	10000	13.3	45000	60.0	0
	normal 110kph	86340						
CAV Arterial	peak 40kph	58200	34800	10000	28.7	7000	20.1	0
	normal 60kph	79800						
CAV Feeder route	50kph	57500	24300	6400	26.3	0	0.0	0
CAV Local arterial	40kph	102600	27200	6400	23.5	0	0.0	1116
CAV Local road	40kph	62460	20800	6400	30.8	0	0.0	1116

ACT TRANSPORT MAX								
CAV Motorway	peak 40kph	58200	75000	10000	13.3	45000	60.0	0
	normal 110kph	86340						
CAV Arterial	peak 40kph	58200	34800	10000	28.7	7000	20.1	0
	normal 60kph	79800						
CAV Feeder route	50kph	57500	24300	6400	26.3	0	0.0	0
CAV Local arterial	40kph	102600	27200	9078	33.4	0	0.0	372
CAV Local road	40kph	62460	20800	8408	40.4	0	0.0	372

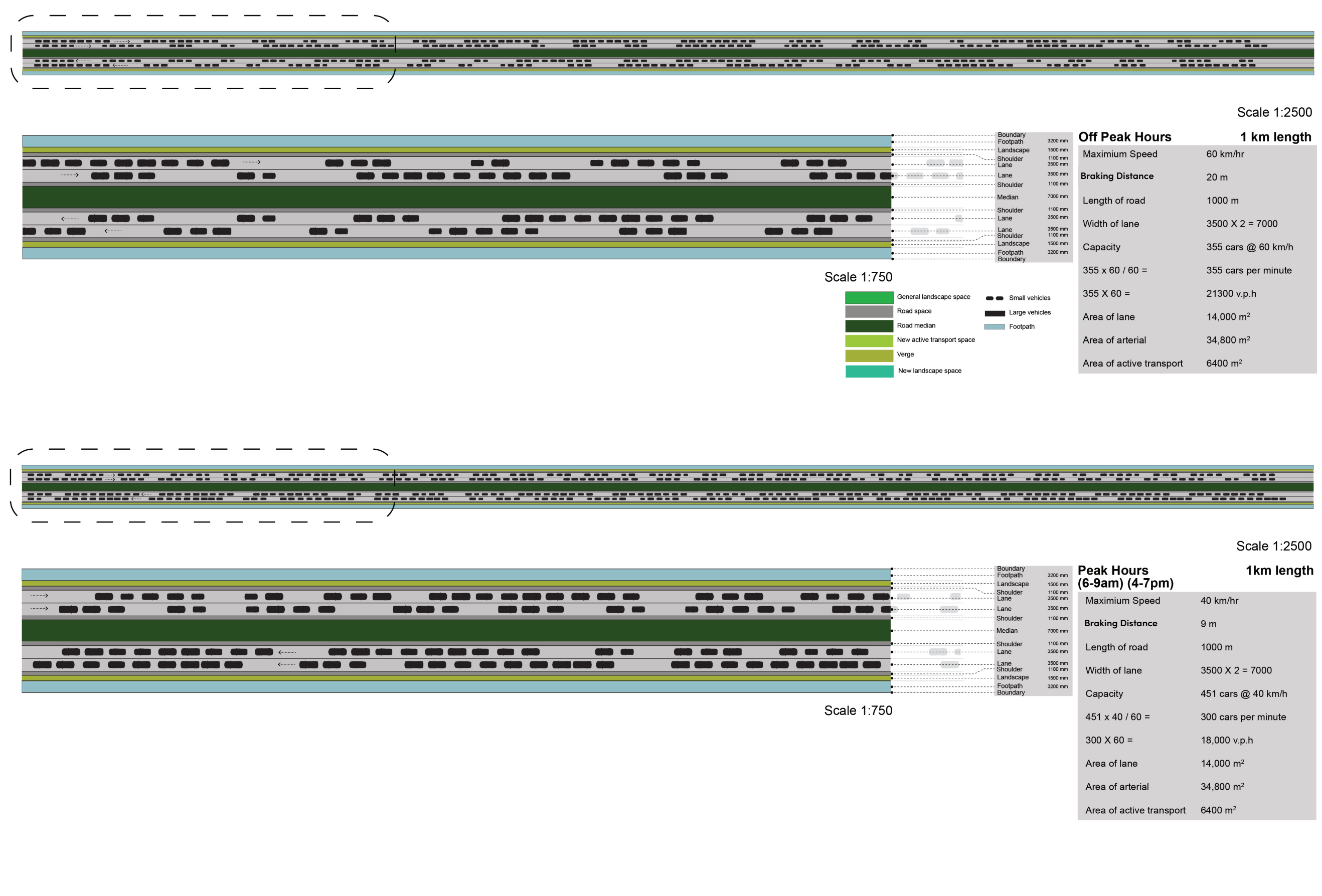
ENVIRO MAX								
CAV Motorway	peak 40kph	58200	75000	10000	13.3	45000	60.0	0
	normal 110kph	86340						
CAV Arterial	peak 40kph	58200	34800	10000	28.7	7000	20.1	0
	normal 60kph	79800						
CAV Feeder route	50kph	57500	24300	6400	26.3	0	0.0	0
CAV Local arterial	40kph	102600	27200	6400	23.5	2678	9.8	372
CAV Local road	40kph	62460	20800	6400	30.8	2008	9.7	372

Motorway - CAREV with current vehicle sizes



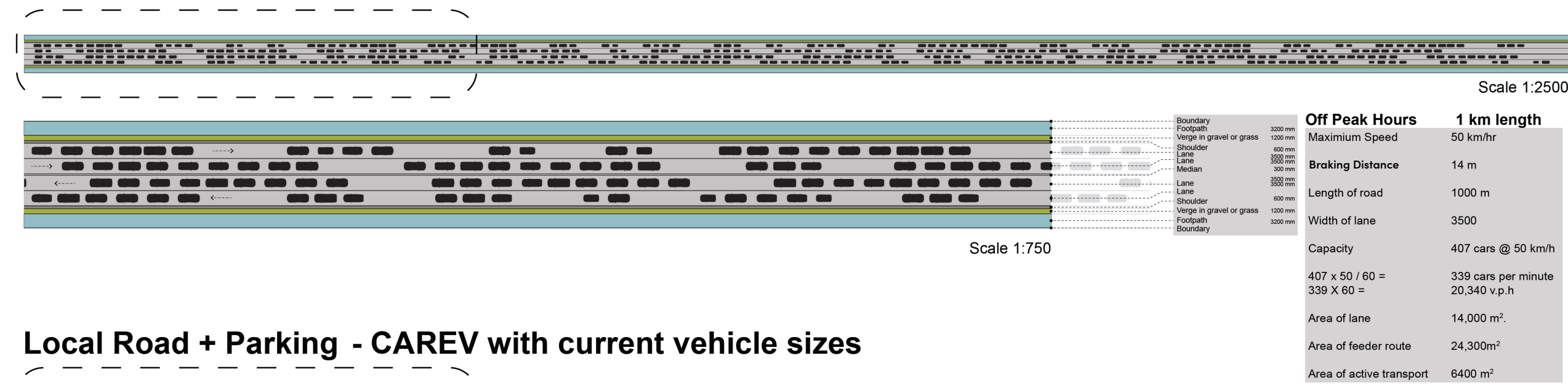
App. Fig. 30. Spatial study - standard - and mixed-size CAREV-S arterial capacity.

Arterial - CAREV with current vehicle sizes

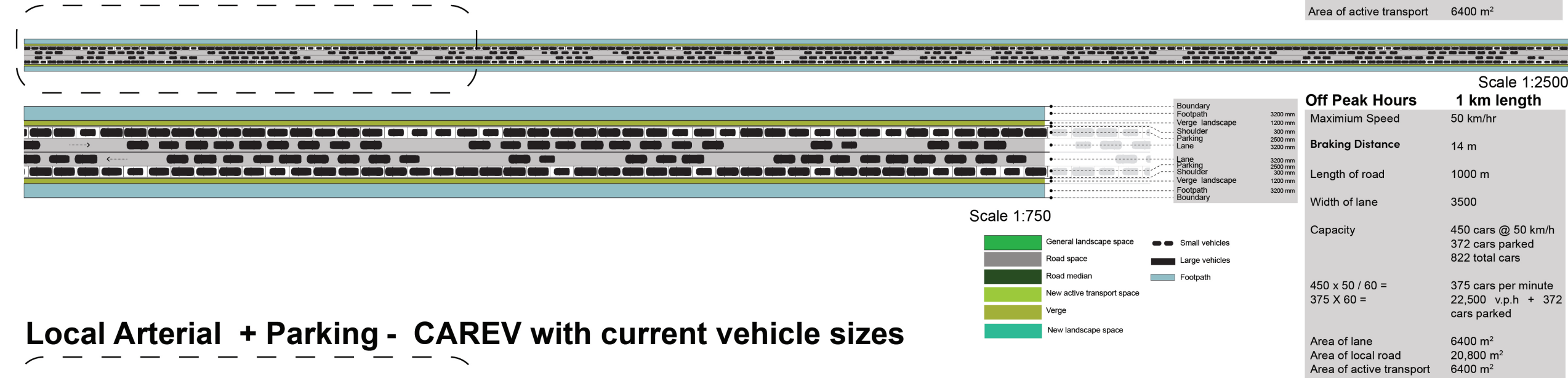


App. Fig. 31. Spatial study - standard - and mixed-size CAREV-S arterial capacity.

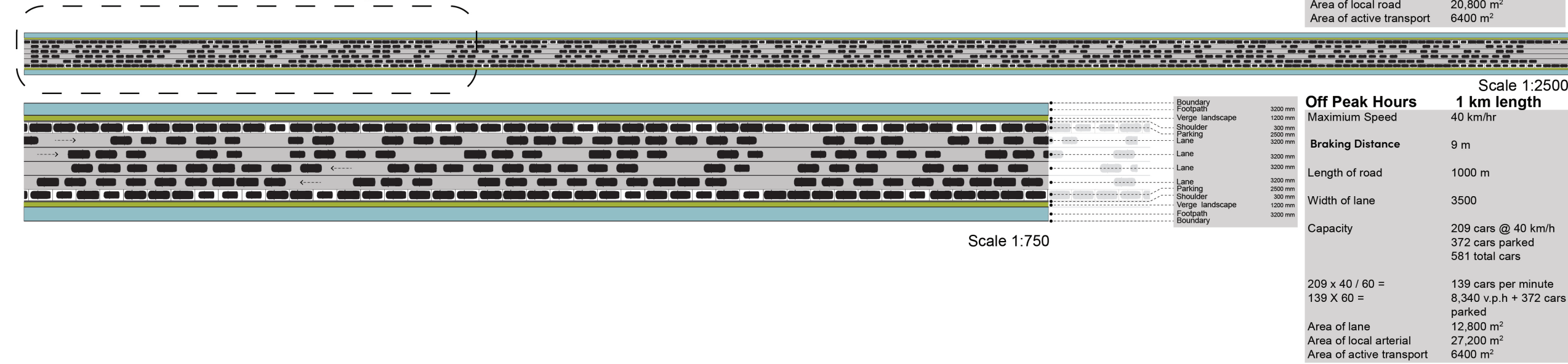
Feeder Route - CAREV with current vehicle sizes



Local Road + Parking - CAREV with current vehicle sizes



Local Arterial + Parking - CAREV with current vehicle sizes



Intentionally blank.



Comparative analysis between CAREV-S road type + existing road types
aim: increase active transport and landscape space through CAREV-S

App. Fig. 32. Spatial study - standard- and mixed-size CAREV-S feeder route, local road and local arterial capacity.

Appendix F.7 Road capacity study with increased environmental area due to CAREV-Ss

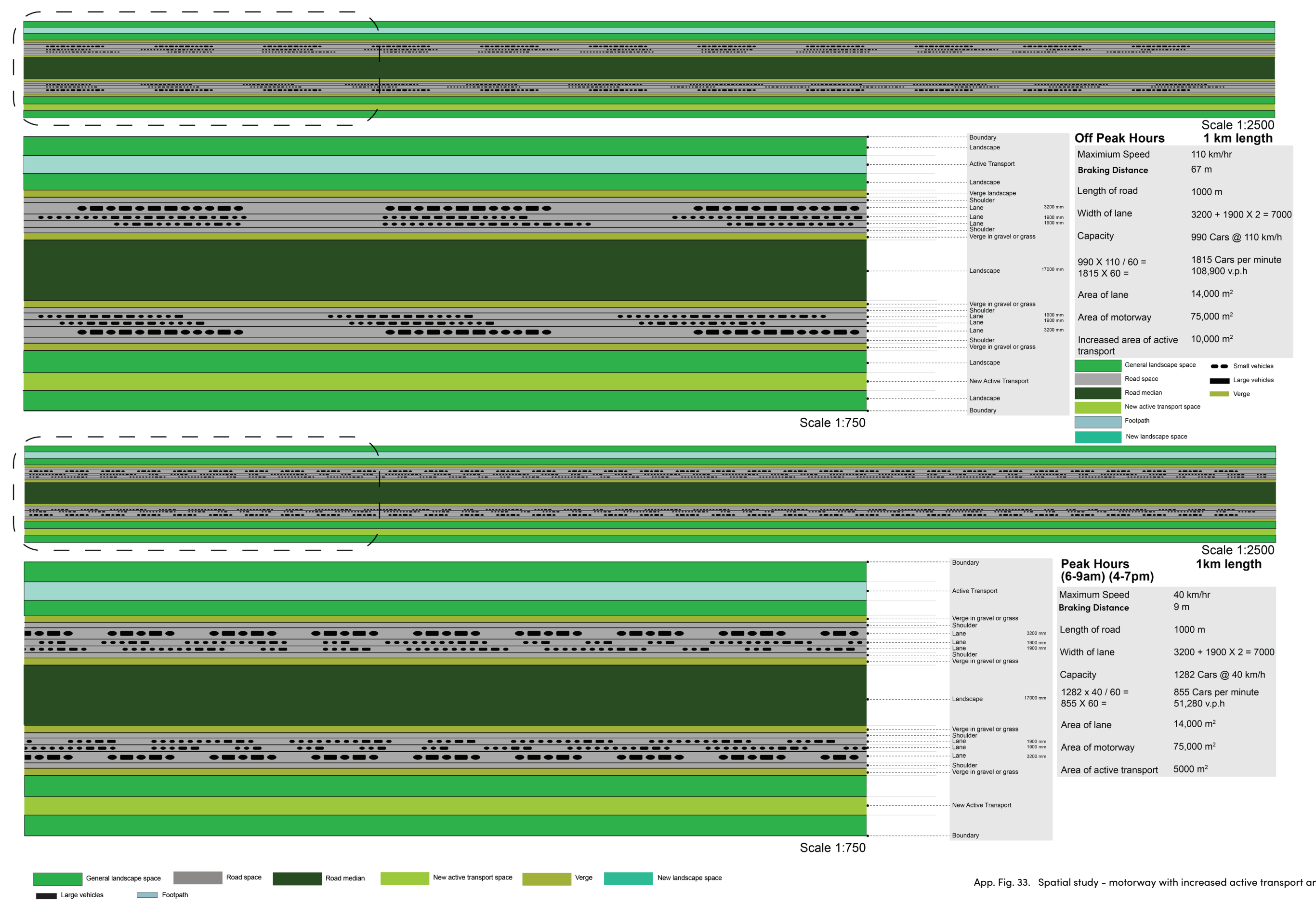
This additional mixed CAREV-S road capacity study was developed to assess an increased landscape / active transport scenario while maintaining the existing five road typologies and adjusting the criteria, as follows:

- Vehicle sizes were reduced: 63% of vehicles had one seat, 7% two seats (CAREV-S) and the remaining 30% four or more seats. These figures are consistent with current average use patterns in Australia.
- The lane width was reduced (3200 mm) for larger CAREVs, and two 1750 mm tango lanes were added as a CAV does not require the same lane space as a human driven vehicle.
- The environmental and active transport options and parking were redistributed to allow for re-imagining of the streetscape.

The study investigated how many additional lanes could be added with Should this say something like 'when using CAREV-Ss (CAV technology and smaller vehicle types). The research explored three options that could arise from the use of smaller vehicles, as follows:

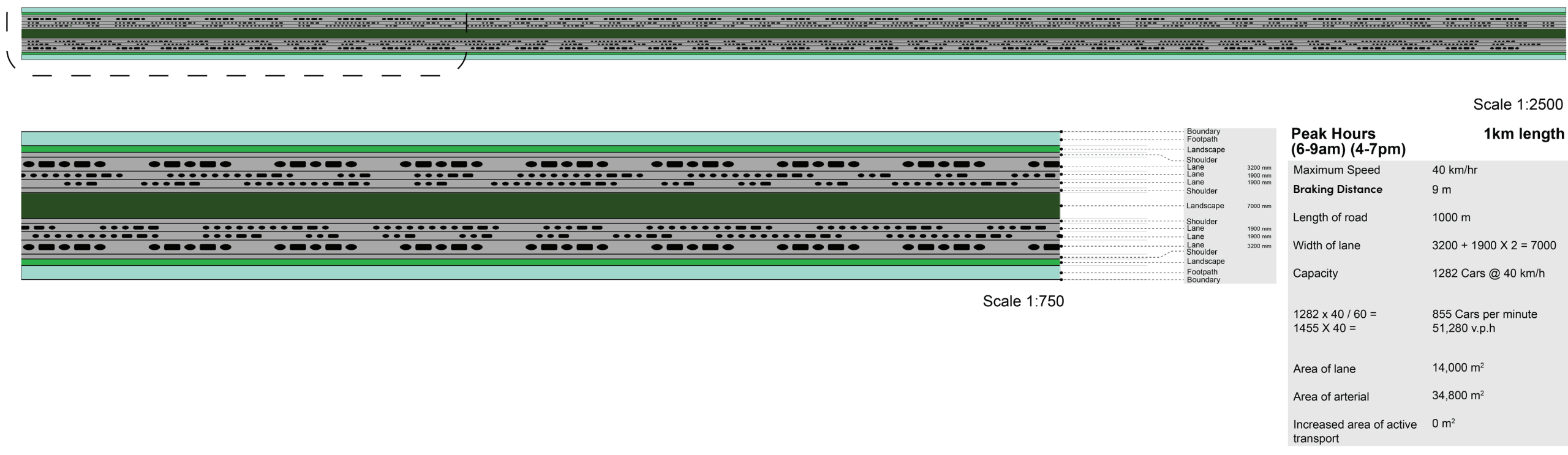
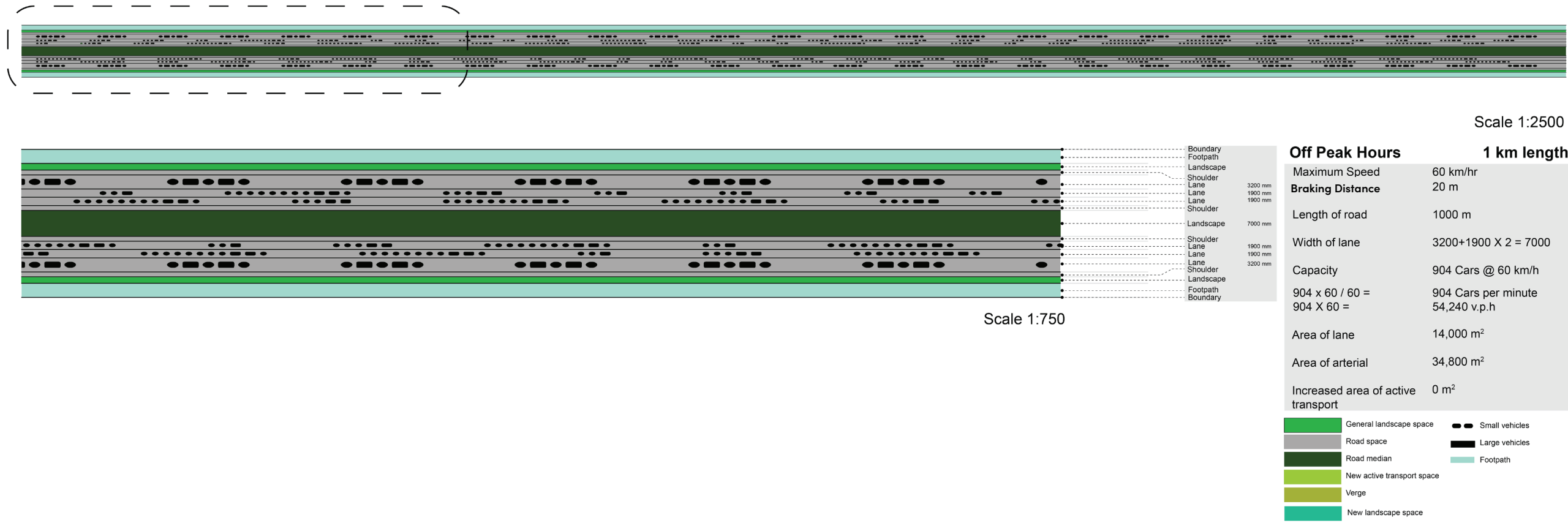
1. Redistributed parking to increase shared paths and environmental areas
2. Redistributed active transport pathways to improve street functionality and aesthetics
3. Optimised environmental (landscape) space

Motorway - CAREV-S (mixed vehicle) + increase active transport



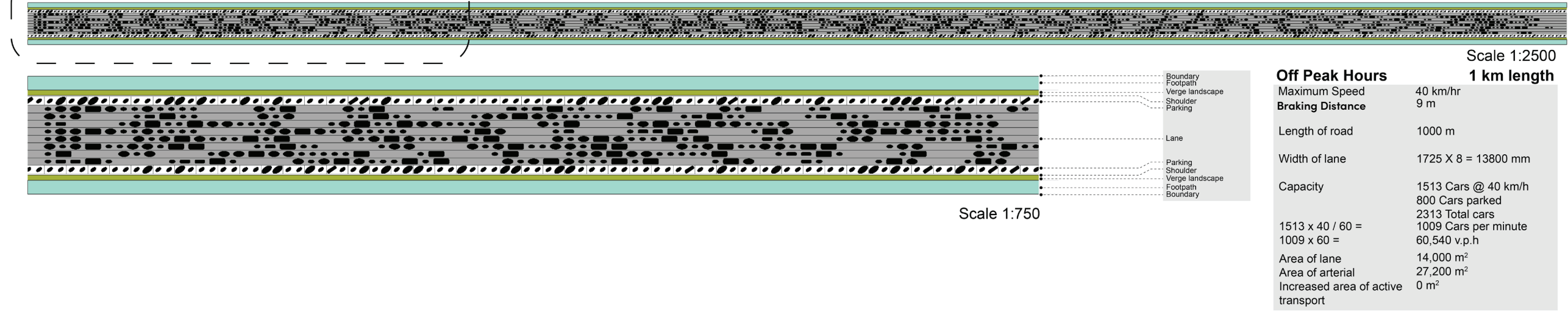
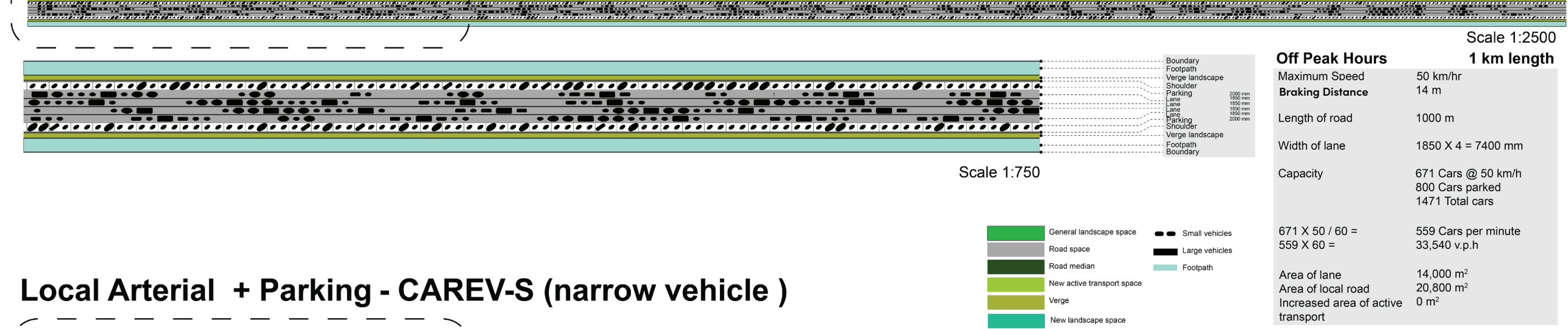
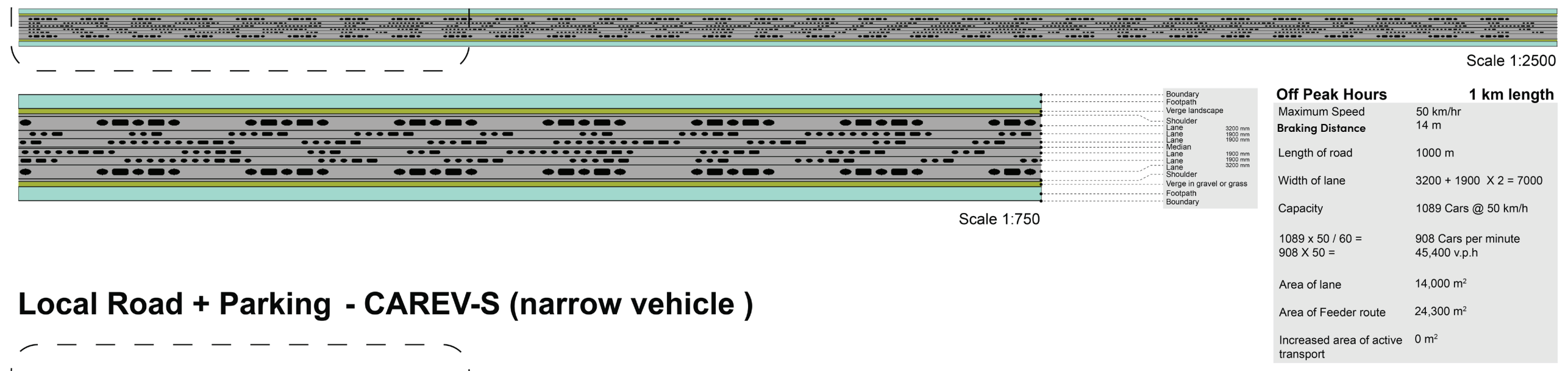
App. Fig. 33. Spatial study - motorway with increased active transport and landscape area.

Arterial - CAV (mix vehicle)+ increase active transport



App. Fig. 34. Spatial study - standard- and mixed-size CAREV-Ss on a feeder route, local road and local arterial, with increased landscape area.

Feeder Route - CAREV-S (narrow vehicle)



App. Fig. 35. Spatial study - comparative analysis of existing vehicles and CAREV-Ss, with increased landscape area.



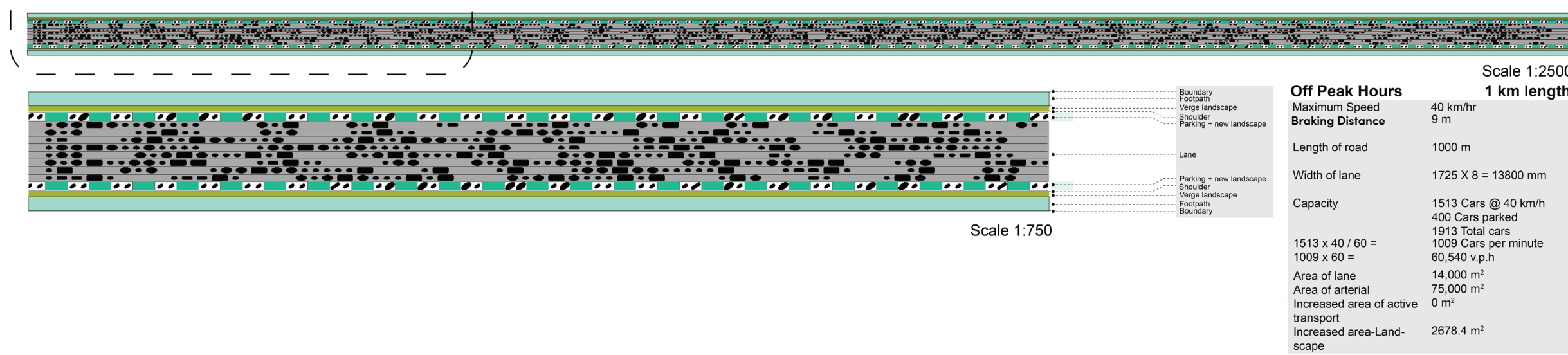
Appendix F.8 Comparative analysis

This section of the spatial investigation synthesised the data as a comparative tool. It is presented as a table to associate the type of the investigation with the criteria and the likely policy that would emerge.

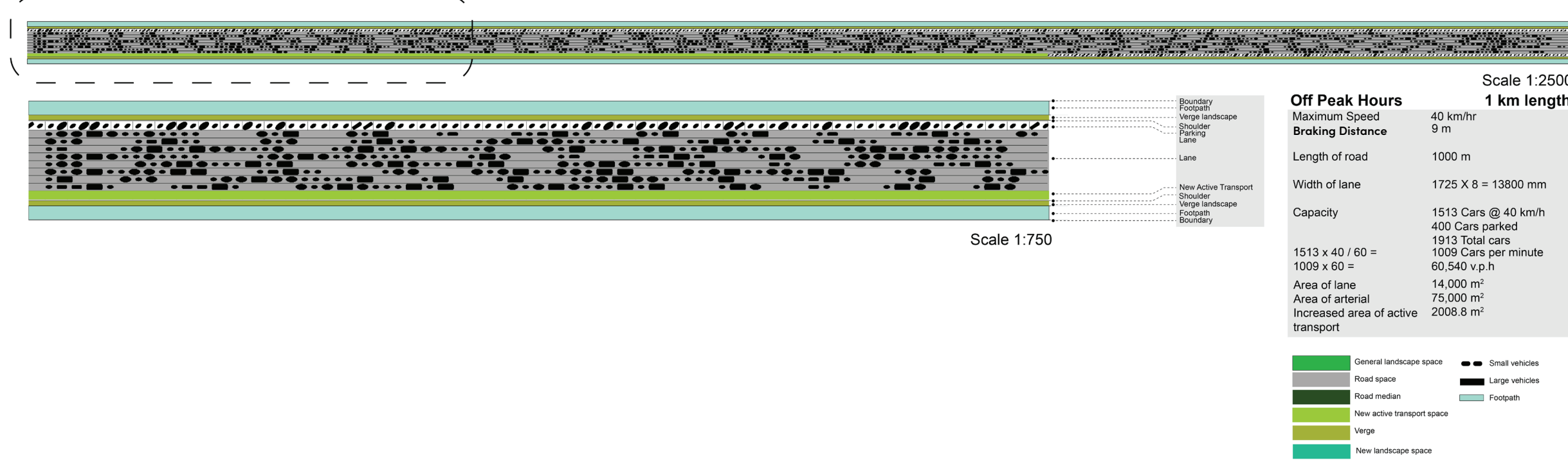
Consolidated table of criteria and related policy.

TYPE OF STUDY	CRITERIA APPLIED	RELATED POLICY
(A1) Vehicle ergonomic study	<p>Use universal access principles for a variety of user types, including minority groups, disability groups and families, for a diversity of users, including non-binary people, large and small people, and children.</p> <p>Develop a range of vehicle typologies, including seat configurations that reflect current passenger motor vehicle use patterns, such as 63% of vehicles with one person, 7% with two people and the remaining 30% with four and six people.</p>	<p>Universal access provisions can be found in the Disability and Discrimination Act, for example. The model should be flexible enough to accommodate a variety of user types and a diverse community as a human rights issue.</p> <p>Policy could set taxes or incentives for vehicle seating types, road space occupancy and vehicle mass; this could involve a computerised calculation based on use to encourage certain types and patterns of use.</p>
(A2) existing road typology, to gain baseline control data	<p>Utilise existing road layouts with 3.5-m lanes; this is an international USA/UK/EU/Australian standard.</p> <p>Utilise a variety of road types (e.g. five) commonly seen in an inner-city suburb , such as a motorway, arterial, feeder route (with and without parking) and local road.</p> <p>Utilise typical footpath dimensions of 3.2 m.</p>	<p>Designing CAREVs for cities is the policy approach. A physical and legal limitation would be that road space allocation (3-5m lanes and 3.2-m footpaths) would remain. This would allow large vehicles to continue to use existing roads.</p> <p>The retaining of existing footpath dimensions and locations in this study is associated with drainage and utility locations in Australia, which would be prohibitively expensive to change.</p> <p>The study should consider basic urban network layouts and road typologies; otherwise, it will lose validity.</p>
(A3) Investigation of the capacity of roads using standard-size CAVs	<p>Investigate reconfiguring the road space to accommodate the new vehicle typology (e.g. in which 63% of vehicles hold one person, 7% two people and the remaining 30% four and six people) with the aim of increasing environmental space or active transport space.</p> <p>Ensure the modelling does not exclude large vehicles formats, such as a variety of buses, cranes, emergency vehicles, trucks, delivery vehicles and other large vehicle types.</p> <p>Provide metric analysis of the increased capacity of roads for smaller vehicles and the resulting environmental benefits.</p>	<p>See item A2 in the Related Policy column.</p> <p>Policy settings for large vehicles, such as buses, cranes, emergency vehicles, trucks and delivery vehicles, have established universal dimensions; this includes considerations such as freight storage systems. The study set some limitations which are likely to persist into the future.</p>
(A4) Heat island study using UHTC metrics associated with the CAREV-S capacities	<p>Using the baseline conditions of an existing 2021 urban heat island study for the selected area, compare this to:</p> <p>New heat island study using the new capacity increases of environmental space to shade the study area with mature trees</p> <p>The current CAREV-S study indicates a ±9% increase in environmental space</p> <p>Accept the limitations of the UHI model for shadowing the model surface with tree-shade only, ie. no material changes between models</p>	<p>Policy settings for future CAREV-S cities could establish principles that say 9.3% of all hard surface spaces be converted to environmental space to allow for increased vegetation and shading to reduce heat island effects and improve environmental conditions.</p> <p>Policy setting could also be make to increase the amount of road space made available for active transport users</p> <p>Policy setting could be established to ensure that heat island effects in cities are minimised by say 3 degrees centigrade through vehicle design, additional shading, biodiversity offsets and other environmental mechanisms</p>

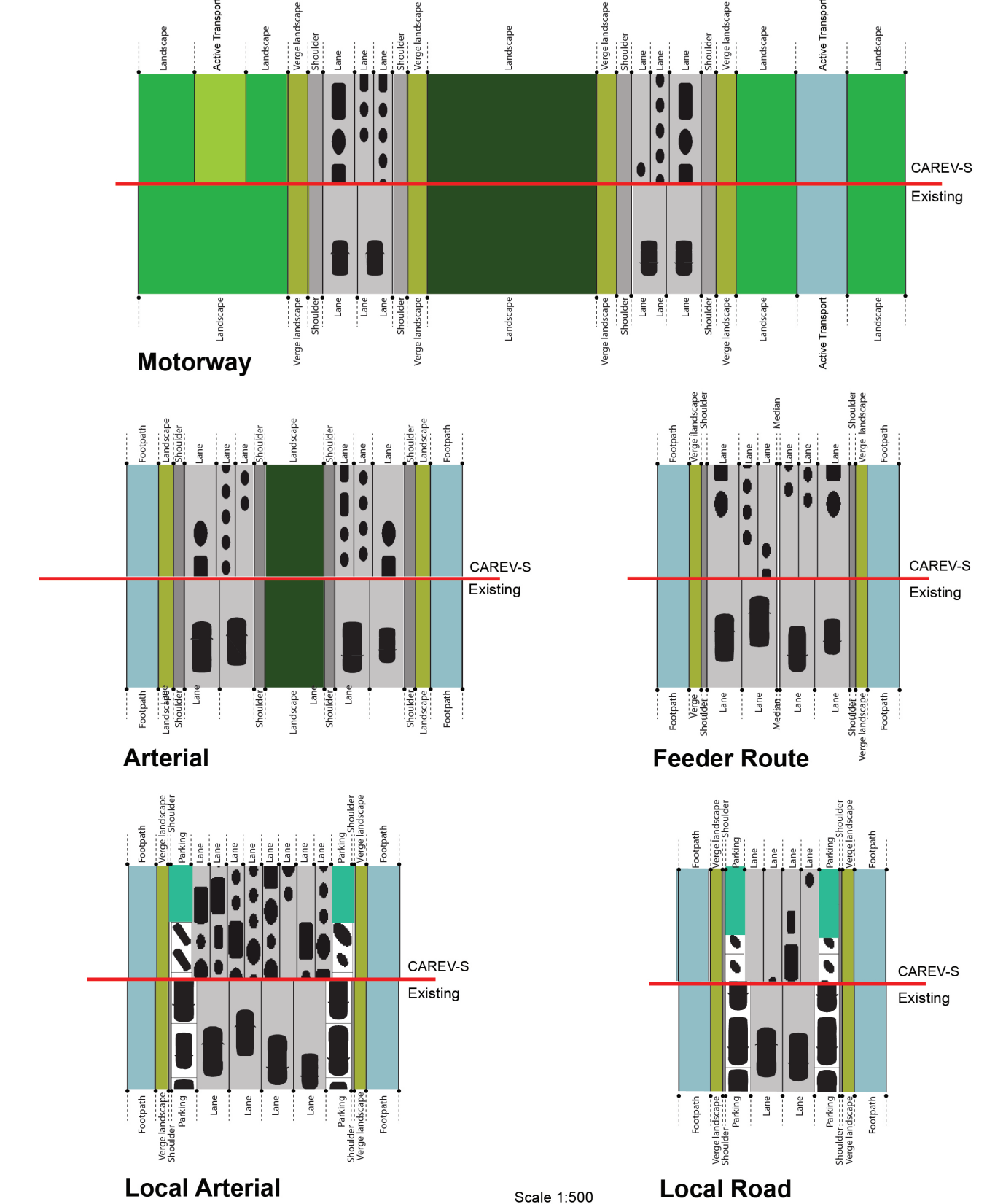
Local Arterial + Parking - CAREV-S (narrow vehicle)+increased landscape



Local Arterial + Parking - CAREV-S (narrow vehicle)+ increased active transport



App. Fig. 36. Spatial study - CAREV-S dominant + mixed vehicle size on feeder with increased landscape.



App. Fig. 37. Spatial study – comparative analysis of existing vehicles and CAREV-Ss.

Appendix F.9 Urban heat island study for CAREV-Ss in Surry Hills

Appendix F.9.1 Introduction

Urban areas, especially those associated with developed economies, such as Surry Hills in Sydney, are likely to respond to increased temperatures with forced air and air cooling / air-conditioning responses, which in turn will draw upon the energy uses peaks at both night and day to alleviate the effects of UHIs as a result of climate change. It can be deduced that future urban developments are likely to require assessments of UHI effects and the establishment of mitigation measures in passive systems.

City policymakers should have a larger role in the vehicle design and manufacturing processes, including the determination of the vehicles' UHI, as the modelling from this study demonstrated a direct link among increased UHI temperatures, types of vehicles and the ways in which the vehicles use the city.

Urban heat islands studies assess the occurrence of higher temperatures in urbanized areas. During the warmer seasons, UHI effects lead to thermal discomfort, higher energy consumption, and aggravated pollution effects (in ICE / fossil fuel scenarios). Urban heat islands may also contribute to climate change by increasing the demand for air conditioning during heat waves, when the energy for air conditioning comes from the burning of fossil fuels. The data provided in this study could assist in understanding the systemic modelling of an existing UHI compared to a UHI in the same study area, but with CAREV-S vehicles and additional tree shading.

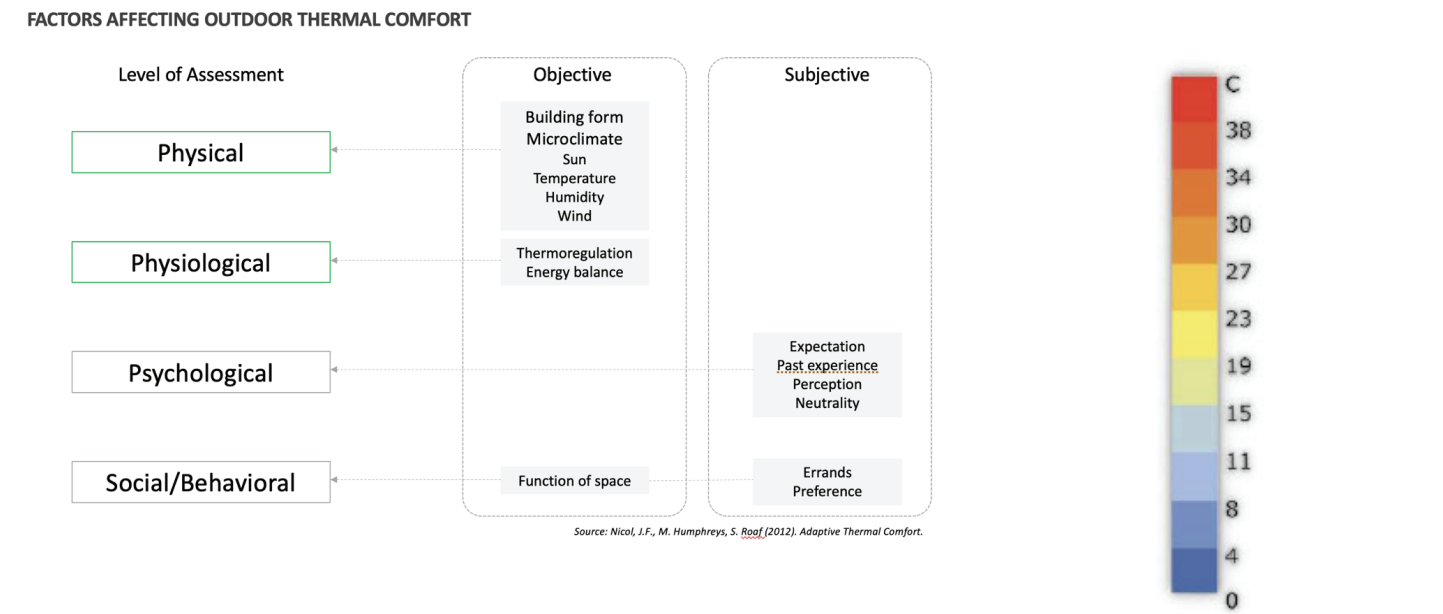
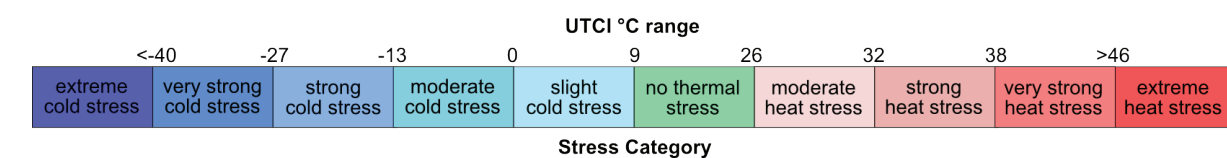
Part of the CAREV-S systemic study involved developing a simulation model to understand whether the additional 9% landscape area derived from the CAREV-S spatial study could assist in reducing UHI effects. Appreciating the magnitude of reductions of heat island effects through CAREV-S requires further research. A basic universal thermal climate index (UTCI) model would provide control model results that could then be used to assess the impacts of CAREV-Ss on the city.

The UTCI is the 'felt like' temperature based on parameters such as the following :

- Air temperature
- Wind speed
- Solar radiation
- Relative humidity
- Clothing level
- Activity level

Limitations associated with this research

The Universal thermal climate index (UTCI) models are regarded by academia and industry as general approximations. They are not intended to model all parameters and climatic effects, as this would require supercomputing, a process beyond the scope of this research. The UTCI values simulate approximate conditions. Their are relatively easy models to run tests on, notwithstanding the fact that this study required considerable hardware and software augmentation to obtain the limited - parameter UTCI results. The results provided are both metric and graphic and provided basic data with which findings could be made. This study focussed on one variable, that is, creating passive shade systems through an increase in tree shade cover in the existing model only. The modelling was also based on a limited human factors stress



App. Fig. 38. Spatial study -UHI factors affecting outdoor thermal comfort and colour scale.

categorisation, given below:

The study was set in the same area in which the CAREV-S capacity study was undertaken. The study area of the model and suburb was approximately 370,000m². The study area modelling tested the limits of the computer operations, beyond this modelling, a supercomputer would be required. To compile the model, a series of sub-models were joined. The climatic data for the Grasshopper software was supplied by the Australian Bureau of Meteorology for Surry Hills, Sydney in 2020.

The simulation took place in September and October 2021¹

The temperature scale bar was computer generated (Grasshopper) with graphic representation of hot (red), warm (orange yellow) and cool (blue). The colours seen above in the colour scale can be seen graphically on the UHI study drawings on the following pages.

Appendix F.9.2 Other UHI Variables

Other variables that could be developed to refine the UHI modelling include, but are not limited to the following:

- Material surface changes of the model can have a significant impacts on reducing heat island effects¹
- Additional 9.8% area landscape change from hard surfaces to vegetated surfaces.
- Reductions in air / engine temperature associated with changes from fossil fuelled motor engines to electric engines.²
- Reductions in energy consumption associated with EV and the reductions in temperatures from fossil fuelled vehicles to renewable energy (which would have a broad temperature reductions)³ in both operational and manufacturing cycles.
- Lower local area temperatures through (CAREV-S) could result in lower domestic energy use (in Australian conditions) as air-conditioning energy consumption / heat output would be reduced.
- Other additional resources for UHI effects can be found through USA EPA - Urban heat island effects.⁴

Appendix F.9.3 UHI Research findings

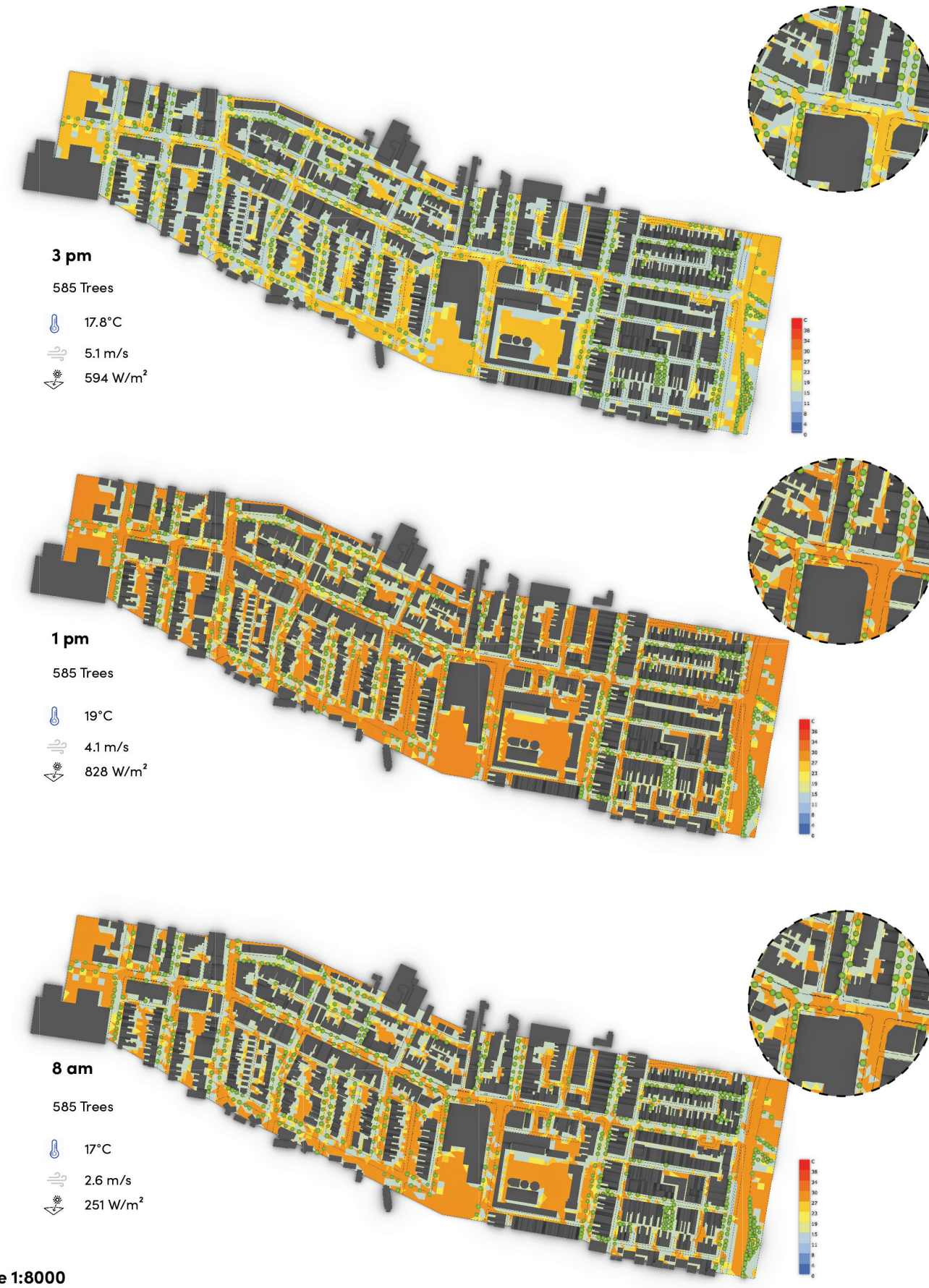
Notwithstanding the modelling limitations⁵, it can be assessed that CAREV-S (a mixed small vehicle format) could be anticipated to provide multiple environmental benefits by increasing landscape space, reductions in engine temperatures (electric vehicles), increases in shade trees (the model included mature trees). Overall the model shows that the study area could expect reductions in UHI effects through mass and distributive tree planting across the study area within the public realm. This initial and basic UTCI model testing could be re-run, the software and model is available to others for testing and verification.

DATES		Existing (control group)			CAREV-S trees shading			Trees added	Difference in degrees centigrade
		8am	1pm	3pm	8am	1pm	3pm		
Summer solstice	22 Dec	27	34	30	19	27	19	585	-3
Autumn Equinox	21 March	23	30	27	15	23	15	585	-3
Winter solstice	21 June	11	27	23	11	23	19	585	-4
Spring Equinox	23 Sept	23	30	27	18	27	23	585	-3

The summary results are that for a CAREV-S city with 9.8% extra landscape area and approx. 10% area for 585 mature shade trees approximately equally distributed across the model.

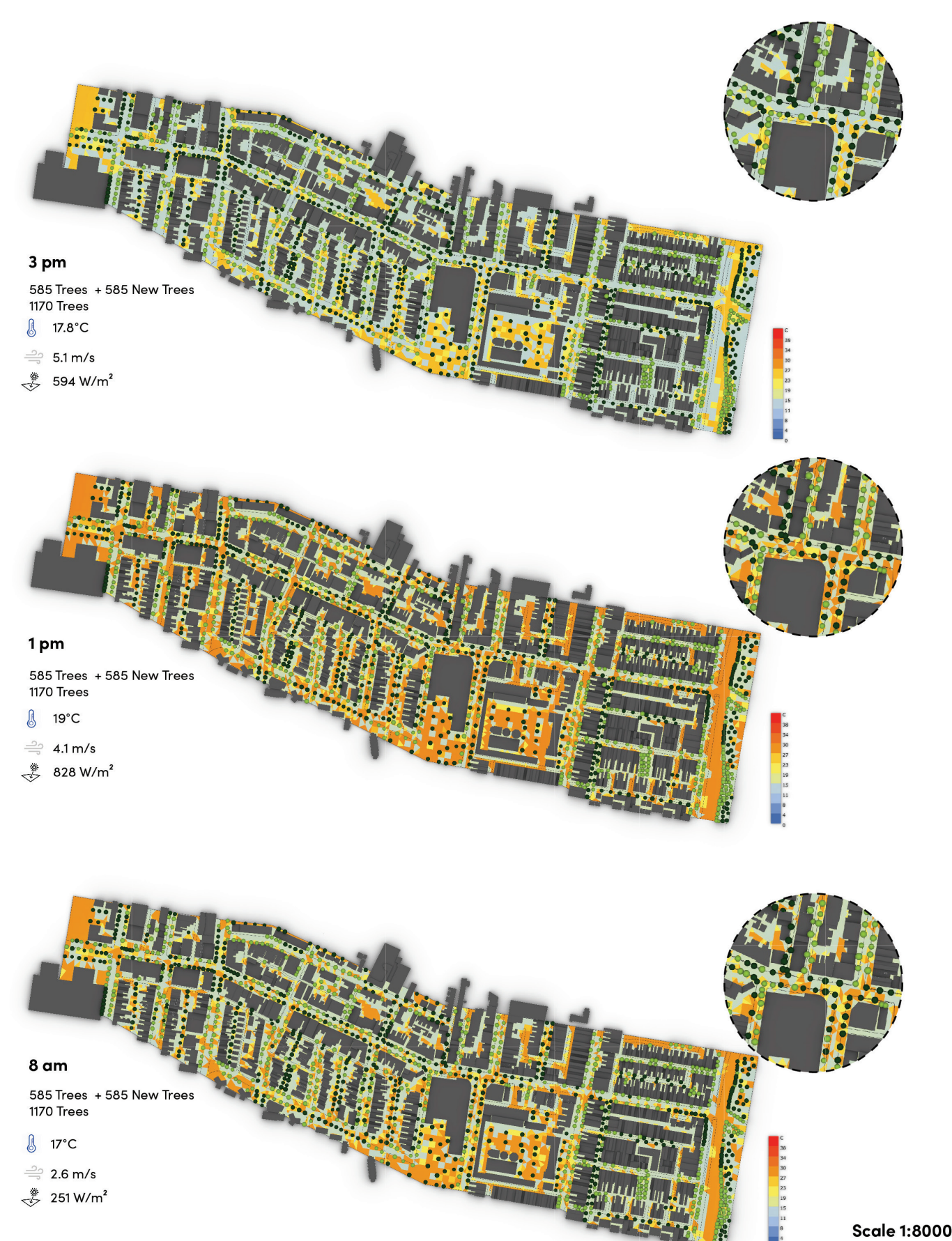
¹ Matthaios Santamouris, 'Minimizing Energy Consumption, Energy Poverty and Global and Local Climate Change in the Built Environment: Innovating to Zero: Causalities and Impacts in a Zero Concept World' (Amsterdam: Elsevier, 2019).
² Mausbach (2010) has noted a number of authors providing data on energy lost as heat and through the exhaust of fossil - fuelled vehicles is as much as 80% of the energy of the vehicles. Furthermore, Andrews et al. (2007) have provide data on the output of vehicle manufacturing heat and energy consumption. Lovell (2020) from the Australian Energy Council has confirmed the increased efficiency of electric engines and overall reductions in energy consumption from EVs. Refer to Andrews, D, P Nieuwenhuis, and P.D Ewing, 'Living Systems, "Total Design" and the Evolution of the Automobile: The Significance and Application of Holistic Design Methods in Automotive Design, Manufacture and Operation', WIT Press, 27. WIT Transactions on State of the Art in Science and Engineering (2007) and Mausbach, Artur Grisanti, 'Paradigm Shift: The Aesthetic of the Automobile in the Age of Sustainability' (unpublished Thesis, Royal College of Art, 2010) <https://researchonline.rca.ac.uk/1164/> [accessed 4 August 2021]
³ Lovell, Justine, 'EVs: Are They Really More Efficient?', Australian Energy Council, 2020 <https://www.energycouncil.com.au/analysis/evs-are-they-really-more-efficient/> [accessed 25 April 2022].
⁴ US EPA, OAR, 'Heat Island Effect', 2014 <https://www.epa.gov/heatislands> [accessed 25 April 2022]
⁵ A number of preoccupations complicated this research. For example CAREV-S technologies are currently unavailable, and a complete fleet change to smaller CAREV-Ss is a hypothetical condition. The model also assumes that the use of fully mature trees effects reductions in temperature, but trees require at least 10 to 15 years to reach maturity and full shade effects. Furthermore, the study assumed the presence of fully evergreen trees, whereas in Surry Hills, the City of Sydney street tree palette includes many deciduous trees, the use of which would impact the results, especially in winter. Furthermore, additional model simulation inputs for materiality and reductions in temperature through the general plant (shrubs etc) types and areas could also affect the results, leading to lower temperature effects.

Existing case study area UHI model (control model)



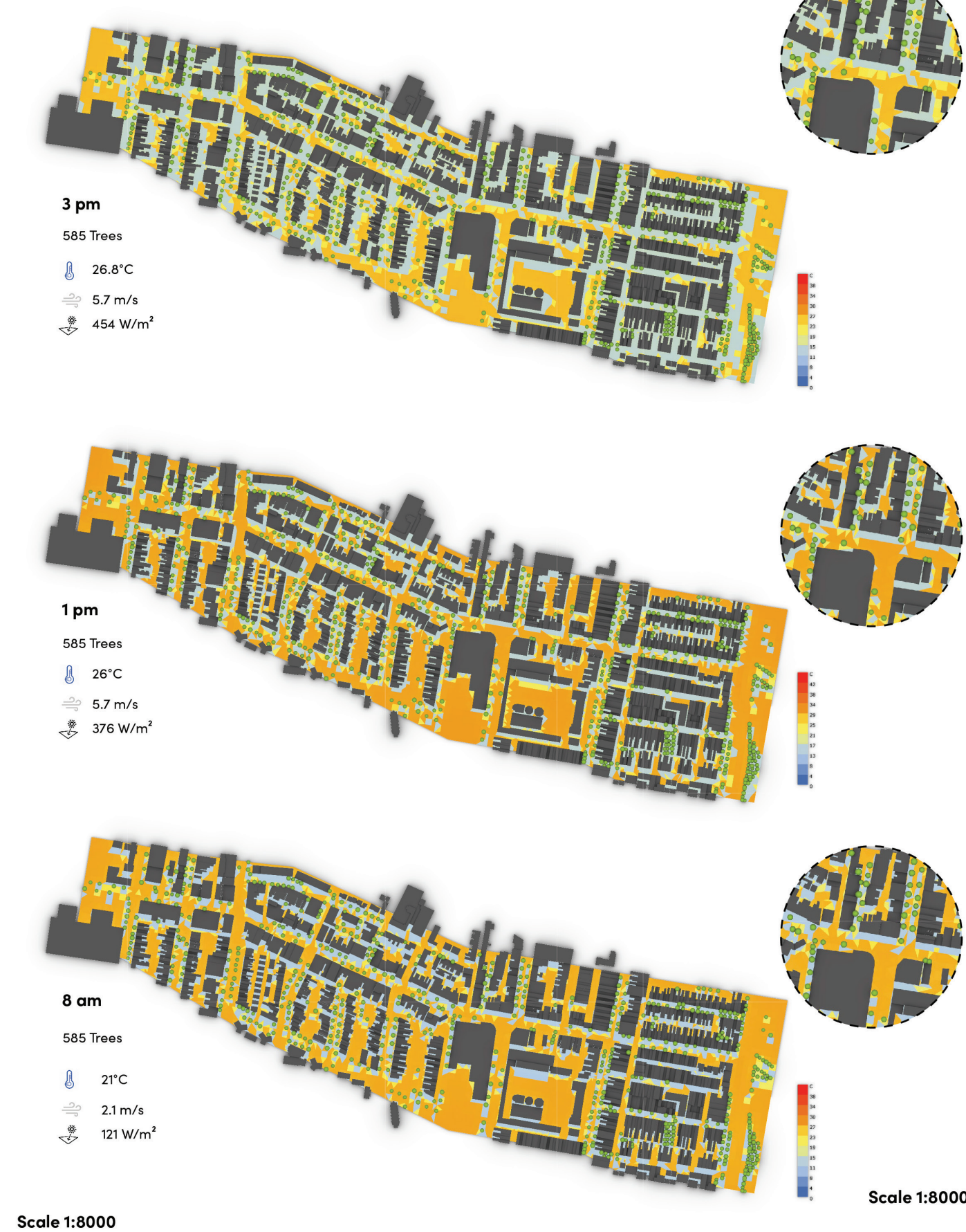
App. Fig. 39. Spatial study -UHI 8am, 1pm, 3pm September 2021 existing UTCI Surry Hills.

CAREV-S case study area UHI model with 585 additional trees



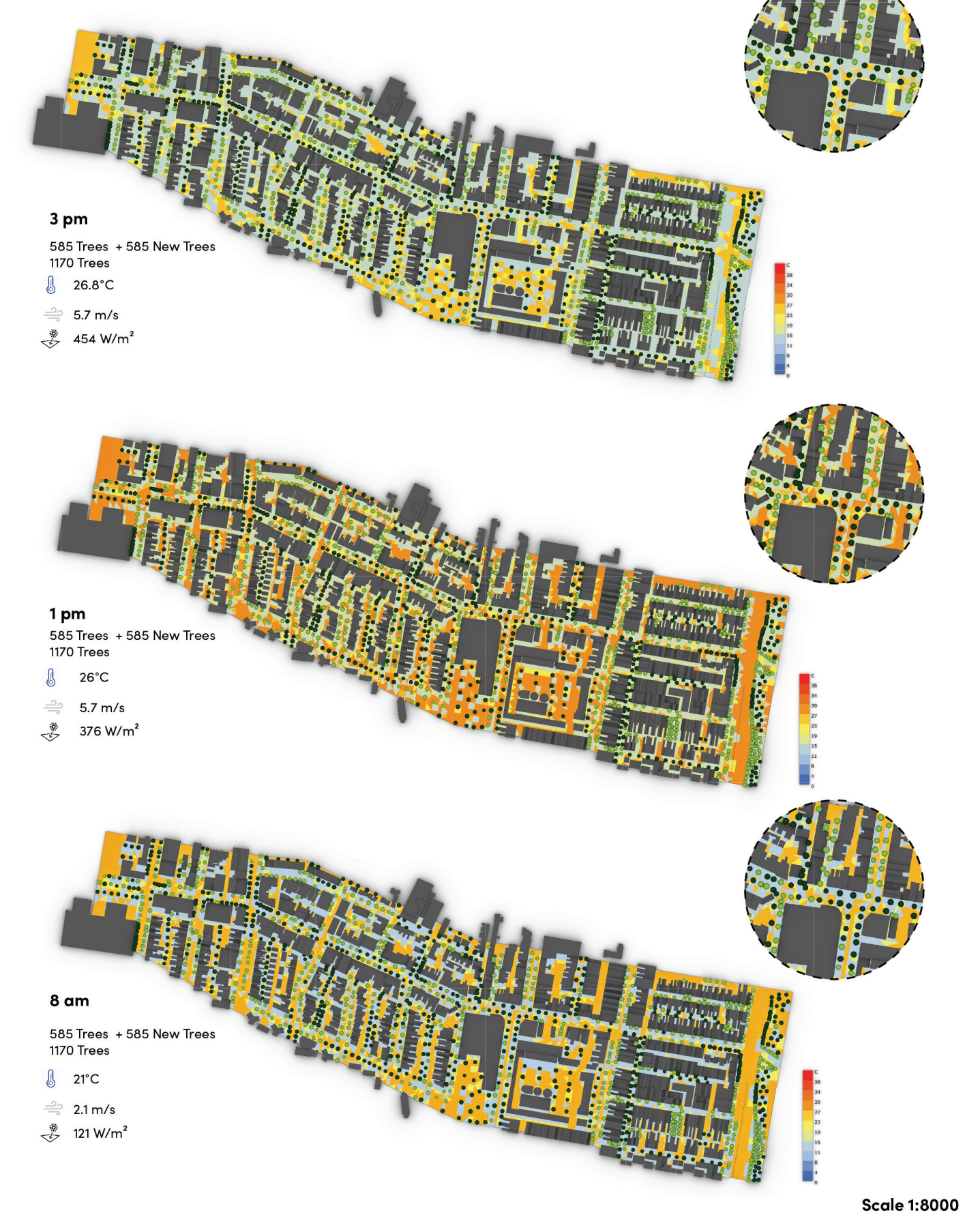
App. Fig. 40. Spatial study -UHI 8am, 1pm, 3pm September 2021 CAREV-S additional tree shading UTCI Surry Hills.

Existing case study area UHI modelling (control model)

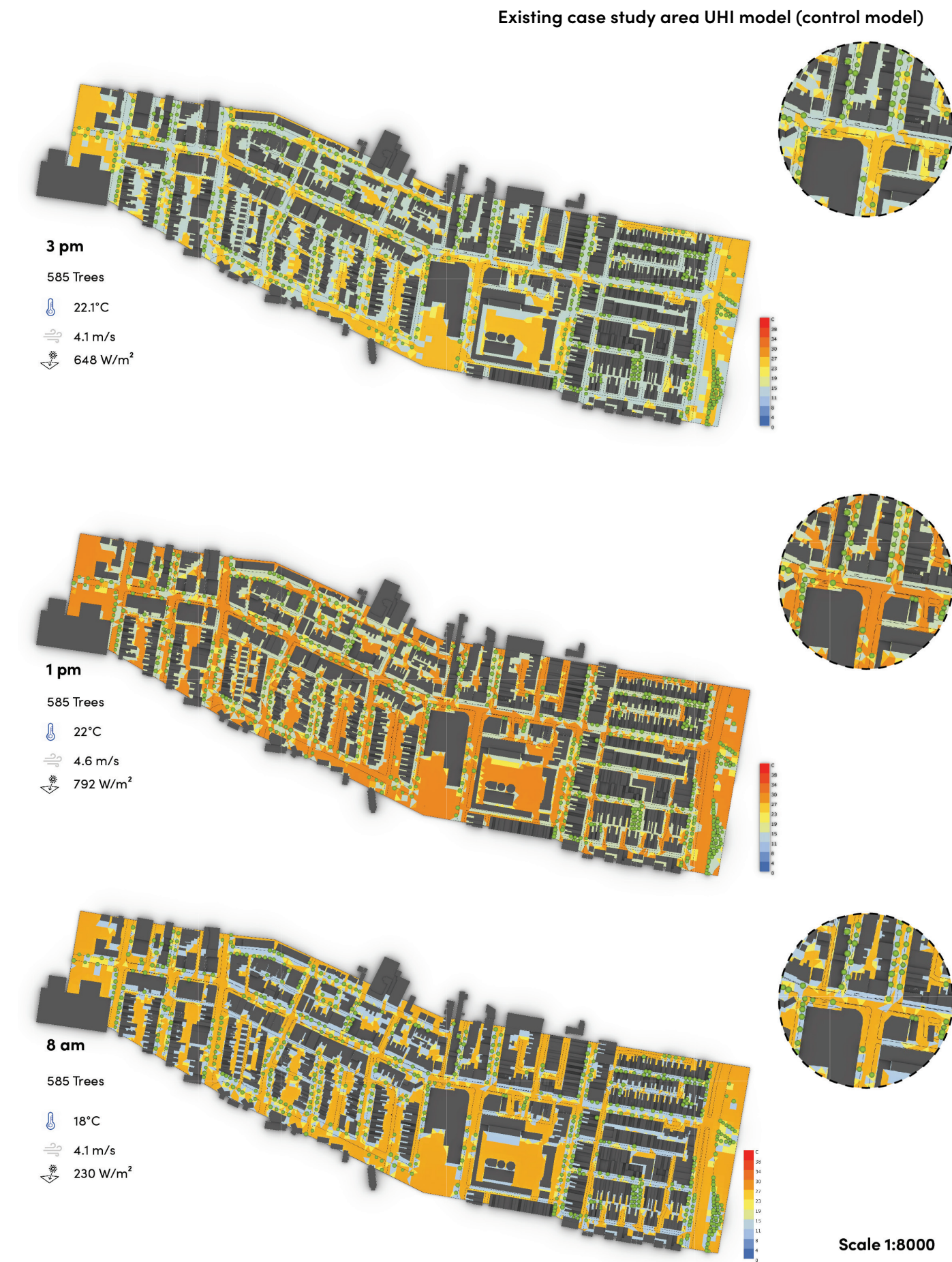


App. Fig. 41. Spatial study -UHI 8am, 1pm, 3pm December 2021 existing UTCI Surry Hills.

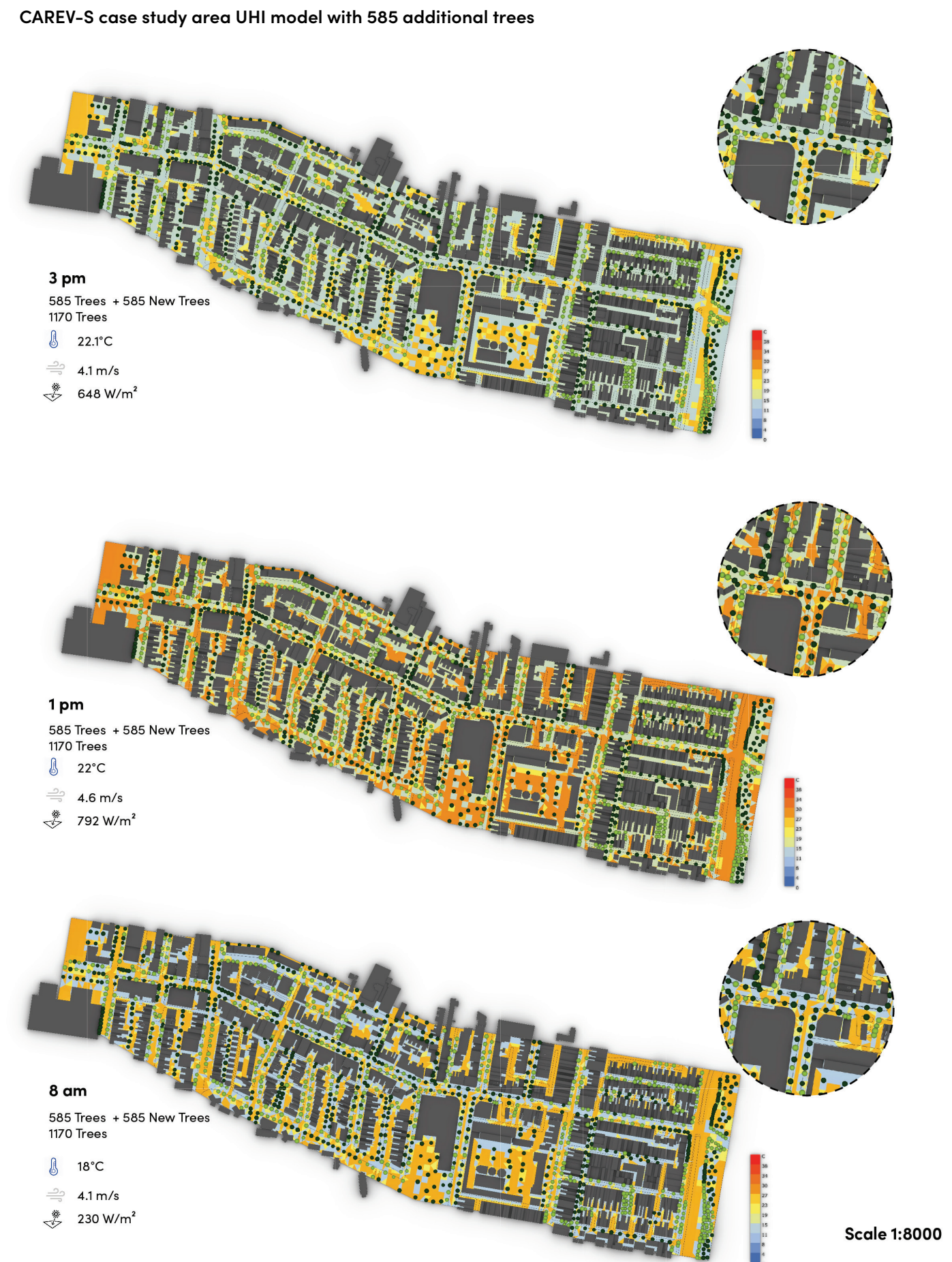
CAREV-S case study area UHI model with 585 additional trees



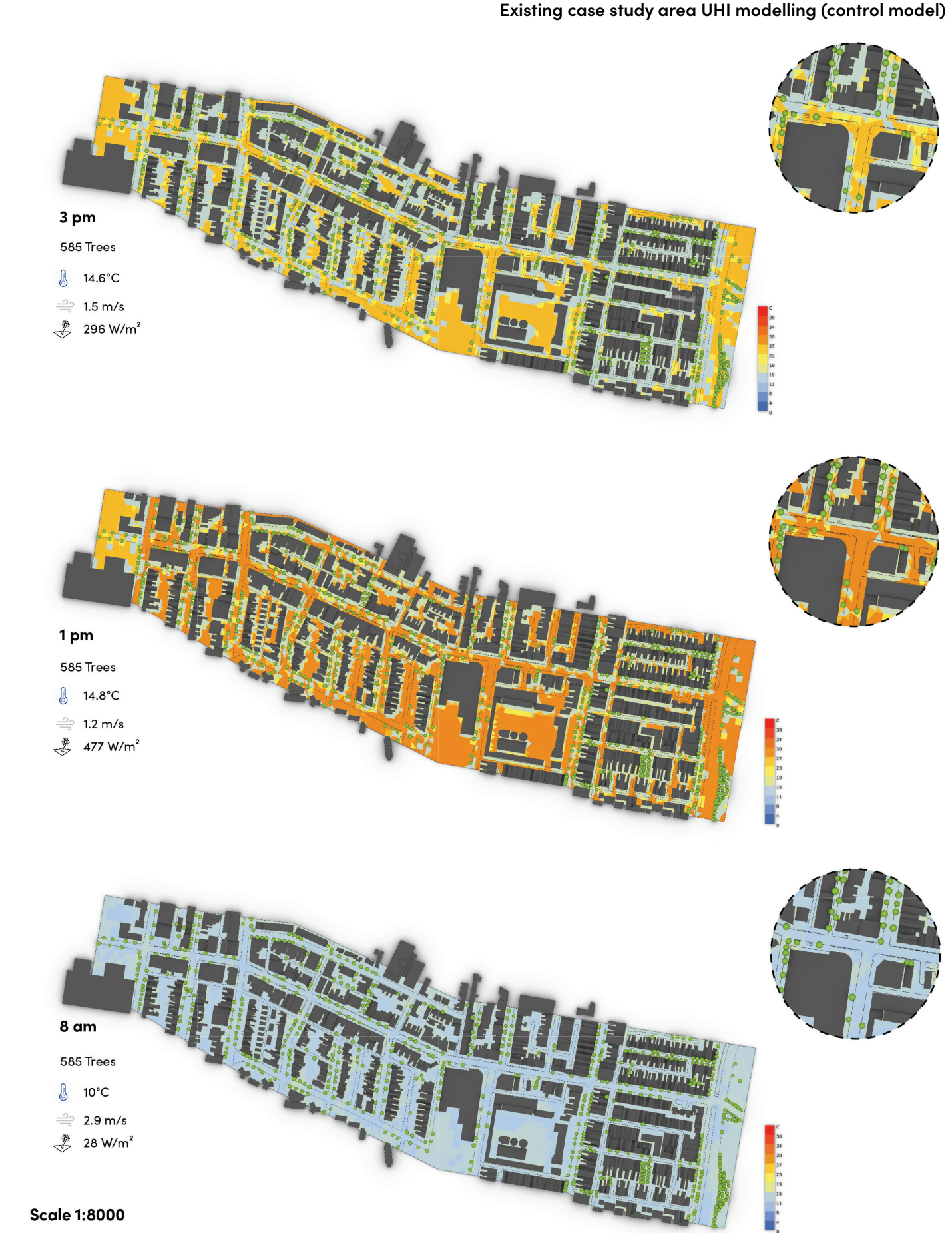
App. Fig. 42. Spatial study -UHI 8am, 1pm, 3pm December 2021 CAREV-S additional tree shading UTCI Surry Hills.



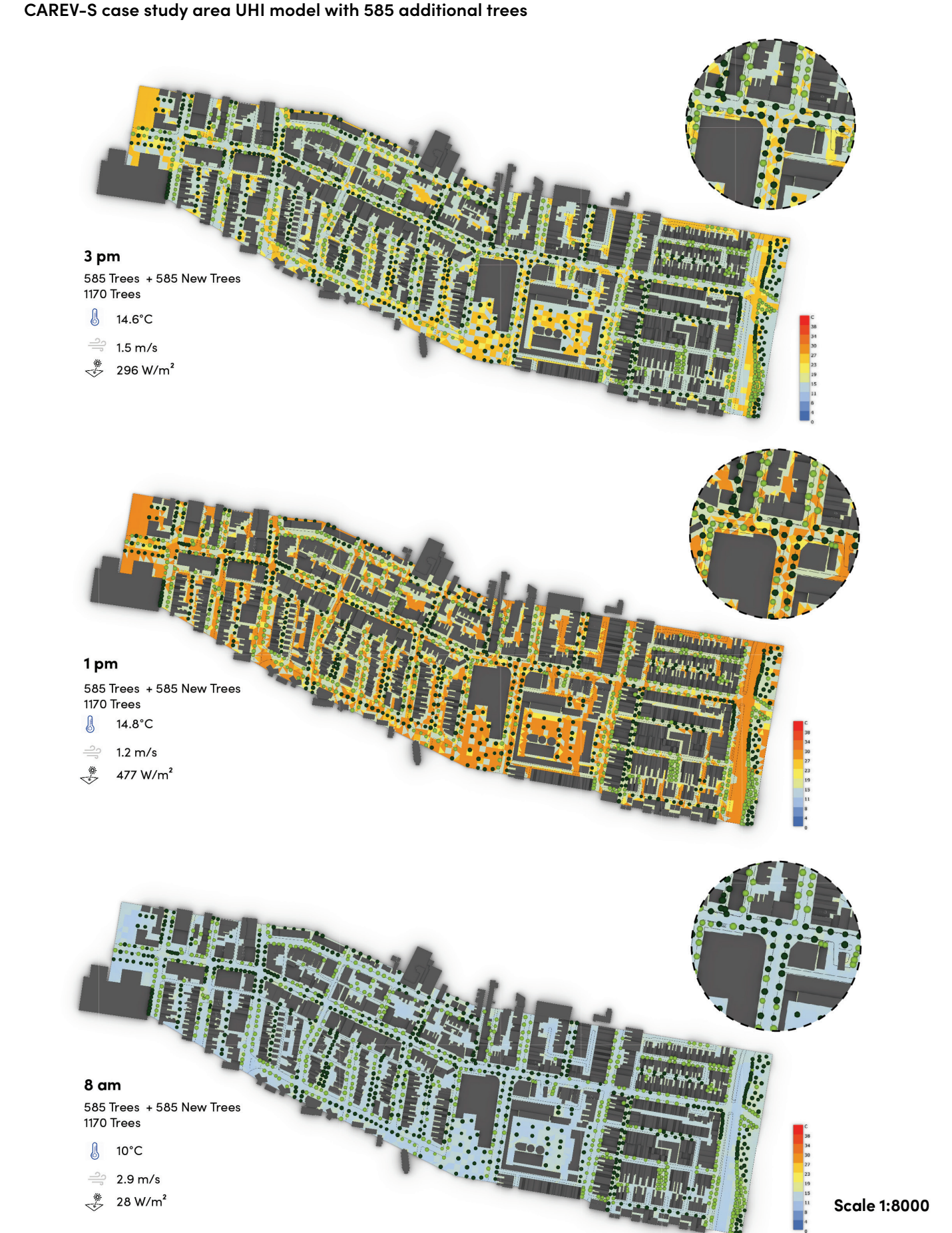
App. Fig. 43. Spatial study -UHI 8am, 1pm, 3pm March 2021 existing UTCI model for Surry Hills.



App. Fig. 44. Spatial study -UHI 8am, 1pm, 3pm March 2021 CAREV-S additional tree shading UTCI Surry Hills.



App. Fig. 45. Spatial study -UHI 8am, 1pm, 3pm June 2021 existing UTCI Surry Hills.



App. Fig. 46. Spatial study -UHI 8am, 1pm, 3pm June 2021 CAREV-S additional tree shading UTCI Surry Hills.

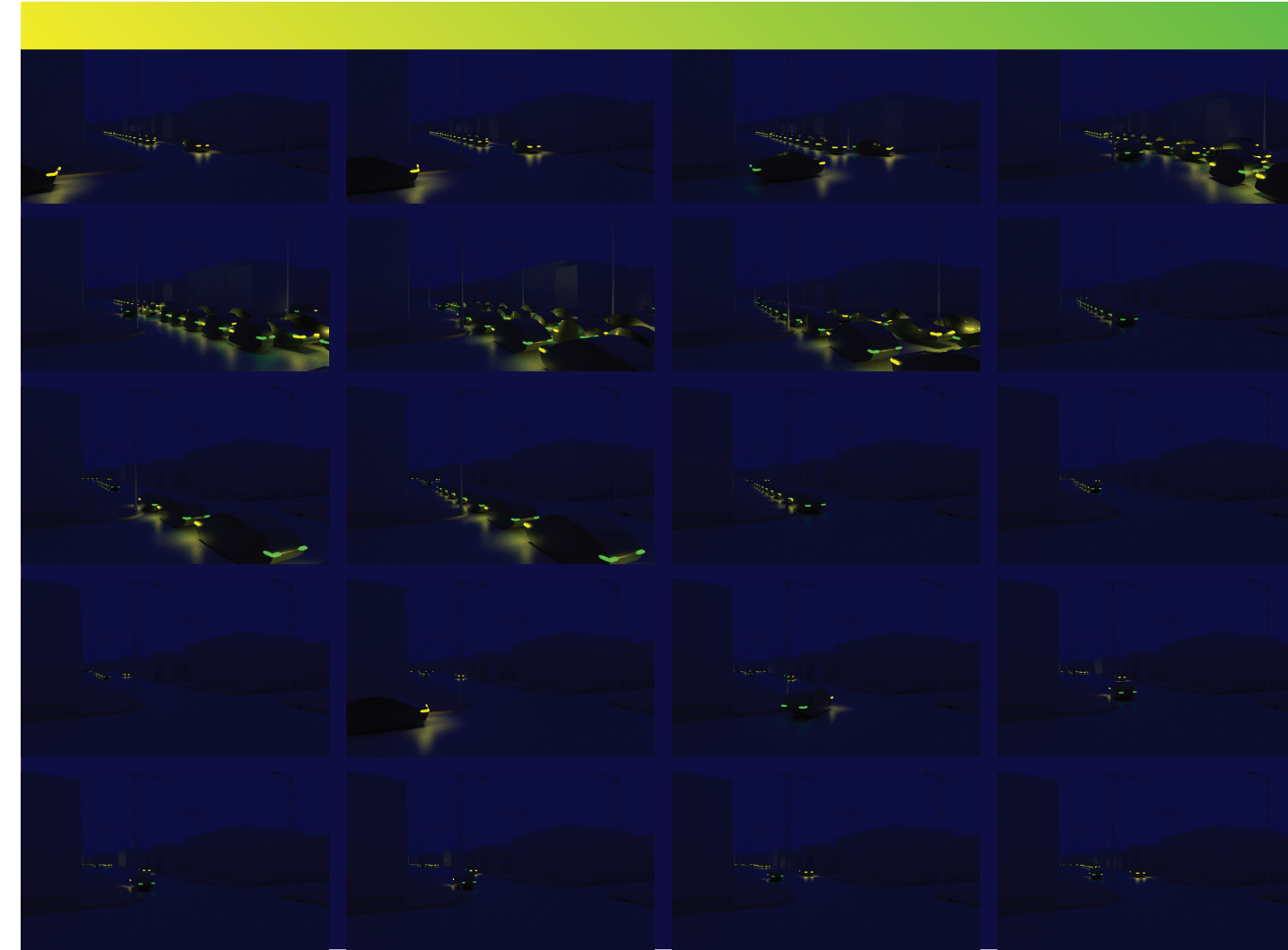
Appendix F.10 Visualisations of existing vehicle scenario versus CAREV-S in Surry Hills

This visualisation study was developed in response to Symposium 5 feedback that further visual scenario testing should be undertaken. The visual assessment was an aesthetic scenario comparison. The visualisations showed an increased landscape / active transport scenario while maintaining the existing Crown Street / Cleveland Street intersection, Surry Hills.

- Mixed CAREV + CAREV-S: 63% of vehicles had one seat, 7% two seats (CAREV-S) and the remaining 30% four seats.
- The lane width (3,200 mm) was reduced for larger CAREVs, and two 1750 mm tango lanes as a CAV does not require the same lane space as a human - driven vehicle.
- Environmental and active transport options and parking were redistributed to allow for a re-imaging of the streetscape.

The study investigated the visual impact of more vehicles driving and more people being transported in the CAREV-S scenario versus the existing vehicle scenario.

1. Video 1 is the animated version of this image and shows the dynamic semiotic systems
2. Increased CAREV movements lead to more people moving with less energy expended
3. Parking is redistributed to increased CAREV movements lead to more people moving with less energy expended shared paths and environmental areas
4. Active transport pathways are redistributed improve street functionality and aesthetics
5. 'Environmental (landscape) space with increased tree and vegetation areas
6. The CAREVs include new semiotic systems, which are integrated with novel city - wide traffic management systems
7. The SI traffic management system assists a variety of active transport users at the intersection, which is choreographed with CAREV traffic movements.



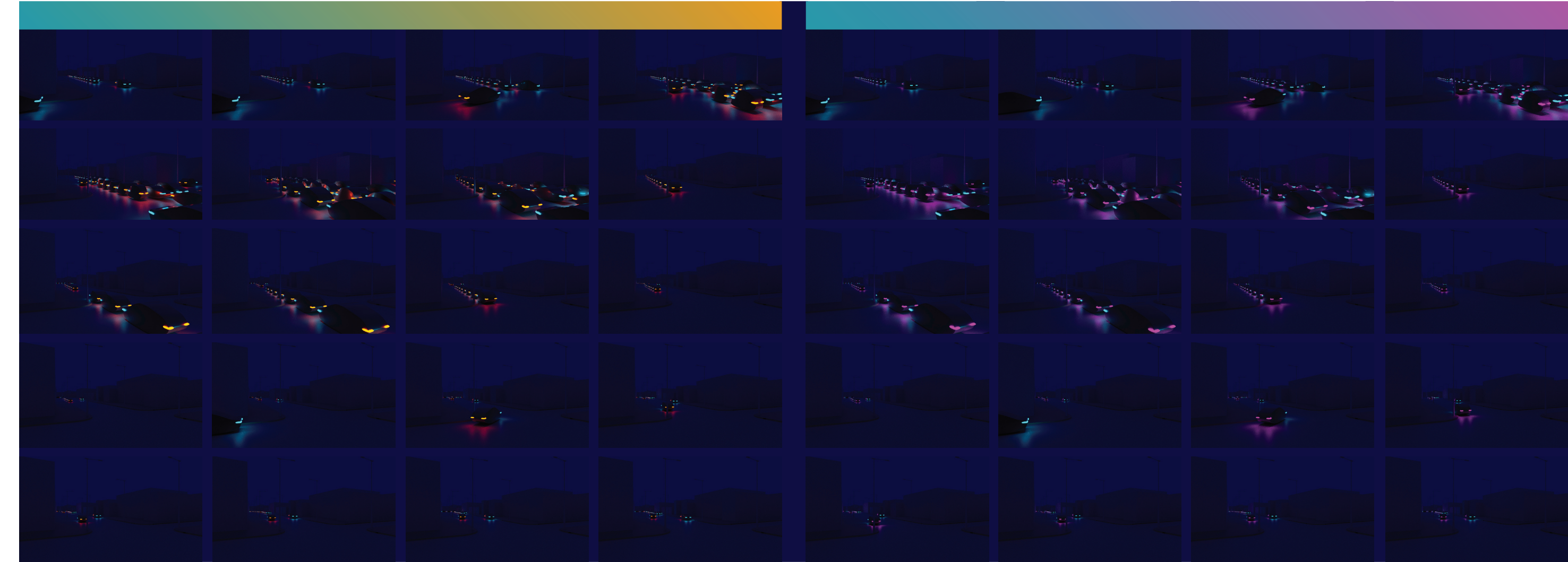
App. Fig. 47. Mosaic of frames from the CAREV colour study using green-yellow combination (yellow - oncoming vehicle, green - rear lighting)

Appendix F.10.1 CAREV colour study

Figures 47, 48 and 49 are still frames from the CAREV colour study and form part of synthesising the semiotic and spatial study with the visualisations of CAREV in the study area (Appendix F.10.) In the animation, the CAREVs are associated with a novel communications unit that displays culturally appropriate semiotics as an interface between SI and human intelligence, refer to Figures 13, 14 and 15 in this Appendix. .

The animations used in the symposium facilitated and provoked discussions about designing the future CAREV/ AV transport system with the community, artists, industry and urban designers in a transdisciplinary and integrated manner. As a systemic approach, the semiotic system is a critical component of a future positive ecological outcome that is ethical and cognitive.

The colour study was not intended to be conclusive but rather to provide a conceptual position for CAREV-S and the possibility of future studies to address cultural manifestations, disability and minority cohorts, colour blindness, CAREV logistical movements and a range of complex and broad (e.g. visual, auditory and haptic) semiotic responses.



App. Fig. 48. Mosaic of frames from the CAREV colour study using blue-orange combination (orange - oncoming vehicle, blue/green - rear lighting)

App. Fig. 49. Mosaic of frames from the CAREV colour study using cyan-purple combination (cyan - oncoming vehicle, purple - rear lighting)

People with colour blindness represent about 8% of the population. Various colour combinations, intensities, tones and saturations would have differing results, depending on the type of colour blindness.¹ The colour study investigated yellow-green; blue/green-orange and cyan-purple colour combinations. Future studies such as these could be used to develop strategies to understand efficacy related to various forms of colour blindness and the relationship of colours to various cultural groups.

The animation can be seen in Video 1. The colour study provoked discussion in Symposium 3 about the role of architects and artists in the development of CAREV semiotics in the public realm to enhance visual, functional, semiotic, cognitive and aesthetic outcomes.

¹ National Eye Institute.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape area
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 50. Analysis visualisation Crown Street, existing vs CAREV mixed environmental area.



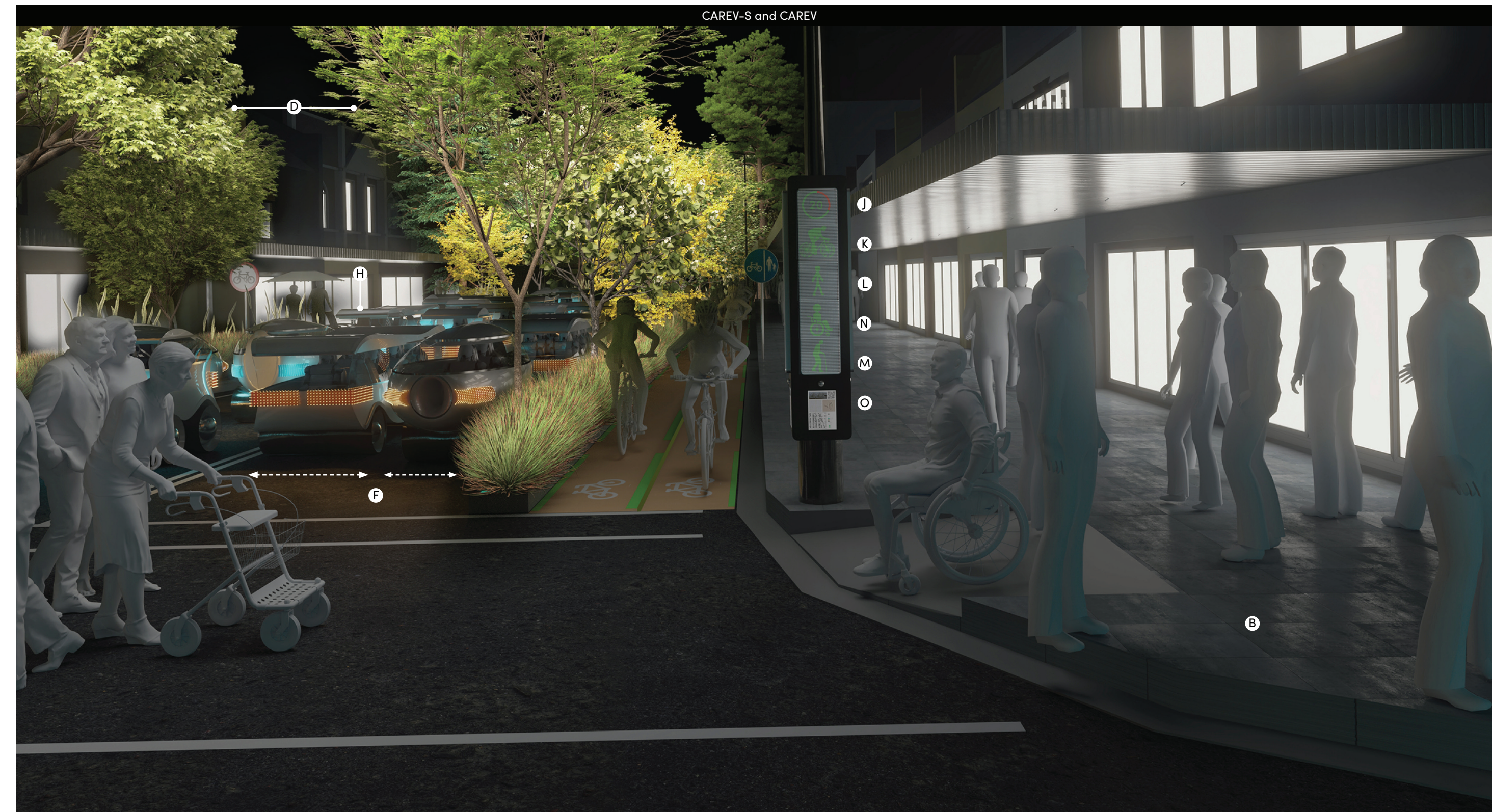
- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape & road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 51. Analysis visualisation Crown Street, existing vs CAREV mixed lane configuration and SI management.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape area
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 52. Analysis visualisation Crown Street, existing large format.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape & road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

The CAREV in this visualisation are spatial envelopes with semiotic systems attached. The CAREV are not intended to be representative of vehicle design.

App. Fig. 53. Analysis visualisation Crown Street, CAREV large format.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape area
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

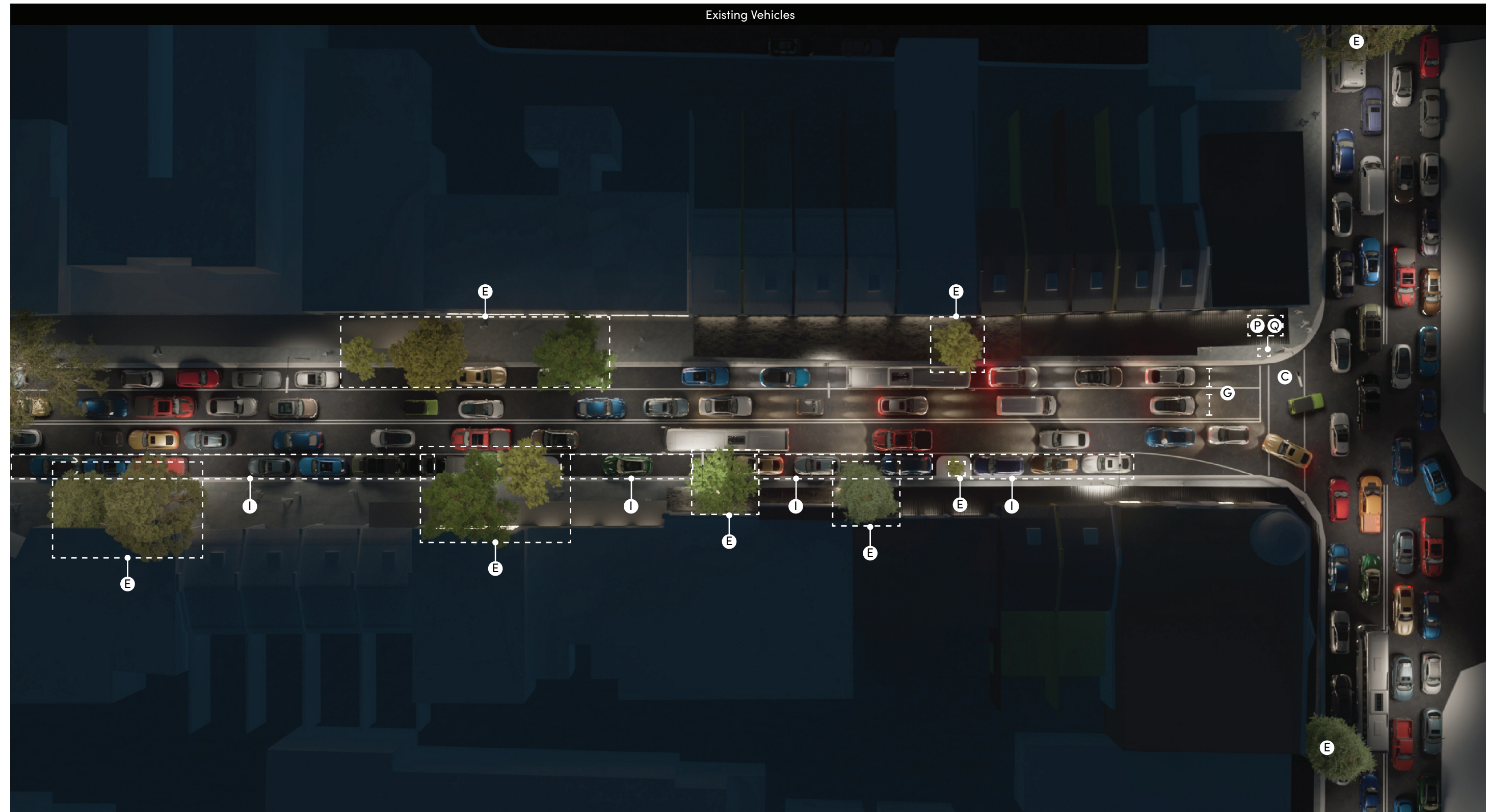
App. Fig. 54. Analysis visualisation Crown Street, existing aerial.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape & road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape
- I** Parallel parking city
- J** Time management
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- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
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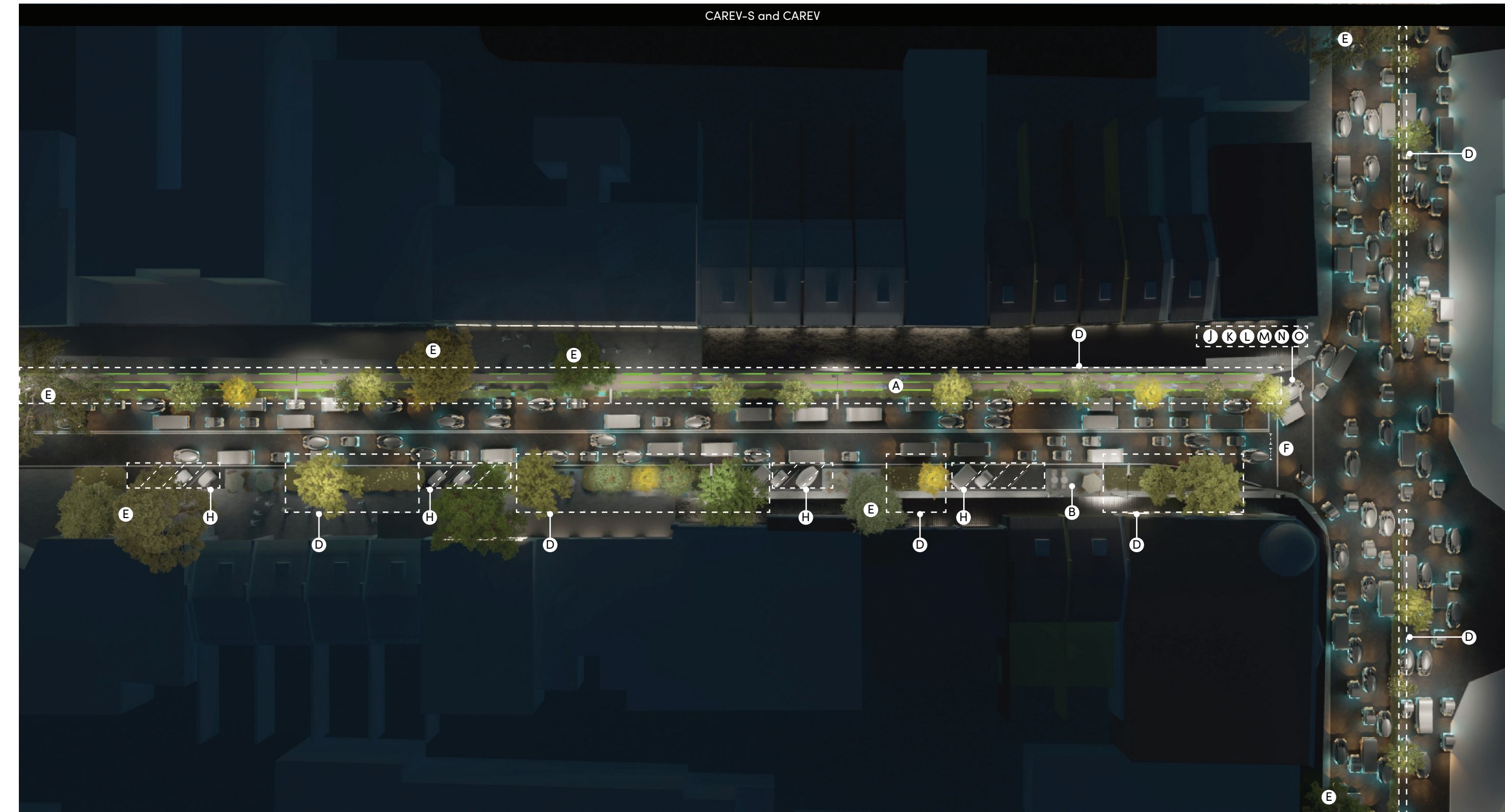
The CAREV in this visualisation are spatial envelopes with semiotic systems attached. The CAREV are not intended to be representative of vehicle design.

App. Fig. 55. Analysis visualisation Crown Street, CAREV aerial.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape area
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 56. Analysis visualisation Crown Street, existing plan.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape & road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 57. Analysis visualisation Crown Street, CAREV plan.



- A** Redistributed active transport area
- B** Variety of actors & abilities in the public realm
- C** Existing street scape road
- D** Increased environmental area with tree landscaping
- E** Existing trees & landscaping
- F** CAREV-Ss & CAREVs using less street space
- G** Vehicles using more street space
- H** Redistributed parking with landscape area
- I** Parallel parking city
- J** Time management
- K** Cyclist / personal mobility management
- L** Pedestrian management
- M** Disabled persons facilities
- N** Pedestrian management
- O** Braille / QR code communications
- P** City traffic management
- Q** Pedestrian management

App. Fig. 58. Analysis visualisation model of existing aerial of Crown Street.



The CAREV in this visualisation are spatial envelopes with semiotic systems attached. The CAREV are not intended to be representative of vehicle design.

App. Fig. 59. Analysis visualisation of Crown Street with CAREVs (aerial view).

Appendix G. AI Open Source ChatGPT questions and answers

'On 22 September 2023, the open-source AI ChatGPT was asked several questions. Its responses are given below :

Q: How can artificial intelligence sustainability guide a more ecologically and socially just mobility?

AI:

1. **Sustainability** can play a crucial role in guiding the development of autonomous vehicle (AV) mobility systems that are not only environmentally responsible but also socially just. Here are several ways in which sustainability principles can be integrated into AV mobility to achieve these goals:
2. **Reducing Emissions:** AVs can be designed to run on electric or other low-emission power sources, reducing greenhouse gas emissions. This transition to clean energy sources is essential for mitigating climate change and improving air quality.
3. **Energy Efficiency:** AVs can be programmed to optimize routes and driving patterns to minimize energy consumption. This includes features like regenerative braking, smooth acceleration and deceleration, and choosing the most energy-efficient routes.
4. **Shared Mobility:** Encourage shared AV mobility services to reduce the number of vehicles on the road. Shared rides can decrease traffic congestion and lower the overall environmental impact of transportation.
5. **Integration with Public Transit:** AVs can be integrated with public transit systems to provide first-mile and last-mile connectivity. This makes public transportation more accessible and reduces the need for individual car ownership.
6. **Smart Infrastructure:** Develop smart infrastructure that supports AVs. This includes dedicated lanes, charging stations, and traffic management systems that optimize traffic flow and reduce energy consumption.
7. **Incentives for Eco-Friendly AVs:** Governments and cities can provide incentives for AV manufacturers to produce environmentally friendly vehicles. These incentives might include tax breaks or subsidies for electric AVs.
8. **Environmental Impact Assessment:** Conduct thorough environmental impact assessments before implementing AV mobility solutions. This ensures that potential negative environmental consequences are identified and addressed.
9. **Equity and Accessibility:** Ensure that AV mobility services are accessible to all members of society, including low-income and underserved communities. Address issues of affordability and accessibility to prevent mobility disparities.
10. **Job Transition Programs:** Implement programs to retrain workers in industries affected by the transition to AVs, such as truck drivers. This ensures that the shift towards automation does not disproportionately harm certain groups.
11. **Data Privacy and Security:** Address concerns related to data privacy and cybersecurity to build trust in AV systems. This is essential for the social acceptance and responsible deployment of AVs.
12. **Community Engagement:** Involve local communities in the planning and decision-making process for AV

deployment. This ensures that the needs and concerns of the community are taken into account.

13. **Monitoring and Accountability:** Establish mechanisms for monitoring the environmental and social impacts of AV mobility systems. Regularly assess their performance and make adjustments as needed.
14. **Long-Term Planning:** Develop long-term sustainability plans for AV mobility that align with broader environmental and social goals, such as reducing carbon emissions and promoting equity.

END

The next ChatGPT reply was as follows:

Q: How can sustainability guide a more ecologically and socially just mobility?

AI:

Sustainability should be a guiding principle throughout the entire lifecycle of AV mobility systems, from design and manufacturing to deployment and operation. By integrating ecological and social considerations into the development of AVs and the infrastructure supporting them, it is possible to create a more sustainable and socially just transportation system. This approach can contribute to a future where autonomous vehicles are not only convenient but also environmentally responsible and accessible to all.

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