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An environmental approach to connected autonomous renewable energy vehicles, associated semiotics and the synthetically intelligent city

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An environmental approach to connected autonomous renewable energy vehicles, associated semiotics and the synthetically intelligent city

Creating an ecological view of a future transport modality

Submitted for the Degree of Doctor of Philosophy, School of Architecture

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Video 1

2

Video 2

3

Thesis

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Appendices

i.i Making the components of the research accessible

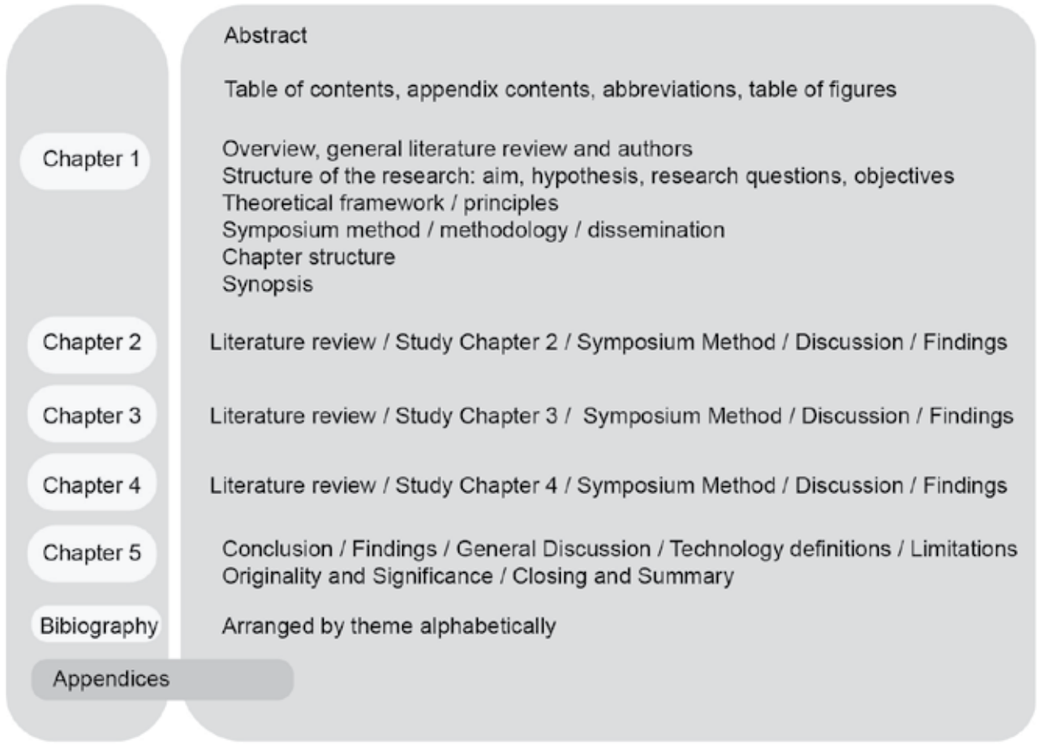
I recommend first viewing the two videos in number order. The videos provide a brief overview of the research and the architectural multimedia (animations, film, prototype and drawings). Please use Safari or Firefox browsers.

- Video 1 – The symposium method for CAREV and its systemic semiotic technoecology (12.5 minutes) available on Vimeo: https://vimeo.com/manage/videos/952154609
- Video 2 – A spatial investigation of a future smaller CAREV (CAREV-S) and the synthetically intelligent city (6 minutes) available on https://vimeo.com/manage/videos/952178359

Then, I suggest scanning through and leaving open the Appendix, which contain the drawings and architectural multimedia and supplementary information supporting the thesis. It will be helpful to access in the Appendix the large landscape A3 SPREADS format as full sets of drawings. The thesis contains selected drawings only.

The thesis is compiled in an A4 vertical format. The written A4 thesis, including drawings, photographs, and architectural multimedia, are cross referenced to the videos and the appendices. It is helpful to have the videos and appendices available when reading the thesis as they are interrelated.

The thesis structure is graphically represented as:



Thesis format and wordcount:

Thesis: 75000 words (allowed 60000 - 80000, not including, glossary abstract bibliography)

Footnotes and appendix: 20000 words (allowed 20000)

This thesis uses the MRHA referencing system.

The font used for the main text is Sofia Pro 10pt regular with 18pt spacing. The font used for captions is Sofia Pro 9pt with 12pt spacing, and footnotes are 8pt with 12pt spacing. The document has 20mm borders for printing, where full bleed images are used for screen display, the printing layout accommodated the print layout. The print version will be available with page 2 on the left and 3 on the right (filepath: PRINT).

For screen viewing the thesis is available in two facing page landscape A4 vertical format, as an unpublished PhD thesis (filepath: SPREADS).

Figure 1: A window on a semiotic colour study for a future CAREV and SI city.

i Abstract

Connected autonomous renewable energy vehicles (CAREV) will change our cities. CAREV are cited as environmentally regenerative, systemic future advanced transport modality integrated with the synthetically intelligent (SI) city to improve liveability and safety. This research is motivated by a concern to couple these changes to the wider changes needed to make our cities more environmentally sustainable, equitable, safe and just. This research argues for a social and environmental framework for the introduction of autonomous vehicles into our cities, as part of a diverse transport ecology.

The project developed a 'symposium method' to include continuous feedback, iterative, diverse voices, and opinions in the design, thinking and transdisciplinary processes. The symposium method provided a formal structure to both bring other voices, informal dialogue and imaginative approaches into the work, and is replicated in the structure of this thesis.

Several sub-questions arise:

- Can we live with autonomous vehicle intelligence in the public realm?
- Can we co-define an ecological framework in which technology positively influences the environment?
- What opportunities and threats does this technology hold, regarding spatial or social justice, and which parts of societies might be affected?
- Beyond the designs of cities and vehicles, what can we observe that will change due to autonomous vehicles (AVs) connected autonomous vehicles (CAVs) or connected autonomous renewable energy vehicles CAREVs?
- Does a change in the fleet from human-driven vehicles to CAREVs allow for deeper changes in the city fabric and its semiotics and communications, and might a 'systemic semiotic technoecology' arise?

The project achieves its creative and cognitive contribution through design, and its symposium method. It is an investigation through an interwoven relationship of research practice in design, architectural multimedia, experimentation, thinking and writing. A layering of knowledge and creative insights emerge. The short videos provide access to the architectural multimedia, animations, film and a summary of the symposium method, the videos make the research accessible to a wide audience and form part of future consulting instruments.

This research has been disseminated through publications, the research interface website, lectures and, ultimately, this PhD submission, which comprises a thesis and the two videos which create an ecological view of a future transport modality.

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i.ii Contents of Appendices

i.iii Abbreviations used in this research

ABC	Australian Broadcasting Corporation
ADS	Automated driving system
ADVI	Australian and New Zealand Driverless Vehicle Initiative
AI	Artificial intelligence (In this thesis, AI is defined as machine intelligence and includes consciousness
ARC	Australian Research Council
AREV	Autonomous renewable energy vehicle
ASI	Artificial super intelligence (Refer also to the Glossary for ANI and AGI.)
AV	Autonomous vehicle
BISA	Biologically inspired super-intelligent alien
CAEV	Connected autonomous electric vehicle
CAREV	Connected autonomous renewable energy vehicle
CAREV-S	Smaller CAREV (a one- or two-seater CAREV)
CAV	Connected autonomous vehicle
CBD	Central business district
CCAA	Centre for Connected and Autonomous Vehicles of the United Kingdom
CCAM	Connected Cooperative and Automated Mobility
CES	Consumer Electronics Show, California
CFMEU	Construction, Forestry, Maritime, Mining and Energy Union of Australia
DARPA	Defence Advanced Research Projects Agency (USA Government agency)
DDA	Disability and Discrimination Act
DT	Doctoral Training
EPA	Environmental Protection Agency of the United States of America
EU	European Union
EV	Electric vehicle
GM	General Motors (automobile company)
GPS	Global positioning system
H+	Transhuman
ICCT	International Council on Clean Transportation
ICE	Internal combustion engine
IDVS	International Driverless Vehicle Summit
IEEE	Institute of Electrical and Electronics Engineers
IM	Intelligent mobility
IMDC	Royal College of Art, Intelligent Mobility Design Centre
IP	Intellectual property
ITS	Information technology systems
LGBTQIA+	Lesbian, gay, bisexual, transgender, queer/questioning, intersex, asexual and non binary plurality
LIDAR	Light detection and ranging
LoT	Language of thought
MA	Master of Art (a degree)
MaaS	Mobility as a service
MI	Machine intelligence
MIT	Massachusetts Institute of Technology
ML	Machine learning
MOP	A hypothesis of symbolic modes of presentation
MUA	Maritime Union of Australia
MUTCD	Manual on Uniform Traffic Control Devices
NHTCA	National Highway Traffic Safety Administration (Washington, USA)
NSW	New South Wales, a state of Australia
OECD	Organization for Economic Co-operation and Development
ODD	Operational design domain (an SAE classification)
OLED	Organic light emitting diode
ORAD	On-Road Automated Driving. A Society of Automotive Engineer's (SAE) working committee
PhD	Doctor of philosophy
PMV	Personal mobility vehicle
PPP	Precise point positioning
RA	Roads Australia (a national industry-led organisation)
RCA	Royal College of Art, London
RE	Renewable energy
REV	Renewable energy vehicle
SAE	Society of Automotive Engineers
SCATS	Sydney Coordinated Adaptive Traffic System
SCP	Studio Colin Polwarth PL
SI	Synthetic intelligence
SoA	Royal College of Art, School of Architecture
SoC	Royal College of Art, School of Communications
SUV	Sport utility vehicle
UHI	Urban heat island
UK	United Kingdom
UN	United Nations (international organisation)
UNIDIR	United Nations Institute for Disarmament Research
UNSW	University of New South Wales, Australia
USA	United States of America
UTCI	Universal Thermal Climate Index
V2C	Vehicle-to-city communications (a classification of CAV)
V2V	Vehicle-to-vehicle communications (a classification of CAV)
V2X	vehicle to everything
VW	Volkswagen (German automaker)
WHO	World Health Organization (part of the UN)
WMDs	Weapons of mass destruction
WWI	World War I
WWII	World War II

i.iv Glossary of terms

For the readers' convenience, these terms and other definitions are included in the text, at the first use only.

TERMS	GLOSSARY OF DESCRIPTIONS USED IN THIS RESEARCH
Algorithm	A process or a set of rules that are followed in calculations or other problem-solving computation.
CAREV	Connected autonomous renewable energy vehicles (CAREVs) are vehicle-to-everything (V2X) aspirational transport technology and advanced transport modality using a systemic synthetic intelligence (SI) that society trusts. The V2X systems utilise synthetically intelligent city systems to increase the resilience, flexibility and functionality of a city as a positive regenerative environmental outcome. A distinction of this vehicle type is that it is part of a circular economy and it uses renewable energy sources or manufacturing and operations stages. These vehicles can autonomously operate in the public realm, complying with all legislated tasks and cultural aspirations systemically.
CAREV-S	A narrow footprint one or two-seat vehicle that retains all the definitions of CAREV. This vehicle type specifically aims to increase city functionality and have multiple positive environmental benefits over current vehicle systems using synthetically intelligent systems and spatial justice principles.
Circular economy	An economic system based on the reuse and regeneration of materials or products, especially as a means of continuing production in a sustainable or environmentally friendly way.
Ecological consciousness	Ecological consciousness recognises conscious human awareness of environmental impacts.
Environment	Environment is defined as the total of all the living and non-living elements and their effects that influence human life. While all living or biotic elements are animals, plants, forests, fisheries, and birds, non-living or abiotic elements include water, land, sunlight, rocks, and air.
Incident	Incident is used throughout this thesis as a preferable term to accident. This reflects that human induced vehicle crashes (incidents) are not unforeseeable or unavoidable but rather preventable.
Intelligent mobility	Intelligent mobility (IM) is a concept of synthetically intelligent advanced transport systems which incorporate efficiency, convenience and resilience utilising existing infrastructure. IM provides transport solutions that operate differently from the transport methods we currently use and incorporates research, immersion, innovation, experimentation and synthesis to provide novel transport modalities.
Machine learning	Machine learning (ML) is a field of inquiry devoted to understanding and building methods that learn. This includes methods that leverage data to improve performance on some set of tasks. It is seen as a part of artificial intelligence. ML algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so.
Planned obsolescence	Planned obsolescence, in economics and in manufacturing design, involves intentionally designing products with limited lifespans to make them obsolete after a predetermined period. It is a deliberate tactic of reducing a product's lifespan to compel consumers to buy newer versions.
Positive environmental outcomes	Positive environmental outcomes are defined as strategies, tools, or targets that aim at improving environmental outcomes.
Regenerative ecology	Regenerative ecologies actively restore and revitalise ecological systems through innovative and restorative practices.
Semiotics	Semiotics is the systematic study of sign processes and the communication of meaning. In semiotics, a sign is defined as anything that communicates intentional and unintentional meaning or feelings to the sign's interpreter. Contemporary semiotics is a branch of science that studies meaning-making and various types of knowledge. This research is focussed on the semiotics of CAREV and the public realm.
Spatial justice	Spatial justice is a form of social justice that is linked to space, and spatial outcomes, most notably in the works of geographers David Harvey. The field analyses the impact of regional planning and urban planning decisions.
Synthetic intelligence	Synthetic intelligence (SI) is an alternative term for artificial intelligence emphasising that the intelligence of machines need not be an imitation or in any way artificial. Ethically, it is a genuine form of intelligence. Synthetic means that which is produced by synthesis, combining parts to form a whole, or, colloquially, a human-made version of that which has arisen naturally and operated by algorithmic computation. In this research, synthetic intelligence includes machine consciousness, a form of synthetic consciousness.
Synthetically intelligent city	A synthetically intelligent city (SI city) is a systemic approach to advanced combined human and synthetic intelligence which improves operations including communications, semiotics, the flexibility, resilience, liveability and environmental outcomes of the city. It expands the established notion of a city and its fleet of vehicles evolving as a shared mobility together.
Systems thinking	Systems thinking is a way to approach issues by looking at them as systems. Rather than considering only how to solve an immediate problem, all of the pieces connect to make the whole in this approach. Systems thinking considers networks and processes as well as objects. A systems thinker is able to look at a complex system and consider its interconnectedness and interdependencies, not just isolated components.
Technoecology	Technoecology are transformative technological advancements for studying species and environments. This also includes fostering transdisciplinary and collaborative processes. In this research the technoecological approach assists with regenerative and positive environmental outcomes.
Transdisciplinary	Transdisciplinary research crosses disciplinary boundaries to create a holistic approach. It focuses on problems that cross the boundaries of two or more disciplines, specialisations or specialists and refers to concepts or methods that were originally developed by one discipline, but are used by several others. Transdisciplinary processes are an inherent quality of systems thinking, listening, conceptualising, designing, acting, measuring, reflecting and changing as a continuous improvement process.

i.v Table of Figures

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i List of Tables

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0.v.1 Acknowledgements

An environmental approach to connected autonomous renewable vehicles, associated semiotics and the city is part of a long winding journey through time, through technology and human conditions. This study would not have existed without the insights of Emeritus Professor Ian Howard (UNSW), who suggested I advance my Master of Arts research. I am deeply thankful to Professor Catherine Dormer (former Head of research RCA), Professor Adrian Lahoud (Dean, School of Architecture RCA) and Dr Hala Mansour (Head of research RCA) for the support for the research being conducted from Australia and part-time. I am indebted to the RCA School of Architecture, Intelligent Mobility Design Centre and the School of Communication's Professor Teal. Studio Colin Polwarth provided the funding, I am grateful to the many clients who, through their support of the company made the research possible, Steve Griffith, Edmond Lee, Rob Vuksic, Greg Edwards, Mike Hassey, Eka Onggo, Mike Dickens, Gareth Collins and Greg Jackson and Steve Kiddle.

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CHAPTER 1 - INTRODUCTION + SYMPOSIUM METHOD

Chapter 1.0 Introduction + symposium method

1.1 Overview

This project takes a positive and regenerative environmental approach to the connected autonomous renewable energy vehicle (CAREV) system, associated semiotic systems and the synthetically intelligent (SI) city. CAREV are a systemically advanced transport modality; the vehicles communicate with each other and the city, the people and objects within, employing synthetic intelligence. CAREV are manufactured and operate using renewable energy, and form part of a circular economy industry to create positive environmental outcomes which benefits the health of all ecologies, the city and its people.

These systemic qualities, the ability to conceive CAREV as a communal, just, transport ecology, public and private, and their potential technological advances can change the way we think and operate AV in the public realm and form the subject of this research. A synthetically intelligent city (SI city) is a systemic approach to advanced combined human and synthetic intelligence which improves operations including communications, semiotics, the flexibility, resilience, liveability and environmental outcomes of the city. It expands the established notion of a city and its fleet of vehicles evolving as a shared mobility together.

Before I deepen the research into CAREV and the SI city, semiotics and the environmental approach, this overview is structured to situate the research in a selected, broad and general context of the complexity of human transportation, the city and interactions with AV/CAV/CAREV. This is part of the systemic approach that underpins the research, the contextual setting can be regarded as part of the research foundation.

The research starts with observations of the interrelationship between vehicles, people, and the city over many years, with the aim of supporting academics, practitioners, policymakers and wider communities in contributing their visions for the future of CAREV technology through a selected history. The research and its method is multi-scaled and transdisciplinary.[1] Its specific symposium method was developed to obtain data through design, thinking and multi-voiced feedback and dialogue.

Fossil-fuelled internal combustion engines (ICE) have dominated road transport for more than a century,[2] with planetary-scale and systemic impacts.[2] Fossil-fuelled vehicles are those that utilise an internal combustion engine (ICE). The impacts of vehicles on cities are well known and form part of the city and vehicle taxonomy, including congestion, air pollution, noise pollution, and water, soil and systemic pollution, resulting in economic and social impacts. Therefore the environment is a research theme within this study.

Road traffic congestion occurs when a volume of traffic generates demand for road space greater than the available road capacity. Globally, road-based vehicles have been responsible for about 1.3 million deaths annually for the past decade.[3] These predominantly human-induced road incidents also lead to temporary, serious and permanent injury with severe community and social impacts.[4] The combined effects of congestion, incidents and pollution on the city form major community and urban design and policy concerns, resulting in highly contested urban discourse.[5]

1 In this research, transdisciplinary research crosses disciplinary boundaries to create a holistic approach. It focuses on problems that cross the boundaries of two or more disciplines, specialisations or specialists and refers to concepts or methods that were originally developed by one discipline, but are used by several others. In this research the transdisciplinary fields are architecture, urban design, master planning, landscape design, spatial sciences, ergonomics, vehicle consumption, design and manufacture, environmental philosophy, environmental science, environmental design, environmental communications, computer sciences, semiotics, computer cognition, synthetic intelligence sciences, ethics, philosophy, architectural multimedia, animation, methods and systems sciences.

2 Erik Eckermann, 'World History of the Automobile', trans. by Peter I Albrecht (Warrendale, PA: Society of Automotive Engineers, 2001).

3 United Nations and World Health Organization, 'Global Plan for the Decade of Action for Road Safety 2011-2020' (Geneva: United Nations, 2011) <https://cdn.who.int/media/docs/default-source/documents/un-road-safety-collaboration/global_plan_doa_2011-2020.pdf?sfvrsn=a34009ff_3&download=true> [accessed 5 December 2023]

4 World Health Organization, 'Global Status Report on Road Safety. 2009: Time for Action' (Geneva: World Health Organization, 2009).

5 Transport Action Network,'Community Action Groups' (Our Transport, 2023) <https://ourtransport.org.au/community-action-groups/> [accessed 16 October 2023]

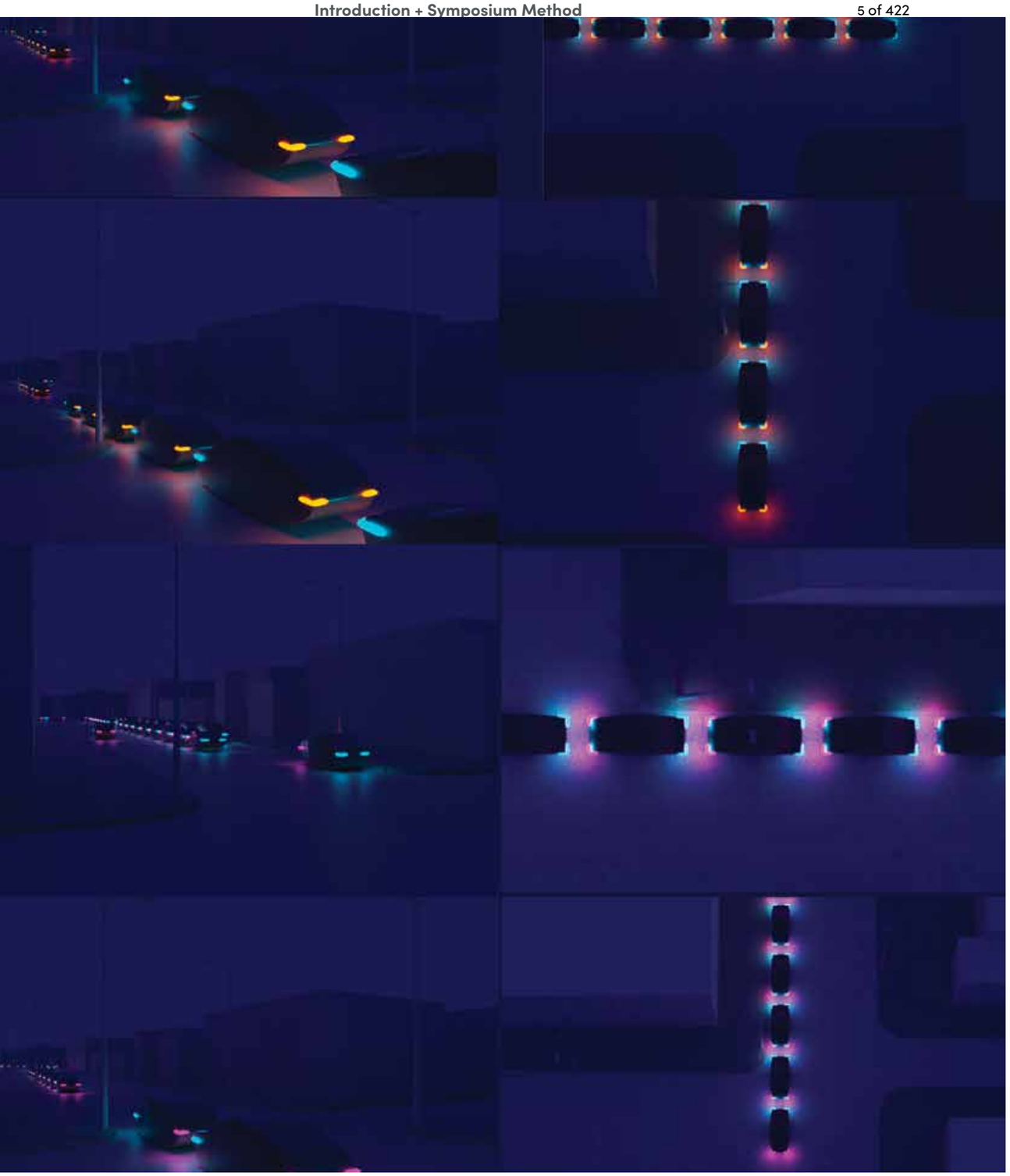


Figure 2: A mosaic of frames from CAREV semiotics in the city colour study animation.

CAREV communicate with each other, the city and their movement and intentions are understood by people in the city. This study expresses visually the hypothesis of s*ystemic semiotic technoecology*. The platooning choreographed movements are seen in Video 2.

Leading causes of road death are associated with human driving limitations and incidents.[6] However, recent incidents involving autonomous vehicles (AV) and connected autonomous vehicles (CAV)[7] have headlined in the press.[8] These fatal accidents erode society's trust in the safe deployment of AV/CAV/CAREV, with evidence of a pessimism emerging in the AV industry in recent years. Technology, specifically CAREV, is therefore a research theme in this study. The transition to AV/CAV/CAREV points to a pattern of vehicle evolution that impacts the city by deploying the vehicles and then observing what happens and responding;[9] it is a cause-and-effect approach. The social and cultural history of AV and research into the technologies are discussed in Chapter 2.5.[10]

The legal requirements for use of the public realm are communicated through road- and vehicle-based semiotics, such as road signs and markings, traffic lights and vehicle indicator lights. Therefore semiotics is a research theme in this study. Semiotics is the systematic study of signs and their processes (semiosis) and meaning-making (refer to Figure 2). This is a visually and legally complex field. Wager discusses some of the cultural and social implications of universal principles of road semiotics, and attempts to simplify the system.[11] Chapter 3 focusses on CAREV semiotics.

The Vienna Convention on Road Signs[12] and the UN Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles are interrelated systems that attempt to provide universal semiotics for the public realm. Despite such efforts, however, over the past fifty years these semiotic systems have become too, possibly unacceptably, complex. For example, Falkmer et al. report that community conversations about road safety in a Western Australian community, noted the overwhelming amount of road sign

6 OECD International Transport Forum, 'Australia Road Safety Report 2021' (OECD, 2021) <https://www.itf-oecd.org/sites/default/files/australia-road-safety.pdf> [accessed 24 March 2023]. This report lists in order speed, drink driving, drugs and driving, mobile phone use while driving and seat belt and helmet use as the leading causes of fatalities in Australia in 2021.

7 Connected autonomous vehicles (CAV), and connected autonomous renewable energy vehicles (CAREV) are defined in Chapter 5.6 as part of answering the research questions.

8 Robert Munoz, 'How Many Fatalities Have Been Due to Self-Driving Vehicles?' *(2023 Stats!)* (Sensible Motive, 5 January 2023) <https://sensiblemotive.com/self-driving-car-statistics/> [accessed 9 January 2023]

9 Maria Alonso Raposo et al., '*An* Analysis of Possible Socio-Economic Effects of a Cooperative, Connected and Automated Mobility' *(CCAM) in Europe* (Brussels: Publications Office, European Commission, 2018) <https://doi.org/10.2760/777>

10 Benjamin K. Sovacool et al., 'Income, Political Affiliation, Urbanism and Geography in Stated Preferences for Electric Vehicles (EVs) and Vehicle-to-Grid (V2G) Technologies in Northern Europe', *Journal of Transport Geography*, 78 (2019), 214–29 <https://doi.org/10.1016/j.jtrangeo.2019.06.006>

11 Anne Wagner, 'The Rules of the Road, a Universal Visual Semiotics', *International Journal for the Semiotics of Law*, 19.3 (2006), 311–24 <https://doi.org/10.1007/s11196-006-9025-x>

12 United Nations, '1968 Vienna Convention on Road Signs and Symbols', 1968 <https://treaties.un.org/doc/Treaties/1978/06/19780606%2000-35%20AM/CTC-xi-b-20-searchable.pdf>

information as a safety issue.[13] Confusing road signage is often responsible for congestion and traffic-related issues, as noted by Hyland.[14]

This thesis argues that the change from human-driven vehicles to AV will require changes in the current semiotics[15] to reflect machine intentionality. This research seeks to design a vision and system[16] as an alternative pathway as a new way of designing for the future. Through the process of addressing the research questions using the symposium method, design investigations and experiments have produced outputs including:

- City and vehicle taxonomy investigations (refer to Figures 3 and 4),
- Environmental and technology-themed hand-drawn stop-motion animations (refer to Figure 7),
- Semiotic and semaphore investigations including an experimental CAREV communications unit (refer to Figures 2 and 7) and,
- A spatial study comprising ergonomic, road capacity, heat and case studies (refer to Figure 8).

Chapter 4 of the thesis, focusses on the spatial, environmental and social justice fields of CAREV. The spatial study is systemic and includes identifying issues, a literature review, defining research questions, undertaking a systemic research in vehicle ergonomics, lane width considerations, a case study in Surry Hills Sydney, parametric modelling of vehicle capacity in various road configurations, an urban heat island study and a comparative analysis, all leading to scenario testing with visual modelling and animations. The spatial study focusses on the relationship between vehicle occupancy, the CAREV technology as the vehicle driver and the combined effects of various forms of CAREV on the synthetically intelligent (SI) city.

In this introductory chapter the drawings are composed together in one page, in Figure 8; the full set of annotated drawings at larger scale is located in the Appendices. I return to the findings and a summary of the design-based method in Chapter 5.8, in the closing and summary.

13 Torbjorn Falkmer et al., 'Road Safety Community Conversation Report' (Western Australia Health Translation Network and Curtin University, 2019) <https://cciprogram.org/wp-content/uploads/sites/2/2020/06/Road-Safety-Community-Conversation-Report.pdf>.
Refer to Category #3.

14 Jesse Hyland, 'Clear It Would Be a Disaster: Sydney's Rozelle Interchange Issues Will Be Ongoing, Road Experts Say' (ABC News, 5 December 2023) <https://www.abc.net.au/news/2023-12-05/nsw-rozelle-interchange-design-experts/103186410?utm_source=abc_news_app&utm_medium=content_shared&utm_campaign=abc_news_app&utm_content=other>

15 Chunsheng Liu et al., 'Machine Vision Based Traffic Sign Detection Methods: Review, Analyses and Perspectives', IEEE Access, 7 (2019), 86578–96 <https://doi.org/10.1109/ACCESS.2019.2924947>

16 The CAREV system and the vision of its strategic operations in an SI city are summarised in Chapter 5.4, the conclusion, the vision is for a systemic and environmental approach.

The research is structured to assist in understanding and responding systemically to the multiple issues by addressing three major themes: technology, semiotics and environment and the links between. I will return to a detailed response to the themes and the methodological approach, and the rationale for selecting the themes, later in this introduction in section 1.4, in the theoretical framework. The authors associated with the theoretical framework, Fritjof Capra, Pier Luisi Luigi, Susan Schneider, systems thinkers Capra-Luisi, Meadows, the main AV cultural, technical and social justice authors Harvey, and Young referred to in this research are discussed in the theoretical framework with outlines of their research in the general literature review in Chapter 1. Chapters 2, 3 and 4 contain detailed literature reviews which expand upon the outline discussed in this chapter.

Research overview

This research combines practice based and academic qualitative methods, (the symposium method) to explore the intersection of positive environmental responses, semiotics, and SI in the context of CAREV environments. CAREV form part of a circular economy using renewable energy for manufacturing and operations. The research is underpinned by the Capra–Luisi environmental systems thinking framework and Schneider's reimagined LoT hypothesis to investigate CAREV technologies as a response to learning to live with this technology in the public realm, in the SI city.

Motivated by a desire to apply transdisciplinary expertise to road based transport and infrastructure, the writings thread a cultural and social history of AVs through the thesis. This approach aims to clarify historical cultural expectations for CAREVs as safe, convenient, reliable, flexible, sustainable, just, comfortable and a magical, transport modality.

The research utilises a three stage symposium method - context immersion, experimentation, and synthesis. The method is also characterised by design experimentation, inquiry, feedback, and multi-voiced dialogue to generate new data. Action research and interview methods[17], along with continuous improvement through reflection and critique, were key components of the symposium method. Public engagement was encouraged and included an open source research interface (www.transfig.com), highlighting the importance of participation and diversity in transdisciplinary systems thinking.

17 I discuss these supporting methods in detail in Chapter 1.6.

The study examines the potential of SI systems, particularly CAREVs, to address road safety, urban infrastructure adaptive reuse, public health, and climate change impacts if designed with principles to change current practices. Despite recent setbacks in AV technology[18], the research underscores the importance of investing in research and in safer, environmentally conscious transportation systems. CAREVs, if designed with a focus on social and environmental outcomes could revolutionise road-based transport modalities in the SI city.

The research proposes a *systemic semiotic technoecology* hypothesis, suggesting that CAREVs communicate with vehicle occupants, actors in the public realm and the SI city through environmentally and semiotically conscious technologies. The application of the Capra–Luisi and Schneider (LoT) frameworks enables researchers, the public, industry and policymakers insights into CAREVs environmental consequences and it utilises a regenerative, positive environmental civic and semiotic technoecology approach.

Key decisions during the research included integrating a social and cultural history thread, challenging the Society of Automotive Engineers (SAE) automation classification on cultural and environmental grounds, and by applying the Capra–Luisi and Schneider frameworks through the symposium method to the field.

These decisions led to an environmentally systemic and semiotic approach rather than a cause-and-effect analysis. A multilevel approach, as part of the complex systems thinking, was developed to understand how personal mobility choices affect macro-level outcomes.

The symposium method was essential for creating and obtaining new data, uniting practice and academic processes, and incorporating design experiments and architectural multimedia with open dialogue. A spatial study and diverse ownership patterns, including private use and ownership of vehicles, were crucial research decisions. This opens new opportunities in understanding CAREV typologies through systemic research.

18 Robert Munoz, 'How Many Fatalities Have Been Due to Self-Driving Vehicles? (2023 Stats!)', Sensible Motive, 5_January_2023 <https://sensiblemotive.com/self-driving-car-statistics/> [accessed 9 January 2023]

The research questions evolved iteratively through the symposium method, resulting in key findings: 1. Successful integration depends on aligning the CAREV system with cultural expectations and developing community trust, 2. Guided by the Capra–Luisi framework the research aims for positive environmental outcomes, emphasising social justice principles, 3. CAREVs, if designed with a focus on spatial, environmental, and social justice, can benefit diverse societal groups, including minorities, the elderly, and LGBTQIA+ communities, 4. Diverse ownership models could enhance transport system resilience and flexibility, addressing spatial injustices, 5. The spatial study demonstrated benefits such as increased flexibility and resilience in the CAREV transport ecology, reduced urban space use and increased environmental areas, leading to a more liveable and equitable SI city, 6. Combined the CAREV and SI city could be conceived as a shared transport ecology, shifting current thinking and the orthodox debate about vehicles and the city.

The research also noted potential impacts of CAREVs, including increased traffic movement and vehicle consumption which could be managed through environmental principles and circular economy practices. Communication with the motor vehicle industry posed challenges, highlighting the need for more inclusive approaches to the development of technology and research as an approach to urban, spatial and semiotic design.

The research advocates for reshaping societal perceptions regarding future city design to achieve an ecologically conscious civic transport system through CAREV. CAREV-Ss, if designed systemically and spatially, could transform road-based transportation into a more socially, culturally, and environmentally sustainable system, benefiting communities and enhancing urban liveability. This research, which has an empirical foundation supported by hypothesis, will continue to develop and mature.

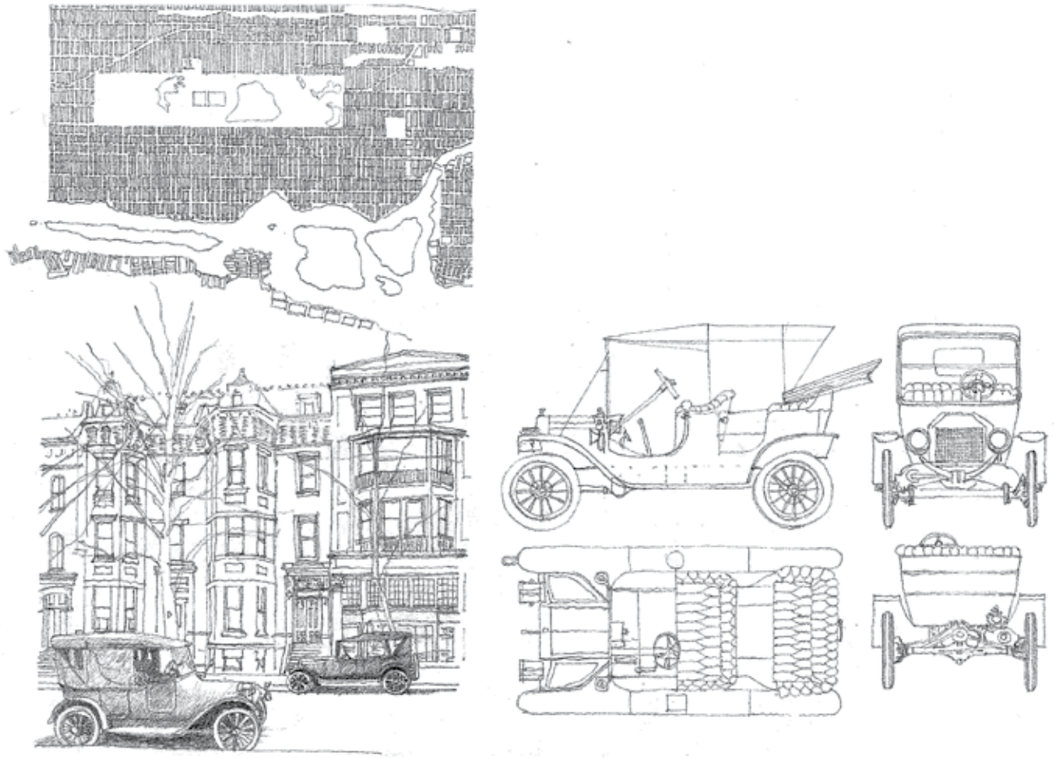


Figure 3: Composite hand drawings of the aesthetic taxonomy of city and vehicles New York 1900-1930.

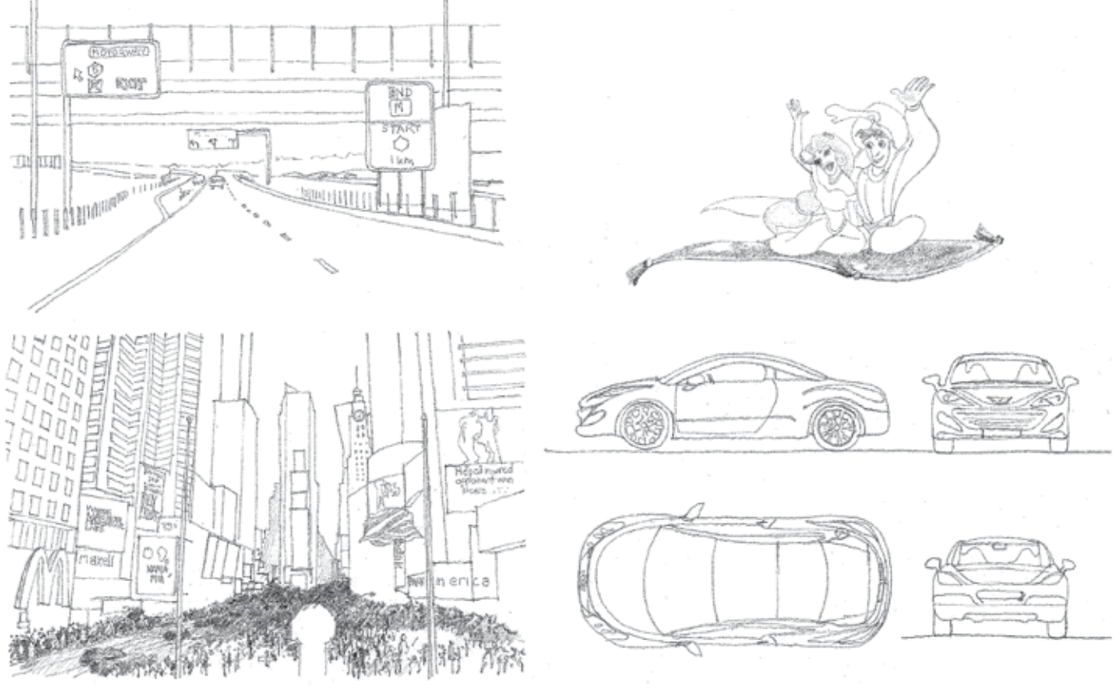


Figure 4: Composite hand drawing of the aesthetic taxonomy of city and vehicles Sydney, Australia 2000.
The taxonomy investigates the relationship between vehicles and the city in evolutionary steps of 30 years from 1860 - 2000. There are six drawings in the set. Refer to Appendix D for the drawings at a larger scale.

1.2 An overview of the general literature and authors

This general review of the literature includes the research references, writers, thinkers, designers and manufacturers referred to in this research. The literature review is structured by theme. It commences with a outline of the social and cultural history of AV, part of which is the SI and semiotic literature, and outlines the technological writers and researchers including output from industry. The review includes an overview of the semiotic and SI authors, smart city, and environmental writers and thinkers, it outlines the research method literature. The general literature review also contains an outline of writers on social justice, the orthodox debate about vehicles and the city, and the technical and environmental literature for the spatial study.

Each chapter of the thesis contains specific and detailed literature reviews focussed on Chapter 2 technology, Chapter 3 semiotics, and Chapter 4 spatial and environmental justice writings.

Understanding the social, cultural, intellectual, and emotional settings that shaped people's lives and actions in the past is important to the appreciation of the development of past and future technologies and how these histories are intertwined. There are many ways to approach social and cultural histories. I chose to review literatures including film and animation to reveal the selected social and cultural history of AV, as a research thread that flows through the writings and into the specific literature of the three main thesis chapters (Chapters 2, 3 and 4). The social and cultural history of AV has provided enriching cultural insights into all aspects of a field dominated by safety, economic and technological issues. It has played an important and defining role in the research, especially in understanding cultural expectations of AV through the exploration of myth, film, science fiction and philosophy.

The selected social and cultural history of AVs presented in this research is structured thematically using Forty's[19] multi-layered, themed, chronological approach. The multi-layered approach divides an application into several distinct layers, each layer is dedicated to a specific aspect of the analysis (such as city planning, visualisation, semiotics). Themes such as technology, semiotics and environment, assist in creating stratifications of information and, finally by applying a chronological (period) approach a time based taxonomy arises. The formatting of the taxonomy can be rearranged to create alternative views of the data, as seen in Figures 3 and 4.

19 Adrian Forty, 'Objects of Desire: Design and Society, 1750-1980' (London: Thames and Hudson, 1986)

I used this technique visually in compiling the taxonomies of vehicles and the city , refer to Figures 3 and 4 and Appendices C and D. The historical narratives in AV social and cultural history are thus arranged into the following three themes, which inform the research questions and the hypothesis:

1. Myth, magic, science fiction and philosophy in autonomous transport.
2. Synthetically intelligent city, civilian and military AVs.
3. Unionism, labour disputes, disruptions, corruption and environmentalism in the vehicle industry.

Mythical writings have had a significant pathway in the development of technology, including religious scripts in The Bible's Old Testament,[20] The Koran,[21] Torah,[22] Hindu Sanskrit and sculptures.[23] I reviewed about thirty-five major AV films and animations. Of these, 'The New Car',[24] 'The Love Bug',[25] 'I, Robot',[26] Disney's 'Aladdin',[27] 'Minority Report'[28] and 'Ender's Game'[29] are examples of science fiction films that I argue have substantially influenced cultural conceptions of AV. In each of Chapters 2, 3 and 4, I relate the importance of these films and animations as cultural sites of rehearsal.

I argue that AV film and fiction has played a role in cultural perceptions of future technology and thus have influenced social thinking and the future development of the technology. These insights partly contribute to a deeper understanding of the transformations through CAREV technology and the SI city as a body of literature developed over centuries, a thread of knowledge that add to the research aim. In Chapter 3, I present the social and cultural views of AV that suggest AV has the potential far to exceed the limitations of the Society of Automotive Engineers (SAE) levels of automation, and consequently question the current SAE automation classification system.

20 Bible Gateway, *Ezekiel 1:4-28 NIV* - 'I Looked, and I Saw a Windstorm Coming '(Online Bible, 2023) <https://www.biblegateway.com/passage/?search=Ezekiel+1%3A4-28&version=NIV> [accessed 28 April 2023]

21 Sam Shamoun, 'Solomon's Flying Carpet' (Fables and Legends of the Quran, 2021) <https://www.answering-islam.org/Quran/Sources/Legends/flying_carpet> [accessed 4 August 2021]

22 Emil G. Hirsch et al., 'Solomon' (*Jewish Encyclopaedia*, 2018) <https://www.jewishencyclopedia.com/articles/13842-solomon> [accessed 3 August 2021]

23 K.R. Shruthi and Rajani Jairam, 'Probable Technologies behind the Vimanas Described in Ramayana', *International Journal of Engineering Research and Applications*, 6.6 (2016), 47–52 <https://www.ijera.com/papers/Vol6_issue6/Part%20-%203/H0606034752.pdf> [accessed 2 May 2023]

24 *The New Car - Flip the Frog*, dir. by Ub Iwerks and Pat Powers (Celebrity Prod. & Disney, 1931) <https://www.youtube.com/watch?v=0wyF9nyVmNg> [accessed 9 August 2021]

25 'The Love Bug', dir. by Robert Stevenson (Buena Vista, 1968)

26 'I, Robot', dir. by Alex Proyas et al. (20th Century Fox, 2004)

27 'Aladdin', dir. by Ron Clements and John Musker (Walt Disney, 1992)

28 'Minority Report', dir. by Steven Spielberg (20th Century Fox, 2002)

29 'Ender's Game', dir. by Gavin Hood (Summit Entertainment, 2013)

The cultural manifestations[30] of AV historically can be summarised as:

- AVs independently transport humans safely and comfortably, often with spiritual or magical properties.
- AVs have systemic levels of communication between the machine and human occupants and the environment through which they are transported, this includes voice, semiotic and telepathic communications.
- Many mythical AVs have multi-modal abilities, such as being able to fly and undertake ground transportation.
- AVs have feelings, are sentient beings, or have highly developed cognitive responses with the vehicle occupants and the environment.
- Some AV machines have explored transhumanist properties; they are extensions of driver consciousness.
- AVs in most of the science fiction settings, there is a sense of being environmentally sustainable, for example the Vimana and Aladdin's carpet are magically self propelling. The Maglev in the Minority report are so sophisticated there is no sense of energy use. In Avatar the ecology of Pandora is self sustaining with 'unobtainium'.
- AVs have anthropometric facilities to increase relational responses with the occupant or human in control of the AVs. These phenomena will be discussed in detail in Chapters 1, 2 and 3.

Examination of the cultural and social aspects of motor vehicles in society also included a review of Wollen and Kerr's compilation of a variety of authors in *Autopia*;[31] while Wollen and Kerr do not explicitly consider AV, they discuss the cultural and social impacts of vehicles in society more broadly. I also refer to Bayley[32] and to the work of Schneider, who has compiled the writings of leading philosophers and science writers.[33] Schneider also provides an overview of cognitive sciences and synthetic intelligence in her *The Language of Thought: A New Philosophical Direction* (LoT).[34]

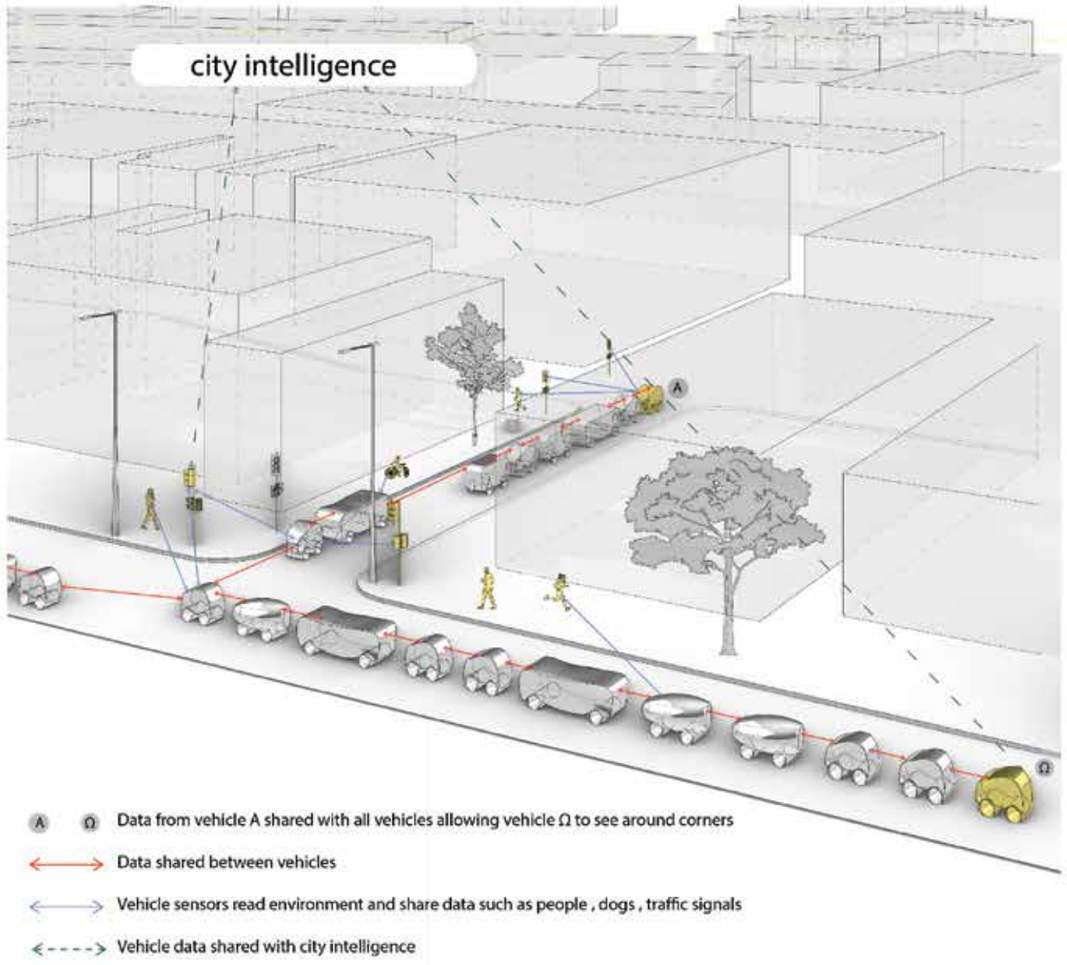
30 Culture can manifest itself in a number of ways. Examples include the way language is used, customs and traditions practiced, and rituals employed. The way people interact and their historic literatures are also cultural manifestations.

31 Peter Wollen, 'Autopia: Cars and Culture', ed. by Joe Kerr (London: Reaktion Books, 2002)

32 Steven Bayley, 'Cars: Freedom, Style, Sex Power Motion, Colour Everything Is Necessary for the Social History Research' (London: Lorriane Dickey, ebook, 2012)

33 Susan Schneider, ed., '*Scie*nce Fiction and Philosophy: From Time Travel to Superintelligence' (Chichester: John Wiley & Sons Ltd., 2009)

34 Susan Schneider, 'The Language of Thought: A New Philosophical Direction by Susan Schneider' (Cambridge, MA: MIT Press, 2011)



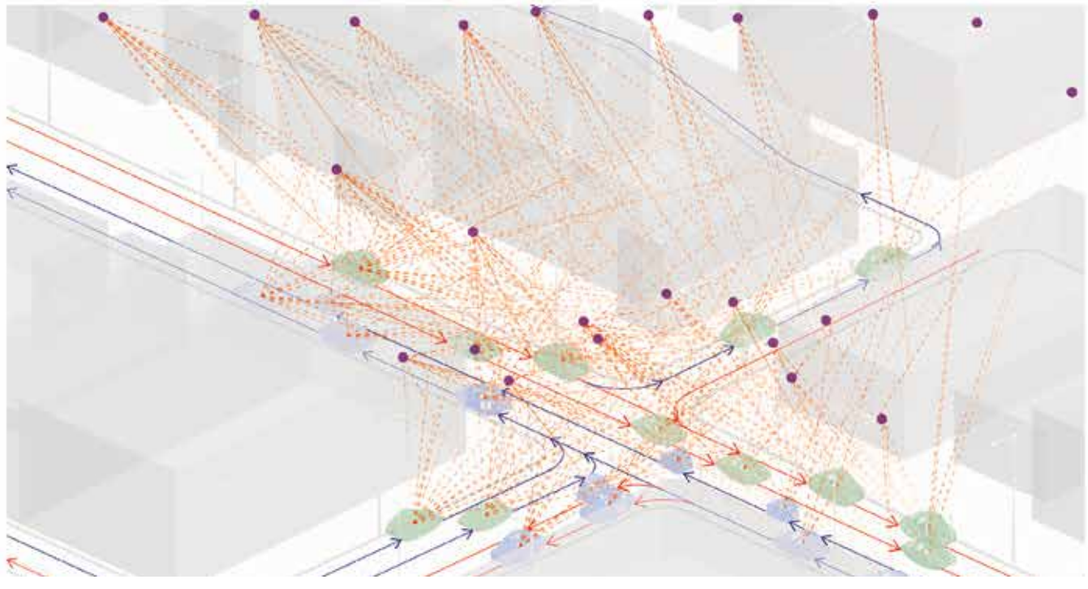


Figure 5: Abstraction diagrams of the communication networks which result from the CAREV system. The network is a cloud based system.

Synthetic intelligence (SI) is an alternative term for artificial intelligence emphasising that the intelligence of machines need not be an imitation or in any way artificial[35]. Ethically, it is a genuine form of intelligence. I have applied the LoT cognitive science[36] hypothesis to this research into AV/CAV/CAREV. It directly references the vision and environmental findings of the research, which I explain in the concluding chapter (5) as the research is synthesised. Figures 5 and 6 are diagrams of the abstraction of CAREV and SI city (V2X) communications as cloud based system.

The Society of Automotive Engineers (SAE)[37] is central to the global industry and professional development of AV technology, and it is their automation classification that has been adopted worldwide.[38] The SAE automation taxonomy, while driver-focused, is important for AV from an industry and engineering perspective.[39] The SAE classification system, as well as the definitions of automation, the rejection of autonomy as a term, and the use of Operational Driving Domain (ODD) as a reference of the public realm, are assessed and criticised in Chapter 3; extracted portions of the SAE automation taxonomy are included in the Appendix A.

Figure 6: An abstraction of the vehicle to vehicle (V2V) and vehicle to city (V2C) and city to people in the public realm communications (top).

The cultural history of AV has had a direct influence on the development of the SAE's driver-focused automation classification.[40] In this thesis, I explore the value of AV's cultural and social history and argue that it is an essential ingredient of understanding the social licence to operate AV in the public realm.

The technical writings on AV technology are substantial and have grown dramatically during the development of this research over seven years. According to Google Scholar, between 2018 and 2024 about 77,800 'results' or articles have been added using the words 'autonomous vehicles' and 10,500

35 Artificial intelligence (AI) in this thesis refers to developing systems that can mimic human intelligence, while SI involves the creation of entirely synthetically intelligent systems that are not based on biological structures or processes only. Machine learning (ML) is a field of inquiry devoted to understanding and building methods that 'learn', that is, methods that leverage data to improve performance on some set of tasks.

36 The Language of Thought (LoT) cognitive science hypothesis studies the philosophy of the human mind and brain, focusing on how thought represents and manipulates knowledge and how mental representations (semiotics) and processes are realised in the brain as part of computational science and its relationship to SI. This is discussed in Chapter 3.

37 'Society of Automobile Engineers' <https://www.sae.org/site/> [accessed 28 July 2024]. The mission of SAE is to advance mobility knowledge and solutions for the benefit of humanity.

38 S&P Global, 'Autonomous Vehicle Reality Check: Widespread Adoption Remains at Least a Decade Away' (IHS Markit, 2023) <https://www.spglobal.com/mobility/en/research-analysis/autonomous-vehicle-reality-check-widespread-adoption.html> [accessed 25 January 2024]

39 The SAE automation classification is included in the Appendix A.J3016B: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles'

40 Society of Automotive Engineers, USA, 'J3016B: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles', *SAE International*, 30 April 2021 <https://www.sae.org/standards/content/j3016_201806/> [accessed 5 August 2021]

using ‘driverless vehicles’. A 2024 Google Scholar search using the term ‘autonomous vehicles’ revealed 1.8 million results, 54,000 ‘driverless vehicle’ results, and 1.65 million results for ‘connected autonomous vehicles’. This suggests there have been on average 250 new entries weekly for ‘autonomous vehicles’, 34 for ‘driverless vehicles’ and 19 for ‘connected autonomous vehicles’ from 2018 to 2024. While this informal approach gives only a limited and approximate insight into the content or merit of the publications, it gives an insight into the interest and magnitude of literature in the field. A more rigorous and scholarly approach, is presented in the specific chapter reviews of selected literature. Despite this research interest, research gaps are evident, and I discuss these below.

According to the United Nations (UN), by 2050 more than seven billion people, representing 75% of the global population, will live in urbanised areas and will require transport, not everybody requires road transport.[41] AV safety and traffic assessments such as published by the Foundation for Traffic Safety[42] and Kockelman,[43] confirm that the majority of incidents on roads are human-induced which AV will assist in mitigating. Is this true? Is the mitigation of incidents, the AV zero incident target an unrealistic expectation? This matter will be discussed in more detail in Chapter 2 - Technology.

CAREV technology sets up moral and ethical problems and opportunities as discussed by Lim and Taeihagh[44] for the AV industry to expand research into the field. The rationale behind the development of AV, other than commercial exploitation, is that AV will remove human drivers from vehicles (see, for example, Peterson[45] and Bagloee[46]) to create a safer, fully AV transport ecology – the subject of this research. A typical recent AV technical review by Rana and

41 World Population Review, and United Nations, ‘2023 World Population by Country (Live)’, 8 January 2023 <https://worldpopulationreview.com/> [accessed 8 January 2023]

42 Foundation for Traffic Safety, ‘Examining the Safety Benefits of Partial Vehicle Automation Technologies in an Uncertain Future’ (AAA Foundation, 2023) <https://aaafoundation.org/wp-content/uploads/2023/07/AAAFTS-Safety-Benefits-of-ADAS.pdf>

43 Kara Kockelman, ‘An Assessment of Autonomous Vehicles - Traffic Impacts and Infrastructure Needs - Final Report’ (Center for Transportation Research at The University of Texas at Austin, 2017) <https://library.ctr.utexas.edu/ctr-publications/0-6847-1.pdf> [accessed 20 January 2022]

44 Hazel Si Min Lim and Araz Taeihagh, ‘Algorithmic Decision-Making in AVs: Understanding Ethical and Technical Concerns for Smart Cities’, *Sustainability*, 11.20 (2019), 5791 <https://doi.org/10.3390/su11205791>

45 Bela Peterson, ‘The Vision of Automated Driving: What Is It Good for? Answers from Society with Economical and Organizational Perspectives’, in *2014 11th European Radar Conference* (IEEE, 2014), pp. 420–26 <https://doi.org/10.1109/EuRAD.2014.6991297>

46 Saeed Asadi Bagloee et al., ‘Autonomous Vehicles: Challenges, Opportunities, and Future Implications for Transportation Policies’, Journal of Modern Transportation, 24.4 (2016), 284–303 <https://doi.org/10.1007/s40534-016-0117-3>

Hossein[47] concludes:

> *...continuous technological developments are accelerating the commercial initialization of connected and autonomous vehicles (CAVs) on the highway. The deployment of CAVs will provide more benefits to transportation sectors. A lot of uncertainties about the benefits of CAVs and the potential impacts on pavement infrastructures are noticeable.*

The major CAV technical publications from which the technology learnings and assessment for this research are drawn focus on the compiled writings of Mouftah et al. [48] This comprehensive technical book has 18 chapters covering five areas: connected autonomous electric vehicles (CAEV) and systems integration for smart cities; networking for connected vehicles; localisation and navigation for AV; wireless charging for CAEVs; and network security for CAEVs. While the publication has a dominant electrical and communications approach, it provides insights into the complex engineering and technical aspects of various CAEV systems.

Another secondary source that formed an important part of the background research for this thesis was Paret and Rabaine[49] – particularly Part One in which Paret and Rabaine examine the SAE automation taxonomy, specifically noting the taxonomy’s undefined operational design domain (ODD).

In the same sub-field as Paret and Rabaine, Bratton provides a philosophical view of communications systems and the inherent difficulties of digital and surveillance capitalism.[50] Bratton identifies the complexity of the evolution and systems already apparent in surveillance capitalism and the impacts of various related industries, including autonomous vehicles and the commercial interests in shared data, which have a global impact.

47 Md Masud Rana and Kamal Hossain, ‘Connected and Autonomous Vehicles and Infrastructures: A Literature Review’, *International Journal of Pavement Research and Technology*, 16.2 (2023), 264–84 <https://doi.org/10.1007/s42947-021-00130-1>. p 279.

48 ‘Connected and Autonomous Vehicles in Smart Cities’, ed. by Hussein Mouftah T., Melike Erol-Kantarci, and Sameh Sorour, 2021st edn (Boca Raton, Florida, USA: CRC Press, 2020).

49 Domenique Paret and Hassina Rebaine, ‘Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Internet’, trans. by Benjamin A. Engel (Chichester: John Wiley & Sons Ltd., 2022) p. 15-19.

50 Benjamin H. Bratton, ‘The Stack: On Software and Sovereignty,’ Software Studies (Cambridge, MA: MIT Press, 2015).

Bratton describes six hierarchical layers or 'stacks' of data that computation relies on at a planetary scale. His multi-layered approach to data management helped this research in appreciating the complexity and management of data communications at a philosophical level for CAREV. This research accepts safety, confidentiality and privacy principles for de-identified data sharing, refer to Principle 5.

A technical literature review would be incomplete without understanding the current technology status and its readiness indexing in various countries. For this task, among others, I have referred to the Transport for New South Wales readiness index.[51] While this policy document is important for the literature, the real-world situation is also considered through articles by Threewitt,[52] Cellan-Jones[53] and Hendry.[54]

AV and CAV case studies and primary research can be found in several publications, many of which are IP-restricted by designers and manufacturers such as Tesla.[55] According to GlobalData, the leading adopters of AVs include BMW, GM, Tesla, BYD, and Toyota.[56] This is a fast-moving and dynamic field. Access to AV's IP remains a major concern for the industry (despite Musk's commentary)[57] as discussed by Lim and Taeihagh[58] and is discussed with reference to planned obsolescence in Chapters 4 and 5.

Specific academic research for CAVs and AVs is drawn from articles, journals and publications from various technical sources, such as the TRL GATEway,[59]

51 Transport New South Wales, 'Connected and Automated Vehicle (CAV) Readiness Strategy' (Transport NSW, n.d.) <https://www.transport.nsw.gov.au/node/12453> [accessed 12 January 2023]

52 Cherise Threewitt and Frank Nieto, 'This Is What Tesla's Full-Self Driving Mode Actually Does' (US News & World Report, 20 December 2022) <https://cars.usnews.com/cars-trucks/advice/tesla-full-self-driving> [accessed 16 February 2023]

53 Rory Cellan-Jones, 'Uber's Self-Driving Operator Charged over Fatal Crash' (BBC News, 19 September 2020) <https://www.bbc.com/news/technology-54175359> [accessed 9 January 2023]

54 Nina Hendry, 'Hyundai - The Autonomous Elements Already Here' (Sydney Morning Herald, 2022) <https://hyundai-innovation-hub.smh.com.au/the-autonomous-elements-already-here/>

55 Megan Guess, 'Teslas Will Now Be Sold with Enhanced Hardware Suite for Full Autonomy' (Ars Technica, 20 October 2016) <https://arstechnica.com/cars/2016/10/tesla-says-all-its-cars-will-ship-with-hardware-for-level-5-autonomy/> [accessed 4 August 2021]

56 Vasanthi Vara, 'Leading Vehicle Manufacturing Companies in the Autonomous Vehicles Theme' (Just Auto, 9 December 2022) <https://www.just-auto.com/data-insights/top-ranked-vehicle-manufacturing-companies-in-autonomous-vehicles/> [accessed 12 January 2023]

57 Tesla maintain their IP is not protected. Musk, Elon, 'All Our Patent Are Belong To You' (Tesla, 12 June 2014) <https://www.tesla.com/blog/all-our-patent-are-belong-you> [accessed 5 August 2021]

58 ibid. Lim and Taeihagh.

59 TRL The Future of Transport, 'GateWay Project' (*TRL*, 02 February 2017) <https://trl.co.uk/projects/gateway-project> [accessed 5 August 2021]

Harrow,[60], Harrow et al.,[61] Kockelman and Fagnant,[62] Mahdavian,[63] Urry[64] and Bagloee.[65] I review this literature in detail in Chapters 2, 3 and 4 as it has helped inform technical and social responses in my thinking. Many of these contemporary writers, such as Kockelman, Mahdavian, Urry and Bagloee, diminish their output by not fully exploring historical literature (myth, magic, animation, fiction, films) that has significantly contributed to the social understanding and appreciation of, and desire for, autonomous vehicles over centuries. The hubris surrounding the new technical outcomes obfuscates or dominates the discussion.

Kockelman's[66] somewhat dated research (2017) remains important in understanding the social and traffic impacts of AVs/CAVs/CAREVs within the study's limits. In this article, Kockelman notes zero occupancy relocations and measures zero occupancy vehicle movements AV on the urban fabric at about 10% - 15% of all vehicle movements (P.114), noting congestion may reduce due to other AV and city technological advances. The research remains a benchmark investigation. As Kockelman wrote:

> *Our findings indicate that CAVs will lead to increased vehicle miles travelled (VMT) because, essentially, drivers experience falling travel time burdens. Their values of travel time that make using a vehicle 'costly' tend to decrease because they are more comfortable heading to more distant locations and those unable to drive themselves, such as the handicapped, can now safely travel.*[67]

60 Dale Harrow, 'Our Future Towns' (RCA Website Intelligent Mobility Design Centre, 2020) <https://www.rca.ac.uk/research-innovation/projects/our-future-towns-community-placemaking-and-transport-planning/> [accessed 4 August 2021]

61 Dale Harrow et al., 'Driverless Futures: Design for Acceptance and Adoption in Urban Environments' (London: Royal College of Art, 2020) <https://researchonline.rca.ac.uk/4627/> [accessed 21 January 2021]

62 Daniel J. Fagnant and Kara M. Kockelman, 'The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios', *Transportation Research Part C: Emerging Technologies*, 40 (2014), 1–13 <https://doi.org/10.1016/j.trc.2013.12.001>

63 A. Mahdavian, A. Shojaei and A. Oloufa, 'Assessing the Long- and Mid-Term Effects of Connected and Automated Vehicles on Highways' Traffic Flow and Capacity' (International Conference on Sustainable Infrastructure 2019) <https://www.academia.edu/41467916/Assessing_the_Long_and_Mid_Term_Effects_of_Connected_and_Automated_Vehicles_on_Highways_Traffic_Flow_and_Capacity> [accessed 8 August 2022]

64 John Urry, 'Mobilities', 1st edition (Cambridge: Polity, 2007)

65 Bagloee et al.

66 ibid. Kockelman. 2017.

67 ibid. Kockelman 2017. p. ii (Abstract)

While there are a few published urban design books on AVs, Burns[68], Townsend[69] and Schwartz[70] have provided various general literature on the field and its development. Townsend's 'Ghost Road' is the most academic in structure but is written from a uniquely American perspective focussed on capitalist agendas of the private 'car' perspective. This is tied into the American perspective on the design and manufacture of vehicles as a cultural and economic phenomenon and everything that emerges from that perspective, including town and city planning. I found this approach helpful to the development of strategies regarding private vehicle ownership in this research. Townsend broadly focusses on a the private AV ownership model, a subject on which academic research tend to inadequately address.

Townsend's slightly earlier book *Smart Cities*[71] provides a broad view of the smart city concept in the late 1990s and early 2000s. According to Townsend, smart city is a technologically modern urban area that uses electronic methods and sensors to collect specific data. Information gained from that data is used to manage assets, resources and services efficiently.[72] One valuable insight Townsend offers, with which this research agrees, is the extent of the hidden technological advances that make up the modern city. I return to this issue in Chapter 4 when discussing the synthetically intelligent city, which logistically and semiotically manages the city traffic infrastructure.

The synthetically intelligent city , as defined in this research is a future technological urban area that utilises human and synthetic intelligence combined with computerised systems and integrated with electronic methods and sensors to collect specific data and to operate the city with flexibility and resilience. It aims to improve operations including communications, semiotics, the flexibility, liveability and environmental outcomes of the city. It expands the established notion of a city and its fleet of vehicles evolving as a shared mobility together.

68 Lawrence D. Burns, 'Autonomy: The Quest to Build the Driverless Car – and How It Will Reshape Our World' (London: Williams and Collins, 2018)

69 Anthony Townsend, 'Ghost Road Beyond the Driverless Car' (New York: W.W. Norton & Co., 2020)

70 Samuel Schwartz, 'No One at the Wheel: Driverless Cars and the Road of the Future' (New York: Public Affairs Hachette Book Group Inc, 2018)

71 Anthony M. Townsend, 'Smart Cities: Big Data, Civic Hackers, and the Quest for a New Utopia', 1st edition (New York: W. W. Norton & Co., 2013)

72 ibid p. 15

Despite the volume of smart city-related publications, there are few focused on the semiotics of AVs/CAVs/CAREVs and the city. There is, however, a substantial social and cultural history of AV signs and semiotics, which I explore in Chapter 3 of this thesis. The backbone of semiotic philosophical research is founded on the writing and thinking of Charles Sanders Peirce, as discussed in Chapter 3.[73]

The specifics of the legalities of public realm and vehicle semiotics reflect the Vienna Convention on Road Signs and Symbols[74] and the UN Uniform Technical Prescriptions[75] respectively. I also refer to the UK Highway Code,[76] the legal semiotic framework for human driven vehicles in the public realm, as noted by Wager.[77] The argument put forward in this research is that the future AV/CAV/CAREV system will require a new systemic approach to semiotics, a field in which there is currently a knowledge gap.

In part to address this gap, I turned to Schneider's Language of Thought (LoT)[78], a hypothesis which reinvigorates the 30-year-old Fodor theory of cognition. Schneider re-imagines the LoT program in contemporary terms of computational semiotics. This facilitates a discussion about how we can learn to understand synthetically intelligent vehicles' intentionality in the public realm and advances in city synthetic intelligence. The application of Schneider's LoT hypothesis to AV and its influence on this research are discussed in detail in Chapter 3. In a later work,[79] Schneider also discusses the implications of synthetic consciousness and artificial and synthetic intelligence, which form part of the discussion in this thesis about humans learning to interact with SI.

73 Torkild Thellefsen and Bent Sorensen, eds., 'Charles Sanders Peirce in His Own Words: 100 Years of Semiotics, Communication and Cognition', 1st edition (Boston: De Gruyter Mouton, 25_August_2014)

74 United Nations, '1968 Vienna Convention'.

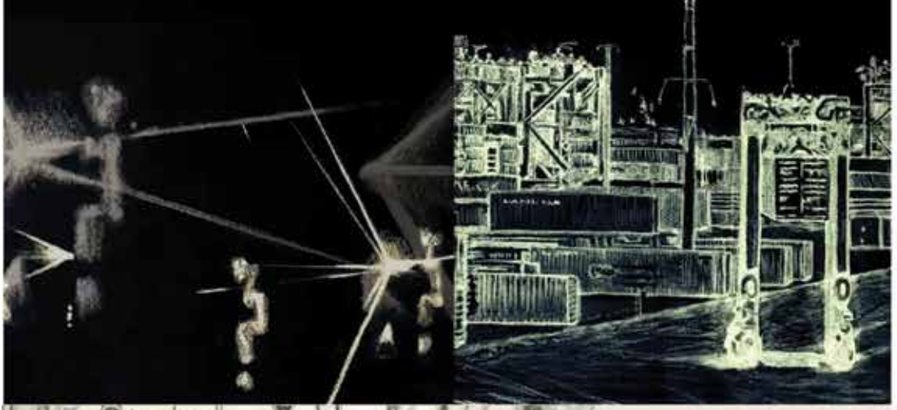
75 United Nations and Transport and Communications, 'United Nations Treaty Collection: Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of These Prescriptions' (New York, 2014) <https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XI-B-16&chapter=11&clang=_en> [accessed 4 August 2021]

76 UK Government, 'The Highway Code 2022' (2022) <https://www.highwaycodeuk.co.uk/uploads/3/2/9/2/3292309/the_official_highway_code_-_27-07-2022.pdf> [accessed 13 January 2023]

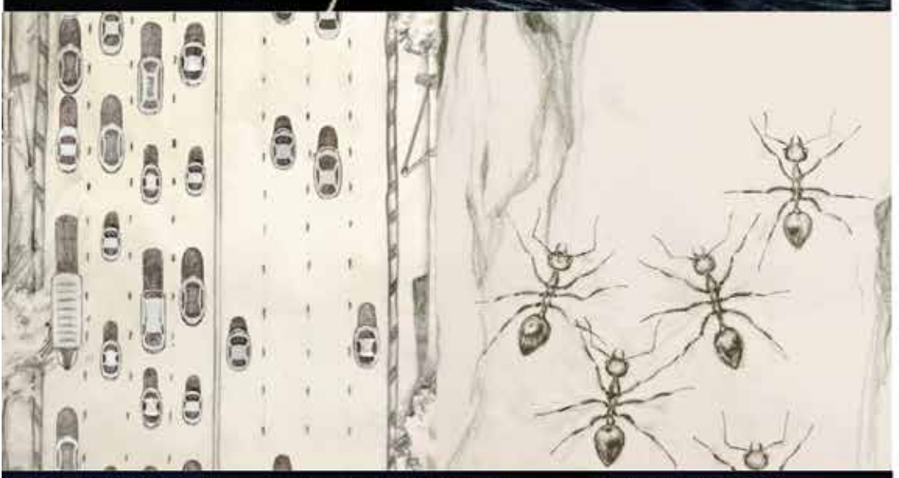
77 Anne Wagner, 'The Rules of the Road, a Universal Visual Semiotics', *International Journal for the Semiotics of Law*, 19.3 (2006), 311–24 <https://doi.org/10.1007/s11196-006-9025-x>

78 Susan Schneider, 'The Language of Thought: A New Philosophical Direction by Susan Schneider' (MIT Press, 2011).

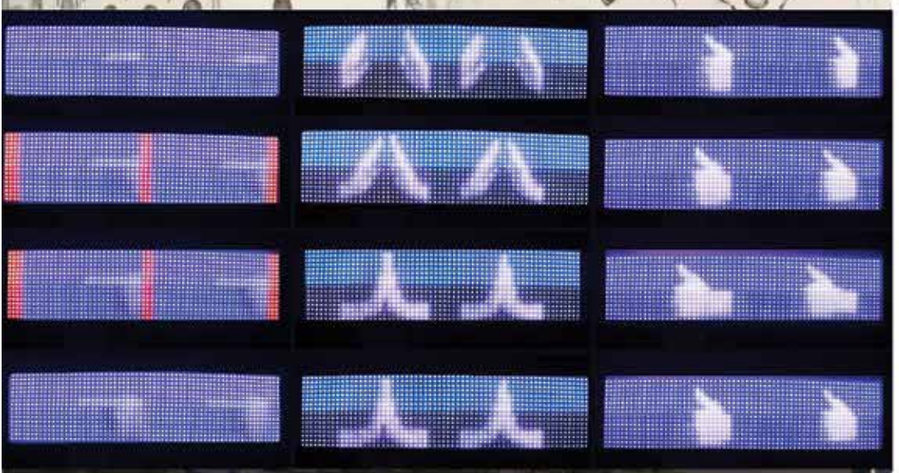
79 Susan Schneider, 'Artificial You: AI and the Future of Your Mind', Illustrated edition (Princeton: Princeton University Press, 01_January_2019).



Symposium 3 - frame from palimpsest animation: (Left) Mylene Farmer dancing robots 2013 concert is compared with (Right) the Autostrad Port Botany Sydney fully autonomous port cranes which appear as having choreographed movement



Symposium 3 - frame from palimpsest animation: (Left) Vehicles on a motorway (Right) compared with the movement of ants across the forest floor. Dorego and Marco investigated the movement of ants as an algorithm. Thorpe investigated biophillic movement of bird murmurings



Symposium 3 - mosaic of the animations of film from the semaphore design investigations using a CAREV digital communications unit, a prototype was designed and manufactured for the research

Synthesis - a frame from an animations of the CAREV semiotic systems including the semaphore investigations. The CAREV-S vehicles allow for increased active transport and environmental space leading to a systemic environmental improvement for the public realm with a systemic semiotic synthetically intelligent city

Figure 7: A composition of a selection of drawings from the CAREV/CAREV-S semiotic study.

Specifically, understanding the synthetic consciousness of the SI city is part of understanding the role of this technology in the future city.

Lui et al., provides insights into the field, albeit with a focus on sign recognition of AI[80], while Sawaragi[81] focuses on human-movement recognition through semiotic ML intelligence. There is a direct relationship between semiotics, especially road-based semiotics, and smart cities and a critical understanding is that the legislative controls of the public realm are communicated to everybody, including the vehicles, through the semiotics of the public realm. Discussions about semiotic systems for CAREV and the SI city were undertaken in Symposium 3; Figure 7 is a compilation of some of the experimental architectural multimedia that provided data for the research.

Ethical dilemmas associated with motor vehicle economics and consumption also form part of a systemic approach and the implications for environmental outcomes. According to Carlier,[82] by 2030, the global motor vehicle industry will be valued at nine trillion US dollars and one of the largest global industries. Consequently, industry is vested in maintaining or growing its position economically as the dominant transport modality. Capitalism, global economics and intergenerational justice should form part of systems thinking.

I also frequently refer to *The Oxford Handbook of Ethics of AI*[83] as the legal and ethical framework underpinning semiotics is moral and ethical in nature, this handbook features writings by leading authors on a variety of interrelated specific subject areas which I discuss in detail in literature reviews in Chapters 2.5, 2.7, 3.4, 4.4 and 4.5. Likewise, I drew on the Institute of Electrical and Electronics Engineers (IEEE) as a foundation on which to base the principles guiding AI ethics in the research.[84]

80 Chunsheng Liu, Shuang Li, Faliang Chang, and Yinhai Wang, 'Machine Vision Based Traffic Sign Detection Methods: Review, Analyses and Perspectives', IEEE, 7 (2019), pp. 86578–96, doi:10.1109/ACCESS.2019.2924947

81 Tetsuo Sawaragi, 'Semiotic Design of Human-Machine and Human-Environment Systems', *IFAC Proceedings*, 43.13 (2010) <https://www.sciencedirect.com/science/article/pii/S1474667015325714?ref=pdf_download&fr=RR-2&rr=84acaebb4a7fdfb5> [accessed 16 February 2023]

82 Mathilde Carlier, 'Global Automotive Market Size 2030' (Statista, 5 August 2021) <https://www.statista.com/statistics/574151/global-automotive-industry-revenue/> [accessed 17 August 2021]

83 Markus D. Dubber, Frank Pasquale and Sunit Das, eds., 'The Oxford Handbook of Ethics of AI' (Oxford: Oxford University Press, 2020)

84 According to their website, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity. The IEEE was cited by a number of leading authors as one of industries leading industry resources in this field. Raja Chatila and John C. Havens, 'The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems', in *Robotics and Well-Being*, ed. by Maria Isabel Aldinhas Ferreira et al. (Cham: Springer International Publishing, 2019), XCV, 11–16

Fritjof Capra in 'The Web of Life: A New Scientific Understanding of Living Systems' notes that:

> *'According to the systems view, the essential properties of an organism or living system, are properties of the whole, which none of the parts have. They arise from the interactions and relationships between the parts'.*[85]

This systemic[86] and theoretical approach which he developed further in the later publication is based on what I have called in this research, the Capra-Luisi framework on their 'A Systems View of Life: A Unifying Vision', the premise is that:

> *'... a sustainable society must be designed in such a way that its way of life, business, economy, physical structures and technologies do not interfere with natures inherent ability to sustain life.'*[87]

Their environmental and systemic framework is further expanded in this research by applying a cognitive science approach to human and synthetic intelligence adapted from Schneider's LoT.[88] I will return to this interrelationship in more detail in the theoretical framework later in this chapter. The systems approach requires amongst others, consideration of the socio-economic and environmental fields associated with AV/CAV/CAREV. Or in other words the way society conducts its economic policies have environmental implications. Capra and Luisi note, in relation to economics and capitalism:

> *The fundamental dilemma underlying the major problems of our time seems to be the illusion that unlimited growth is possible on a finite planet. This in turn reflects the clash between linear and nonlinear patterns in our biosphere – the ecological networks and cycles that constitute the web of life.*[89]

85 Fritjof Capra, 'The Web of Life: A New Scientific Understanding of Living Systems', 1st edition (Anchor Books/Doubleday, 01_September_1996) p. 15.

86 Donella H. Meadows, 'Thinking in Systems: A Primer' (Chelsea Green Publishing, 2008) p. 2. defines a system as a 'set of things - people, cells, molecules or whatever - interconnected in which a way that they produce their own pattern of behaviour over time.

87 Fritjof Capra and Pier Luigi Luisi, 'The Systems View of Life: A Unifying Vision', 1st edition (Cambridge: Cambridge University Press, 2014) p. xi.

88 Schneider, 'The Language of Thought'.

89 Capra and Luisi, 'The Systems View'. p. 363.

Gorz[90] similarly questions changing cultural attitudes to work and economic rationality in autonomous human activity. Accelerationist principles appear to underpin the AV industry and its scale. There are likely to be major disruptions in employment settings due to AV. Disruption refers to radical changes to an existing industry or market due to technological innovation. Gorz provides a base on which to assess social justice issues. A focus on social, climate and spatial justice – which is inextricably linked to economics and the complexity of planned obsolescence – informs the literature review and discussion in Chapter 4.5 and 5.3.

> *The glorification of material consumption has deep ideological roots that go far beyond economics and politics. Its origins seem to lie in the universal association of manhood with material possessions in patriarchal cultures.*[91]

In another section of their book, Capra and Luisi note:

> *The obsession with perpetual economic growth, in turn, is driven by the relentless pursuit of corporate growth, which is built into the very structure and legal framework of the corporation.*[92]

Planned obsolescence, in economics and industrial design, involves intentionally designing products with limited lifespans to make them obsolete after a predetermined period. Essentially, it is the deliberate tactic of reducing a product's lifespan to compel consumers to buy newer versions. Each update or newer version requires a new purchase. Each new purchase increases consumption, the more that is consumed the greater the environmental impact though extraction, design and manufacturing.

Environmental in this research refers to the circumstances, objects or conditions by which one is surrounded as a complex system of physical, chemical and biotic factors (such as climate, soil, and living and material things) that act upon an organism or an ecological community and ultimately determine its form and survival. It is an aggregate of social and cultural conditions that influence the life of an individual or community.[93]

90 Andre Gorz, 'Capitalism, Socialism, Ecology' (UK: London: Verso, 2014) <https://www.bklynlibrary.org/item?b=11827319> [accessed 6 August 2021].

91 Gorz ibid. p 32.

92 Capra and Luisi. 'The Systems View'.p. 398.

93 Environment 'Definition of Environment', 2024 <https://www.merriam-webster.com/dictionary/environment> [accessed 28 July 2024]

The work of Newman and Jennings[89] also influenced this research deeply, and I reference their environmental principles in Chapters 1 and 2. Their theoretical framework of cities assisted with the specific tools used to develop ecological principles for CAREVs and the city. Ecological in this research is the systemic interrelationship between organisms, human and non-human, and their co-evolution with the environment.

Newman expresses a strong objection to society's dependence on automobiles,[94] both fossil-fuelled vehicles[95] and AVs,[96] which he suggests present more of the same problems – a sentiment I share if the current evolutionary pattern of planned obsolescence in vehicle manufacturing remains unchanged. I expand on planned obsolescence as a method for designing products (vehicles) to become obsolete in short term cycles to increase consumption, and its complexity in Chapter 4.5.

Chapter 4.4 expands upon what I have called the 'orthodox debate' which encapsulates the anti-car and pro-pedestrian/public transport narrative as well as low-traffic neighbourhood and other anti-vehicle debates that continue to rage globally. The relevance is to finding methods to shift this debate, through the technological disruptions offered by AV/CAV/CAREV. In developing an approach to the multilevel complexity of vehicle dependency, I drew on Rodrigue's[97] insights into transport geographies, returning to his writings whenever I take a more localised approach, as a reminder of the complexity of working simultaneously at multiple scales.

94 Peter Newman, 'Reducing Automobile Dependence', *Environment and Urbanization*, 8.1 (1996) <https://journals.sagepub.com/doi/pdf/10.1177/095624789600800112> [accessed 23 March 2023]

95 Peter Newman, 'Going down the Same Old Road: Driverless Cars Aren't a Fix for Our Transport Woes' (The Conversation, 1 December 2015) <http://theconversation.com/going-down-the-same-old-road-driverless-cars-arent-a-fix-for-our-transport-woes-50912> [accessed 25 March 2023]

96 Ibid.

97 Jean-Paul Rodrigue, '1.4 – The Setting of Global Transportation Systems', in 'The Geography of Transport Systems' (New York: Routledge, 2017) <https://transportgeography.org/contents/chapter1/the-setting-of-global-transportation-systems/> [accessed 27 February 2023]

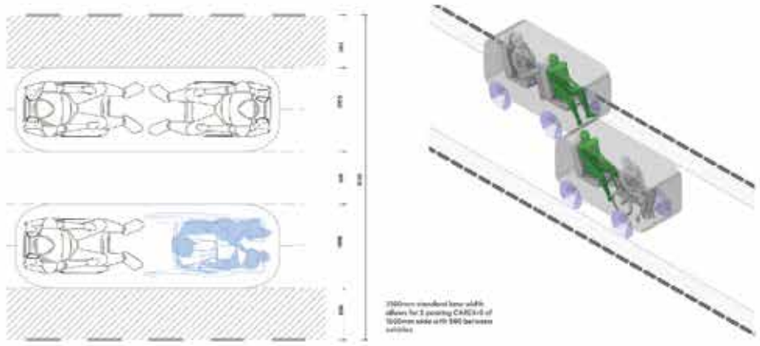
Rodrigue provides macro scale insights into the effects of fossil-fuelled vehicles and the economics that underpin the system. Rodrigue's approach and feedback from participants in Symposium 2 on spatial and social justice considerations of AV initiated the research development of the spatial study which forms Chapter 4. Broadly, there is a research gap in systemic research in AV/CAV/CAREV spatial outcomes and this furnishes the motivation for exploring this important field of inquiry.

The philosophical background for the spatial research into AV relied on the writings of Harvey[98] and, in relation to social justice for minority groups, of Young.[99] Their insights, combined with technical research into spatial redistribution and intergenerational justice, were significant to positive environmental outcomes formulated in Chapters 2 and 4 of the research. Positive environmental outcomes are strategies, tools, or targets that aim at improving environmental outcomes. Despite the extensive literature, thinking and research in the subject area, there remain gaps in the knowledge base which the present research identifies.

These include knowledge gaps associated with the social and cultural history of AV and how these fields influence the definitions of AV and the industry-accepted classification of the AV driving ability. Another knowledge gap includes CAREV's ability to benefit the environment and how to apply an appropriate environmental framework for the AV/CAV/CAREV industry. Semiotics, cognitive systems, and communications between humans outside of vehicles and AV/CAV/CAREV intentionality also have gaps in their fields of knowledge.

98 David Harvey, 'Social Justice and the City,' Revised edition 2009 (London: The University of Georgia Press, 1973_Revised_2009) <https://pdf.wecabrio.com/social-justice-and-the-city-harvey.pdf> [accessed 4 August 2021].

99 Iris Marion Young, 'Justice and the Politics of Difference' (Princeton, N.J: Princeton University Press, 1990).

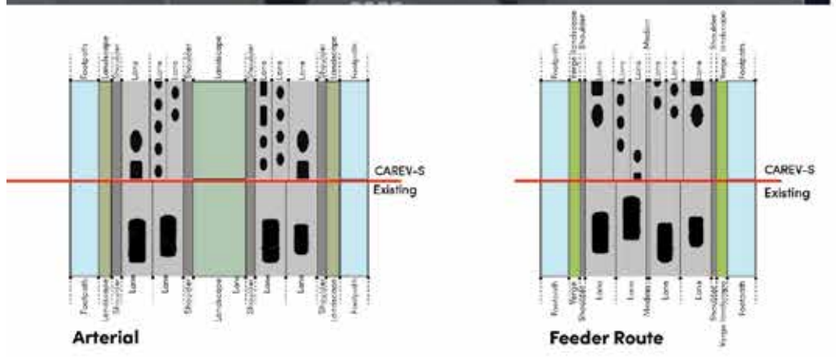


Symposium 5 - Spatial study:

Ergonomic study for narrow one and two seat CAREV-S which form part of a parametric modeling to increase throughput of vehicles in the city. The one and two seat formats represent 70% the current occupancy capacity of all vehicles currently using the road in Australia

Video 1 - Spatial study:

Ergonomic study for narrow one and two seat CAREV-S, this animation was created to understand the three-dimensional effects of a narrow footprint CAREV



Symposium 5 - Spatial study:

Comparative analysis of road capacity using parametric modelling. The analysis diagrams allows one to compare the relationship of the existing road/vehicle configuration in a variety of road formats with the narrow one or two seat CAREV format vehicles which increase road capacity, and by extension, increase the functionality of the city as an environmental outcome.

Symposium 5 - Spatial study:

Urban heat island study in Surry Hills Sydney. The CAREV-S vehicles allow for an increase of 9.8% environmental area. In this heat island study the increased environmental area allowed for the modeling of 585 additional mature shade trees which reduced the UHI temperature by 3 to 4 degrees centigrade across the study area in the hottest periods of the year. This links CAREV-S to direct positive systemic environmental outcomes.

There are also gaps in the knowledge base associated with spatial and environmental justice of AV/CAV/CAREV. There are many ways to approach spatial justice investigations; for this thesis I chose a systemic process to deepen understanding of the effects of AV/CAV/CAREV combined with worst and best case scenario planning. The detailed literature reviews and knowledge gaps in spatial, environmental and intergenerational justice in the current, and future CAREV and CAREV-S modalities are discussed in Chapter 4. Figure 8 is a compilation of drawings from the spatial study detailed in Chapter 4.

I also investigate gaps in knowledge and practice about strategies to explore design as part of a way of thinking, inventing and critically assessing research findings. I discuss the method and principles developed to arrive at the findings in Chapter 1 and the findings and conclusion in Chapter 5. The combined and synthetic approach assists in answering the research questions, which are also answered in Chapter 5.

Figure 8: A composition of a selection of drawings from the CAREV/CAREV-S spatial study.

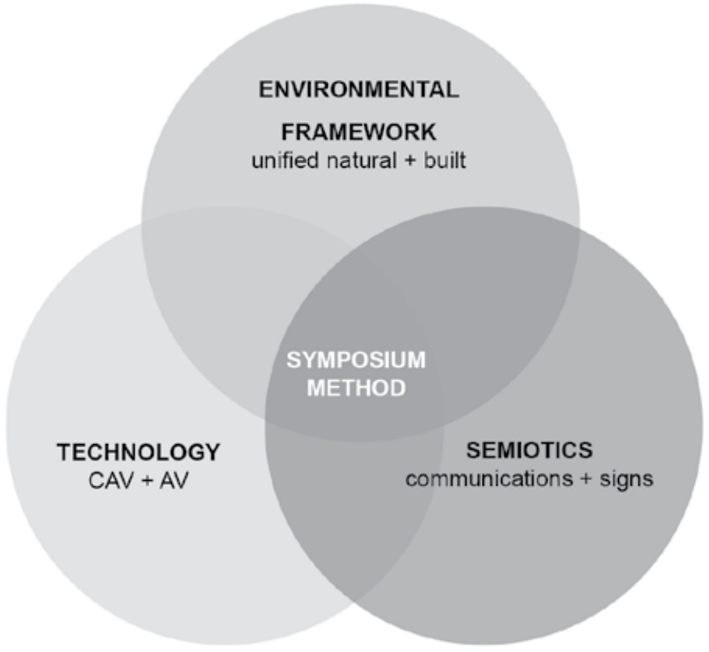


Figure 9: The transdisciplinary method as a Venn diagram.

The Venn diagram is intentionally reductionistic to assist in showing the interrelationships between the research themes, with the central symposium method.

1.3 Structure of the research

The Venn diagram in Figure 9, shows the interlocking research structure themes of environmental framework (built and natural), technology (AV/CAV/CAREV) and semiotics, with the transdisciplinary symposium method interlocking the three themes at the heart of the research. The themed structure assists in discussing subjects separately and together as a transdisciplinary framework. The spaces between the themes in the Venn diagram are areas of research inquiry explored throughout the research, through modules of within the symposium method.

The themes are structured to answer the research metaquestion and the sub-questions. The research sub-questions are answered in the findings of each of the themed research themes in Chapters 2 (environmental), 3 (semiotics) and 4 (spatial justice).

1.3.1 The hypothesis

The project hypothesis is that achieving the cultural aspirations of magical, safe, efficient, convenient, reliable and synthetically intelligent transportation through CAREVs, requires a transdisciplinary approach to conceptualising the integration of CAREVs with the city, the environment and humanity. A framework for achieving environmental, spatial and social justice is required through holistic research practice. A living transport ecology, or a *systemic semiotic technoecology*, could improve safety, communications, spatial justice and public health. To clarify the terminology used in this hypothesis:

Systems thinking is a holistic approach that focuses on the way that a system's constituent parts interrelate and how systems work over time and within the context of larger systems.[100] An important feature of systems thinking is its approach to nested systems, systems within systems which are approximately addressed in the overlapping spaces between the three themes (refer to Figure 9.). The relationships and networks between the subjects are significant to systems thinking[101]. The 'spaces' between themes the fields between disciplines often formed interesting dialogues explored through the symposium method. Their transdisciplinary qualities and communication networks enriched the research.

100 Meadows, Donella H., 'Thinking in Systems: A Primer' (Chelsea Green Publishing, 2008) p.2.

101 Capra, Fritjof, and Pier Luigi Luisi, The Systems View of Life: A Unifying Vision (Cambridge University Press, 2014) p. 10.

Technoecology refers to the advanced study of transformative technological advancements for studying species and environments, this also includes fostering interdisciplinary collaborative processes.[102] Techno-ecological processes are those that aim technology at maintaining life at an ecologically balanced or regenerative rate, avoiding the depletion of natural resources. In short utilising technology for positive environmental outcomes.[103]

Semiotics is the advanced study of signs and symbols.[104] In this research context, it specifically pertains to the cognitive processes involved in the interaction between synthetic intelligence semiotics (SI such as algorithms) and human intelligence (Language of Thought, LoT) in the public realm. Algorithms are processes or sets of rules to be followed in calculations or other problem-solving operations, especially by a computer[105]. The systemic aspect of semiotics refers to the interrelationships between different parts, forming a unified conceptual network within the semiotic technology.

1.3.2 The research aims

The aims of the research are to understand if transformations through CAREV technology serves to improve environmental justice and equality, including deeper insights into the impacts of SI in the public realm. It aims to collect new data[106] and collaborate[107] with a broader research and transdisciplinary community to hear multiple voices, perspectives, and opinions, introduce new ideas, to advocate for a new way of thinking about AV/CAV and CAREV.

102 Blake Allan M., Dale G. Nimmo, Daniel Ierodiaconou, Jeremy VanDerWal, Lian Pin Koh, and Euan G. Ritchie. "Futurecasting Ecological Research: The Rise of Technoecology." Ecosphere 9, no. 5 (2018): e02163. https://doi.org/10.1002/ecs2.2163.

103 ibid., Allan

104 Albert Atkin, , 'Peirce's Theory of Signs', Stanford Encyclopedia of Philosophy, Summer 2013 (13_October_2006) <https://plato.stanford.edu/archives/sum2013/entries/peirce-semiotics/> [accessed 5 August 2021]

105 'Algorithm', Wikipedia, 2022_12_30T_23:23:00Z <https://en.wikipedia.org/w/index.php?title=Algorithm&oldid=1130589391> [accessed 5 January 2023]

106 New data includes design experiments, design drawings and animations and the dialogue, feedback and material collected at the symposia, through the symposium method.

107 Refer also to the symposium method as a practice method in Chapters 2.8, 3.7 and 4.8 which explains how this collaboration was managed and developed. The dissemination of the data is discussed in Chapter 1.6.8.

1.3.3 The research meta-question

This research asks a meta-question about the combined effects of a future CAREV system on the public realm.

1.3.4 The research sub-questions

The research sub-questions are interrelated with the meta-question and have been refined in response to iterative research and gaps in our knowledge. The sub-questions are clarified in each chapter of the thesis. The sub-questions ask the following:

Principal sub-questions

SQ 1.1 How can we live with CAREV machines and synthetic intelligence in the public realm?

SQ1.2 Can society intervene? Can we co-define an ecological framework in which CAREV and SI technology positively influences the environment?

SQ1.3 Can CAREVs reverse current pollution levels and lead to improved public health and safety?

SQ1.4 Does a change in the fleet from human-driven vehicles to CAREV-S allow for deeper changes in the city fabric, its semiotics and communications. Can a *systemic semiotic technoecology* arise?

SQ1.5 What opportunities does CAREV hold for spatial or social justice, and which societies are affected?

SQ1.6 Do current industry definitions of autonomous vehicles fall below historical, cultural and social expectations? Are the current definitions appropriate?

The meta- and sub-questions are answered in Chapter 5.5 and 5.6 respectively in number order.

Chapter sub-questions

The following sub questions are presented and answered in each chapter as they relate to the subject of each chapter and contribute to the overall research meta questions.

Chapter 2 sub-questions

SQ2.1 In the evolution of vehicles, semiotics and the city, what are rhythms and patterns that can be seen?

SQ2.2 Can the pace of vehicle technology change and urban evolution be visualised?

Chapter 3 sub-question

SQ3.1 How will a change in the fleet to CAREV allow for deeper combined changes in the city fabric, its semiotics and communications?

SQ3.2 How will a *systemic semiotic technoecology* arise, and what will it look like?

Chapter 4 sub-question

SQ 4.1: How can autonomous mobility be beneficial for cities, people and the environment?

SQ 4.2: How can shared mobility promote a fair, equitable and inclusive city?

SQ 4.3: Can regenerative principles in CAREV guide more ecologically and socially just mobility?

SQ 4.4: What are the impacts (negative and positive) of CAREV-S on the public realm?

SQ 4.5: Do spatial studies assist with social and environmental assessments of CAREV and the SI city?

1.3.5 The research objectives

The research developed the following objectives:

- **Objective 1.** Identify the issues, challenges, gaps in knowledge in the future AV/CAV/CAREV mobility and its future city field.
- **Objective 2.** Develop methods to explore a systemic approach combining Capra-Luisi ecological framework and practice design research methods.
- **Objective 3.** Define environmental principles for the future AV/CAV/CAREV mobility field.
- **Objective 4.** Utilise architectural multimedia to disseminate the research, to assist in making the field accessible.

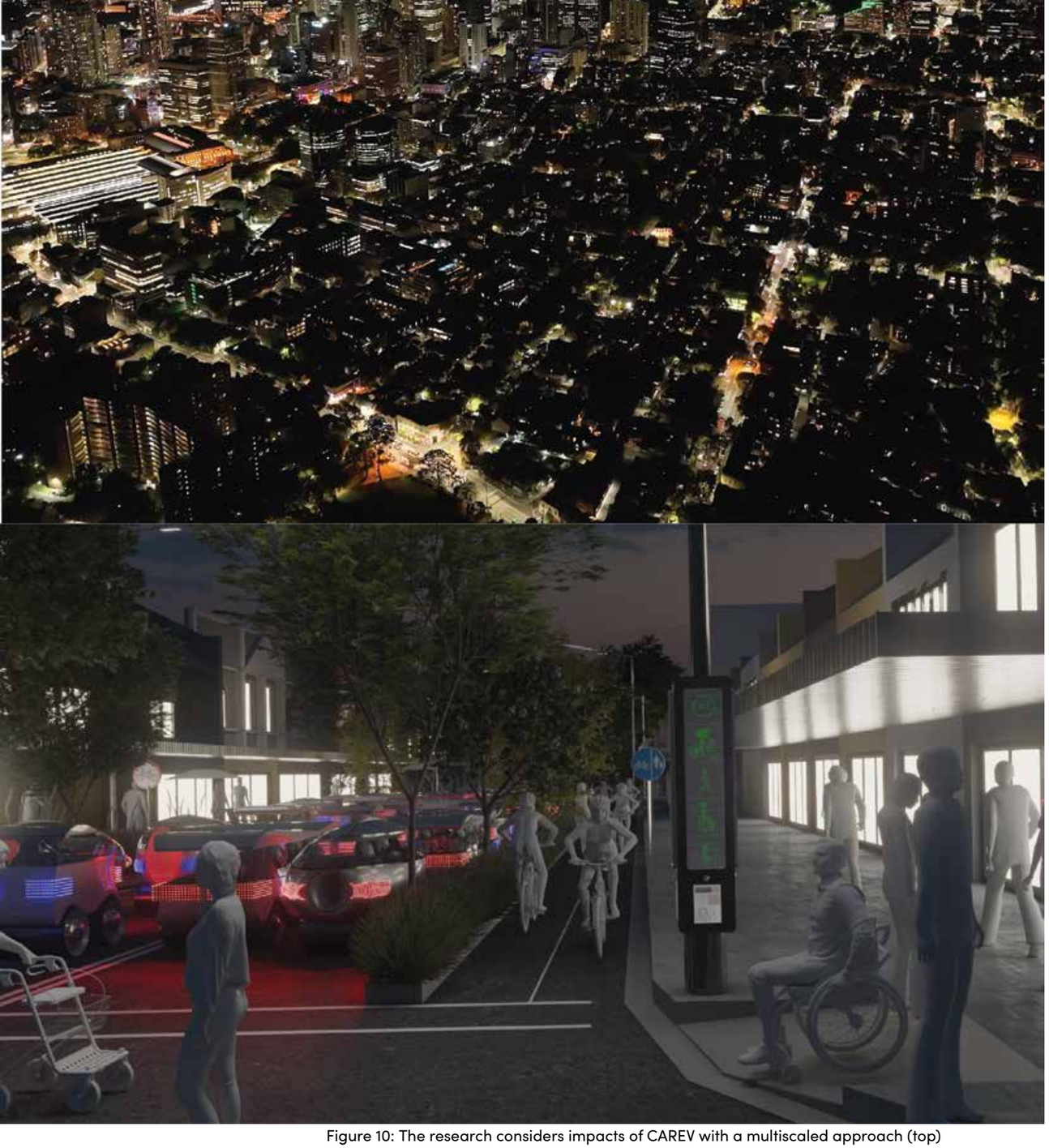


Figure 10: The research considers impacts of CAREV with a multiscaled approach (top) city scale bottom (local) scale. Ruth Gold aerial photography copyright released to Colin Polwarth.

This research considers macro (city) scale and local scales (streets). The top macro scale image is an example of aerial night time view of the City of Sydney - the road network is visible at night the road network is an environmental consideration). The bottom image is from an animation of a local neighbourhood scale consideration. The bottom image includes an animation of the CAREV semiotic systems, Crown Street is managed by the city's synthetically intelligent systems which communicate semiotic controls to a variety of users at an intersection - Crown / Cleveland Street intersection in Surry Hills, Sydney. The semiotic study is in Chapter 3.

In this image, Crown Street is reimagined with an additional active transport lane, redistributed parking, landscaping and trees, all positive environmental outcomes of the narrow format CAREV-S. The spatial and case studies including vehicle ergonomic study is in Chapter 4.

1.3.6 A multi-scaled and systemic approach

The research project was also undertaken at various scales and as a multilayered approach, an inherent quality of systems thinking. Separate scales in the order of the project as the research developed:

- A city techno-ecology scale, which has global characteristics.
- A CAREV/CAREV-S scale which is street-scale related.
- Underlying principles guided all aspects of the research as it developed; the principles operate at multiple scales.

In terms of connections between these scales, the city techno-scale tends to be theoretical and has wide ecological and philosophical underpinnings. Concurrently, the CAREV/CAREV-S street scale has a practical, case study application. These two scales were investigated together but represented and discussed separately. The interrelationship between the macro and local scales was managed through principles guiding both research scales. Figure 10 describes the dynamic qualities and multilayered, system thinking approach at various scales.

The principles arranged under themes are contained in section 1.6.

1.4 The theoretical framework

The research themes of environment, technology and semiotics assist in conceptualising and describing the complex structure for the theoretical framework. The primary and unifying theoretical approach lies in applying Capra and Luisi's *Systems View of Life* (SVL) to the research project. The environmental framework these eminent physicists have developed has ecological systemic properties. The SVL states:

> *The term 'environment' can represent quite different things, depending on the levels of life we consider: it can be a milieu in which cells swim, of the habitat where animals live, or the urban environment of humans. In all cases, as is the case of bio-logic of life, there is a conceptual similarity: the interaction between the living organism and the environment is dynamic based on co-emergence, where the living organism and the environment become one through cognitive interactions. With cognition, we have recognised the notions of recursive structural coupling and structural determination, which relate to biological evolution.*[108]

The Capra–Luisi systemic framework is fundamental to deepening knowledge and understanding of the field. It provides a foundational theoretical structure on which the objectives, hypothesis and research aims can be discussed, as well as the historical applications, how the system behaves and how nested systems are related.

A feature of the system's approach is that it is necessary and fundamental to continually assess all aspects of the research within the system's framework. This complicates things as there are several continuously moving parts, each influencing the other: nested systems and sub-systems at both macro and local scales. This is the nature of systems thinking. I explored nested systems and sub systems as an animated diagram, refer to Figure 11.

108 Capra and Luisi, p. 143.

Balaguer notes of Capra's transdisciplinary communication that:

> *Systems thinking is inherently multidisciplinary; it focuses on patterns of relationships that are common to all living systems — individual organisms, social systems, and ecosystems. In our educational system, unfortunately, there is tremendous resistance to multidisciplinarity. That's the main problem. In our universities we have specialized departments, textbooks, academic journals, and so on. The entire organization of knowledge is fragmented, and many academic individuals and institutions have invested heavily in this fragmentation of knowledge — intellectually, emotionally, and financially.*[109]

To further assist with the development of a systems framework and transdisciplinary methods, I turned to Meadows, who writes:

> *Self-organising, nonlinear, feedback systems are inherently unpredictable. They are not controllable. They are understandable in the most general way. The goal of foreseeing the future exactly and preparing for it is perfectly unrealisable. The idea of making a complex system do just what you want it to do can be achieved only temporarily, at best. We can never understand our world in the way our reductionistic science has led us to expect. Our science itself, from quantum theory to the mathematics of chaos, leads us into irreducible uncertainty .... The future can't be predicted, but it can be envisioned and brought lovingly into being. Systems can't be controlled, but they can be designed and redesigned.*[110]

The practice-based research for this thesis was undertaken by observing movement, transportation, semiotics, people, the built form and its interrelationship with the wider environment. Practice methods are specific, purposeful, and repeated methods used in the delivery of professional or artistic service and in some academic settings. Some would argue that practice is not theoretical; however, from a systems point of view, practice and theory are the same, albeit with differing emphases. This is an empirical study.

109 José Esteban Gabarda Balaguer, 'Interview with Fritjof Capra - A systemic view of life in organizations', *Plataforma OSICO*, 2021_09_10_T14:58:12+00:00 <https://www.osicoplatform.com/interview-with-fritjof-capra-a-systemic-view-of-life-in-organizations/> [accessed 18 March 2023]. Ref. Item 7

110 Donella H. Meadows, 'Thinking in Systems: A Primer' (New York: Chelsea Green Publishing, 2008). p. 167.

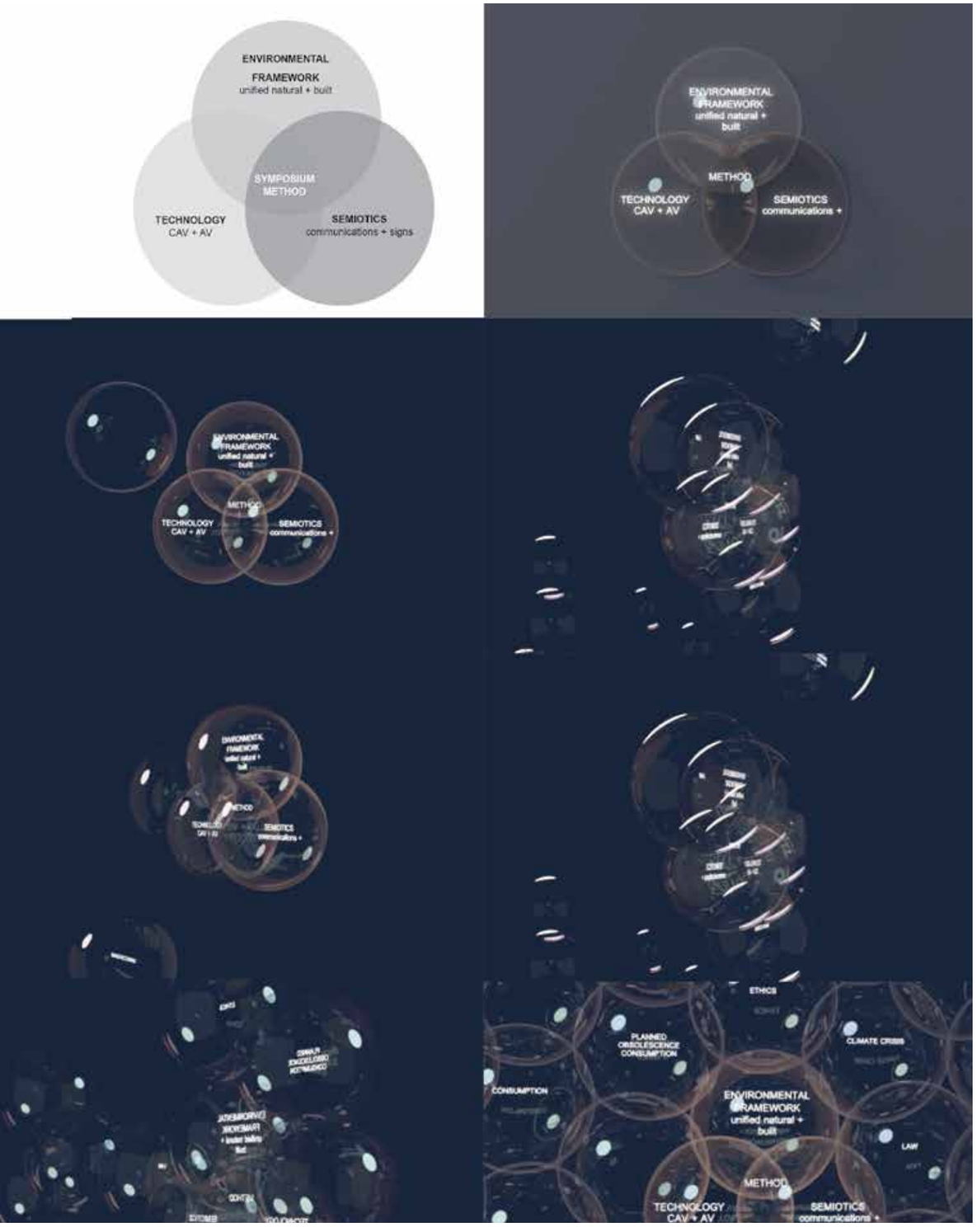


Figure 11: A mosaic of animation frames of dynamic and complex systems thinking with using the theoretical framework of the research.

The theoretical framework forms the basis of the animation. Refer to Video 1 for the animation. This diagram shows the three dimensional qualities of systems thinking, the animation from which the frame mosaic was made creates the sense of a dynamic field (Video 2). The three dimensional qualities also relate to the multi-scaled approach, nested systems and sub-systems which are features of systems thinking.

As Archer notes:

> *The most fundamental intellectual data in any discipline are from its history, using the word in its strictest sense, meaning a systemic account of what is generally the case at various periods in time in relation to design phenomena. It would include the history of knowing how, as well as of knowing what.*[111]

The principle Archer advances is that design and its practices are a source of new data. They allow researchers to systematically investigate, assess, validate and expand the knowledge base.

In Video 1, I explore the dynamic nature of the theoretical framework with its multilayered and dynamic relationships. The dynamic nature of animation assisted me in describing the complex interrelationships between the symposium method and the three research themes. The animation conceptualises a dynamic systemic ecology with nested systems; it is scaled at local and macro levels, referencing its three-dimensional, movement and network oriented qualities of complexity. Figure 11 presents a mosaic of the images from the animation of dynamic systemic thinking found in Video 1.

The animation of the theoretical framework represents an abstraction of a three-dimensional Venn diagram of systems thinking. In the animation, nested subject areas emerge as the complexity of the multi-layered subject area unfolds. The research fields are represented by transparent, fragile 'bubbles' that dynamically move and float into the viewer's frame. These subject areas are linked and join the system, each influencing the other as nested systems. The final frame shows the organic complexity of theoretical positions within systems thinking.

111 Bruce Archer, 'Time for a Revolution in Art and Design Education' (RCA Papers No.6)' (London: Royal College of Art, 1978) <https://researchonline.rca.ac.uk/385/> [accessed 3 August 2021]. p. 7.

Figure 12: Comparative analysis plan of the existing condition and CAREV-S in Crown Street from the spatial investigations.

This drawing synthesis the CAREV-S approach as a spatial investigation and includes the vision of a systemic semiotic technoecology.

Left - the existing Crown Street, Surry Hills model with dominant four seat vehicles; two lanes in each direction at night with typical current lighting and semiotic systems.

Right - the reimagined CAREV-S dominated street. The image shows how one and two seat CAREV-S occupy the same road space, the smaller vehicle allows for an increase in the road capacity and therefore the number of people being moved. CAREV-S parking is redistributed, there are the same number of parking bays but relocated to the right side of the road. The left side of the road features a new active transport route (a shared path) and additional environmental space. transport.

Refer to Chapter 4 for details.

1.4.1 Synthesising Capra Luisi and Schneider as a theoretical framework

The Capra–Luisi framework supports the transdisciplinary conceptual and design position at the heart of the research hypothesis. This approach facilitates the conceptual integration of CAREVs with the city, the environment and humanity.

In this research, the synthetically intelligent city collectivises CAREV/CAREV-S as a logistically orientated transport modality. As a transformational technology, CAREV are structured to increase city resilience, functionality and liveability, and systemically improve human health and safety.

New and emerging technological advances are regarded in this research as part of the Capra-Luisi environmental framework (technoecology). They are emergent properties and represent a transhumanist approach to leveraging technology to benefit the environment, safety, communications and public health outcomes. A transhuman is a being that resembles a human in most respects but has powers and abilities beyond those of standard humans. The research incorporates Schneider's reimagined Language of Thought (LoT) and Modes of Presentation (MoP)[112], which provide a common systemic platform for sharing and augmenting human intelligence with synthetic intelligence as a cognitive computational program. The combination of technological development, environmental and the semiotic is visualised and detailed in Chapter 5 as a synthesis of the research. Figure 12 is an comparative analysis of the spatial and semiotic findings (plans) expressing the *systemic semiotic technoecology* hypothesis.

Combining Schneider's LoT/MOP cognitive research with the Capra-Luisi environmental framework in the future synthetically intelligent city creates a technologically systemic cognitive and environmental framework for various vehicle formats such as CAREV/CAREV-S. This approach allows for reimagining the debate about shared mobility via a systemic proposal that transforms road-based transport as a collective ecology.

The collective notion of a diversity of vehicles within the CAREV/CAREV-S system moves beyond the notion of Mobility as a Service (MaaS), shared vehicle modalities, and private and public ownership issues into a fundamentally cognitive behavioural and unified relationship between CAREV, people and the

112 Schneider, Susan, 'The Language of Thought: A New Philosophical Direction by Susan Schneider' (MIT Press, 2011) p. 5-6.

city's SI environment. MaaS is a type of service that, through a joint digital channel, enables users to plan, book and pay for multiple types of mobility services. The concept describes a shift away from personally owned modes of transportation and towards mobility provided as a service, but does not preclude private ownership.

The symposium method in this research extends the Capra–Luisi and Schneider philosophical approaches to transdisciplinary systemic academic research methods and the three themes of technology, environment, and semiotics.

CAREV and CAREV-S as a systemic emergent transport modality, should be designed to respond to AV's historical cultural and social expectations. This would disrupt the current paradigm of unsustainable, congested, polluting, chronic and unsafe conditions. It can do so by leveraging the immense intellectual power of SI, augmenting human intelligence, and approaching the road-based transport ecology as a collective, ethical and socially just transport modality. Paradigm shifts are successive transitions from one paradigm to another through revolution.

This approach shifts current thinking to a system responding to the cultural dream of a transport system that is safe, efficient, convenient, reliable, and synthetically intelligent and which, compared to current systems, could be viewed as magical. Through transdisciplinary processes, magical outcomes can be achieved by systemically transforming current paradigms with improved environmental, safety, ethical, spatial justice, communications and cognitive principles, which are included and used to guide this research, refer to Chapter 1.5.

The practical application of the concept can be thought of as a deep systemic environmental consciousness at combined human and synthetic intelligence levels and the practical built-world outcomes that arise from it. Ecological consciousness recognises conscious human awareness of environmental impacts, this includes positive environmental outcomes at all stages of manufacture and operations – thinking, acting and responding.

1.5 Principles used in this CAREV study

A new way of thinking regarding relationships, connectedness and context is required in the public realm of systemic thinking to leverage the CAREV transition to benefit society. In the Capra–Luisi environmental framework, the organic (the living) and inorganic (materials) are inseparable and considered one networked system. Living systems are complex and built upon networks, nested systems, layers, objects and syntaxes between fields. A deep appreciation of the principles of ecology and our relationships to the environment requires contextual thinking. This involves several shifts in paradigms, which are never absolute; they are shifts in emphasis and balance, in constant flux and movement. They are dynamic, inherent and, therefore, desirable as part of living systems. These principles were adapted for this research from Capra's 'Sustainable Living, Ecological Literacy, and the Breath of Life'.[113]

PRINCIPLE 1 – the systems approach to life

Living systems are a whole; their properties cannot be reduced to those of their smallest parts. According to this concept, the organic and inorganic Cartesian divide is unified, with each component networked to the other. The systemic qualities are the nature of the whole organism; the parts do not have the same qualities. The properties of the parts may be essential and must be perceived as part of the whole. Thinking and related actions must change from 'elements and objects' to 'networks and communities'. Communities, whether ecosystems or human–machine systems, are characterised by sets or networks of relationships. Cooperation and decision-making by consensus through transdisciplinary processes change thinking from objective knowledge to contextual knowledge. Creativity, design, theory, the mind, practice education, communication and cognition are part of the system.[114]

113 Fritjof Capra, 'Sustainable Living, Ecological Literacy, and the Breath of Life', *Canadian Journal of Environmental Education*, 12 (2007), 1–11 <https://cjee.lakeheadu.ca/article/viewFile/624/507> [accessed 18 October 2021].

114 Peter Newman and Isabella Jennings, 'Cities as Sustainable Ecosystems: Principles and Practice' (Washington DC: Island Press, 2008) sets out environmental, social and economic principles for sustainable cities: 'Vison', pp. 8–32.

PRINCIPLE 2 – transdisciplinary systems thinking

An inherent transdisciplinary thinking process is to ask questions through observations about systems, networks, patterns, urban forms and the operations of the community making up the city. The three principles of ecology are networks, flows and cycles. Precautionary principles must be integrated into decision-making to reduce impacts and protect the planet's resources for present and future generations' benefits.

Appreciating the 'whole system' requires listening to its parts as unstructured, transient and dynamic systems. Rather than adopting reductionist strategies, the system's complexity should be celebrated. The basic pattern of organisation of all living systems is the network.[115] Because a network is a particular pattern of connections and relationships, thinking about patterns and relationships is the essence of systems thinking. Paying attention to what already exists will ultimately add to the value of the system.

PRINCIPLE 3 – environmental systems

The environmental system is living and includes all parts of the system, organic and inorganic. It is a process comprising objects, elements, forms and networks. The material and living worlds are inseparable and should be considered a highly complex circular unity.

Humans have a significant impact on the environment. All societies have a duty of care to each other to manage themselves, the environment and its resources and to ensure their ongoing sustainability for future generations. Our combined duty of care is to protect our planet's systemic ecological integrity. Our rights as human beings are integral to social and economic justice with improved intergenerational environmental outcomes. Renewable energy,[116] the circular economy[117] and transport-sharing modes are principles that underpin this research. The circular economy is an economic system based on the reuse and regeneration of materials or products, especially as a means of continuing production in a sustainable or environmentally friendly way.

In addition to providing health and safety benefits, the CAREV system must have positive environmental outcomes.[118] Environmental and social challenges should be addressed by building integrated networks combining creative thinking with practical outcomes.

115 Thinking through other disciplines' methods and processes is a necessary component of systems thinking and of cooperative networks. Hearing a diversity of voices and inputs and responding to them is an inherent quality of systemic thinking and acting.

116 Energy derived from resources that are not depleted on timescales relevant to the economy; examples include wind, solar, hydropower, hydrothermal, wave and tidal, geothermal and biogas from anaerobic processes.

117 Ellen MacArthur Foundation, 'How to Build a Circular Economy' (Ellen MacArthur Foundation, 2023) <https://ellenmacarthurfoundation.org/> [accessed 25 July 2023]

118 Conceptualising the CAREV-Ss and the city with synthetic intelligence systems should be considered as a pattern rather than a structural change.

PRINCIPLE 4 – social justice, rights to the city and sustainability

All living systems interact cognitively with their environment in ways determined by their internal organisation. An essential principle of social justice and sustainability is communication and cooperation that is balanced, just, transparent, traceable and ethical.

Social justice concerns the fairness with which the goods and the burdens arising from collective life are shared fairly among members of society. Therefore, the main questions raised by the social justice problem relate to the different dimensions involved in distributing social goods. According to Kelly:

> *Ownership is the underlying architecture of our economy; it is the foundation of our world. Questions about who owns the wealth-producing infrastructure of an economy, who owns it, whose interests it serves are amongst the largest issues that any society faces.*[119]

A focus on social justice in CAREVs and the synthetically intelligent city is how market mechanisms secure and entrench social balances. Ethical behaviour in terms of CAREVs and the synthetically intelligent city should be based on the two fundamental values of human dignity and ecological sustainability. The right to the city is more than the individual liberty to access urban resources; it is a right to change ourselves by changing the city.[120] It is a common rather than an individual right because the transformation inevitably depends upon the experience of a collective power to reshape urbanisation processes.

119 Kevin Kelly, 'Out Of Control: The New Biology Of Machines, Social Systems, and the Economic World' (New York. Basic Books, 2009).

120 David Harvey, 'Social Justice and the City' (University of Georgia Press, 2009) <https://pdf.wecabrio.com/social-justice-and-the-city-harvey.pdf> [accessed 4 August 2021] p. 315

PRINCIPLE 5 – thinking through human behaviour and connected autonomous renewable energy vehicles as an integrated system

As synthetic intelligence evolves as a socio-technical force, society must ensure it is accountable and transparent as a part of systems thinking.[121] Governance frameworks, including standards and regulatory bodies, must be established to oversee processes, ensuring that synthetic intelligence and autonomous systems do not infringe upon human rights, freedoms, dignity and privacy and that they include traceability to contribute to building public trust. The historical social and cultural dream of magical, safe, efficient, convenient, reliable and synthetically intelligent transportation is important for the cultural and social investment in AVs through the centuries; responses should think through the historical conceptual notions and respond appropriately.

Synthetically intelligent systems have increasing autonomy in decision-making and manipulating their environment. Thus, they must be designed to adapt, learn and follow the norms and values of the specific community and neighbouring or linked communities they serve, and they must assist and be subordinate to humans to reduce inequality. The UK Government Bletchley Declaration[122] and IEEE Ethics of AI and SI principles are reflected in the present research. The objective of embedding cultural norms and values into synthetically intelligent systems requires the following:

1. Identify and clarify the values and norms of a specific community in which autonomous systems operate, this acknowledges the importance of AI/SI in the international arena.
2. The implementation of synthetic intelligence through computational norms, values and justice provisions must serve the community.
3. Establish social and cultural criteria in response to the historic development of the technology and define its future social licence to operate.
4. AI/SI must protect and service human rights, transparency and explainability, fairness, accountability, regulation, safety, appropriate human oversight, ethics, bias mitigation, privacy and data protection needs. This includes the de-identification of shared data.
5. AI/SI much be used to strengthen efforts towards the achievement of the United Nations Sustainable Development Goals.

121 IEEE, 'The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems' (2021) <https://standards.ieee.org/industry-connections/ec/autonomous-systems.html> [accessed 4 August 2021].

122 UK Government, 'The Bletchley Declaration by Countries Attending the AI Safety Summit, 1-2 November 2023' (GOV.UK, 2023) <https://www.gov.uk/government/publications/ai-safety-summit-2023-the-bletchley-declaration/the-bletchley-declaration-by-countries-attending-the-ai-safety-summit-1-2-november-2023> [accessed 6 November 2023]

6. Continuous evaluation, monitoring and improvement of the implementation of identified norms in the synthetically intelligent system is required. The process must include transparency to ensure conformity with norms that reflect the specific community.
7. Substantial risks may arise from potential intentional misuse or unintended issues of control through AI/SI relating to alignment with human intent, especially in fields not fully understood and therefore hard to predict. A precautionary principle is required to ensure there are no catastrophic harms, either deliberate or unintentional, stemming from the most significant capabilities of AI/SI.
8. Developers must support, assess and develop AI/SI within an internationally inclusive network of scientific research on frontier AI/SI safety that encompasses and complements existing and new multilateral, plurilateral and bilateral collaboration, including through existing international initiatives, to facilitate the best science available for good public policy making.
9. As a precautionary principle, AI/SI including synthetic consciousness, should not be granted rights and privileges equal to human rights and should remain subordinate to human judgment and control.

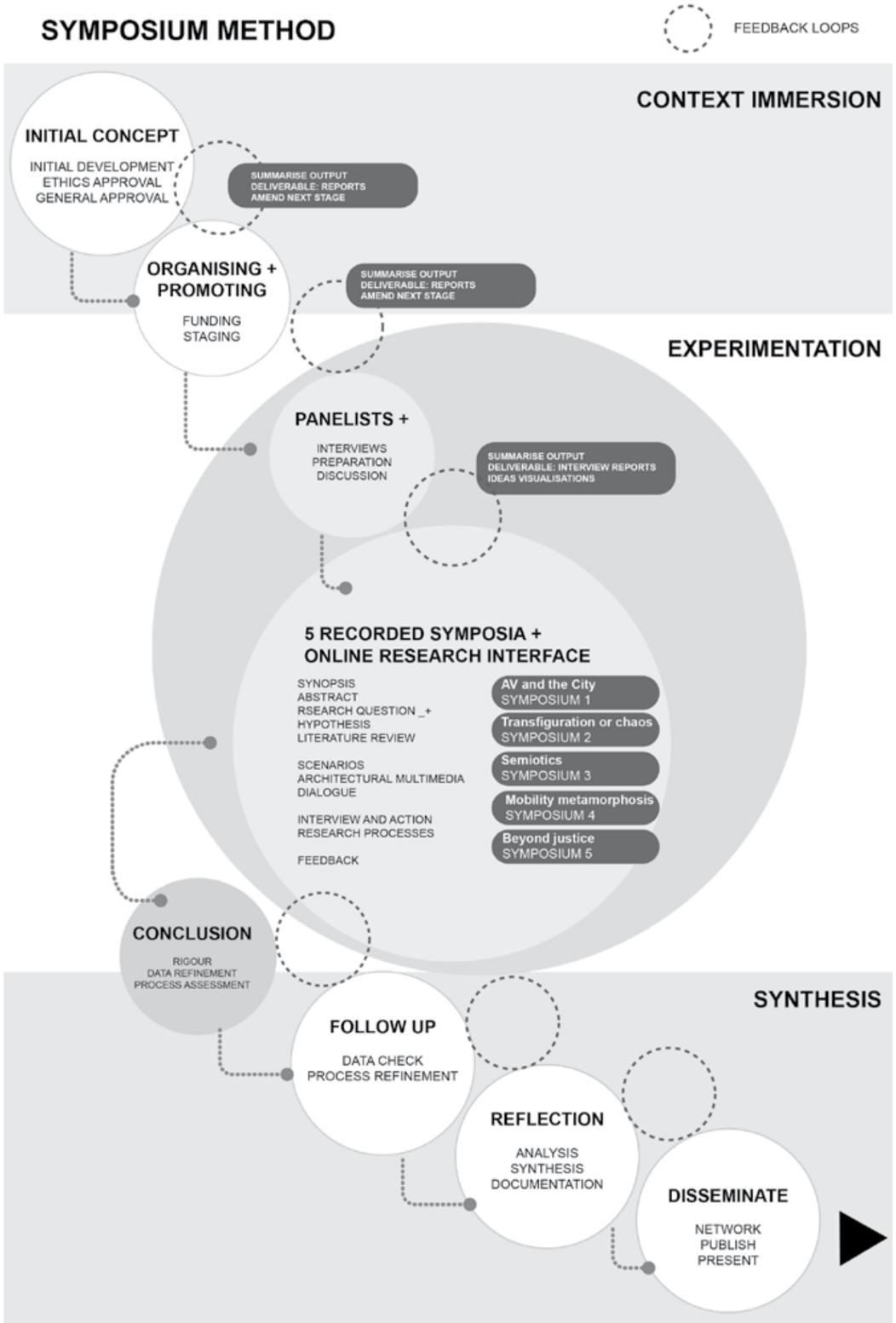


Figure 13: The symposium method as a diagram.

1.6 The symposium method

The symposium method used for this research is qualitative. The symposium method can be described a as a systemic transdisciplinary process to collect data through structured collaboration, presentation and multi-voiced dialogue as a bottom-up and top down approach to developing strategies and novel data for research. Its transdisciplinarity, invites multiple opinions and voices into the design and feedback process; it also incorporates other disciplines' methods, which is necessary as the subject incorporates the three major themes, technology, semiotics and environmental, as shown in Figures 9 and 13. The symposium method is an integral part of the subject and the research development, as is evidenced throughout the thesis. In each chapter there is a section on the outcomes of the symposia as a practice method. For this reason I have included the introduction and the outline the structure of the symposium method integrated in Chapter 1.

The symposium method is an extension of practice-based processes and employs rigorous scholarly feedback and assessment, thus providing validation and feedback on various design experiments and conceptual positions. The symposium method includes three stages of development: context immersion, experimentation and synthesis. Figure 13 shows the feedback system and the transdisciplinary nature of the research components.

Some 140–150 people participated across the five symposia and 26 speakers offered their diverse insights, observations and feedback, the speakers list is included in Appendix B. The research supervisors attended all symposia. The sessions were recorded, and all research participants provided informed consent. Personal particulars have been de-identified in this thesis, as agreed with all participants.

The three stages of the symposium method (refer to Figure 13) included:

Context immersion was the initial research development stage. It included research into the cultural and environmental framework for CAVs and semiotics in the public realm along with investigations into formal and informal literature, empirical research, practice-based observations, feedback processes and research methodology refining. Context immersion also included the development of the research sub-questions and the development of an abstract and hypothesis. The contextual inquiry also included systemic research modules in three areas: technology, environment and semiotics. Context immersion also included ethics and general approvals, which flowed through all stages of the research development.

Experimentation, the second stage, included organising, promoting and arranging funding and panellists for the symposium. This stage included developing architectural multimedia to answer the research sub-questions through the multi-layered symposium method. The experimental stage also included refinement of the synopsis, abstract and research questions.

The details of the symposia, the specific modules of research and the methods used, such as action research[123] and interview methods[124], are detailed in the description of each symposium later in this section. The interview method is a qualitative research method used to collect primary data by asking one or more people about their opinions. Data collection involved interview methods, action research and discourse analysis[125], as well as literature reviews[126], scenario testing[127] and transdisciplinary discourse techniques.

The research also used framework analysis, thematic frameworks, drawings, experimentation, interpretation, and synthesis combined with feedback and synthetic writing. My research practice includes design, drawings, animations (with sound), photographs and small prototypes of communication pieces. For example, I set up a stop motion animation workspace, shown in Figure 14, for the palimpsest animations. Palimpsest animations are obtained from the erasing of the image so that the page or background can be reused for another animation, and traces of the original animation remain. Critical analysis of the concepts behind these practices and how they assisted the research dissemination was part of the architectural dialogue and development; this will be discussed in the section on method.

Architectural animation through computer-generated processes has established itself as a major practice method and has shown significant improvements due to computing and software advances since the 1970s. Hougaard examines the idea of animation in architectural drawings and architectural media, such as models and renderings, as part of her PhD[128],

123 Kemmis, Stephen, and Robin McTaggart, 'Participatory Action Research; Communicative Action and the Public Sphere', Denzin & Lincoln (Strategies), 2000, p. 60 <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.473.4759&rep=rep1&type=pdf> [accessed 13 October 2021]

124 Knott, Eleanor, Aliya Hamid Rao, Kate Summers, and Chana Teeger, 'Interviews in the Social Sciences', Nature Reviews Methods Primers, 2.1 (2022), pp. 1–15, doi:10.1038/s43586-022-00150-6

125 Johnson, Melissa N. P., and Ethan McLean, 'Discourse Analysis', in International Encyclopedia of Human Geography (Second Edition), ed. by Audrey Kobayashi (Elsevier, 2020), pp. 377–83, doi:10.1016/B978-0-08-102295-5.10814-5

126 Rowley, Jennifer, and Frances Slack, 'Conducting a Literature Review', Management Research News, 27.6 (June_2004), pp. 31–39, doi:10.1108/01409170410784185

127 'Scenario Planning', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=Scenario_planning&oldid=1239238010> [accessed 10 August 2024]

128 Anna Katrine Hougaard, 'The Animate Drawing: PhD Dissertation,' ed. by Kunstakademiet (Kbh.: Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conversation, 2016) <http://annahougaard.com/wp-content/uploads/2017/06/The_Animate_Drawing_web_small.pdf> [accessed 20 January 2022].

building on the theoretical position of architectural representation developed by Evans[129]. Hougaard and Evans's writings influenced my thinking about architectural multimedia and the role in plays in practice research.

Animation provided an architectural media tool for the symposium method to assist the transdisciplinary discussion by visualising time-based design concepts, see Figure 14. The discussion led to the process of collecting data for my research. The animations were focused on obtaining data to assist in revealing participants' responses to research questions, the synthesis is found in the research findings in the concluding chapter.

The research adopted a de-identified and synthesised approach to the dialogue that emerged in the symposium method. This was in part due to the ethical approach[130] to including a diversity of opinions in the methodological process. The interview method and the action-based research facilitated open dialogue with me, during interview processes I repeatedly requested speakers to express their opinions openly in the symposium as this would provide rich data, especially if it was contrary to the theme or aim of the symposium. Dissenting opinions allowed for refinement and reconsideration through the feedback process. Open dialogue occurred, different opinions and recommendations for improvement also occurred and I responded by constantly improving and adjusting the process and by synthesising the data qualitatively. I corresponded with a tutor at the University of East Anglia, as part of the research methods course which I attended online in agreement with the RCA Research Office and with my supervisors prior to formalising the method.[131]

129 Robin Evans, 'Architectural Projection'. In 'Architecture and Its Image'., ed. by Eve Blau and Edward Kaufman, Centre of Canadian Architecture (Montreal: Canadian Centre, 1989).

130 RCA Research Ethics courses as part of Doctoral Training and Certification with the Epigeum Online Course System. Refer also to www.transfigcav.com/ethics.

131 Simon Watts and Paul Stenner, Doing Q Methodological Research (SAGE Publications, 2013) <https://www.booktopia.com.au/doing-q-methodological-research-simon-watts/ebook/9781446290705.html> [accessed 28 April 2022]

Figure 14: Colin creating an animation in his studio.
The palimpsest, stop motion animation is practice-based research.

Synthesis was the final stage of research, where the various research modules were integrated; it is the concluding stage, which includes rigour in assessing the implications of the new data. This also required follow-up on data validity and checking of information as a feedback loop system. The final stages included reflecting on the synthesis of the research and writing, thinking, and refining the architectural multimedia and the design experiments into a coherent research outcome. This stage also included disseminating the research. The method was finalised in the later stage of the research.

An incentive for this PhD research, and by extension, this symposium method, was to critically reflect on and expand my understanding of practice with theoretical underpinnings as a research practice, see Figure 14. For me, research practice forges new pathways between academics and practice; it brings contemporary academic thinking into practice, which has its routine in established traditions and refinement. It is challenging to describe and practice through design and writing and to specify the parts of a system that are parts or modules of the investigation that structure thinking. The interrelated research modules were distilled to create an original and creative project in its totality.

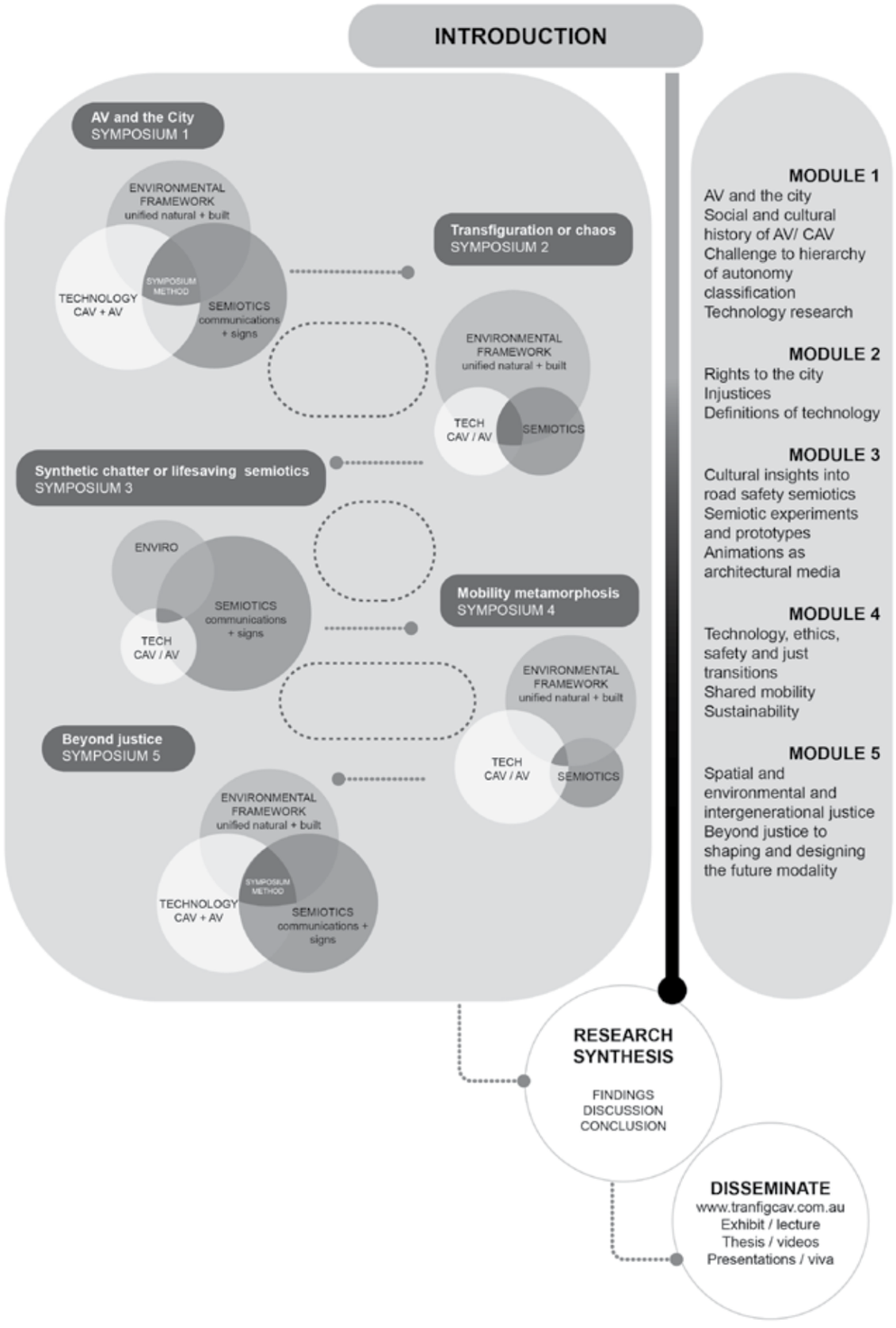


Figure 15: The methodology diagram.

This diagram shows how each symposium emphasised modules of research within the overall theoretical framework. The diagram also shows how the 'spaces between the themes' have a changing emphasis in each of the symposia, which enriches the dialogue.

1.6.1 Structuring the symposia

The symposia are critical to expanding transdisciplinary knowledge through reviews of literature, reflecting on current research contexts, creating new data through design research, provocations, dialogue and reflection. The five symposia were structured to provide increasingly complex data about:

- Symposium 1 - the general implications of AV and the city
- Symposium 2 - rights to the city, AV/CAV/CAREV technology implications on liveability, social justice and communications between humans and AV
- Symposium 3 - focussed on the semiotic aspects of Language of Thought, cognition, anthropomorphism and city, AV and human communications
- Symposium 4 - Mobility Metamorphosis gathered leading researchers of AV, shared mobility and environmental impacts of AV from within and beyond the RCA
- Symposium 5 - Beyond justice - this symposium focused on the spatial and environmental study of CAREV and the SI city.

The symposium methodology in this research was iterative, it included assessment, encouraged flexibility and changing emphasis which suits answering and focussing on the research questions. Figure 15, diagrammatically shows how the symposia were interrelated to the next with feedback loops and a non-linear but interrelated progression.

Each symposium maintains the overall PhD framework of environmental, technology and semiotics with the symposium method at the heart of the process which respond to the major issues identified in the contextual overview in this chapter. Each of the symposia has a slightly different emphasis to assist in answering specific research sub-questions logically and rigorously testing the hypothesis and reviewing the research questions through an increasing complexity and narrowing of subject field.

1.6.2 Methodology

The methodology was developed to generate novel and compelling qualitative data and influenced how the research method was implemented.

Asking relevant questions and developing multimedia associated with the research sub-questions is an important component. The summary output of the symposium dialogue and the synthesis of the discussions provided sources of rich and new data that would not otherwise have been available. The architectural multimedia, in the form of the two videos, was developed to capture the research visually. The accompanying architectural multimedia, animations, design experiments and conceptual positions provoked the discussions. I think of the symposium method as both a creative provocation[132] and a validation/testing method.

In the next section, I discuss the challenges of each research module, which are shown in Figure 15, the methodology diagram. Developing a systemic methodology was necessary to develop the research, but as new data emerged from the changing emphasis of the research over the seven years of development, the process non-linear and creative, systemic and rigorous. Figure 15 depicts the interrelationship of the symposia to each other and the modules of research output as well as the pathway to the synthesis and dissemination of the research.

This is a novel method on two grounds; firstly, it combines the specific transdisciplinary researchers in vehicle autonomy, semiotics, environment and rights to the city (social study) into a single space unique to the project. Secondly, the data collected from the symposium is essential for combining a thematic mix of disciplines to generate new data for the research. The data collected affirmed the process and many pre-symposium findings that required clarification.

1.6.3 Key information from each of the symposia

Table 1: Key symposium information tabulated

The table alongside summarises the key information from the five symposia.

132 Edward de Bono's 'provocation' method, which is a lateral thinking technique, is not referenced here. The provocations used in the symposium method are visually and design-oriented and combined with dialogue.

SYMPOSIA	1 AV and the city	2 Transfiguration or chaos	3 Synthetic chatter or lifesaving semiotics	4 Mobility metamorphosis	5 Beyond justice
OBJECTIVES	Identify the issues, challenges, gaps in knowledge.	Understand AV social and cultural history, right to the city and spatial justice.	Define semiotic systems in future transportation networks and environmental consciousness.	Foster cross-disciplinary collaboration in AV themes: 1. AV 2. shared mobility, 3. environmental.	Develop spatial and environmental justice research on CAREVs and the SI city.
METHODS	Presentation method for a transdisciplinary group. Discussion method.	Interview method. Action and Role Play methods.	Interview method. Action research. Role play and Provocation methods.	Participatory method - transdisciplinary method. Community -based analysis.	Interview method.
DATA TOOLS	Taxonomy presentation, drawing presentation. Slide presentation. Data collection through minutes.	Online research interface. Online symposium with slide presentation. IMDC MA submissions. Data collection by recording.	Online research interface. Online symposium with animations and experiments. Data collection through recording and transcripts.	Online symposium with animations. Data collection through recording and transcripts.	Online research interface. Online symposium with animations. Data collection through recording and transcripts.
SPEAKER SPECIALISATION numbering = number of speakers	1. Intelligent mobility 2. Urban environments 3. Systems 4. Manufacturing.	1. Social justice 2. Philosophy 3. Right to the city 4. Spatial justice 5. Synthetic intelligence.	1. Environmental activism 2. Semiotics 3. Synthetic intelligence 4. Multimedia.	1. Autonomous transport 2. Environmental sciences 3. Materials and systems.	1. Synthetic intelligence 2. Urban transport infrastructure 3. Autonomous transport systems.
PARTICIPANTS not identified as part of the ethics agreement to participate	1 x facilitator 3 x speakers 8 x scholars.	1 x facilitator 2 x presentations 4 x speakers 39 x scholars 7 x public participants.	1 x facilitator 3 x speakers 2 x public members 9 x participants.	1 x facilitator 18 x presentations 18 x speakers approx 30 participants (hybrid format).	1 x facilitator 3 x speakers 4 x scholars 4 x public participants.
DATA OBTAINED + SYNTHESIS	Validated taxonomy and transdisciplinary approach. Established zero incidents, emissions + congestion. Extend planned obsolescence research.	Suggested AV spatial justice + definitions research. Recommended cultural and social history and rights to the city. Suggested research into SI. Validated the symposium method.	Validated animation and experimentation process and feedback in the symposium method. Recommended environmental semiotic research.	Advanced transdisciplinary processes. Validated general research direction. Exposed other academic research within RCA and beyond. Recommended further systems thinking.	Validated spatial study as a data collection method. Validated the research system approach. Recommended further synthesis and scenario planning strategies.

1.6.4 Selecting speakers and participants for the symposia

The speaker and participant selection process was an inherent property of the general structure of the five interwoven symposia and their themed emphasis, refer to Chapter 1.6.1. Speakers were selected based on their knowledge and insights of the main themes of the symposia, refer to the Speakers List and links to biographies in Appendix B. Each symposium needed a speaker focused on one aspect of the theoretical framework involving environment, semiotics, and technology. This ensured that each thematic response could be addressed in the symposia, with appropriate responses to the research framework; with one speaker representing technology, semiotics and environmental or hybrids respectively. I also required speakers to represent a diversity of scholarly views or published research on the topic, or with emphasis on relevance to the symposium aims. Other criteria included speakers being an attraction for the symposium, their availability and costs.

Overall I was successful in securing speakers to cover all the fields. As the increasing level of specialisation occurred, obtaining speakers who were comfortable addressing specific issues, such as spatial justice for example, became challenging. In symposium 2, I decided to facilitate and take the role of environmentalist - in this there was a learning lesson as the double task was too much for a single person to manage.

Practically, many of the speakers emerged from within the RCA, both acknowledging the institutions extensive knowledge base and also a willingness for speakers to assist in student-led symposia. Speakers from outside the college were more difficult to secure, the combined insights of industry, academia, policymakers and the public were represented in the symposia. Symposium 4, the Mobility Metamorphosis was largely structured by the planning committee around the three themes of AV, sharing and environment. As a day long event and with the considerable resources of IMDC, this symposia attracted participation from other universities, industry and across the college. The diversity of speakers and thought leaders was extensive and had a strong influence on developing the spatial and social justice approach of this research.

I also invited participants with specialist interests to attend the symposia as challengers or provocateurs or audience speakers to prompt debate and discussion from the audience. This proved an invaluable addition to the symposia as it introduced a 'spontaneous' quality. All of the symposia had cross college researcher attendance. As semiotics and synthetic intelligence mobilities were an inherent feature of the study, I made an effort to invite students and researchers from SoC and IMDC to participate in the symposia.

An interesting aspect of the selection process was that many of the speakers had much wider knowledge and specialisations than I anticipated - the additional benefit of social science, social justice and ethics/legalities for example significantly enriched and deepened the research. The spatial justice study emerged from symposium 2, and had not been planned in the initial research stages. The speakers' contributions and their influence on the research is discussed in detail in chapters 2.8, 3.7, and 4.8.

Despite the challenges of the selection and management processes the contributions of the speakers and participating audiences, both invited and public, significantly enriched the research outcomes by emphasising systems thinking through dialogue. Between the symposia, I was able to re-frame research questions and previous outcomes and readdress issues at the following symposia. Inevitably I learnt to trust the views and impressions of collective thinking and the winding path that this research undertook as shown diagrammatically in Figure 15.

Figure 16: Composition of frames from the research interface www.transfigcav.com.

Left to right: symposia 1, 2, 3, 4 and 5; registration page; contact page; and YouTube link for running animations.

1.6.5 Open source research interface and ethics

The research commenced in 2018, at which time a hybrid in-person/online process was envisaged. The COVID-19 pandemic struck Sydney in March 2020, which impacted the research method to the extent that the research was conducted almost completely online for the next two years and to the last symposium. In February 2020, in conjunction with my supervisors and the Royal College of Art (RCA) research office, I reassessed the method and translation of the physical symposium format to an online format.

As a result of moving to an online symposium method, I developed a research interface website called (www.transfigcav.com), which remains live and will continue to provide an open-source research interface beyond the PhD research. Figure 16 is a composition of screenshots of the research interface, including the voluntary consent process, part of the ethics requirements of the RCA.

All uploaded material was assessed through the RCA's annual examination process before being refined for publication on the research portal. The symposia were recorded to assist with the research into the future. Controls of voluntary participation and the use of the recordings were established in consultation with the RCA ethics team (Research Office). Voluntary consent was a prerequisite for attending the symposium. The recordings of the symposia are held by the author and some recordings are in RCA audio visual storage systems. Quotations from the symposia are de-identified in the thesis as part of the ethics agreements between the researcher and the participants and as part of RCA ethics for this research. Participants could remain anonymous should they wish and could withdraw consent at any time before the publication of the PhD thesis.

1.6.6 The limitations of the symposium method

The symposium method requires careful data management and strong facilitation to keep the conversations developing and focused on the specific goals of the research. Researchers should carefully consider the input requirements of the symposium, as the demands are significant. The capital costs of setting up the website and running, recording and collecting the data were considerable.

The most challenging task was finding suitable speakers. The speaker searches and management consumed scores of hours and were, at times, frustrating and demanding. Student-run symposia may attract participation from within the college, but not reliably. External participation is easier to arrange if financial incentives are offered, and a number of invitees declined to participate based on the limited incentives offered.

Difficulties with the method included finding interested speakers and their availability over international date/time zones. The process was enriched by its internationally diverse attendance. Some speakers were only willing to participate in a non-professional research format. Interestingly, industry participants (broadly) were disinterested or detached, despite considerable effort to engage them.

1.6.7 Assessment of the method by symposia

The following section of the thesis systematically describes the five symposia. The speakers list for all the symposia is included in the Appendix B. The content, insights, the data from the symposia are described and detailed in the practice method sections of each of the detailed chapters 2.8, 3.7, and 4.8.

Symposium 1 – 'Communications for the future autonomous renewable energy vehicle in the urban context'

Symposium 1 was held on 18 June 2018, at the RCA Darwin Building, London. The emphasis of the symposium was the relationship between vehicles, the city and the future autonomous vehicle. Based on literature reviews leading to this symposium, my initial research suggested insufficient cross-disciplinary research being undertaken in future AV, the city and semiotics. The symposium format facilitated inter-college researchers discussing the vehicle and city relationship. Specific disciplines of communication (semiotics), the urban form (urban design), and autonomous vehicle design perspective RCA Intelligent Mobility Design Centre (IMDC researchers). Intelligent mobility is a concept of advanced transport systems, suggesting synthetic intelligence, which incorporates efficiency, convenience and resilience utilising existing infrastructure.

The symposium was attended by eight RCA Intelligent Mobility Design Centre (IMDC) and RCA School of Communications (SoC) researchers, moderated by the author and attended by Dr Jon Goodbun and Dr Artur Mausbach. Mr Andrew Collinson, then strategy leader of Land Rover Jaguar, also attended. The symposium included an agenda and a presentation by Dr Mausbach on the IMDC's research and his field. This was followed by Colin presenting his work. The speaker selection process was not fully developed in symposium 1.

After the presentations, the symposium evolved into a discussion workshop. The facilitation method included action research methods, with attendees invited to discuss and respond to the presentation material. The action research method included the researchers and supervisors making suggestions about how the research could be improved and what future directions may be suited to the ongoing research. The subject data and summary findings are presented in Chapter 2.8.2.

The symposium method was developed between symposium 1 and 2 and in response to the meaningful research contribution from the dialogue that emerged in symposium 1.

Figure 17: Symposium 2: a screen-shot of the online symposium.

Permission to include photographs of symposium speakers and attendees has been granted by everybody shown in Figures 17 to 20 and 50.

Figure 18: Symposium 3 (4th March 2022): a screen-shot of the online symposium.

Symposium 2 – 'Transfiguration or chaos'

Symposium 2 was held on 10 July 2020 as an online symposium. The symposium emphasised understanding the social and cultural implications of AV/CAV/CAREV as part of entertaining the environmental and social impacts of future technology on the city. The symposium aimed to provide data about the relationship between the city and CAREVs, with its main role being to identify information that was not yet available.

The author facilitated the symposium with speakers including Dr Adam Kaasa (senior tutor (research) in the RCA SoA), Despina Papadopoulos (PhD candidate at the RCA School of Humanities) Dr Chris Thorpe (acting head of Program Intelligent Mobility at the RCA School of Design) and Kam Rehal (PhD candidate in the SoC and a Senior Digital and Graphic Design Lecturer at the University of Greenwich). Scenario planning through RCA IMDC MA student led contributions were also used in this symposium to provoke discussion, the submissions are discussed in Chapter 2.8.2. Refer to Figure 17.

Action research methods[133] were used in the symposium to identify the unique issues, present relevant data (from the research interface material), interpret the data and act on evidence that arose out of the discussion. Data was also derived from the dialogues from a diversity of researchers and the public. This symposium was part of the Doctoral Training week and was attended by 39 scholars and seven members of the public. This included discussing the research questions presented in drawings and other architectural media. During the symposium, the speakers used role-play methods; while secondary to the action research, the role-play method was assessed as a suitable method for speakers to illustrate their discipline's methods for the benefit of other disciplines. Role play is a form of experiential learning.[134] Researchers or participants in the method take on assigned roles and act out those roles. The data obtained from this symposium is presented in Chapter 2.8. Refer to Figure 17 for a screen-shot of the online symposium.

133 Noella Mackenzie and Sally Knipe, 'Research Dilemmas: Paradigms, Methods and Methodology', Issues in Educational Research, 16 (2006), pp. 13; 193–205 <http://www.iier.org.au/iier16/mackenzie.html> [accessed 15 December 2022]

134 'Assessing with Role Plays and Simulations', UNSW, 2024 <https://www.teaching.unsw.edu.au/assessing-role-play-and-simulation> [accessed 29 July 2024]

Figure 19: Symposium 4: a screen-shot of the hybrid online symposium.

Figure 20: Symposium 4: a screen-shot of the hybrid panel discussion and online symposium.

Symposium 3 – 'Synthetic chatter or lifesaving semiotics'

Symposium 3 was held over two online sessions on 25 February and 4 March 2022. The focus of Symposium 3 was on the semiotic research into AV/CAV/CAREV, deepening the initial research undertaken in Symposium 1. The two day format was used to assist with fatigue.

Expanding and improving on the success of the previous symposia, Symposium 3 focused on refining the interview and action research method processes. I utilised a mixture of the interview method, action research and provocations to obtain the required data based on my research and my supervisor's advice about the data from the previous symposia. 'Role swapping' was encouraged and a question-and-answer session was provided for the full participation of the audience in the process. Participatory research methods engage community or interest group stakeholders in the research process. Initially, the symposium was designed as a breakout process in which participants would leave the room and rejoin later, but time limitations of the symposium precluded this. Refer to Figure 18 for a screen-shot of the online symposium.

Notwithstanding the struggles – including marketing difficulties - limited diversity of speakers, online participation tools and low participation of the wider audience, 15 in total – the symposium provided appropriate transdisciplinary data through the dialogue and responses to the display of architectural multimedia.

I created Video 1 as a single mediated narrative in response to feedback during this symposium. In Video 1, I discuss the method, aims, research questions, and how they generated and influenced specific animations. Refer to Chapter 3.7, for the subject data output of this symposium.

Symposium 4 – 'Mobility metamorphosis'

Symposium 4 was a whole-day event held on 6 May 2022. The RCA Research Office supported the symposium, which was hosted by the IMDC at Battersea and online. Refer to Figures 19 and 20 for screen-shots of the hybrid symposium 4.

Eighteen speakers presented, covering a diversity of research in mobilities in architecture, cities, mobility, technology and the environment. An objective of the symposium was to address the need for cross-disciplinary collaboration to develop intelligent mobility solutions. Symposium 4 included a diversity of global speakers from leading research institutions and industry. The presentations

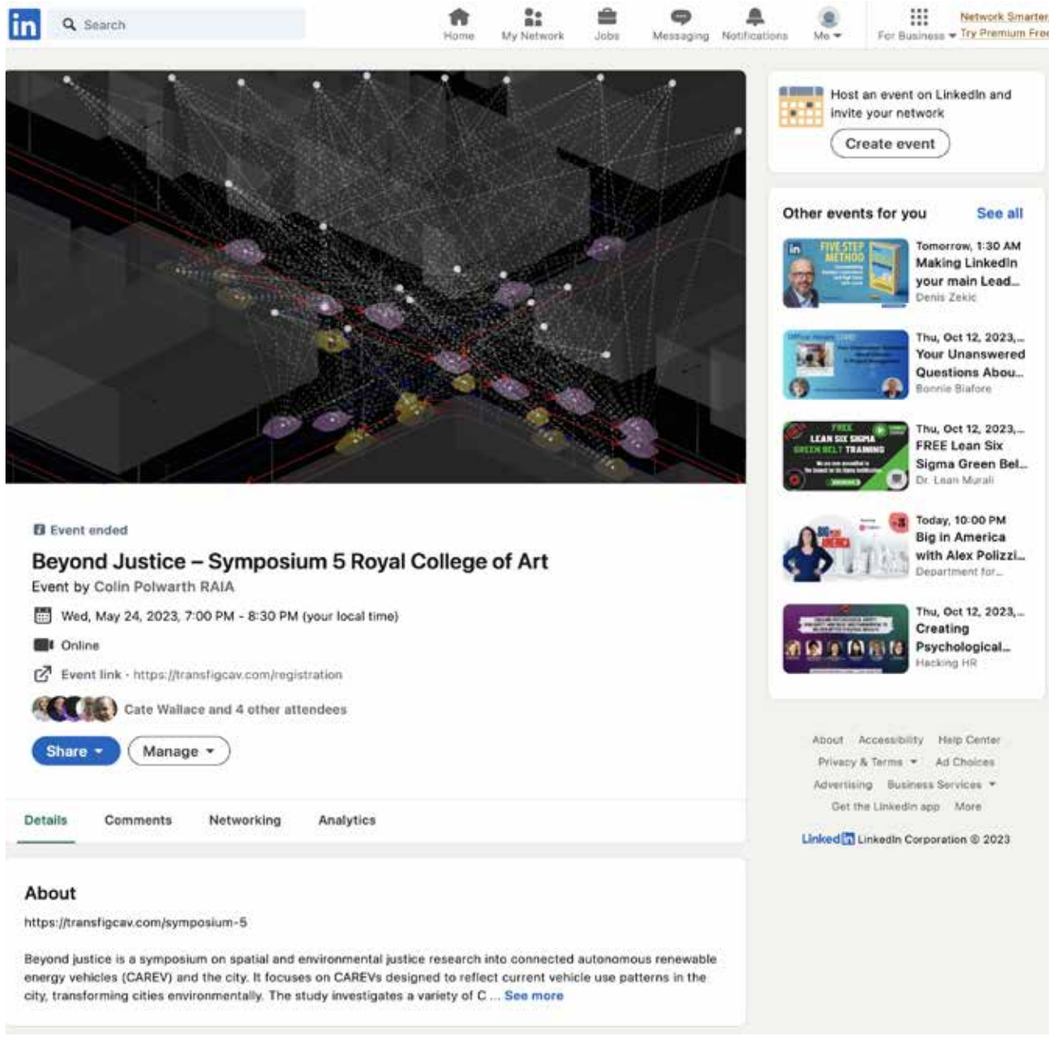


Figure 21: A screen-shot of LinkedIn advertising of Symposium 5.

and discussions broadened my research context at a critical stage of research development. The discussions and general structure of the symposium allowed me to locate my research in a broader context of AV academic research and to some extent, research being conducted by industry.

The tools used in this symposium followed a traditional participatory method including community (in this case the audience)-based analysis of social problems. Under the three areas of interest (autonomous vehicles, shared mobilities and environmental issues), the speakers formed interest groups focusing their discussion on specific topics and the latest developments within their specified field.

After four or five presentations, the speakers moved to an open discussion format between the speakers, with a question-and-answer opportunity for audience participation. The data obtained from this symposium is presented in Chapter 4.8.

Symposium 5 – Beyond Justice.

Symposium 5, on spatial and environmental justice research into connected autonomous renewable energy vehicles and the city, was held online on 24 May 2023. The symposium was advertised across the college and on LinkedIn by IMDC and by the author on the SCP website, through LinkedIn, on www.transfigcav and on Instagram. A screen-shot of the LinkedIn advertising is shown in Figure 21.

I facilitated the symposium with attendees including Gareth Collins of Transport New South Wales; Dr Timea Nocta, Assistant Professor at the Institute of Local Government Studies at the University of Birmingham; Dan Phillips, Senior Research Fellow at RCA IMDC, and supervisors Dr Jon Goodbun and Dr Artur Mausbach. The symposium was also attended by eight public members. The low participation was due to several factors including the specialist area of inquiry, the date of the symposium coinciding with a number of other public events and the event being twice rescheduled to accommodate speakers and the UK teachers strike.

Based on the previously tested methods from Symposiums 1, 2 and 3, this symposium followed an interview method process in which I discussed the research interface material for the symposium with the speakers before the symposium and made minor editorial changes where required. The speakers confirmed their areas of interest and, specifically, which areas of interest they felt required additional input. The action research method was used in the symposium.

1.6.8 How effective is the symposium method in achieving the research aims?

The symposium method was specifically designed to provide effective tools and systems to assist in developing the research aims and objectives, answer the research questions, and obtain new data. Like all methods, many difficult tasks arose and requires substantial resources to operate and maintain efficacy, including the advertising of the events such as that shown in Figure 21.

Specifically, the PhD research required unavailable data or data otherwise only available in a form that did not assist meaningfully in developing the research. The research aims were to collect new data and collaborate with a broader research and transdisciplinary community to hear multiple voices, perspectives, and opinions, introduce new ideas, and reflect upon spatial studies. The symposium method used in this research provided rich data from the initial to the final symposium. The open-source research interface and synthesis stage allowed for the validation of various positions being developed. The action research method allowed for continuous feedback and input from various speakers, my supervisors, and other academics in developing the research based on the data from the symposium.

The symposium method invited the participation of many thought leaders, interested parties and the public in the process and provoked dialogue through the presentation and the discussions around architectural multimedia; this, for me, was a measure of high efficacy. This direct access to diverse opinions gave me unmediated feedback on specific research questions. While at times the feedback was emotionally challenging, architects are trained in this approach from early-stage education processes.

The www.transfigcav.com.au research portal was important to the speakers and audience being able to investigate and contemplate answers before the symposium. The speaker validation processes through transdisciplinary and open dialogue were important to me in assessing and synthesising the research in a comprehensible and insightful manner. The recording process was an essential part of being both the facilitator and researcher in appreciating the complexity of the subject and the dialogue after the event. The symposium method provided a formalised structure from which new data that is not currently available could be obtained, a key contribution to the research.

1.6.9 Other methods investigated

The Capra–Luisi transdisciplinary research methods were inherent in the process and developed in the early methodological analysis for the project. I investigated various methods that appeared to be relevant to the research. These included active research[135], interviews[136], mixed methods[137], grounded theory[138] and systemic methods[139]. Action research[140] is an interactive inquiry process that balances problem-solving actions through collaborative processes including dialogue. This methodological research was not a systemic approach to researching methods or a methodological taxonomy of methods. I limited my investigations to those that developed a method for the specific requirements of the research. The symposium method was partly developed from practice-based multi-disciplinary design dialogue, a daily practice method suited to my personality.

1.6.10 How is this method different from other methods?

The transdisciplinary method has practice-based and formal, rigorous academic processes for obtaining new data. A feature of the symposium method, which is different from other methods, is the ability of the researcher to respond to the dialogue that emerges and expands through the informal dialogue of the symposia.

The symposium method facilitates the creation of data through design research and also from the dialogue that emerges from the design research. I used the discussions and the responses to expand or deepen the discussion and often referred the points being made to others in the discussion for commentary for clarification or assessment, emphasising the differences between the points. In the reflection and synthesis phases I persistently followed through on advice, recommendations and feedback to improve the research output including design improvements. Across the five symposia, I was also able to re-examine previous responses to the research questions in the light of the differing emphasis of the research which assisted me clarifying my thinking. The feedback and refinement method allowed me to modify my thinking and writing continuously. The expanded time of the research over the part-time seven years allowed me to reflect on the data obtained, method and make refinements.

135 'Active Research', Harvard, 2024 <https://researchsupport.harvard.edu/active-research> [accessed 29 July 2024]

136 Noella Mackenzie and Sally Knipe, 'Research Dilemmas: Paradigms, Methods and Methodology', Issues in Educational Research, 16 (2006), pp. 13; 193–205 <http://www.iier.org.au/iier16/mackenzie.html> [accessed 15 December 2022]

137 ibid. Mackenzie. 2006.

138 ibid. Mackenzie. 2006.

139 Antony Bryant, Grounded Theory and Grounded Theorizing: Pragmatism in Research Practice (Oxford University Press, 2017)

140 Meadows, Donella H., Thinking in Systems: A Primer (Chelsea Green Publishing, 2008).

Figure 22: Colin next to the monitor with Video 2.
Exhibition of the PhD research on display at the Copeland Gallery, London. RCA Bienniale, 22 June 2023. Refer to Video 2.

Figure 23: Colin presenting his research as one of the EDRA keynote speakers. Photograph courtesy of ANFA, permission has been granted.

Environmental Design Group Association (EDRA) were keynotes speakers at the 20th Anniversary Conference Academy of Neuroscience for Architects, 13 September 2023. University of San Diego, California (associated with the Salk Institute)

1.6.11 Dissemination of the research

The symposia formed a framework for the dissemination of the research, as does the *www.transfigcav.com* portal and the ANFA 2023 conference.

In 2022, I submitted an abstract of the research to the Environmental Design Research Association (EDRA) as part of the dissemination method. The abstract was accepted as part of the EDRA keynote team. In September 2023, I presented my research at the twentieth-anniversary conference of the Academy of Neurosciences for Architects keynote team in San Diego, California.

The conference was attended by about 200 architects from across the USA and another 150 online from various countries worldwide. I spoke to about 20 people after the presentation about the research, the process and the findings, as shown in Figure 23 of the presentation. I expected to have to defend the spatial investigation, especially my specific request for Americans to give up their oversized vehicles. However, there was general support and interest. The presentation provided an opportunity to discuss the CAREV-S spatial findings with this specialised architectural neurosciences and environmental research community internationally. It fulfilled a research objective to disseminate the research findings.

On 20–23 June 2023, I presented Video 2 ('Spatial Investigation of CAREV and the City') at the 2023 RCA Biennale at the Copeland Gallery, London. The RCA Bienniale provides a platform for RCA PhD cross-college researchers to showcase their research. This exhibition provided an opportunity for me to present some of the research findings to other RCA researchers and to the broader research community. Refer to Figure 22.

The 2023 RCA Bienniale also featured the School of Communications itinerant spaces, which explores research practices. I was later invited to submit an abstract for the second edition and was successful. According to the RCA website in which Video 1 is presented:

'*itinerant space sets out to explore, interrogate and critically reflect on communication research practices, and we begin with the contributions of School of Communication postgraduate researchers. The gestation period of the journal has been lengthy. We began the process in a world reeling from the arrival of COVID-19 in 2020, and continued with the key conversations taking place during a period of lockdown and reliance on online platform technologies. Issue 2 is a catalyst for knowledge sharing.*

Figure 24: Royal College of Art, School of Communications, Itinerant Space, screenshot from Volume 3, Issue 2, July 2024.

https://itinerant-space.co.uk/mini-abstract/an-environmental-approach-to-connected-autonomous-renewable-energy-vehicles-associated-semiotics-and-the-synthetically-intelligent-city/

It was always in the journal's five-year plan that issue 2 would build on the learning of the pilot issue to iteratively develop an expanded network of the RCA's wider doctoral research community, and to stretch beyond the academy. We felt the urgency of our own research, but also the desire to connect with other PGRs [post graduate researchers] in learning more about individual research practices. As an experimental platform, the journal offered a unique opportunity to inform interdisciplinary conversations and modes of research dissemination.' Editor-in-chief: Professor Teal Triggs, founding editors: Nick Bell, Karen Bosy, Kirsty Smith, Issue 2 editors: Nick Bell, Karen Bosy, Kam Rehal[141]

Ongoing dissemination of the research includes

- A request for an updated research summary for an industry journal
- An invitation to submit a proposal for a book on the subject area
- A standing invitation to present the research findings at the next appropriate EDRA conference.

141 https://itinerant-space.co.uk/

1.7 Structure of the thesis

This chapter has introduced the area of research and the research question and sub-questions, It has also detailed the theoretical framework and principles used in developing the research and outlined the symposium method and its limitations.

Chapter 2 contains information about SI and the vehicle to city operations, big data, smart city and digital city literature and how this research has influenced the research. The role of synthetic intelligence and its impact on all aspects of human endeavour and will play a leading and critical role in AV/CAVCAREV into the future.[142]

Our ability as humans to understand how synthetic intelligence will operate in the public realm, its role in managing vehicle intentionality, communication of legislative controls in the public realm,[143] city logistics[144] and environmental outcomes[145] is an emerging field of inquiry and is discussed in Chapter 3, emphasising the role of semiotics, the change in public realm semiotics as a result of AV.[146]

Chapter 4, the systemic spatial study, investigates how technology, environmental and semiotic considerations can assist in spatial justice redistribution in road-based transport through CAREV. The AV industry can be categorised as powerful, political, global and systemic. It has vested interests in developing AV, a subject discussed in Chapter 4.

Finally, Chapter 5 synthesises the research findings from Chapters 2, 3 and 4 and discusses the hypothesis and the research aims. The conclusion is a synthesis of the research, which reveals a combined human intelligence and SI along with the advanced CAREV modality as contributing to the definition of the synthetically intelligent city. The conclusion contains summaries of the research significance, assumptions and originality.

142 Vivek Wadhwa and Alex Salkever,The Driver in the Driverless Car: How Our Technology Choices Will Create the Future', 1st edition (Oakland, CA: Berrett-Koehler Publishers, 2017)

143 Chunsheng Liu et al., 'Machine Vision Based Traffic Sign Detection Methods: Review, Analyses and Perspectives', *IEEE Access*, 7 (2019), 86578–96 <https://doi.org/10.1109/ACCESS.2019.2924947>

144 ibid. Lim and Taeihagh.

145 ibid. Sawaragi.

146 Ariel Bogle, 'Can We Trust Big Data to Build Our Giant Future Cities?' (ABC News, 14 March 2018) <https://www.abc.net.au/news/2018-03-15/big-data-algorithms-equality-future-cities/9544138> [accessed 16 October 2023]

1.8 Synopsis

This project investigates a new way of thinking and approaching CAREV technology in a synthetically intelligent city with positive environmental outcomes through a systemic transdisciplinary method. This research asks a meta-question about the combined effects of a future CAREV system on the public realm. Its response is an imaginative study in CAREV, semiotics, and the synthetically intelligent city in which human intelligence is augmented with synthetic intelligence.

Chapter 2.0 Technology: CAREVs and the SI city

2.1 Introduction and identifying issues

This chapter delves into the discourse surrounding AV/CAV/CAREV technology within urban environments. It highlights the historical impact of fossil-fuelled vehicles on cities over the past century and a half and illustrates how congestion and road transportation dynamics have evolved. The interaction between vehicles and urban spaces has undergone significant changes, encompassing congested city centres in the early twentieth century and contemporary congestion taxing and pedestrianisation efforts.

The chapter introduces the concept of the 'orthodox debate,' which represents the polarised discourse between anti-vehicle sentiments and pro-vehicle perspectives. It discusses how this debate is deeply entrenched globally and outlines the characteristics of this discourse. In response to the polarisation, a transdisciplinary approach to vehicle and infrastructure design is outlined, which aims to incorporate diverse voices and promote dialogue through such methods as symposia.

The complexity of the city–vehicle discourse is emphasised, spanning across the academic, public, political, economic and social realms. The chapter addresses many issues posed by differing viewpoints at various levels, including individual and local communities and international policy arenas, which are often influenced by powerful lobbies and self-interest groups.

Furthermore, it explores the lived experiences of communities in such cities as London and Sydney and highlights the significant impact of vehicles on urban life and the complex relationship between residents and city traffic. Despite frustrations with congestion, many individuals lack viable alternatives, leading to a communal desire for a future urban and transportation landscape that addresses these problems.

The chapter also discusses the exploration of futuristic visions and utopian/dystopian conditions related to AVs through various mediums, such as myth, fiction, literature and film. It mentions the emergence of recommendations to examine the social and cultural history of AVs and offers insights into broader societal discourses surrounding vehicle impacts and the perceived potential of AVs as a solution.

Overall, the chapter navigates through the multifaceted discourse surrounding AVs and their implications on cities and emphasises the need for inclusive dialogue and understanding across diverse perspectives. I explore the social and cultural history of AVs by analysing various forms of literature, myths, fiction, animations, films and philosophies. In Symposium 2, I presented findings from about 35 AV-related media sources and suggested how these cultural representations have influenced the development of AV technology. I noted that despite its significance, AV social and cultural history has not received adequate academic attention, possibly due to its association with science fiction or informal history. Therefore, I argue that in response to urban vehicle impacts, a communal dream emerges – a desire for a different urban and transport future that alleviates the undesirable qualities of the relationship between humans, vehicles and the city.

During Symposium 2, the discussions also emphasised the importance of defining technology clearly to advance the field, alongside considerations of social implications, rights to the city and environmental concerns related to CAREVs. In Chapter 3, I test and question the automotive industry's classification of autonomous driving and suggest opportunities to create a new way of looking at the established paradigms.

This chapter also identifies key authors and their approaches to CAREV technology development and provides insights into the current state of the industry, its potential to transform urban transportation and public health and its impact on the environment. The discussion delves into the complexity of vehicle design, manufacturing, marketing and consumption and raises questions about industry responsiveness to societal concerns.

Critics of the automotive industry argue that it prioritises financial objectives and safety regulations over broader societal and environmental considerations. This chapter highlights the complexity of positions within the field. It discusses the transition from human-driven vehicles to AVs and emphasises the potential for CAREVs to reshape the relationship between vehicles and cities.

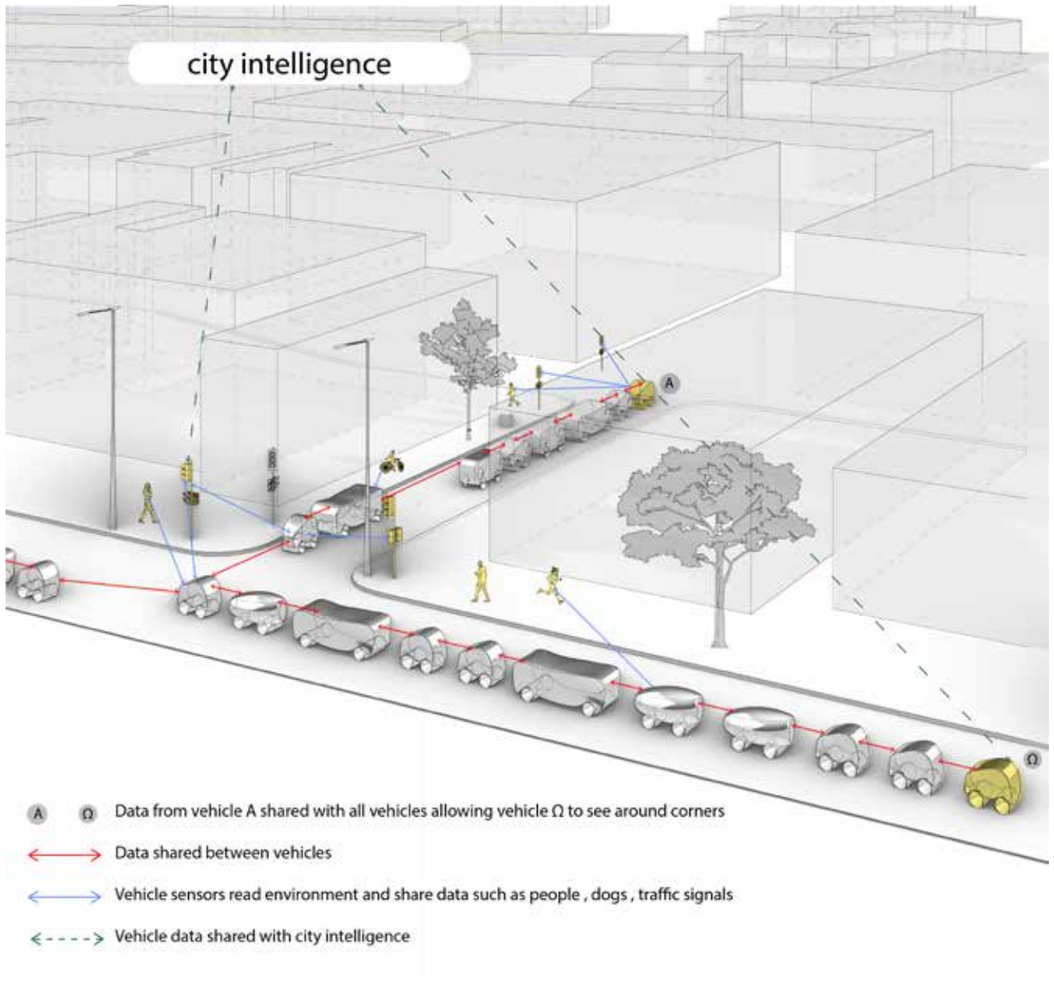


Figure 25: A diagram representing the abstraction of CAREV and city cloud based SI communications.

The diagram shows vehicle-to-vehicle (V2V) and vehicle-to-city (V2C) communications as well as the sharing of data between vehicles and the city. City intelligence in the diagram is denoted as a cloud-based system; the reality would be that it would be ubiquitous (V2X).

A definition of the SI city threads through the research. This chapter introduces the notion of the CAREV city, one in which this vehicle technology is the dominant road-based transport modality. The literature review in this chapter outlines the resources used to understand CAREV communications systems. The technical qualities of CAREVs are still in development, as there are vehicle-to-vehicle (V2V) systems, vehicle-to-city (V2C) and (V2X) vehicle to everything systems. This is shown in Figure 25, as an abstract diagram of CAREV communication. A variety of other AV and AV-to-city methods are under development.

Ultimately, this research asks questions and provides responses to the interactions between CAREVs and the environment and contributes to shifting perspectives on CAREV urban transportation.

2.2 Research sub-questions related to the technology theme

The research sub-questions emerged during the research and are specific to the theoretical framework research themes. They are as follows:

SQ2.1 In the evolution of vehicles, semiotics and the city, what are rhythms and patterns that can be seen?

SQ2.2 Can the pace of vehicle technology change and urban evolution be visualised?

The research sub-questions are answered in this chapter (Chapter 2.8.3)

2.3 Identifying knowledge gaps in designing systems for CAREVs and the SI city

Any city's road network evolution requires flexibility, resilience and constant finessing as the city evolves in response to social and economic needs. The road network is a highly contested area of the public realm, and more attention should be paid to this area of research.[107] Resilience refers to the adaptive capacities of complex urban systems to manage change, order and disorder over time.

AVs/CAVs are currently being considered primarily as a transport modality, however, research into the environmental benefits is insufficient. The main research gap identified through this literature review is the need for CAREVs as an environmental system. While various publications, such as Taiebat et al.,[108] Sovacool et al.,[109] Silva et al. and Kopelian et al.,[110] acknowledge that CAREVs can lead to improved environmental operations, most leading authors on the technology have yet to take a systemic view of CAREVs, their cultural context and environmental conditions.

Associated with a systemic environmental approach is a social and cultural approach to CAREVs that requires cohesion and appreciation. The integration of CAREVs and the city tends to focus on technological issues instead of an urban and lifestyle response that addresses how humans in the public realm are likely to interact with the CAREV city and CAREVs. The GATEway[111] publication has a unique urban lifestyle-oriented approach.

107 Evidence of this can be seen in cities worldwide where tunnels are required to increase transport resilience. See Christopher Knaus, 'WestConnex: Bitter Battles Mark the Road to Australia's Urban Future', Guardian, 4 April 2017, <https://www.theguardian.com/australia-news/2017/apr/05/sydney-westconnex-road-bitterly-disputed-future> [accessed 19 October 2021].

108 Morteza Taiebat and others, 'A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles', Environmental Science & Technology, 52 (2018), 11449–65, <https://doi.org/10.1021/acs.est.8b00127>.

109 Benjamin K. Sovacool and Jonn Axsen, 'Functional, Symbolic and Societal Frames for Automobility: Implications for Sustainability Transitions', Transportation Research Part A: Policy and Practice, 118 (2018), 730–46, <https://doi.org/10.1016/j.tra.2018.10.008>.

110 Pantelis Kopelias and others, 'Connected & Autonomous Vehicles - Environmental Impacts - A Review', Science of the Total Environment, 712 (2020), 135237, <https://doi.org/10.1016/j.scitotenv.2019.135237>.

111 Dale Harrow and others, Driverless Futures: Design for Acceptance and Adoption in Urban Environments (London: Royal College of Art, 2020), <https://researchonline.rca.ac.uk/4627/> [accessed 21 January 2021].

2.4 Vehicles, people and the city: An evolved and complex relationship

A visual taxonomy of the relationship between vehicle development, urban form, semiotics and environmental rhythms forms part of the insights provided in this chapter. The industrial scale of vehicle manufacturing is a sound place to start this discussion. Manufacturing, by its nature, is focused on repetitive standardisation. Professor David Hounshell,[112] cited in the journal *Enterprise and Society*, describes how the utilisation of 'transfer machines' between the 1920s and 1940s brought about a significant advancement in automated manufacturing, which revolutionised manufacturing processes. This innovation is considered one of the contributing factors to the controlled transformation in manufacturing known as planned obsolescence. Planned obsolescence is a complex subject that involves deliberate strategies to render products obsolete, and it is discussed in more depth in Chapter 4, particularly concerning its implications for consumption patterns and environmental impacts.

The economic dominance of General Motors (GM) from 1920 to 1950 under the leadership of Alfred P. Sloan is often associated with the development and implementation of the principles of planned obsolescence.[113] Sloan's strategic approach to evolving technology greatly influenced the economic principles of the automotive industry during this era. As a systemic practice, planned obsolescence remains a significant factor in the automotive industry's operations even today.

Planned obsolescence has several benefits, including driving technological advancements and safety improvements, updating systems to meet changing needs and fulfilling commercial objectives in response to social and cultural trends. However, it also entails numerous drawbacks. For instance, it safeguards intellectual property (IP) rights while limiting societal involvement in the design process.

Additionally, it can foster consumerism and contribute to resource extraction. Of particular concern is the perceived exclusion of urban designers from influencing the design of vehicles tailored for cities. This exclusion raises questions about the alignment of vehicle design with urban planning objectives and highlights potential implications for urban sustainability and liveability. Something that is sustainable can be maintained at an ecologically balanced rate by avoiding depletion of natural resources.

112 David Hounshell, 'Automation, Transfer Machinery, and Mass Production in the U.S. Automobile Industry in the Post–World War II Era', *Enterprise & Society*, 1 (2000), 100–138, <https://www.jstor.org/stable/23699655> [accessed 19 March 2023].

113 *Planned Obsolescence*, Wikipedia, 13 November 2022, <https://en.wikipedia.org/w/index.php?title=Planned_obsolescence&oldid=1115808369> [accessed 29 October 2022].

Figure 26: Peak hour traffic on a typical Australian motorway, general photograph.

This photograph of a motorway in Perth is typical of most peak-hour motorway traffic in urban settings in Australian cities. While the scale may be larger in the United States of America, the United Kingdom and the European Union, the conditions are similar. https://thewest.com.au/lifestyle/motoring/congestion-linked-to-road-rage-and-stress-on-perth-roads-c-9824569

Figure 27: Congestion, Lahore 2020.

Congestion in Lahore, Pakistan. The proliferation of 'tuk-tuks' dominates this vision of light, open internal combustion engine vehicles. All roads eventually become congested as demand overwhelms throughput. Image courtesy of AFP. Park in CNN/Forbes 2014. https://www.reddit.com/r/InfrastructurePorn/comments/195khj/traffic_jam_on_a_bridge_entering_lahore_pakistan/

Figure 28: Congestion, The Esplanade London c.1930.

Congestion in the Esplanade, London, the United Kingdom, in the 1930s. Note the relatively uniform size of the vehicles. Image from Forbes, article by Reid, 2021. Photo by © Hulton-Deutsch Collection, Getty Images.

Contradictions emerge. In broad terms, vehicles have a shorter lifespan than the urban fabric, resulting in different timings of change. Added to this discordance is a trailing rhythm of older and heritage vehicles and urban conservation areas. A rhythmic discordance in time through the public realm is evident in the debates about the impacts of vehicles on the city. This results in complex vehicle and city rhythms of evolution and consumption patterns, which add layers of complex polarity and pulses. These contradictions, commercial IP and the constant consumption and manufacturing aspects of the behemoth industry increase the complexity of our understanding of the relationship between vehicles and the city. At one level, unsurprisingly, few wish to address the historic and possibly intractable issues. The complexity and industry's inability or low desire to address the issues has and will continue to have consequences, including anti-vehicle, car-banning and low-traffic neighbourhood outcomes. Ideally, the automotive industry can view the orthodox debate as an opportunity to address various issues and respond.

According to Joe McCarthy, who writes for Global Citizen, nine cities are attempting to ban vehicles, including Barcelona, Oslo, Mexico City, New Delhi, Paris and Chengdu. Despite localised conditions, vehicles, society and urban forms experience similar impacts and benefits in differing quantities. Florin Ameriei, writing in *An Anti-Car Revolution*,[114] provides an excellent example of the complex public debate. She uses 'brewing' as a euphemism for a subject that has dominated community discourse and planning issues for much of the last two centuries:

> *The anti-car community essentially agrees that building the roads and the needed utilities creates 'an unwanted economic burden on communities' that has proven to be costly everywhere, especially when you look at the yearly amount of dollars spent on maintenance.*

A central feature of this orthodox debate in the past century is that cities are congested (refer to Figures 26, 27, & 28), with fossil-fuelled vehicles and that vehicle operations have polluting and detrimental human health effects (e.g. emissions, spills, noise, environmental impacts, planning and UHI effects, exacerbated by congestion and consumerism).[115] The central argument is that public funding should focus on increased public transport facilities – preferably rail –rather than road infrastructure.[116]

114 Amariei, *An Anti-Car Movement*.

115 Guy Baeten, 'The Tragedy of the Highway: Empowerment, Disempowerment and the Politics of Sustainability Discourses and Practices', *European Planning Studies*, 8 (2000), 69–86, <https://doi.org/10.1080/096543100110938>.

116 Tom Rabe, 'NSW Government Accused of Lining Private Sector's Pockets with Toll Subsidy', *Sydney Morning Herald*, 7 June 2022, <https://www.smh.com.au/national/nsw/nsw-government-accused-of-lining-private-sector-s-pockets-with-toll-subsidy-20220607-p5arsg.html> [accessed 22 November 2022].

Critics argue that investment to encourage private vehicle use further exacerbates city traffic congestion. Traffic planners have formally observed this cyclical and disparaging feature called Braess's paradox.[117] Braess's paradox is an observation that adding one or more roads to a road network can slow overall traffic flow. The paradox was discovered by the German mathematician Dietrich Braess in 1968. Adding extra spatial capacity to a network when the moving entities selfishly choose their route can, in some cases, reduce overall performance. This is because the equilibrium of such a system is not necessarily optimal. The counterargument is that vehicles are necessary for human transport in cities, as identified by Giulio Mattioli and others in 'The Political Economy of Car Dependence'.[118] Even during fever-pitch arguments, a notable feature is the automotive industry's almost complete absence from the discussion. Perhaps it is convenient for the outrage to continue as long as the factory has a new vehicle, a new feature that is at the forefront of the marketing and selling strategy.

Over the past two decades, governments in Australia have increased the role of road-based public transport and related facilities. This approach is an attempt to change or redistribute the nature of the debate and to make road-based transport more appealing and just. Dedicated busways have transformed roads, specifically high streets, throughout Sydney.[119] Dedicated bus lanes have become high-speed, public transport corridors, creating polluted, dangerous, unattractive and retail-vacant high streets.

117 *Braess's Paradox*, Wikipedia, 2022, <https://en.wikipedia.org/w/index.php?title=Braess%27s_paradox&oldid=1075509227> [accessed 21 March 2022].

118 Giulio Mattioli and others, 'The Political Economy of Car Dependence: A Systems of Provision Approach', *Energy Research & Social Science*, 66 (2020), 101486, <https://doi.org/10.1016/j.erss.2020.101486>.

119 Gladys Berejiklian and Transport for NSW, *Sydney's Bus Future* (Sydney Australia: Transport for NSW, 2013), ISBN 978-1-922030-39-9, <https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/sydney-bus-future-final-web_0.pdf> [accessed 23 March 2023].

Evidence of this pattern of development can be seen in Sydney's Oxford Street,[120] Parramatta Road,[121] and Victoria Road, are examples of major arterial road corridors and other similar corridors suffering from severe urban decay and neglect. Governments use the 'road bus' argument to justify further investment in road-based transport development, including creating tolled facilities that support government funding pipelines.

The symptoms of dedicated bus lanes and their social impacts are not unique to Sydney. London's Oxford Street[122] and Kensington High Street, amongst many others examples in London are transport corridors dominated by bus movements. Pollution increases, congestion increases and a cycle of infrastructure redevelopment is required to assist with temporary decongestion through lane dedication processes.

120 Matt O'Sullivan, 'Push to End the Dividing Lines over Sydney's Faded Oxford Street', *Sydney Morning Herald*, 11 December 2022, <https://www.smh.com.au/national/nsw/push-to-end-the-dividing-lines-over-sydney-s-faded-oxford-street-20221209-p5c51m.html> [accessed 19 March 2023].

121 Matt O'Sullivan, 'Why Sydney's Parramatta Road Can't Have More Dedicated Busways', *Sydney Morning Herald*, 2 March 2023, <https://www.smh.com.au/national/nsw/why-sydney-s-parramatta-road-can-t-have-more-dedicated-busways-20230302-p5cosh.html> [accessed 19 March 2023].

122 Sadiq Khan, *Reality Check: Is Oxford Street the World's Most Polluted?*, BBC News, 19 August 2016, <https://www.bbc.com/news/uk-politics-37131138> [accessed 19 March 2023].

Figure 29: Maglev, the vertical dedicated AV transport system in 'Minority Report'.

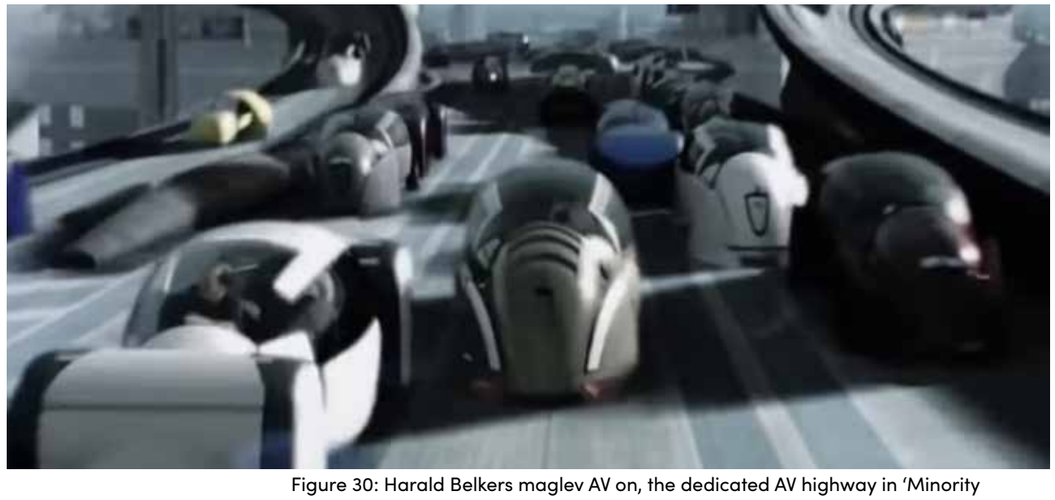


Figure 30: Harald Belkers maglev AV on, the dedicated AV highway in 'Minority Report'.

The blockbuster film *Minority Report*[123] explores the dystopian notion of dedicated AV lanes with a 'Maglev' vehicle. This fictional perspective can be seen as a site of rehearsal of an intractable urban issue. It is also an example of exploring alternative transportation through film, refer to Figures 29 and 30.

One argument that is infrequently discussed by Australian governments is that public rail infrastructure requires a capital investment that is substantially more onerous than that of road projects.[124] Governments subsidise rail travel, and capital investment restricts government investment in other areas. By contrast, tolled road infrastructure, such as motorways, has a substantive history of being economically advantageous for governments through road privatisation. One of the largest toll operators in Australia almost has a monopoly on tolled motorways.[125]

Through tolling, governments are assured of substantial economic benefits through user-pay strategies.[126] The economic debate about road infrastructure investment will continue and remain complex. Tolling also includes sophisticated traffic and economic models screened by 'commercial-in-confidence' interests. The advent of AVs/CAVs/CAREVs as a systemic approach to road-based transport is of interest to toll operators and governments as future funding sources through maker or operator user schemes that can be taxed, tolled or both.

Minority Report explores dedicated mass highway systems. In this scene, a Maglev vertical autonomous vehicle road is shown.

The film explores narrow one-seater autonomous vehicles in this Maglev vehicle chase scene.

William Mitchell, dean of MIT City Lab at the time, served on an advisory committee for Steven Spielberg for this film.

Figures 29 and 30 from Youtube extract of film: https://www.youtube.com/watch?v=Vrxyr1CjiSM

123 *Minority Report*, dir. by Steven Spielberg (20th Century Fox, 2002).

124 Hugh Batrouney and Marion Terrill, *Stuck in Traffic: We Need a Smarter Approach to Congestion than Building More Roads'*, The Conversation, 2021, <http://theconversation.com/stuck-in-traffic-we-need-a-smarter-approach-to-congestion-than-building-more-roads-84774> [accessed 9 August 2021].

125 Phineas Harper, *Cities Should Not Just Build Green Transport but Actively Dismantle Car Infrastructure'*, Dezeen, 11 January 2023, <https://www.dezeen.com/2023/01/11/congestion-roads-cities-traffic-sustainable-transport-phineas-harper/> [accessed 12 February 2023].

126 Adrian Dwyer, 'The journey Towards a fairer road toll system', *Sydney Morning Herald*, 25 November 2021, Roads edition, <https://www.smh.com.au/national/the-journey-towards-a-fairer-road-toll-system-20211124-p59bso.html> [accessed 21 March 2022].

Climate change is influencing another part of the orthodox debate. Transitioning from fossil-fuelled to RE-operated vehicles will lead to cleaner air, improved water quality and lower-noise environments. Current electric vehicle (EV) trends are replacing the fossil-fuelled fleet with electric and/or other renewable energy vehicles (REVs). Other renewable energy vehicles are being conceptualised using green hydrogen and/or biofuels.[127] Several countries in the Organization for Economic Cooperation and Development (OECD) are legislating to phase out or ban fossil-fuels (and by implication ICE vehicles) by 2030.[128] This research has taken the position that the AVs of the future must be manufactured and powered (i.e. operated) from entirely renewable resources as part of a circular economy process.

Renewable energy vehicles are operated and manufactured using renewable resources that are naturally replenished on standard human timescales. This introduces the CAREV, the main subject of the thesis. The research also applies circular economy principles[129] required for CAREV and the industry, as outlined by Mausbach and others in 'Ecofitting Circular Economy'.[130] Refer to 'PRINCIPLE 3 – Environmental systems'.

In public health, safety remains the most significant challenge that road-based transport faces and involves society and industry. According to the World Health Organization's (WHO) Global Status Report on Road Safety 2021, approximately 1.2–1.3 million deaths from vehicle incidents were recorded annually in the past decade. Between 8.4 to 9.1 million people died due to vehicle incidents globally during the seven years of the development of this research, a sobering and essential statement about the significance of research in this field. Tanya Mohn commented in *Forbes* that the Foundation for Traffic Safety estimated that advanced driving systems in partial automation will prevent 37 million incidents over 30 years.[131]

127 M. Khan, H. Anwar, Sophia Bonifacio, Joanna Clowes, Amy Foulds, Rayne Holland, James C. Matthews, and others, 'Investigation of Biofuel as a Potential Renewable Energy Source', Atmosphere, 12.10 (2021), 1289 <https://doi.org/10.3390/atmos12101289> [accessed 24 March 2024].

128 Aakash Jagadeesh Babu and Samantha Machado, '*Fossil fuel-based vehicle bans across the world*', by Gareth Jones', *Reuters*, 18 November 2020, <https://www.reuters.com/article/climate-change-britain-factbox-idINKBN27Y19F> [accessed 5 August 2021].

129 Ellen MacArthur Foundation, *How to Build a Circular Economy*. See also Chapter 1.5 - Principles pages 36 to 40 of this thesis.

130 Mausbach and others, 'Ecofitting Circular Economy'.

131 Tanya Mohn, '37 Million Crashes Could Be Prevented Over Next 30 Years, New Research Finds', *Forbes*, 20 August 2023, <https://www-forbes-com.cdn.ampproject.org/c/s/www.forbes.com/sites/tanyamohn/2023/08/20/37-million-crashes-could-be-prevented-over-next-30-years-new-research-finds/amp/>.

In the current ICE vehicle context, serious injury statistics are much higher in a field with inconsistent results, with estimates ranging from 10 to 50 million a year, as the reporting conditions vary across jurisdictions.[132] Serious injury statistics are further complicated by differing and inconsistent reporting conditions occurring in developing countries compared with developed economies.[133] Incidents and road safety are discussed in relation to the UN's, the WHO's and nations' (including Australia) persistent attempts over 20 years to reduce incident statistics, as seen through their continual financial and institutional support in the field. The death and incident trends in ICE are unlikely to change without a severe disruption in the field. AVs may provide a technology safety disruption, but it is not an inevitable safety outcome, as evidenced by the ongoing AV incidents.[134]

Human causality is the most striking feature of this ongoing epidemic of incidents. According to the New South Wales (NSW, Australia) government, speed-related incidents significantly contribute to road trauma in that jurisdiction.[135] A second cause is related to negligent driving because of alcohol or drug use while driving.[136] Vehicle speed and acceleration remain major selling features of most vehicle manufacturers' marketing. Speed is also directly related to vehicle status, comfort and consumption. Crister Hyden, writing in the *International Journal of Injury Control and Safety Promotion*,[137] argued that 'other stricter measures' must be leveraged. I believe that international regulatory safety controls should be imposed on the industry. Governments should impose statutory controls on vehicle speed. It is a social and moral responsibility that lacks political or bureaucratic leadership. The questions here are, 'Why has limiting vehicle speed not been attended to, and what forces are acting on governments worldwide?' Katherine Fidler writing in Metro on 18 July 2024, notes that Tesla are investigating deploying speed limiting technology in their 'parent mode' future technology upgrades.[138] A notable socio-technology advancement in this field.

132 World Health Organization, *Road Traffic Injuries* (New York: United Nations, 2023), <https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries> [accessed 14 October 2023].

133 World Health Organization, *Global Status Report on Road Safety: Time for Action* (2009), p. 12.

134 Mauro Reyna, 'Examining Autonomous Car Accidents and Statistics', Lee, Gober & Reyna, 2024 <https://www.lgrlawfirm.com/blog/examining-autonomous-car-accidents-and-statistics-2/> [accessed 23 July 2024]

135 NSW Government, *Speed Fact Sheet* (2023), <https://roadsafety.transport.nsw.gov.au/downloads/speed-fact-sheet.pdf> [accessed 24 March 2023].

136 OECD International Transport Forum, 'Australia-Road-Safety Report 2021', *OECD*, 2021, <https://www.itf-oecd.org/sites/default/files/australia-road-safety.pdf> [accessed 24 March 2023].

137 Crister Hyden, 'Speed in a High-Speed Society', *International Journal of Injury Control and Safety Promotion*, 27 (2010), 44–50, <https://www.tandfonline.com/doi/epdf/10.1080/17457300.2019.1680566?needAccess=true&role=button> [accessed 24 March 2023].

138 Katherine Fidler 'Tesla Is Testing out a "parent Mode" for Its Cars', Metro, 18_July_2024 <https://www.msn.com/en-au/news/other/tesla-is-testing-out-a-parent-mode-for-its-cars/ar-BB1pEVYt?ocid=entnewsntp&pc=U531&cvid=f4b33e96eada40dfa485a1529e87d645&ei=34> [accessed 18 July 2024]

The global AV initiative seeks to reduce serious road safety incidents. However, it is unlikely from a complex systems point of view that an AV future would have a zero-incident rate. Notwithstanding complexity theory, morally, a zero-incident target would be appropriate. The aim of technology safety is, therefore, to increase safety over current conditions, but it is an uncertain outcome. Reed et al. published their findings in June 2021 in 'A Review of CAV Safety Benchmarking and a Proposal for a "Digital Commentary Driving" Technique'.[139] This publication identified the metrics of human and SI driving systems to compare safety outcomes and noted broadly that driving quality is insufficiently defined. Reed et al. also suggested the SAE's operational driving domain (ODD) classification is insufficient due to the variables and testing of vehicle driving ability, a subject I return to in Chapter 3.4.

Concerning CAREVs, these advanced-technology vehicles will be programmed to travel within city-wide speed limits, and perhaps this will be the lifesaving stricter measure for which we are searching.

The AV/CAV/CAREV industry has experienced substantial investment from within industry. The public sector and academia have also invested heavily in this form of technology development over the past decade, including from the European Union (EU) Parliament[140] in 2019 and the EU Commission in 2021,[141] and as identified by numerous authors, such as Bagloee et al.[142] and the Centre for Connected and Autonomous Vehicles (CCAV UK).[143] The hopes, promises and projections of improved safety through SI underpin the development of the technology and its commercial potential. AVs are often cited as the dominant force in an earnest attempt to replace human drivers with a more reliable, efficient and safe system.[144] They are frequently cited as a possible mechanism or disruptor in the market, with the specific aim

139 Noting the 'digital commentary driving' technique proposal in this publication, I discuss the interface between human and synthetic intelligence by applying Susan Schneider's LoT approach in Chapter 3.5.

140 *Self-Driving Cars in the EU: From Science Fiction to Reality*, European Parliament, 14 January 2019, <https://www.europarl.europa.eu/news/en/headlines/economy/20190110STO23102/self-driving-cars-in-the-eu-from-science-fiction-to-reality> [accessed 24 March 2023].

141 European Commission Joint Research Centre, *The Future of Road Transport: Implications of Automated, Connected, Low-Carbon and Shared Mobility* (Luxembourg: Publications Office, 2019), <https://data.europa.eu/doi/10.2760/524662> [accessed 3 August 2021].

142 Bagloee and others, 'Autonomous Vehicles', p. 291.

143 Centre for Connected & Autonomous Vehicles, 'Centre for Connected and Autonomous Vehicles UK', 2018, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/737778/ccav-research-and-development-projects.pdf> [accessed 28 July 2021].

144 Stephen Parkes and Ed Ferrari, *Connected and Autonomous Vehicles: The Challenges Facing Cities and Regions* (New York: Taylor and Francis with Routledge, 2023).

of improving safety outcomes.[145] Despite the promises and investments, the automotive industry has thus far failed to realise its potential, as seen through USA recorded AV deaths[146] and ongoing trials.[147]

The significance of the industry can also be measured through its scale. Andre Grant noted that research indicates that the AV/CAV/CAREV industry may grow to an annual global market value of US$220 billion by 2030.[148] According to the UN International Labour Organization, the automotive industry significantly contributes to the global economy.[149] The industry's annual turnover is equivalent to the world's sixth-largest economy. In 2017, global direct employment in the industry was estimated at nearly 14 million workers.[150]

While estimates vary, Insider Monkey's Trish Novicio measured the global industry as the ninth-largest global industry, valued at US$3 trillion annually in 2021.[151]

What is evident is that the automotive industry is a hegemonic economic industry with social and environmental significance. AVs will likely be part of the future of road transportation, as cited by various writers, such as Parkes and Ferrari,[152] Mahdavian, Shoaej and Oloufa[153] and the EU Commission in 2019.[154] Critics argue that the industry has vested interests.[155] It is also an industry beset

145 Phillip Kampshoff and Padhi Asutosh, *Autonomous-Driving Disruption: Technology, Use Cases, and Opportunities*, McKinsey & Company, 13 November 2017, <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-driving-disruption-technology-use-cases-and-opportunities> [accessed 9 January 2023].

146 'Data Analysis: Self-Driving Car Accidents [2019-2024]', Craft Law Firm <https://www.craftlawfirm.com/autonomous-vehicle-accidents-2019-2024-crash-data/> [accessed 27 December 2024]

147 Munoz, *How Many Fatalities*.

148 Andrew Grant, *This $220 Billion Market Opens up a Path for Driverless Cars*, Bloomberg, 2022, <https://www.bloomberg.com/news/newsletters/2022-11-29/this-220-billion-market-opens-up-a-path-for-driverless-cars>.

149 International Labour Organization, 'Global Labour - ILO Sectoral Brief Motor Vehicle Industry', United Nations, 8 April 2020, <https://www.ilo.org/wcmsp5/groups/public/---ed_dialogue/---sector/documents/briefingnote/wcms_741343.pdf> [accessed 8 January 2023].

150 ibid.

151 Trish Novicio, *10 Biggest Industries in the World in 2021*, Insider Monkey, 2021, <https://www.insidermonkey.com/blog/10-biggest-industries-in-the-world-in-2021-925224/> [accessed 9 January 2023].

152 Parkes and Ferrari, *Connected and Autonomous Vehicles*, p. 1.

153 Mahdavian, Shojaei, and Oloufa, 'Assessing the Long- and Mid-Term Effects'.

154 European Commission Joint Research Centre, *The Future*.

155 Gude and others.

by serious environmental concerns,[156] corruption[157] and criminality[158] at local, national and international scales.[159] Emissions scandals,[160] safety scandals[161] and financial scandals[162] are solidly documented. AVs' social and cultural history can be regarded an antidote to these questionable ethical positions.[163]

The promise of improved safety through AVs was seriously challenged in 2016[164] with the first AV fatality. On January 20, 2016, Gao Yaning[165], the driver of a Tesla Model S in 'Autopilot mode' (approximately Level 2 automation) in Handan, Hebei, China, was killed when his car crashed into a stationary truck. On March 18, 2018, pedestrian Elaine Herzberg[166] was pushing a bicycle across a four-lane road in Tempe, Arizona, United States, when she was struck by an Volvo - Uber test vehicle operating in its fully autonomous mode with a human safety backup driver. This was a significant moment in AV safety history.

Problems with AV technology were reinforced by more fatalities between 2020[167] and 2024.[168] According to Lee, Gober & Reyna attorneys, 'The California DMV (Department of Motor Vehicles) reported 674 autonomous vehicle collisions as of December 1, 2023.'[169] Fatal incidents involving Telsa's partially

156 *Sustainable Manufacturing: A Growing Automotive Trend*, Industry Today, 2022, <https://industrytoday.com/sustainable-manufacturing-a-growing-automotive-trend/> [accessed 22 November 2022].

157 Ryan Luke, *The 10 Biggest Company Scandals of 2020*, Ladders, 2021, <https://www.theladders.com:443/career-advice/the-10-biggest-company-scandals-of-2020> [accessed 9 January 2023].

158 Jacob Oliva, *Nissan Found Guilty, Fined $1.7 Million over Ghosn Income Scandal*, Motor1.com, 2022, <https://www.motor1.com/news/571293/nissan-guilty-carlos-ghosn-scandal/> [accessed 9 January 2023].

159 Soren Amelang and Benjamin Wehrmann, *'Dieselgate' – A Timeline of the Car Emissions Fraud Scandal in Germany*, Clean Energy Wire, 2020, <https://www.cleanenergywire.org/factsheets/dieselgate-timeline-car-emissions-fraud-scandal-germany> [accessed 9 January 2023].

160 Geoff Colvin, 'Volkswagen Emissions Damages Are Still Rolling in 5 Years Later', *Fortune*, 7 October 2020, <https://fortune.com/2020/10/06/volkswagen-vw-emissions-scandal-damages/> [accessed 31 August 2021].

161 Ryan Luke. *The 10*.

162 Emily Stewart, '10 of the Biggest Automotive Scandals Ever', *TheStreet*, 23 September 2015, <https://www.thestreet.com/investing/stocks/10-of-the-biggest-automotive-scandals-ever-13297513> [accessed 9 January 2023].

163 The bibliography contains some 45 AV films and animations reviewed.

164 Munoz, *How Many Fatalities*.

165 'List of Tesla Autopilot Crashes', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=List_of_Tesla_Autopilot_crashes&oldid=1257236496#GaoYaning> [accessed 27 December 2024]

166 'Death of Elaine Herzberg', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=Death_of_Elaine_Herzberg&oldid=1261677969> [accessed 27 December 2024]

167 Joshua Dowling, *Tesla Driver Busted in the Passenger Seat Testing "Autopilot" on a Freeway*, News.com.au, 30 April 2018, Motoring <https://news.com.au/technology/innovation/motoring/motoring-news/tesla-driver-busted-in-the-passenger-seat-testing-autopilot-on-a-freeway/news-story/9ac5bf9bf6f979d7335fe632005ab7fc> [accessed 14 October 2023].

168 Bryan Pietsch, '2 Killed in Driverless Tesla Car Crash, Officials Say', *New York Times*, 18 April 2021, <https://www.nytimes.com/2021/04/18/business/tesla-fatal-crash-texas.html> [accessed 10 August 2021].

169 Mauro Reyna, 'Examining Autonomous Car Accidents and Statistics', Lee, Gober & Reyna, 2024 <https://www.lgrlawfirm.com/blog/examining-autonomous-car-accidents-and-statistics-2/> [accessed 23 July 2024]

automated system[170] (SAE Level 2) and Uber's driverless taxi,[171] among others, create headline news around the world when they occur. According to Craft Law Firm blog, as of October 2024, some fifty-one fatalities were recorded as a result of the engagement of 'full self-driving' capabilities.[172]

The hubris surrounding the promise of technological advances and the lack of trust in the industry appears to have slowed the implementation and operational stages.[173] The slowing of the development of the AV industry, as discussed in the McKinsey report by Kampshoff and Asutosh,[174] allows time for a deeper consideration of the combined impacts of this major transport-disrupting[175] technology as society transitions from human-driven to synthetically-driven vehicles. As this transition is important yet uncertain, this research is focused on a speculative, fully AV environment in which safety is properly addressed and benchmarked and in which there are no human drivers of motor bikes or motor vehicles.

The aesthetics of the combined functional and visual responses to a future fully AV environment are unknown.[176] Authors such as Xie and Lui,[177] Silva and others[178] and Kopelias and others[179] have confirmed that the environmental impacts of CAVs are unknown. One approach is to study cause and effect – that is, to let the technology develop and then respond. This practice has been well established over a century of vehicle design and manufacturing. The pattern of evolution whereby the industry utilises and evolves vehicle design, including safety and other measures, is through the complex processes of planned obsolescence. However, speculative research is required as a precautionary principle. Simulated research is both desirable and essential for a future technology with disruptive potential.

170 Jordan Mulach, 'Tesla Autonomous Tech Investigated after Two New Fatal Crashes Last Month', *Drive*, 22 November 2022, <https://www.drive.com.au/news/two-fatal-tesla-crashes-us-nhtsa/?utm_campaign=syndication&utm_source=smh.com.au&utm_content=article_1&utm_medium=partner> [accessed 23 November 2022].

171 Rory Cellan-Jones, *Uber's Self-Driving Operator Charged over Fatal Crash*, BBC News, 16 September 2020, <https://www.bbc.com/news/technology-54175359> [accessed 9 January 2023].

172 'Data Analysis: Self-Driving Car Accidents [2019-2024]', Craft Law Firm <https://www.craftlawfirm.com/autonomous-vehicle-accidents-2019-2024-crash-data/> [accessed 27 December 2024]

173 Biondi, *Why We Still Don't Have*.

174 Hussein Dia, *Three Reasons "Self-Driving" Cars Are Still a Long Way Off*, Tech Xplore, 2021, <https://techxplore.com/news/2021-04-self-driving-cars-1.html> [accessed 9 January 2023].

175 Kampshoff and Asutosh, 'Autonomous-Driving Disruption'.

176 Pantelis Kopelias and others, 'Connected & Autonomous Vehicles - Environmental Impacts - A Review', *Science of the Total Environment*, 712 (2020), 135237, <https://doi.org/10.1016/j.scitotenv.2019.135237>.

177 Tingting Xie and Yang Liu, 'Impact of Connected and Autonomous Vehicle Technology on Market Penetration and Route Choices', *Transportation Research Part C: Emerging Technologies*, 139 (2022), 103646, <https://doi.org/10.1016/j.trc.2022.103646>.

178 Óscar Silva and others, 'Environmental Impacts of Autonomous Vehicles: A Review of the Scientific Literature', *Science of the Total Environment*, 830 (2022), 154615, <https://doi.org/10.1016/j.scitotenv.2022.154615>.

179 Kopelias and others, 'Connected & Autonomous Vehicles'.

Figure 31: Harrow and others, 'Driverless Futures'. Figure 28 a transport interchange.

Figure 32: Harrow and others, 'Driverless Futures'. Figure 31 Commercial centres.

Figure 33: Harrow and others, 'Driverless Futures'. Figure 18 a future street.

I argue that CAREVs must achieve a high social and intergenerational licence level to operate. The past century of evolving fossil-fuelled vehicle dominance, incidents and urban impacts and the significant role of these vehicles in the climate crisis make research in this field essential. Principles should be established as part of the design and development process to achieve environmental outcomes. Principles developed through this research are provided in Chapter 1.5 (pages 46 to 51 of this thesis). Impact measurement and socially accepted mitigations should be associated with vehicle deployment's research and development stages.

2.5 A selected social and cultural history of AVs

The discussion of AVs' selected social and cultural history in this research proceeds through a review of film, animation and science fiction. It responds to the long history of transporting humans safely, efficiently and comfortably. It considers our rights to the city and how we move around the city justly. It also discusses the protagonists in the orthodox debate. A major insight is provided through the role of science fiction and philosophy in the development of AVs and how this has created community expectations. This leads to what current leading authors and the extensive literature on the subject say about the technology and its deployment, realisation and challenges.

2.5.1 Transporting humans: AVs' long history

The transportation of humans has a multifaceted and complex history, of which AVs are a small part. The complexity and enduring qualities of human transportation and the history of AVs are intertwined with the history of settlement, urbanisation and vehicle design evolution. Mark Weber provided an accessible account of the history of AVs in a blog for the Computer History Museum website,[180] which follows a chronological trajectory, from the 1800s (Aladdin's flying carpet) to the early 2020s, covering some 250 years.

A common practice in scholarly writing is to introduce AVs' social and cultural history rather than pursue their more profound influences. A significant issue is that these cursory comments on AVs' social and cultural history must deeply examine the established conceptual positions, imaginative potential and rehearsal sites. Examples of this approach can be found in Townsend's[181] and Harrow's[182] Future Cities, refer to Figures 31, 32 & 33.

180 Marc Weber, *Where to? A History of Autonomous Vehicles*, Computer History, 2014, <https://computerhistory.org/blog/where-to-a-history-of-autonomous-vehicles/> [accessed 9 August 2021].

181 Townsend, *Ghost Road*.

182 Dale Harrow, *Our Future Towns*, Royal College of Art, 2020, <https://www.rca.ac.uk/research-innovation/projects/our-future-towns-community-placemaking-and-transport-planning/> [accessed 4 August 2021].

Lawrence Burns wrote liberally about the advancing AV trials and technology development in *Autonomy: The Quest to Build the Driverless Car and How It Will Shape Our World*.[183] His detailed account provides a step-by-step chronicle of the first AV technology using computerised systems, including its novel use at the 2004 DARPA Grand Challenge.[184]

With some 45 major films[185] and animations on AVs, it is both surprising and disappointing that most social and public perceptions of AVs (i.e. academic and industry assessments) do not start from a position of established, readily accessible cultural knowledge in the field. It is a peculiarity of scholastic research to dismiss science fiction, myth and film as unscientific. I argue that the social and cultural awareness of technology has its foundations and passionate investment in this historic and significant body of literature.

Challenging intellectual bias by appreciating the 'informal' and science fiction is a form of knowledge. In 2009, the distinguished philosopher Susan Schneider compiled writings of noteworthy scholars in her book *Science Fiction and Philosophy: From Time Travel to Superintelligence*[186] and linked science fiction and philosophy historically and through distinguished collected writings. There is much to be gained from research into the engrossing, complex and controversial field of AV literature.

I reviewed literature, film, science fiction, myth and animation as major research themes. This information includes imaginative and philosophical avenues of historical development. I argue here that the historical body of literature through myth, animation, film and science fiction writing has developed a long tradition of social and cultural expectations of AV technology and, through implication, AI. Consequently, I have learned about the value of informal data in both thinking and creative processes.

The dynamic and constantly evolving fields of vehicles and city design influence each other's development as much as they influence society and the environment. This intertwined history of vehicle design, the city, the environment and society and its associated economic forces are not studied deeply enough as a field.

183 Burns, *Autonomy,* p. 317.

184 Burns, *Autonomy*, pp. 16–17. The DARPA Grand Challenge is a prize competition for American AVs.

185 Refer to the film Bibliography.

186 Susan Schneider, *Science Fiction and Philosophy: From Time Travel to Superintelligence* (West Sussex, UK: John Wiley & Sons Ltd., 2009), <https://www.wiley.com/en-au/Science+Fiction+and+Philosophy%3A+From+Time+Travel+to+Superintelligence-p-9781405149068> [accessed 3 August 2021].

For example, the leading urbanist Peter Hall tracked the future city visions of leading architects and urban designers in *Cities of Tomorrow*.[187] He summarised the visions of Edwin Lutyens, Herbert Baker, Ebenezer Howard, Walter Burley Griffin, Le Corbusier, Oscar Niemeyer, Thomas Gateway, Lewis Mumford, Thomas Adams and more recent architects, such as I. M. Pei, eloquently. Hall dedicated two sections of the book, 'Chapter 4: The City in the Garden 1900–1940' and 'Chapter 9: The City of the Highway 1920–1987', to the revolution in cities because of modern industries and took an urban design perspective. However, Hall's *Cities of Tomorrow* is not a study on the impacts or influence of vehicles on humans and the city but rather a siloed account of varied planning practices.

Despite Hall's impressive insights, a larger knowledge base about the evolution of the vehicle and the city and how machines, the city and society have influenced each other historically is needed. This opens an avenue of research for historians. A taxonomy of the city and vehicles is outlined as contextual research. In preparing for Symposium 1, I undertook a visual taxonomy of vehicles, five major cities and semiotics. Appendix C contains the visual taxonomy and chronology of the vehicles, selected cities and semiotic events prepared for this research.

187 Peter Hall, *Cities of Tomorrow: An Intellectual History of Urban Planning and Design Since 1880*, 4th edition (Hoboken: Wiley-Blackwell, 1997).

2.5.2 Vehicle autonomy, cities and humans: A multifaceted history

Anthony Townsend's *Ghost Road: Beyond the Driverless Car* (2020) is a major AV publication from the past decade[188] in which he offered a uniquely American insight into the subject, which has merit, as much of the USA's historic vehicle design strategy impacts global vehicle deployment. This differs from world vehicle production, which has been dominated by Japanese output in the early 2000s and through the last two decades and, more recently, Chinese production in 2020, as noted by leading transport geographer Dr Jean-Paul Rodrique.[189]

Notwithstanding dominant vehicle production issues, Townsend's *Ghost Road* is a broad overview of AVs rather than a specific insight into CAVs or CAREVs. His writings are concerned with the commodification and functional opportunities of AV technology. Consequently, the book has sparing environmental insights. Townsend is not alone, as most studies in the field have only focused on functional opportunities rather than systemic ecological approaches. In the chapter 'Afterword', he wrote:

> *And the US won't be the only place building dream towns in the driverless revolution – China, Canada and many other nations will do so too. If we're to lead the way we'll need to act to adopt favorable [sic] policies for housing, energy, and transportation; mobile national investments; keep progress in artificial intelligence work moving forward; and deploy the roadside infrastructure necessary to ensure that machines can move safely among us instead of rolling over us.*[190]

In 2020, Harrow and others published 'Driverless Futures'[191] in the RCA's GATEway. This significant publication includes scenarios and techniques adopted by UK design researchers since the 1990s and offers insights into the future possibilities of AVs, functionality and urban liveability. Figure 32 from 'Driverless Futures' is an imaginative commercial centre of the future in the UK based on the scenario method and hyper-realism streetscape visualisation, and it includes smaller vehicle typologies. The significance of this publication lies not only in the scenario method used to obtain the data, which includes community perceptions, but also in the design thinking and approaches to the relationships between humans, vehicles and the city. The scenario method to

188 Townsend, *Ghost Road*.

189 Jean-Paul Rodrigue, *Automobile Production, Selected Countries, 1950–2022*, The Geography of Transport Systems, 1 November 2017, <https://transportgeography.org/contents/chapter1/the-setting-of-global-transportation-systems/automobile-production-world/> [accessed 14 October 2023].

190 Townsend, *Ghost Road*, p. 255.

191 Harrow and others, 'Driverless Futures'.

obtain and create data was deeply explored in this publication. In response, I have used the scenario method in some parts of this research, refer to Figures 31, 32, and 33.

In Chapter 1.2, the review of the literature and theorists, I noted the significant contribution that Newman and Jennings' *Cities as Sustainable Ecosystems*[192] made to the discourse on environmental principles and research on cities[193]. An ecosystem consists of all organisms in an area and the physical environment with which they interact. These biotic and abiotic components are linked together through nutrient cycles and energy flows. Newman and Jennings' central argument is that systems thinking is necessary to design a community at an urban environment scale through the development of environmental principles. Newman's insights into car dependency, a dominant feature of Australian city transport, are included there. AVs and urban environmental practices assisted with developing the principles presented in this research (refer to Chapter 1.5.). In 1996, Newman's article about reducing vehicle dependence recommended controls to reduce this urban issue.[194] He offered his views on AVs in 2015 in *Going Down the Same Old Road* – views this research shares but with an emphasis on changing the paradigm.[195]

The extensive list of anti-vehicle proponents includes the local governments of many capitals worldwide, such as Paris, Copenhagen and Sydney.[196] The UK government has invested significantly in the future of cities[197] research, covering a wide selection of city research, such as governance and visual history. The Futures Cities Office published its 'Visual History of the Future' in 2016, which contains an extensive visual taxonomy of envisioning cities historically.[198] This is a rich resource of visual and historical material, including drawings and visualisations of future cities. It is a synthesis of the prevalent patterns across diverse visualisations, overarching narratives and themes for how urban life has been envisaged and projected over specific periods. This material assisted me in developing the visual output of this research as a subtle, relatable, environmentally sensitive outcome and a counter-strategy to iconic or futuristic visualisations.

192 Newman and Jennings, *Cities as Sustainable Ecosystems*, pp. 8–30.

193 Refer to Chapter 1.5 for the principles guiding this research.

194 Peter Newman, 'Reducing Automobile Dependence', *Environment and Urbanization*, 8 (1996), <https://journals.sagepub.com/doi/pdf/10.1177/095624789600800112> [accessed 23 March 2023].

195 Newman, *Going*.

196 McCarthy, *These 6 Cities*.

197 Greg Clark, Office for Science Government of UK, and Sir Alan Professor Wilson, 'Future of Cities: An Overview of the Evidence', *Foresight*, 2016, <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/520963/GS-16-6-future-of-cities-an-overview-of-the-evidence.pdf> [accessed 25 March 2023].

198 Nick Dunn, Paul Cureton, and Serena Pollastri, *A Visual History of the Future* (London: Future Cities Office, 2020).

Banning vehicles through the anti-car movement has a long history. Writing for The Conversation, Arnaud Exbalin[199] stated that in 1790, a citizen posted a petition for a vehicle-free[200] Paris due to fatalities and incidents with horses, carts and pedestrians. Jane Jacobs' decades-long struggle with Robert Moses in New York in the 1960s led to her influential publication *The Death and Life of Great American Cities*,[201] which is not necessarily anti-vehicle but approaches the subject by objecting to Moses' highway intervention solution. She eloquently wrote, 'Streets provide the principal visual scenes in cities'.[202]

Respected scholar Guy Baeten, professor of Urban Studies at Malmö University and director of the Institute for Urban Research, argued in 'Engaging in the Muddy Fields of Planning in Neoliberal Times'[203] that assessments of spatial planning and neo-classical (i.e. neo-liberal) transport economics in relation to the sustainable transport 'greenwashing' discourse should be critically investigated. Baeten clarified that the issues of transport inequality and transport poverty should be re-inserted into the dominant transport policy debates and practices. This is discussed again in Chapter 4.5 in relation to CAREVs and spatial justice.

> *The magnificence of the world has been enriched by a new beauty, the beauty of speed.*
>
> *– Filippo Tommaso Marinetti*[204]

Fantasy associated with danger, speed and death has been explored through literature, film and documentaries. Notable in this genre is the film *Crash*.[205] Several researchers, such as Garvey[206] and Samuels,[207] have reported that vehicle culture presents an opportunity for the fantasy of sex, danger and

199 Arnaud Exbalin, *Car-Free Paris? It Was Already a Dream in 1790*, Phys.Org, 15 November 2018, <https://phys.org/news/2018-11-car-free-paris.html> [accessed 5 January 2023].

200 'Vehicle-free' in the context of 1790 pre-dates automobiles, the Exbalin article demonstrates the symptomatic difficulties of transportation in urban settings historically.

201 Jane Jacobs, *The Death and Life of Great American Cities*, Reissue edition (New York: Vintage, 1992).

202 Ibid., p. 378.

203 Guy Baeten, 'Engaging in the Muddy Fields of Planning in Neoliberal Times', [n.d.] (Sweden: University of Lund, 2009), <https://www.academia.edu/1477642/Engaging_in_the_Muddy_Fields_of_Planning_in_Neoliberal_Times> [accessed 18 October 2021].

204 Filippo Tommaso Marinetti, 'The Founding and Manifesto of Futurism' in *Marinetti: Selected Writings*, ed. by R. W. Flint (New York: 1972), p. 42, quoted in *Utopia: The Search for the Ideal Society in the Western World*, ed. by Roland Schaer, Gregory Claes, and Lyman Tower Sargent (New York: 2000), p. 279.

205 *Crash*, dir. by Paul Haggis (Lionsgate Films, 2004/5).

206 Pauline Garvey, 'Driving, Drinking and Daring in Norway', in *Car Cultures*, ed. by Daniel Miller (Oxford: Routledge, 2001), pp. 133–52. Pauline Garvey provided ethnographic gender case studies of sex, speed and vehicles as transgressive behavioural outcomes in normative circumstances in her study in Norway.

207 Allan Samuels, 'Accidents: The Car and Literature', in *Autopia: Cars and Culture*, ed. by Peter Wollen and Joe Kerr (London: Reaktion Books Ltd., 2002), pp. 51–58.

death to be combined with speed. At the turn of the millennium, danger, speed and death in marketing provoked a report by Sheehan and others for the Centre for Accident Research & Road Safety[208] regarding the content of motor vehicle advertising in Australia.

Rather than resisting the complexity of the field, we can regard contradictions as rich sources for critical assessment and consideration. One intriguing quality of the inquiry into the relationship between vehicles, the city and people is related to transport necessity. The rhythm of daily life and return movements between home, employment and recreation have tangible effects on the aesthetics of the city. Hundreds of thousands of vehicles are moving along the road network daily, which is especially evident in peak and off-peak flows in Sydney, creating a daily energy flow.[209] For many in the daily commute, speed is the dream.

Humans move between home and work for many essential reasons. Large sectors of outer suburban areas in Sydney are only serviced by road-based public transport (buses) – whose systems could be more reliable and comfortable – resulting in vehicle dependency. For many, vehicle ownership and dependency are a way of life. In *Ghost Road*,[210] Townsend remarked on his daily commute and how AVs are likely to promote a 'supercommute'. Comfort and speed in this rhythmic, congested peak-hour traffic commute are part of the daily living experience. Henri Lefebvre, a known anti-car advocate, wrote a disparaging commentary about cars in his critical view of society in *Writings on Cities*: 'I fear that liberalism will be a "free for all", a space abandoned to speculation and the car'.[211]

Lefebvre explored his concept of rhythmanalysis in the last chapter of the book, stating:

> *Relations and refusals of alliances interest the rhythmanalyst to the extent that they intervene in the production of social time. They take place and deploy themselves inside this social time in which they contribute to produce (or reproduce) by imprinting on it a rhythm. Our hypothesis is therefore that every social, that is collective rhythm, is determined by the forms of alliances which human groups give to themselves.*[212]

208 Mary Sheehan, Dale Steinhardt, and Cynthia Schonfeld, *A Content Analysis of Australian Motor Vehicle Advertising*, 2006, <https://www.infrastructure.gov.au/sites/default/files/migrated/roads/safety/publications/2006/pdf/CR228.pdf> [accessed 25 March 2023].

209 Australian Government and Bureau of Infrastructure, Transport and Regional Economics, *Traffic on the National Road Network 2011–12*, 2012, <https://www.bitre.gov.au/sites/default/files/is_063.pdf> [accessed 22 April 2023] p. 16, article Fig 22.

210 Townsend, *Ghost Road*, p. 252.

211 Lefebvre, *Writings on Cities*, p. 234.

212 Ibid., p. 234.

The flow of humans to and from work in their cars, known as the 'commute', is perhaps the strongest representation of all daily urban rhythms. Paradoxically, regarding Lefebvre's urban concepts, vehicles and their drivers form a substantial attribute of the production of space. The production of space is a social product or a complex social construction that affects spatial practices and perceptions. Freight, delivery, construction, office workers, essential services – it is an exhausting list, and almost every facet of urban living is partly or fully in the chain of rhythms associated with some form of vehicle due to its systemic nature.

The road network is a vital structure of the city. Hall emphasised the mass transit systems of major cities in the 1900s but appeared to de-emphasise the role of road vehicles in developing the 'garden city'.[213] Hall pursued sociological and planning design agendas.[214] A view of Canberra, a garden city, is that all its planning and design qualities arise from motorised vehicles[215] and that its spread-out road network with wide boulevards and park spaces is entirely attributable to and only possible because of motor vehicle access. Few writers provide systematic research into urban planning and vehicle design. The road is a highly contested space where we all have common rights. Rights to the city, as examined through literature, are discussed in detail in Chapter 4.5 as a spatial justice issue.

The relationship between society, vehicles, urban form and operations is part of my daily research practice and a philosophical issue for me. The research I have undertaken for decades in urban infrastructure development is deeply rooted in understanding, designing, assessing, creating, maintaining and responding to the effects of vehicles on the city and its people.

The daily transport rhythm is associated with moving people around the city safely and conveniently using a variety of modalities. Intermodal AV research is often cited.[216] However, a major problem with this kind of application is the enormity of the task, its application in a specific localised environment and the conceptual framework through which to commence the task of systemic integration. Intermodal AV research requires further investigation (refer to Chapter 5.7 - Research limitations and assumptions), as SI and logistics combined with mobilities are likely to influence transportation geographies. The assistance of SI may advance this field significantly, as it requires

213 Hall, *Cities of Tomorrow*, p. 86.

214 Ibid., pp. 86–135.

215 Ibid., p. 196.

216 Intermodal AVs in this context refer to the potential of AVs, through synthetic and city intelligence, to be choreographed and logistically managed, along with AV rail, AV air, AV sea and AV personal mobility amenities, to move people.

enormous data management and intelligence. City resilience is most evident when multiple modalities are available and maintained. In *Resilient Cities: Responding to Peak Oil and Climate Change*, Newman, Beatley and Boyer wrote:

> *The many benefits of a resilient city include greater overall physical and emotional health; ease of movement in higher density, mixed-use communities that are walkable and have accessible transit options; better food that is produced locally and is therefore fresher; efficiency of energy resources, greater affordability, healthier indoor environments; easier access to natural environments; and more awareness of the local urban area and its bioregion enabling us to have a greater sense of place and identity.*[217]

While it is beyond the scope of this study to expand or deepen AV intermodal research, an SI city may establish a platform on which logistical intermodal systems can be conceptualised, such as through digital cities or simulation.

2.5.3 Features of the orthodox debate about vehicles, people and the city

The dynamic transport network of a city evolves with the city and its people; it is an organic system. Uncertainty exists in the road network planning field due to its hidden nature and social practices. My approach to this research is to look for pathways to CAREV mobilities to shift the orthodox debate.

Leading anti-car voices include such luminaries as Professor Jan Gehl;[218] Professor Peter Newman;[219] the mayor of Paris, Anne Hidalgo;[220] the mayor of Sydney, Clover Moore;[221] Hanna Marcussen[222] and J. H. Crawford.[223] Many anti-car movements support the shift to cleaner transport, such as the Low

217 Peter Newman, Timothy Beatley, and Heather Boyer, *Resilient Cities: Responding to Peak Oil and Climate Change* (Washington, D.C.: Island Press, 2009), p. 11.

218 Jan Gehl is a professor of Urban Planning at the Royal Danish Academy of Fine Arts. *Jan Gehl*, Wikipedia, 2023, <https://en.wikipedia.org/w/index.php?title=Jan_Gehl&oldid=1141854095> [accessed 26 March 2022].

219 Professor Peter Newman is a renowned environmental scientist, author and professor of Sustainability at Curtin University, Perth. Refer to https://en.wikipedia.org/wiki/Peter_Newman_(environmental_scientist).

220 Since January 2021, a number of Hidalgo's policies have gained international attention, such as her proposal to remove over half of Paris' car parking spaces and turn the Champs-Élysées into a 'fantastic garden'. *Anne Hidalgo*, Wikipedia, 2023, <https://en.wikipedia.org/w/index.php?title=Anne_Hidalgo&oldid=1142681345> [accessed 26 March 2023].

221 The Right Honourable Clover Moore has been the lord mayor of the City of Sydney since 2004 and is currently the City of Sydney's longest-serving lord mayor since its creation in 1842.

222 Hanna Marcussen was Oslo's vice mayor for urban development in 2019. Refer to https://en.wikipedia.org/wiki/Hanna_Marcussen.

223 J. H. Crawford, *Carfree Cities*, revised edn. (International Books, Utrecht. 2022).

Traffic Neighbourhood and Clean Cities,[224] congestion taxing or parking restriction and/or lane restriction processes or combinations - the City of Sydney employs several of these strategies. A low-traffic neighbourhood is a scheme implemented to reduce through-traffic in residential areas with filtered permeability and traffic calming.

In his article 'End of the Car Age: How Cities are Outgrowing the Automobile', Stephen Moss clarified that the effects of fossil-fuelled vehicles are overwhelming in most cities.[225] Tom Rabe provided an example of recent public debates and sociopolitical complexity in his article 'NSW Government Accused of Lining Private Sector's Pockets with Toll Subsidy'.[226] The field is inherently a sociopolitical one. Politicians are deeply involved in the automotive and infrastructure industries, together with various interest groups, lobbyists, unions, manufacturers, academics, philosophers and the community.

Unethical behaviour related to vehicle emissions and various financial and safety scandals has yet to improve the automotive industry's social licence. Through the lens of systems thinking, the automotive industry's scandals form patterns of behaviour. Systems thinking asks whether these scandals and safety issues are related and why. The industry and the community face systemic ethical questioning. Challenging unethical conduct requires a systemic approach and leadership at multiple levels. Ethics has substantive relevance to AV technology. Nicholas Diakopoulos wrote in detail about accountability, transparency and algorithms in *The Oxford Handbook of AI*:[227]

> *Firstly, clear context-specific ethical issues need to be identified as well as system behaviours that would indicate a violation of that ethical issue. Then, the information needed to monitor behaviours for a violation needs to be enumerated and a process of producing that information must be put into place. These steps need to be done with a human-centred sensitivity in order to align them with stakeholders' needs and capacities for processing the information. Finally, the governing regime needs to account for weaknesses or threats that might undermine efficacy, potentially implementing regulatory measures that are contextually specific. In some cases, the countervailing forces may be too great, overcoming the desire or perhaps mandate for accountability that could be promoted by transparency.*

224 Clean Cities, *Clean Cities Campaign*, Clean Cities Campaign, 2023, <https://cleancitiescampaign.org/> [accessed 23 March 2023].

225 Stephen Moss, 'End of the Car Age: How Cities Are Outgrowing the Automobile', *The Guardian*, 28 April 2015, <https://www.theguardian.com/cities/2015/apr/28/end-of-the-car-age-how-cities-outgrew-the-automobile> [accessed 23 April 2023].

226 Rabe, 'Toll Subsidy'.

227 Nicholas Diakopoulos, ed. by Dubber, Pasquale, and Das, *The Oxford Handbook of Ethics*, p. 212-213.

> *Governing algorithms and AI are within humanity's grasp if it approaches the task with a careful but steady process of human-centred design that seeks to engineer context-specific algorithmic transparency policies.*

Seen through the lens of ethical processes, CAREVs may have a significant role in the development of ethical approaches to road use, speed environments, urban function and resilience, vehicle sizes, and spatial and transport justice in the future city if the system is developed to be ethical. In Chapter 1.5, I presented the ethical principles that guided this research.

2.5.4 AVs' role in the safety discussion

When faced with existential threats, shifts in thinking become desirable. New variables, such as CAREVs (a novel technology), an existential climate crisis and disruptions in industry labour, create opportunities to change paradigms. A cognitive, creative output – a systemic shift – becomes possible in a field otherwise locked in its practices.

Disruptions allow for systemic changes. Shifting the discussion with an underlying commitment to intergenerational justice, responsibility and improvement is important, according to the UN commitment.[228] It is also important to know which parts must be improved or changed.

Several studies concur that AVs will likely add a new level of complexity, including Kockelman (2017),[229] Mahdavian, Shojaei and Oloufa (2019)[230] Talebpur and Monmassani (2016).[231] The AV industry, through media presentations,[232] websites[233] and scholarly articles, has made assertions that CAVs, including AV freight trains[234] platooning on highways or in urban settings, will transform peak-hour congestion into a flowing, efficient traffic management system, thereby improving quality of life, especially in urban environments.

228 United Nations, *Ombudspersons for Future Generations: Bringing Intergenerational Justice into the Heart of Policymaking*, United Nations, 2023, <https://www.un.org/en/chronicle/article/ombudspersons-future-generations-bringing-intergenerational-justice-heart-policymaking> [accessed 23 April 2023].

229 Kockelman, *An Assessment of Autonomous Vehicles*, p. 137.

230 Mahdavian, Shojaei, and Oloufa, 'Assessing the Long- and Mid-Term Effects', p. 271.

231 Alireza Talebpour and Hani S. Mahmassani, 'Influence of Connected and Autonomous Vehicles on Traffic Flow Stability and Throughput', *Transportation Research Part C: Emerging Technologies*, 71 (1 October 2016), 143–63, <https://doi.org/10.1016/j.trc.2016.07.007>.

232 Benjamin Preston, 'Rise of the Robocar: Are Connected Cars Safer, or a Target for Hackers?', *The Guardian*, 13 August 2017, <https://www.theguardian.com/technology/2017/aug/13/robot-connected-cars-hacking-risks-driverless-vehicles-ross-now> [accessed 10 November 2019].

233 *COHDA Wireless* <https://cohdawireless.com/> [accessed 7 November 2019]. Cohda Wireless is a leading CAV private company with links to the University of Adelaide, Australia.

234 AV freight trains comprise a series of AV trucks functioning separately but operating together with machine intelligence.

Figure 34: Herbie in 'The Love Bug.'

The Love Bug is an early blockbuster film that translated previous animated depictions of vehicle autonomy into realism. The photograph is a scene of synthetically conscious AV, 'Herbie' and the vehicle occupants having an argument in The Love Bug.

Image from Disney Daily News https://thedisinsider.com/2018/11/03/herbie-the-love-bug-series-retrospective/

Leading researchers in the AV field, such as Fagnant and Kockelman,[235] Sha,[236] Mahdavian, Shojaei and Oloufa,[237] and Gokasar and others[238] concur that there is likely to be an increase in traffic movement due to AVs/CAVs, including from unoccupied vehicle movements. Herein lies a dilemma, as CAREVs are likely to result in more traffic movement, which, considering that most cities are congested, would have an undesirable impact, even if safety and environmental conditions improve. In Chapter 4, the CAREV-S spatial investigation seeks a shift in thinking through CAREV spatial redesign.

With regard to AVs, one illuminating literary pathway concerns the influence of some 3,000[239] years of cultural dreams, myths and passages in various religious scripts, classical Indian sculptures[240] and films since the 1930s. Few studies have investigated the impact of 'Herbie', the delightfully anthropomorphic and sentient car in *The Love Bug*,[241] a blockbuster film, and its influence on the development of AVs.

235 Daniel J. Fagnant and Kara M. Kockelman, 'The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios', *Transportation Research Part C: Emerging Technologies*, 40 (2014), 1–13, <https://doi.org/10.1016/j.trc.2013.12.001>.

236 Hua Sha, 'Investigating the System-Level Performance of Connected and Autonomous Vehicles against Transport and Broader Societal Impacts' (unpublished, School of Design and Creative Arts, Loughborough University, December 2020), <https://repository.lboro.ac.uk/articles/thesis/Investigating_the_system-level_performance_of_connected_and_autonomous_vehicles_against_transport_and_broader_societal_impacts/13342064/1> [accessed 3 August 2021].

237 Mahdavian, Shojaei, and Oloufa, 'Assessing the Long- and Mid-Term Effects', p. 271.

238 Ilgin Gokasar and others, 'A Novel Rough Numbers Based Extended MACBETH Method for the Prioritization of the Connected Autonomous Vehicles in Real-Time Traffic Management', *Expert Systems with Applications*, 211 (2023), 118445, <https://doi.org/10.1016/j.eswa.2022.118445>.

239 I reference King Solomon (990–931 BCE), who claimed to have flying carpets, which were written about in the Talmud and the Old Testament.

240 This references the vimana of the Ellora Caves (600–1000 BCE) and other Sanskrit sources. The Rāmāyana is a Sanskrit epic from ancient India, detailed in this chapter.

241 *The Love Bug*, dir. by Robert Stevenson (Buena Vista, 1968).

Released in 1968, *The Love Bug* heralded a new form of AV reality. The characterful anthropomorphic Volkswagen Beetle 'Herbie' takes a cinematic step from animation to sentimental realism, an important move in the development of philosophical thinking. The simple childhood pleasures of Herbie's anthropometric qualities, the consciousness of the vehicle and its occupants' love entanglement are still memorable for some. Herbie and its human–machine antics are shown in Figure 34.

In making *Minority Report*,[242] Steven Spielberg created an advisory committee to assist with the futuristic city in the film. AVs on dedicated vertical superhighways form the film's dystopian future city transport system. In Spielberg's think-tank committee was leading pedagogue William J. Mitchell, professor and dean of the SoA at Massachusetts Institute of Technology.[243] For this film, the Maglev designed by Harald Belker, is a bullet-like pod with a reclining passenger seat, refer to Figures 29 and 30. Mitchell researched small vehicle formats in his 2010 landmark publication *Reinventing the Automobile: Personal Mobility for the 21st Century*.[244] I return to this subject in the spatial investigation in Chapter 4. Personal mobility vehicles (PMVs) can be defined as vehicles that assist people move; they are power-equipped.

242 Jordan Farley, 'Interview Minority Reports Alex McDowell', *Gamesradar*, 17 May 2010, <https://www.gamesradar.com/interview-e28093-minority-reporte28099s-alex-mcdowell/> [accessed 3 August 2021].

243 *Technologies in Minority Report*, Wikipedia, 21 January 2023, <https://en.wikipedia.org/w/index.php?title=Technologies_in_Minority_Report&oldid=1134881194> [accessed 26 March 2023].

244 Mitchell, Borroni-Bird, and Burns, *Reinventing*.

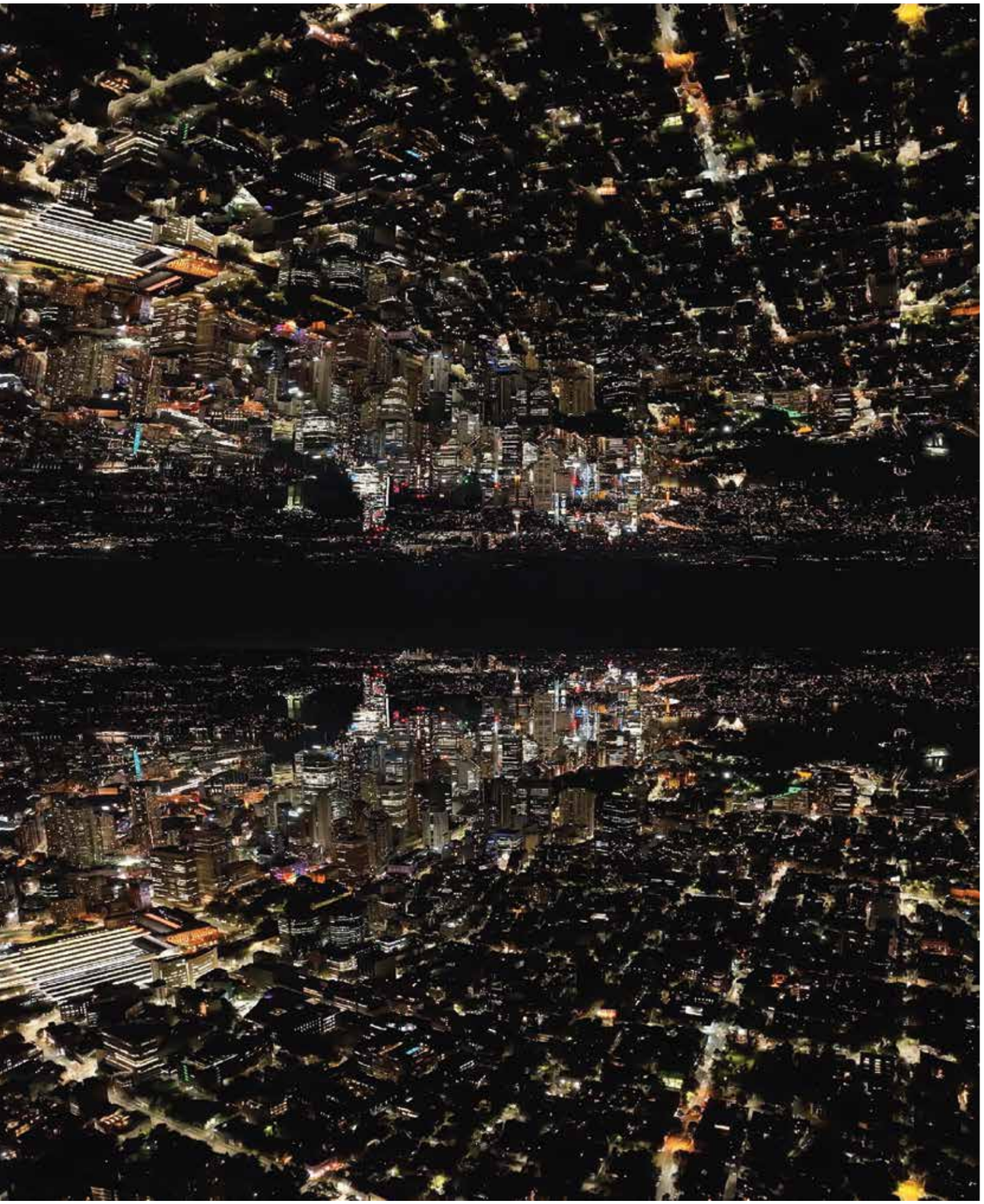


Figure 35: Digital twin city image. The digital model mirrors the real-time model.

Digital twin city modelling allows for testing and scenario planning through digital means as a precautionary principle. The digital format allows for testing and analysis to assist with planning. It is a simulation process. Its complexity requires substantial data management and synthetic intelligence to interpret the output.

Ruth Gold aerial photography, copyright released to Colin Polwarth 2023

Bajpai[245] and Clean Cities[246] suggested that congestion may be alleviated by CAVs, although the actual effects are unknown. Bajpai[247] indicated that the gradual deployment of CAVs in the public arena will determine the impacts. Cause–effect studies are an established vehicle practice: 'Let's try this and see how it works'. To me, this is a flawed praxis. I argue that simulated design investigations, such as digital twin city study methods, are precautionary and preferable (see Figure 35). Simulation, traffic modelling, allows for evolutionary experimentation in the public realm in real-time conditions. They offer an alternative to physical test and trial sites, which have become a global trend. The research notes a rush to AV trial sites and a low output of simulated modelling in the sector.

Worldwide, extensive AV trials are using AV technology in controlled scenarios on dedicated routes through special suburban areas, between university precincts, at airport terminals and with taxi operators in cities. Fully AV sites include mines, ports and agricultural settings, which are rich sites for research inquiry. A 2023 Boolean Google Scholar search revealed 31,000 results for AV trial sites and 78,900 results for AV sites. In 2020, Richard Threlfall, global head of Infrastructure for KPMG,[248] published the organisation's AV Global Index.[249] The brochure provides insights into the implementation status of global AVs.[250] The digital city and city–vehicle model simulation practice presents opportunities for transport authorities and the AV industry to investigate and assess the impacts of AVs/CAVs/CAREVs on the urban form and in digital city format using SI as a non-invasive tool.

245 Jitendra N. Bajpai, 'Emerging Vehicle Technologies & the Search for Urban Mobility Solutions', Urban, Planning and Transport Research, 4 (2016), 83–100, <https://doi.org/10.1080/21650020.2016.1185964>.

246 Clean Cities, *Clean Cities Campaign*.

247 Bajpai, 'Emerging', p. 93.

248 KPMG International Limited is a private English company limited. It is not an initialism; it is the company's name.

249 Richard Threlfall and KPMG, 'Autonomous Vehicles Readiness Index', *KPMG International*, 2018, <https://assets.kpmg.com/content/dam/kpmg/tw/pdf/2018/03/KPMG-Autonomous-Vehicle-Readiness-Index.pdf> [accessed 4 November 2023].

250 AV environments, such as ports and agricultural and mining operations, appear in largely strictly controlled, privately owned settings. These areas are beyond the scope of this research.

2.6 The role of fiction and philosophy in the development of AV technology

Three themes associated with the research methodology 1. technology, 2. semiotics vehicles and the city and 3. environmentalism emerged (refer to Chapter 1.4 Theoretical framework, and have been used to structure the literature review of social and cultural history of AV, they are:

Theme 1 – Myth, magic, science fiction and philosophy in autonomous transport

The role of myth and magic associated with autonomous transport is revealed through review such as the magic of flying carpets, AV semiotics and animation in mass media and its influence on AV technology. Science fiction literature is discussed as a rehearsal site for philosophy.

Theme 2 – The SI city, AV semiotics and civilian and military AVs

A selection of films and literature with notions of the AV city are discussed in relation to rights to the city, technological inequity and inappropriate use of military vehicles in the theatre of war, which are discordant themes. The ethical use of AVs in civilian and military settings is also outlined.

Theme 3 – Unionism, labour disputes, disruptions, corruption and environmentalism in the automotive industry

Social events, union actions and disruptions associated with economics through automation are analysed in relation to a 'technoecology'. Corruption and unethical manufacturing scandals in the automotive industry associated with climate change and pollution are existential issues.

2.6.1 Theme 1 – Myth, magic, science fiction and philosophy in autonomous transport

Religion, myth and legend: King Solomon's flying carpet

Myths and mythologies of AVs are ancient concepts. I argue that the depth of the cultural and social history of AVs is has been mostly restricted to limited references. Some of the earliest mythical writings on AVs, regarding flying or magic carpets, can be found in the Koran,[251] the Talmud[252] and the Bible (the book of Ezekiel), specifically the Old Testament),[253] with all these references leading to King Solomon.[254] King Solomon, a monarch of ancient Israel, is believed to have lived from 970 to 931 BCE and claimed to have had in his possession a flying carpet.[255] This establishes nearly 3,000 years of the broad cultural context of AVs in Western and Middle Eastern literature and associated belief systems which were required to be unchangeable.

Historic social and cultural research is an essential ingredient in understanding social expectations for technology. Research that chooses only the current technological pathway is unlikely to respond to the traditions of social and environmental expectations for this technology, which has developed over centuries. I call this mental picture 'a common dream'.

251 Sam Shamoun, 'Fables and Legends of the Quran: Solomon's Flying Carpet' (Quran: Sura 21:81), <https://www.answering-islam.org/Quran/Sources/Legends/flying_carpet.htm> [accessed 19 March 2019].

252 Emil G. Hirsch and others, *Solomon (Jellinek, l.c. v. 22 et seq.)*, Jewish Encyclopedia, 2018, <http://www.jewishencyclopedia.com/articles/13842-solomon> [accessed 19 March 2019].

253 Ezekiel 1:4–28, <https://www.biblegateway.com/passage/?search=Ezekiel+1%3A4-28&version=NIV> [accessed 22 April 2019].

254 Hirsch and others have suggested that King Solomon was less than honourable in his dealings and had suspicious mythical powers in his later reign. Consequently, he is not regarded as a religious figure but rather as a historical figure in a religious context. In another version of the Solomon story, the king received his magic carpet from God. This carpet was said to have been able to carry 40,000 men in the air at any given time.

255 'When God appointed Solomon king over every created thing, He gave him a large carpet sixty miles long and sixty miles wide, made of green silk interwoven with pure gold, and ornamented with figured decorations. One day Solomon was filled with pride at his own greatness and wisdom; and as a punishment therefor, the wind shook the carpet, throwing down 40,000 men. Solomon chided the wind for the mischief it had done; but the latter rejoined that the king would do well to turn toward God and cease to be proud; whereupon Solomon felt greatly ashamed.' Refer to *Jellinek, l.c. v. 22 et seq.*

Rāmāyana Cycle - Ellora Cave 16, the Kailāsāndtha Temple. B - Ravana, and the Pushpaka vimana
Ravana abducting Sita, Rama's wife with the Pushpaka vimana. D - The Pushpaka vimana.
The Vadavamuka propelling the Pushpaka vimana. F - Abducted Sita (also Seeta) in the vimana.

Figure 36: Photographs of the Pushpaka Vimana at the Ellora Cave 16, India. with the Ramayana Cycle.

The Ellora Caves, India, are a UNESCO World Heritage Site. Kailāsāndtha Temple, Cave 16, has the famous Rāmāyana Cycle sculpture dating from circa 730-950 CE.
The sculpture of hewn stone represents the Hindu Lord Rama's tale, including the abduction of Sita, his wife by the demon god Ravana. Ravana utilises a magical autonomus vehicle controlled the master's will, the pushpaka vimana.

A - Rāmāyana Cycle - Ellora Cave 16.
B - Ravana and the Pushpaka vimana.
C - Ravana abducting Sita in the Pushpaka vimana.
D - The Pushpaka vimana.
E - The Vadavamuka propelling the Pushpaka vimana.
F - Abducted Sita (also Seeta) in the vimana.

Figure 37: Detailed photographs of the Pushpaka Vimana at Ellora Cave 16, India.

Ancient Sanskrit: Early evidence of AVs

The vimana are mythical vehicles or chariots for the gods, they are discussed here as an early form of AV. They offer an example of early evidence of ancient AVs. Comprising hymns, philosophy and rituals, the Vedas of Sanskrit epics appear to have been composed between 1500 and 700 BCE, some of the Vedas narrate tales of Ravana, the demon king and his mythical AV as discussed below.[256] While the literary Sanskrit evidence for the vimana is disputed, sculptures of the vimana provide visual and physical evidence. An early example of a Pushpaka vimana is found at the Maharashtra Ellora Caves in India (refer to Figures 36 and 37). According to Veduveer Arya, the Ellora Caves sculptures and caves represent the architectural activities of the prominent religious practitioners of Buddhism, Brahmanism, Hinduism and Jainism.[257]

Left: the Ramayana Cycle (A) with the Pushpaka vimana (B) nearby, suggesting a similar time frame for the development of autonomous vehicles from approximately 730–950 CE through an early sculptural depiction. Photography by Colin Polwarth.

In Ellora Cave 16, the Kailāsāndtha Temple is a highly recognisable and famous Rāmāyana Cycle heavy bas-relief sculpture, which, according to Arya, dates from approximately 730 to 950 CE.[258] The Cycle and the vimana are shown in Figures 36 and 37. Alongside the temple sculpture complex is the relief sculpture of Ravana, spatially located to the upper right of the Rāmāyana Cycle; the narrative is co-located. Ravana, the demon king of Sri Lanka, is strapped to and flying his Pushpaka vimana, which is propelled by a mythical dragon-like mule, a vadavamuka. Ravana is shown in Figure 37. The Pushpaka vimana is argued to be an early AV, as it can, according to the legend, travel, appear and disappear and fly based on the thoughts of its master.

I interpret these literary and sculptural mythical representations as magical responses and desires for human transportation relieved from the human condition. Notably, the diverse religious setting of the Ellora Caves suggests a wide, common dream of AVs. It can be deduced that the AV cultural dream stretches beyond the Western religious texts of King Solomon to physical representations in Buddhism, Brahmanism, Hinduism and Jainism, extending across Europe, the Middle East and into Asia for at least 1,000 years. The proximity of the Indian religions to each other and their interrelationships also expand the AV chronology and cultural demographic. The notion of an ancient, broad, multicultural and continuous AV narrative is significant in understanding the traditions of cultural aspirations and magical aspirations associated with AVs.

Left: the Ramayana Cycle with the Pushpaka vimana in close proximity. The detailed photograph shows Sita abducting Rama's wife in an autonomous vehicle, the magical Pushpaka vimana.

256 *Vedas*, Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=Vedas&oldid=1210124481> [accessed 26 February 2024].

257 Vedveer Arya, 'The Date of Ellora Kailasa Cave-Temple', undated, <https://www.academia.edu/31158248/The_Date_of_Elloras_Kailasa_Cave_Temple> [accessed 9 May 2023].

258 Ibid.

Figure 38: 'Aladdin's magic carpet'. The tassels communicate AV intentionality with Aladdin.

Figure 39: 'Aladdin's magic carpet' promotional material for the film.

One Thousand and One Nights: Aladdin's flying carpet

Aladdin approaches the magic carpet, a fully autonomous and conscious vehicle animated by Clements and Musker for Disney.

<https://aladdin-wiki.fandom.com/wiki/Aladdin_(1992_film)> [accessed 9 August 2021].

One Thousand and One Nights is a collection of Middle Eastern folk tales compiled in Arabic during the Islamic Golden Age (700–1200 CE). French explorer and author Antione Galland expanded and popularised the tales in *Mille et Une Nuits* in 1704.[259] The tales are called the 'Arabian Nights', from the first English-language edition (c. 1706–1721). Various authors, translators and scholars across West Asia, Central Asia, South Asia and North Africa collected the tales over centuries. Some tales can be traced to ancient and medieval Arabic, Sanskrit, Persian and Mesopotamian literature.[260]

Extending to contemporary culture, *Aladdin* (1992),[149] Clements and Musker's Disney animation, was a blockbuster film that won multiple awards, including an Academy Award, British Academy Film Award and an Annie Award (refer to Figures 38 and 39). The film features a magical flying carpet. Its autonomous, anthropomorphic, semiotic and animated content is discussed in detail in Chapter 3.4. The magic carpet concept originates in King Solomon's wars.

Aladdin's Magic Carpet utilises visual semiotic display, through anthropomorphic tassels at the four corners of the vehicle.

<https://aladdin-wiki.fandom.com/wiki/Aladdin_(1992_film)> [accessed 9 August 2021].

259 Antoine Galland, *One Thousand and One Nights*, 12 vols (Paris: La Veuve Claude Barbin, 1704), <https://doi.org/10.1093/oi/authority.20110803095841203>.

260 *One Thousand and One Nights*, Wikipedia, 2023, <https://en.wikipedia.org/w/index.php?title=One_Thousand_and_One_Nights&oldid=1150929471> [accessed 23 April 2023].

Figure 40: Flip the Frog. 'The New Car' stop animation stop motion by Ub Iwerks c. 1930/1.

These are three still images from the animation with an anthropomorphic and embodied depiction of consciousness in the New Car, an autonomous vehicle.

https://www.youtube.com/watch?v=0wyF9nyVmNg

Film and the magic of AVs

Flip the Frog: The New Car is an exploratory animated film of the 1930s using silhouette-like stop motion.[261] The 'new car' has a humanoid personality and is anthropomorphised. This early animation features an AV with consciousness and an expression of the thoughts of the AV. The cyborg nature of the car, a human in the form of a vehicle, is a striking example of an early cyborg narrative. A cyborg is a hypothetical person whose physical abilities are extended beyond normal human limitations by mechanical elements built into the body.

This animation also reinforces a theme of transhumanism (H+) in depictions of AV. The film features the stop-motion animation and charming drawing skills of Ub Iwerks, who was one of Walt Disney's most respected animators. I argue that these early animations make valuable contributions to the development of AV technology through their imaginative and embodied depictions, as shown in the three still image sequence in Figure 40.

261 *Flip the Frog: The New Car*, dir. by Ub Iwerks (Celebrity Productions, 1931), <https://en.wikipedia.org/wiki/Flip_the_Frog> [accessed 9 February 2019]. This is an early black-and-white cartoon with sound, which features an autonomous anthropomorphised vehicle.

Figure 41: Film frame of Ender in a war simulation, 'Ender's Game'.

Ender's Game includes an autonomous vehicle and also explores simulated models of war as a method to understand and practise 'war games' prior to alien contact. https://www.youtube.com/watch?v=BHJBKd6P3eQ&t=191s

Figure 42: Audi concept vehicle for 'Ender's Game', an AV.

The AV has an inconsequential role in the film. The simulated war which morphs into reality describes the Digital City concept. https://www.dezeen.com/2013/10/29/quattro-fleet-shuttle-concept-by-audi/

Science fiction, philosophy and AVs

In discussing Plato's cave experiment, Schneider argued for the role of science fiction as a rehearsal site for the philosophical imagination.[262] Projections of dystopian or utopian AV ideas have been explored through several films and their related literature. Recent AV films, such as *I, Robot*,[263] *Minority Report*[264] and *Ender's Game,*[265] (Figure 41 and 42) philosophically explore the field of ethics and synthetic learning and include AVs. Contemporary films and literature in which AI and AV feature as science fiction narratives. The magic of autonomy suggested in such films as *Aladdin* (Figures 38 and 39) and *The Love Bug* (Figure 34) suggests humanity's desire to escape mortality magically.

Human mutation – transportation: Clark and Marinetti

Standing on the world's summit we launch once again our insolent challenge to the stars!

Filippo Tommaso Marinetti[266]

Humanity's relationship with machinery is a complex philosophical issue. Filippo Tommaso Marinetti published the *Italian Manifesto* (Italian: *Manifesto del Futurismo*) in 1909, which provides a philosophy for futurism that includes a revelation of speed, machinery, youthfulness and industry.[267]

We declare that the splendour of the world has been enriched by a new beauty: the beauty of speed. A racing automobile with its bonnet adorned with great tubes like serpents with explosive breath ... a roaring motor car which seems to run on machine-gun fire, is more beautiful than the Victory of Samothrace.[268]

Marinetti emphasised that literature will not be supplanted by progress; instead, literature will 'evolve and manifest its progress through instinctive human nature'.[269] Humans will use speed, machinery and industry, not the opposite.[270] This significant manifesto establishes the philosophical link with machines. It is argued that the conceptualisation of augmentation and mutation extends to non-biological forms.[271]

262 Schneider, ed., *Science Fiction and Philosophy*, p. 2.

263 *I, Robot,* dir. by Alex Proyas (20th Century Fox, 2004).

264 Dir. by Steven Spielberg.

265 *Ender's Game,* dir. by Gavin Hood (Summit Entertainment, 2013).

266 Filippo Tommaso Marinetti, *The Futurist Manifesto.*

267 Marinetti, 'Futurism'.

268 Ibid., article 4.

269 Marinetti, 'Futurism' pp. 4–6.

270 Marinetti, 'Futurism' Article 5–6.

271 Andy Clark, *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence* (Oxford: Oxford University Press, 2003), p. 21.

In *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence*, Andy Clark suggested that the real expression of our cyborg nature is revealed through the mind.[272] In Chapter 3.4, I explore cyborgs, H+ notions, synthetic consciousness and alien superintelligence through the writings of Susan Schneider. These fields are likely to influence AV development.

Utopian and dystopian visions of AVs and cities through film

The history of utopian and dystopian visions for AVs and cities by urban designers is substantive.

Metropolis is a critically acclaimed but commercially unsuccessful silent German expressionist science fiction film.[273] *The Matrix*,[274] known for its visual effects scenes, and *Blade Runner*[275] are set in a post-apocalyptic, radioactive world with a polluted atmosphere. Much has been written about Norman Bel Geddes' General Motors Corporation 1939 Futurama[276] . These visions of cities of the future become symbols of thought, language and process. Cities, by their nature social homes for humans, are platforms for communication.

272 Ibid.

273 *Metropolis,* dir. by Fritz Lang (Parufamet, 1927).

274 *The Matrix, dir. by* the Wachowskis (Warner Bros, Village Roadshow Pictures, Groucho II Film Partnership, Silver Pictures, 1999).

275 *Blade Runner,* dir. by Ridley Scott (Warner Brothers, 1982).

276 Norman Bel Geddes, 'Futurama (New York World's Fair)', Wikipedia, 2023_07_14_T21:24:21Z <https://en.wikipedia.org/w/index.php?title=Futurama_(New_York_World%27s_Fair)&oldid=1165387422> [accessed 26 July 2023]

2.6.2 Theme 2 – The SI city, AV semiotics and civilian and military uses of AVs

Cultural history, films, documentaries and news influence society's understanding of AVs, and the misuse[277] of autonomous systems is a discordant theme. Ethics related to the misuse of technology in a military setting apply to the international realm of AI use.

In military settings, the distinction between an AV and an autonomous weapon can be very narrow and potentially lethal. Zachary Kallenborn, writing for Brookings in 2021,[278] clarified an alarming picture of international diplomatic efforts through the UN Convention on Conventional Weapons Group of Governmental Experts on Lethal Autonomous Weapons: in various meetings since 2014, diplomats have 'accomplished little to create an international treaty on autonomous weapons'.[279]

Vanda Felbab-Brown noted that in recent times, perceptions of the military misuse of weapons in mixed civilian and military war scenarios have been leveraged by terror groups in counter-terror claims.[280] Even at the highest levels of international policymaking, such as the Stockholm International Peace Research Institute,[281] ethical questions remain contentious.

Three recent AV films that include major themes of ethics in warfare are discussed in this section of the report: *Avatar,*[282] *Ender's Game*[283] and *I, Robot*.[284] *I, Robot* is based on the 1950s Isaac Asimov *Robot Dreams* (1996) essay.[285] This film deals with synthetic consciousness and the way synthetic-based logic and human ethics have life-threatening outcomes. In her essay on robot dreaming,

277 Cade Metz, 'Pentagon Wants Silicon Valley's Help on A.I.', *New York Times*, 15 March 2018, <https://www.nytimes.com/2018/03/15/technology/military-artificial-intelligence.html> [accessed 19 March 2018].

278 Zachary Kallenborn, *Applying Arms-Control Frameworks to Autonomous Weapons*, Brookings, 5 May 2021, <https://www.brookings.edu/techstream/applying-arms-control-frameworks-to-autonomous-weapons/> [accessed 27 April 2023].

279 Autonomous military vehicles are beyond the scope of this research. It is necessary to clarify that democratically elected governments are unlikely to hold similar ethical positions in relation to autonomous weapons and their vehicles as dictatorial states. It is often in military settings that such technologies as the internet are developed and then expanded to civilian settings – a subject this section of the thesis explores.

280 Vanda Felbab-Brown, *Order from Chaos: Why Pakistan Supports Terrorist Groups, and Why the US Finds it so Hard to Induce Change*, Brookings, 2018, <https://www.brookings.edu/blog/order-from-chaos/2018/01/05/why-pakistan-supports-terrorist-groups-and-why-the-us-finds-it-so-hard-to-induce-change/> [accessed on 23 March 2019].

281 V. Boulainin and M. Verbruggen, *Mapping the Development of Autonomy in Weapon Systems* (Stockholm International Peace Research Institute, 2017), <http//:www.sipri.org> [accessed 9 March 2019].

282 *Avatar,* dir. by James Cameron (20th Century Fox, 2009).

283 Dir. by Gavin Hood.

284 Dir. by Alex Proyas.

285 Schneider, ed., *Science Fiction and Philosophy*, p. 119. This book discusses the writings of Isaac Asimov, the author of *Robot Dreams*, on which *I, Robot* was based.

prominent scholar Susan Anderson[286] argued that Asimov's three laws of robotics are an unsatisfactory basis for synthetic ethics.[287] Asimov's three laws can be thought of as a story-making device in fiction writing rather than a complete definition[288]. Anderson wrote in her concluding statement:[289]

> *I suggest a good way to begin making the task of ethics computable is by creating a program that enables a machine to act as an ethical advisor to human beings. This project, unlike creating an autonomous ethical machine, will not require that we make an ethical judgement about the ethical status of the machine itself, a judgement that would be particularly difficult to make.*

The Oxford Handbook of Ethics of AI provides reliable and scholarly input for this research. With more than 44 contributions from 50 distinguished contributors, the handbook is structured around the five themes of overview, frameworks, concepts, perspectives and cases. It provides invaluable access to current approaches in the SI field and insights into leading researchers' findings and ethical and moral dilemmas.[290]

Historic misuse of military equipment in a civilian setting: Battle of George Square, Glasgow

The misuse of military systems in civilian settings has a long history. Two well-known military events involving the misuse of military hardware in civilian or mixed military collateral events are the Battle of George Square, Glasgow (31 January 1919), and military tank misuse in the Afghanistan/Pakistan wars (1992–2015).[291]

286 Susan Leigh Anderson, 'Asimov's "Three Laws of Robotics" and Synthetic Metaethics', in *Science Fiction and Philosophy*, ed. by Susan Schneider (Chichester: Wiley and Blackwell, 2016), Chapter 22, p. 290–307.

287 Anderson, Chapter 22, pp. 290–291. 'Asimov 1984, The Three Laws of Robots:
A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.'

288 'Three Laws of Robotics', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=Three_Laws_of_Robotics&oldid=1265012038> [accessed 27 December 2024]

289 Anderson, 'Asimov's "Three Laws of Robotics"', Chapter 22, pp. 290–291.

290 Dubber, Pasquale, and Das, *The Oxford Handbook of Ethics*.

291 Other examples include Tiananmen Square, Beijing (15 April to 4 June 1989), again with tank misuse, and the Iraq War (2003–2011) with semi-autonomous warheads.

In *Age of Tanks*,[292] Dedio identified that tanks were first designed in the lead-up to World War I due to the invention of the ICE. The tank became a symbol of defiance and a propaganda tool. The Battle of George Square in Glasgow, Scotland, on 31 January 1919 occurred 82 days after the end of World War I (WWI). Six tanks were moved into George Square to quell a 40,000-person strike associated with degraded economic and employment conditions. The notion that war equipment paid for by the community to win WWI was turned against them in a civilian operation caused considerable upset.[293]

Drone use in the Afghanistan/Pakistan wars (1992–2015)

In 2003, the US military deployed semi-autonomous drones in the Afghanistan and Pakistan wars with devastating consequences for civilian life. Ethical questions have emerged about this action. Unauthorised footage of children screaming and running from a bombarded house under a drone attack in Pakistan published by Valadmanis of Reuters.[294] Though not confirmed, the USA has suggested that it has reduced the use of semi-autonomous drones in active combat, indicating that human rights and ethical issues remain through action. As reported by Stephen Collinson for CNN, on 24 April 2015, President Barack Obama was forced to make an apologetic statement about limiting collateral damage in drone (i.e. semi-autonomous unmanned weapons) attacks in Afghanistan.[295]

Avatar[296] was produced during the International Coalition (between the USA, Australia and the UK, among others) and Pakistan/Afghanistan wars (1992–2015). The film explores the issues of drone and autonomous warfare in a racially charged and environmental setting – a colonial setting. The concepts of species annihilation and genocide of a humanoid species in favour of human imperialism are presented in the film, as are simulations of war.

Testing and experimentation with AVs for military purposes continue globally.[297] The notion that AVs may be used for malevolent non-civilian purposes or because the robotics are 'out of control' is embedded in human consciousness and cultural practice.[298]

292 *Age of Tanks*, dir. by Florian Dedio and others (Netflix, 2017–2018).

293 Ibid.

294 R. Valadmanis, *Review of How Obama's drone war is backfiring*, by S Orlofske and L Adler, Reuters (01_March_2012_T22:30:32Z), section everythingNews <https://www.reuters.com/article/idUS167640935120120301> [accessed 4 August 2021]

295 Stephen Collinson, *Obama Confronts "Cruel" Reality of His Drone War*, CNN, 24 April 2015, <https://www.cnn.com/2015/04/23/politics/obama-drone-warren-weinstein-hostages/index.html> [accessed 27 April 2023].

296 Dir. by James Cameron (20th Century Fox, 2009).

297 Boulainin and Verbruggen, *Mapping the Development of Autonomy*.

298 *The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, Ethically Aligned Design: A Vision for Prioritising Human Well-being with Autonomous and Intelligent Systems (Version 2)*, IEEE Standards Association, 2018, <https://standards.ieee.org/industry-connections/ec/autonomous-systems.html> [accessed 9 March 2019].

United Nations: The weaponisation of increasingly autonomous technologies

Society understands the unethical use of AI and AVs in military operations due to media penetration, such as through literature, films, documentaries[299] and news. In the SI city, the illegal weaponisation of the road transport system will require policy intervention. The development of a future fully AV environment must consider broad community concerns and the moral uses for advanced technology, refer to Chapter 1.5 Principle 5. This will apply to commercial operations such a deliveries, freight and marketing systems requiring space from the public realm. The pleasures of the space of the footpath eroded by delivery and other systems.

As Ariel Bogle of ABC suggested, 'the owners and authors of the algorithms of the future and the morality of the algorithm will require careful consideration to ensure empathy, humanity, emotional awareness and transparency is entrenched in the algorithm's capability'.[300] Refer to 'PRINCIPLE 5 – Thinking through human behaviour and connected autonomous renewable energy vehicles as an integrated system'.

299 *Media Coverage of the Iraq War*, Wikipedia, 2023, <https://en.wikipedia.org/w/index.php?title=Media_coverage_of_the_Iraq_War&oldid=1180591818> [accessed 5 November 2023].

300 Ariel Bogle, 'Big Data is Going to Shape our Future Cities. Will it Treat us all Equally?', *ABC News*, 15 March 2018, <https://www.abc.net.au/news/2018-03-15/big-data-algorithms-equality-future-cities/9544138> [accessed 31 March 2019].

2.6.3 Theme 3 – Unionism, labour disputes, disruptions, corruption and environmentalism in the automotive industry

Historically, societies were impacted by changes in employment conditions due to new technologies. Many cases of these types of disruptions both before the Industrial Revolution and into the twenty-first century are evident. It is likely and necessary that some sections of the road-based transport industry be disrupted so that safer and more environmentally and economically sustainable systems become operational.

Figure 43: The Wapping Dispute, image from Wapping 25 years on in the Morning Star, April 30th by Tony Burke and Ivan Beavis.

Rioting at The Miners Strike was still fresh in people's minds when, in 1986, Murdoch moved against his London Fleet Street employees at Wapping. For over a year the sacked workers mounted a 24-hour picket seven days a week and faced the might of a state which was determined that they should be defeated.

International news broadcasts featured violent British union protests in the mid-1980s. Encouraged by the UK Prime Minister Margaret Thatcher, the Australian–American media mogul Rupert Murdoch led the Wapping Dispute in 1986, forever changing the face of the British trade union movement.[301] At the heart of the disruption was a change in production methods at a print facility in

301 Suellen M. Littleton, *The Wapping Dispute: An Examination of the Conflict and Its Impact on the National Newspaper Industry* (Avebury, 1992).

Figure 44: Maritime Workers Union Sydney 1998.
Stevedores strike at the Australian Waterfront Dispute 1998, Port of Sydney. MCFEU website, photographer unknown.

Wapping in January 1986.[302] Modern computer facilities allowed journalists to directly input text into a new automated printing process and exclude print union workers. Therefore, computers, together with leaders, changed employment conditions, which is a feature of the advancement of AV/SI technology. The disruptive Wapping processes required political (Thatcher), social (economic) and technological (computer) forces to bring about the revolution.[303]

On April 7, 1998, Chris Corrigan, the head of Patrick Stevedores, fired dockworkers across Australia's major ports, locked them out, and replaced them with a non-union workforce trained in Dubai.[304] Paddy Crumlin, the Maritime Union leader, was reported to have said, 'John Howard[305] has finally admitted to conspiring with Christopher Corrigan to bust the Maritime Union of Australia (MUA) in 1998'.[306] Figure 44 is of striking MUA stevedores in Sydney.

The patterns of neo-liberal ideologies, the actions of the unions and employees and an alternative disrupting labour force changed the face of union power. Chris Corrigan commissioned Dr Hugh Durant-Whyte, [307] then a robotics engineer from the University of Sydney,[308] to commence a long-term project to automate ports. It appeared to be a strategy to upend unionised stevedores. An autonomous port project was rolled out in Port Botany (Sydney's industrial port), Port of Brisbane and the Port of London, UK. This social and political history of the forced transitioning of a human workforce to an autonomous system is relevant in the discussion about the transition from driven vehicles to future fully AVs. It is part of the social history of AVs.

Port Botany is now controlled by highly trained computer and robotic engineers.

302 *Wapping Dispute,* Wikipedia, <https://en.wikipedia.org/wiki/Wapping_dispute> [accessed 19 January 2019].

303 Johan Lidberg, *"New Low" for Journalism? Why News Corp's Partisan Campaign Coverage Is Harmful to Democracy*, The Conversation, 9 May 2019, <http://theconversation.com/new-low-for-journalism-why-news-corps-partisan-campaign-coverage-is-harmful-to-democracy-116796> [accessed 24 April 2023]. As noted by Associate Professor Johan Lidberg, writing for *The Conversation*, the downside of Murdoch-owned News Corp's hegemonic new position is neo-liberal bias and the consequent impacts on democracy and climate action.

304 'Who Let the Dogs Out', *Australian Broadcasting Corporation*, 1998, <http://www.abc.net.au/archives/80days/stories/2012/01/19/3412096.htm> [accessed 19 January 2019].

305 John Howard was the Australian Prime Minister at the time. 'John Howard', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=John_Howard&oldid=1237938298> [accessed 10 August 2024].

306 *Howard Finally Admits to Conspiracy Behind the Waterfront Dispute*, Maritime Union of Australia, 2010, http://www.mua.org.au/howard_finally_admits_to_conspiracy_behind_the_waterfront_dispute> [accessed 19 January 2019].

307 Professor Hugh Durant-Whyte was a guest speaker at the IMDV 3 Summit in Adelaide from 31 October to 2 November 2018, he spoke about his role in AV development. He noted that the AV industry was not taking the lessons learned from the Port Brisbane automation seriously. He suggested that at that time, AVs were the 'tail wagging the dog'.

308 Dr Hugh Durant-Whyte was the NSW chief scientist. He is also a professor, ARC Federation fellow and director of the Centre for Translational Data Science at the University of Sydney. From 2010 to 2014, he was the chief executive officer of National ICT Australia, and from 1995 to 2010, he was the director of the ARC Centre of Excellence for Autonomous Systems and the Australian Centre for Field Robotics. He is known for his pioneering work on probabilistic methods for robotics. Refer to <https://sydney.edu.au/engineering/people/hugh.durrantwhyte.php> [accessed 10 March 2019].

Figure 45: Autostrad Port Botany, photograph from company website.

A fully autonomous cargo-handling port with cranes and cargo containers being moved according to programmed systems. Photographs from the AutoStrad website https://patrick.com.au/about/history/. Photo: Peter Rae Wednesday 17 June 2015.

Figure 46: Autostrad Port Botany, control room, photograph from company website.

The port is privately owned, the AV vehicles operate in a highly controlled environment. https://www.smh.com.au/national/nsw/sydneys-patrick-terminal-goes-automated-with-fewer-staff-but-dancing-robots-20150617-ghqc24.html. Photo: Peter Rae Wednesday 17 June 2015. Saulwick, Jacob. "Sydney's Patrick Terminal Goes Automated, with Fewer Staff but Dancing Robots." The Sydney Morning Herald, June 18, 2015. https://www.smh.com.au/national/nsw/sydneys-patrick-terminal-goes-automated-with-fewer-staff-but-dancing-robots-20150617-ghqc24.html.

The port operates 24 hours a day, 365 days a year and, according to the Cargotec Corporation website, is at 'maximum operating efficiency'.[309] This case study of AV ports suggests that acts of resistance can be expected in developing a fully AV environment. Stakeholders who currently earn their living from road-based transport are likely to experience high levels of disruption from the technology. Others may argue that freight and taxis operated by algorithms are likely to be safer, more convenient and more flexible. Figures 45 and 46 are of Port Botany, Sydney, Autostrade, a fully AV port.

Corruption and environmentalism in the automotive industry

But it is a peculiarity of capitalism that each beneficial innovation also brings a sequence of other changes, not all of which are desired by all people so that, in the name of progress, we are compelled to accept a great many distantly related and possibly unwanted changes.

Adrian Forty[310]

Corruption within the automotive industry and its impacts on the development of advanced technology for both CAREVs and AVs will remain a significant issue. In 2018, Alex Gibney created a documentary titled *Dirty Money* for Netflix, which explored international corruption.[311] In Episode 1, 'Hard NOx', Gibney linked his daughter's chronic health issues to his 2017 purchase of a Volkswagen vehicle and suggested that Volkswagen had 'lied to him about the quality of vehicle emissions'. The history of the automotive industry emissions scandal, including a timeline of events with commentary on its international effects, was summarised by Amelang and Wehrmann in Clean Energy Wire.[312] The scandal's implications were international and intergovernmental, as reported by Gude and others in *Der Spiegel*.[313] The nature of corruption, the relationship of corruption to the automotive industry and the complicity of governments in protecting industry and labour remain discordant themes. Refer to 'Principle 4 – Social justice, rights to the city and sustainability'.

309 Cargotec Corporation, *Kalmars Autostrad Delivery to Patricks's Port Botany Sets the Benchmark for the Industry*, Yahoo Finance, 9 July 2015, <https://finance.yahoo.com/news/kalmars-autostrad-delivery-patricks-port-090101914.html> [accessed 31 March 2019].

310 Forty, *Objects*, p. 11.

311 'Hard NOx', *Dirty Money*, dir. by Alex Gibney (Netflix, 2018).

312 Amelang and Wehrmann.

313 Gude and others, 'VW Scandal Exposes Deep Complicity of Government'.

2.7 AV/CAV/CAREV technology authors and researchers

The following section of the research discusses technology authors and researchers that are referred to in this thesis under the AV/CAV/CAREV theme.

Elliott and others provided a comprehensive review of five selected subjects fundamental to technical CAV research, as follows: (i) inter-CAV communications, (ii) security of CAVs, (iii) intersection control for CAVs, (iv) collision-free navigation of CAVs and (v) pedestrian detection and protection.[314] They stated:

> *The main focus of the research is to highlight opportunities to reduce traffic incidents, especially with pedestrians or cyclists. This article provides a comprehensive scholarly overview of the technical attributes of the main variants of the technology.*

However, the review needed more information or insights into the experiential or interface aspects of the CAV in the city, possibly due to the multifaceted nature of the research question being posed.

The quality, status, efficacy and safety of AV systems have become evident through the media.[315] Tesla, Uber and others are implicated in multiple AV driving fatalities.[316] According to Reuters in April 2023, in what appears to be the first trial related to a crash involving partially automated driving software, a jury found that Tesla's autopilot feature did not fail. However, the US Justice Department is investigating Tesla's claims about self-driving capabilities, and the US National Highway Traffic Safety Administration is probing the safety of Tesla's autopilot technology.[317] The probe is ongoing as reported by the BBC in April 2024.[318]

314 David Elliott, Walter Keen, and Lei Miao, 'Recent Advances in Connected and Automated Vehicles', *Journal of Traffic and Transportation Engineering*, 6 (2019), 109–31, <https://doi.org/10.1016/j.jtte.2018.09.005>.

315 *What's the Status of Self-Driving Cars? There Has Been Progress, but Safety Questions Remain*, CBS News, 19 February 2022, <https://www.cbsnews.com/news/self-driving-cars-status-progress-technology-safety/> [accessed 24 April 2023].

316 Munoz, *How Many Fatalities*.

317 ABC News and Reuters, *Tesla Wins Trial over Crash While Car Using Autopilot System*, ABC, 23 April 2023, <https://www.abc.net.au/news/2023-04-22/tesla-wins-trial-over-autopilot-car-crash-never-self-pilot/102255584> [accessed 24 April 2023].

318 'Tesla Autopilot Recall to Be Probed by US Regulator' <https://www.bbc.com/news/articles/c4n17zl39v8o> [accessed 10 August 2024]

In 2022, Silva and others published an in-depth literature review on the impacts of AVs on the environment.[319] In their conclusion, they noted that most studies in the field have only focused on emissions or specific environmental impacts associated with ICE. This is a notable gap in the knowledge base. The Capra–Luisi framework approach advocates for broad environmental considerations, such as behavioural, social and emergent trends, as part of the assessment process.

Writing about CAVs and AVs, Elliot and others indicated that safety improvements can be achieved through autonomous driving, namely the omission of human fault from the driving circumstance and efficiency through connected training or the platooning of vehicles.[320] Other industry leaders, such as Kockelman,[321] the RAND Corporation,[322] Vissers, van der Kint and Hagenzieker,[323] and Parkes and Ferrari,[324] broadly agree. In 2022, Transport for New South Wales published a readiness strategy, which was limited in scope to vehicles and communications systems in the road network and their technology. The report was socially based but needed more insights into urban design and behavioural integration readiness.[325]

Platooning (i.e. creating trains of connected vehicles) utilises swarming and aerodynamic processes, which are seen in natural systems to increase efficiency and improve productivity. Harwood and Reed discussed the methodology they used to understand platooning and train models and noted 'a small increase in carriageway capacity approximately proportional to the percentage of all vehicles travelling in road trains'. [326]

319 Óscar Silva and others, 'Environmental Impacts of Autonomous Vehicles: A Review of the Scientific Literature', *Science of the Total Environment*, 830 (2022), 154615, <https://doi.org/10.1016/j.scitotenv.2022.154615>.

320 Ibid., 'Recent Advances', pp. 111–128.

321 Kockelman, *An Assessment of Autonomous Vehicles*, p. 5.

322 *Autonomous Vehicle Technology May Improve Safety for U.S. Army Convoys*, Rand Corporation, 12 February 2020, <https://www.rand.org/news/press/2020/02/12.html> [accessed 10 August 2021].

323 Luuk Vissers, Sander van der Kint, and Prof Hagenzieker, 'Safe Interaction between Cyclists, Pedestrians and Automated Vehicles', *Institute of Road Safety Research*, SWOV, The Hague, 2016, 49 < https://www.researchgate.net/publication/313165192_Safe_interaction_between_cyclists_pedestrians_and_automated_vehicles_What_do_we_know_and_what_do_we_need_to_know [accessed 20 January 2022].

324 Parkes and Ferrari, *Connected and Autonomous Vehicles*, p. 26.

325 Transport for NSW, *Connected and Automated Vehicle (CAV) Readiness Strategy*, 2022, <https://www.transport.nsw.gov.au/node/12453> [accessed 12 January 2023].

326 Nick Reed and N. Harwood, 'Modelling the Impact of Platooning on Motorway Capacity', in IEEE Road Transport Information and Control Conference 2014 (RTIC 2014), (2014), <https://www.researchgate.net/publication/289723117_Modelling_the_impact_of_platooning_on_motorway_capacity> [accessed 28 January 2024]

Nourmohammadzadeh and Hartmannstate[327] found that in fossil fuel tests, fuel savings can be achieved through platooning:

> *Platooning is an effective approach in which a string of heavy delivery vehicles (HDVs) driving close behind each other is formed. This reduces the aerodynamic drag leading to a reduction in the overall resistive force on vehicles which can provide an amount of fuel-saving in each of the following vehicles.*[328]

Dominique Paret and Hassina Rebaine explored the major technological changes in the field in 2022.[329] Their definitions of the various forms of technology, taken from the view of electrical and communication engineers, offer clear and narrow-field insights. Their examination of the SAE classifications of autonomy point to future alternatives to the SAE vehicle automation taxonomy.[330] Importantly, they defined the systemic nature of the communications between vehicles and the city infrastructure and how these technical communication systems can be achieved and optimised. Thus, their work reveals a high level of complexity in CAV communications and electrification systems. This book is relevant to the appreciation of the terminology and structure of communications systems, as it discusses the complexity of the technical aspects of the CAV field. Nevertheless, its narrow research aims could have benefitted from input from a broader range of disciplines.

In 'Methods and Tools for Comprehensive Impact Assessment of the CCAM Solutions for Passengers and Goods',[331] Kamargianni and others presented a complex study on CCAM modelling; nine scenario tests and business case modelling identifying the uneven readiness of European mobility solutions, impacts and technology acceptance; and the tools to be able to undertake future testing.

327 Abtin Nourmohammadzadeh and Sven Hartmann, 'The Fuel-Efficient Platooning of Heavy Duty Vehicles by Mathematical Programming and Genetic Algorithm', in *Theory and Practice of Natural Computing*, ed. by Carlos Martín-Vide, Takaaki Mizuki, and Miguel A. Vega-Rodríguez (Cham: Springer International Publishing, 2016), pp. 46–57, <https://doi.org/10.1007/978-3-319-49001-4_4>.

328 Ibid.

329 Dominique Paret and Hassina Rebaine, *Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Internet*, trans. by Benjamin A. Engel (Chichester: John Wiley & Sons Ltd., 2022).

330 Ibid., p. 16.

331 Maria Kamargianni, Ana Quijano, Susana Ma Gutiérrez, Laura Pablos, Francisco Verdugo, Hector Canas, and others, 'Methods and Tools for Comprehensive Impact Assessment of the CCAM Solutions for Passengers and Goods', EU, 12 January 2023, <https://discovery.ucl.ac.uk/id/eprint/10167933/1/Quijano%20et%20al%202023%20Cooperative%2C%20Connected%20and%20Automated%20Mobility%20solutions%20-%20review%20and%20gaps.pdf> [accessed 15 January 2024]

Parkes and Ferrari's[332] handbook discusses the different problems that CAVs will pose for the urban built environment and the preparedness of these environments to accept the technology. However, this handbook-format publication needs to be more comprehensive and rigorous in its attention to the subject. Parkes and Ferrari explored how CAVs will interact with other uses and users of cities, including potentially competing efforts to enhance urban well-being and liveability. They also discussed the implications of the development of CAVs. The handbook provides insights into the need for more public debate about deploying CAVs in the public realm. It is aimed at policymaker involvement in readying cities for the CAV technology transition. Its accessibility is one of its strengths; however, its continual references to open-ended uncertainties cement a view of incompleteness in the reader's mind.

In 2021, Mouftah, Erol-Kantarci and Sourer published multidisciplinary writings on the AV and CAV field in their book *Connected and Autonomous Vehicles in Smart Cities*.[333] The book highlights CAVs' roles in future mobility services and intelligent transportation systems in cities. It also details that CAVs may have a broad spectrum of smart city applications, such as mobility-on-demand services integrating with public transit, smart homes and buildings. This book illustrates the security mechanisms, innovative business models, market opportunities and societal/economic impacts of CAVs.

There are many examples of industry and CAV manufacturing publications, for example, on 9 June 2020, media contact Juliet McGinnis posted 'Otonomo and Fiat Chrysler Automobiles to Collaborate on Increasing Car Data Utilization in the European Union' on the Otonomo website,[334] which stated that:

> *Otonomo,[335] the leading automotive data services platform, today announced the signature of an agreement with Fiat Chrysler Automobiles (FCA)[336] to get de-identified, aggregated data from FCA-connected vehicles in Europe to deliver new use cases such as advanced mapping, advanced traffic management and planning, and smart city applications to support the decrease of congestion and pollution in urban environments driven by Otonomo's de-identified data.*

332 Parkes and Ferrari, *Connected and Autonomous Vehicles*, pp. 27–31.

333 Mouftah, Erol-Kantarci, and Sorour, eds., *Connected and Autonomous Vehicles*.

334 'Otonomo and Fiat Chrysler Automobiles to Collaborate on Increasing Car Data Utilization in the European Union', *Otonomo*, 9 June 2020, <https://otonomo.io/press-releases/otonomo-and-fiat-chrysler-automobiles-to-collaborate-on-increasing-car-data-utilization-in-the-european-union/> [accessed 27 April 2023].

335 As the manager of Otonomo, Wejo is arguably a global leader in CAV data. See <https://www.wejo.com/we-are-wejo?utm_source=google&utm_medium=cpc&utm_campaign=competitor-otglobal&utm_term=otonomo&gclid=EAIaIQobChMIs6S8-vbt7wIVwrWWCh3XiADUEAAYASAAEgIqTPD_BwE>.

336 The FCA Group is the Fiat Chrysler Automobiles Group collaborating with Waymo. See <https://www.fcagroup.com/en-US/innovation/Pages/future_mobility.aspx#>.

This is an example of a specific technoecology concept, as well as a typical example of an industry leader's technical description of CAV technologies, where the city and AVs share and respond to SI. The McGinnis article and Otonomo brochures[337] imply AV as opposed to a specific technology advancement. The systemic qualities create potential advanced safety and environmental improvements implied through advanced technologies.

A growing sense of urgency exists to tackle the contradiction between technology development, behavioural and urban interface issues with AVs. The link between the cultural literature, societies' historic aspirations for the transport system and the actual capability of the proposed technology is partly addressed through this research. Refer to 'PRINCIPLE 5 – Thinking through human behaviour and connected autonomous renewable energy vehicles as an integrated system'. Felix Guattari wrote in *The Three Ecologies*:

> *So, wherever we turn, there is the same nagging paradox: on the one hand, the continuous development of new techno-scientific means to potentially resolve the dominant ecological issues and reinstate socially useful activities on the surface of the planet, and, on the other hand, the inability of organised social forces and constituted subjective formations to take hold of these resources in order to make them work.*[338]

According to Stella Nolan of EV Magazine, the leading adopters of AVs in 2024 include Argo (Ford and Volkswagen), Aptiv, Aurora, Baidu, Cruise (GM), Mobileye, Nuro, Tesla, Waymo and Zoox.[339] This field is constantly changing,[340] with various players dropping out of investment, mergers and the like.[341] In 2022, David Welsh noted the disinvestment by many players in the market due to disillusionment with the technology.[342] One notable comment from that article that resonates with themes in this research is from the chief executive officer of the Ford–VW co-invested company Argo, Bryan Salesky. He emphasised the need for CAV manufacturers to partner with cities and stakeholders. According to Kirsten Korosec, writing for TechCrunch, Argo

337 Otonomo, 'One Stop Shop for Connected Vehicle Data', 2024 <https://info.otonomo.io/hubfs/PDF/OOOO-Traffic-Data-Use-Cases.pdf> [accessed 27 December 2024]

338 Guattari, *The Three Ecologies*, p. 31.

339 Stella Nolan, 'Top 10: Autonomous Vehicles', 2024 <https://evmagazine.com/top10/top-10-autonomous-vehicles> [accessed 6 August 2024]

340 Brian Mickle, X Chen and Tripp. "The inside Story of Apple's $15 Billion 'Titanic' Disaster," 2024. https://www.smh.com.au/business/companies/the-inside-story-of-apple-s-15-billion-titanic-disaster-20240301-p5f93f.html?btis.

341 Automotive News Europe. "GM Pauses Production of Cruise Driverless Van." Automotive News Europe, November 7, 2023. https://europe.autonews.com/automakers/gm-temporarily-halts-output-fully-autonomous-cruise-origin-van.

342 David Welch and Craig Trudell, *Tesla, Ford and VW Sound the Death Knell for Driverless Car Hype*, Bloomberg, 2022, <https://www.bloomberg.com/news/articles/2022-10-27/tesla-ford-and-vw-sound-the-death-knell-for-driverless-car-hype> [accessed 22 November 2022].

personnel are being 'absorbed', and the company is closed.[343] A blog post in Change Discussion provides glimpses into the predominantly Chinese and US markets, with insights into SAE level 5 automation deployment, which has started to occur predominantly in California but also with robotaxi trials in two cities in China.[344] The article suggests that regulatory restrictions are no longer the main impediment to deployment, indicating that the issues may be related to insurance and functionality.

Other publications on AVs include Schwartz's *No One at the Wheel: Driverless Cars and the Road of the Future,*[345] which is aimed at a general audience focused on the broader AV industry. Christian Wolmar's *Driverless Cars: On a Road to Nowhere*[346] is a book critical of the technology, discounting its advances and preferring economic and social support for public transport modalities. Mitchell, Borroni-Bird and Burns' *Reinventing the Automobile*[347] does not focus on AVs specifically but rather on the design of vehicles for the future. It emphasises the parking and related spatial benefits of smaller vehicles, a subject discussed in Chapter 4.5.

There are no references to CAREVs in smart city publications, such as Batty and others' *Smart Cities of the Future*[348] and Verrest and Pfeffer's *Elaborating the Urbanism in Smart Urbanism: Distilling Relevant Dimensions for a Comprehensive Analysis of Smart City Approaches.*[349] For many urban designers, the notion of the smart city is undefined and has run its course. Nikitas and others' '*How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context of Smart Cities?*'[350] discusses CAVs as a future technology but does not clarify the environmental benefits. These examples reveal a knowledge gap in general research.

343 Kirsten Korosec, *Ford, VW-Backed Argo AI Is Shutting Down*, TechCrunch, 2022, <https://techcrunch.com/2022/10/26/ford-vw-backed-argo-ai-is-shutting-down/> [accessed 12 January 2023].

344 *Autonomous Cars by 2023 - What Is the Change Coming to Society*, Change Discussion, 23 February 2019, <https://changediscussion.com/autonomous-cars-by-2023/> [accessed 12 January 2023].

345 Schwartz, *No One at the Wheel*.

346 Christian Wolmar, *Driverless Cars: On a Road to Nowhere* (London: London Publishing Group, 2018).

347 Mitchell, Borroni-Bird, and Burns, *Reinventing*.

348 M. Batty and others, 'Smart Cities of the Future', *European Physical Journal Special Topics*, 214 (2012), 481–518, <https://doi.org/10.1140/epjst/e2012-01703-3>.

349 Hebe Verrest and Karin Pfeffer, 'Elaborating the Urbanism in Smart Urbanism: Distilling Relevant Dimensions for a Comprehensive Analysis of Smart City Approaches', *Information, Communication & Society*, 22 (2018), 1–15, <https://doi.org/10.1080/1369118X.2018.1424921>.

350 Alexandros Nikitas and others, 'How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-as-a-Service Shape Transport Futures for the Context of Smart Cities?', *Urban Science* 1 (2017), 36, https://doi.org/10.3390/urbansci1040036.

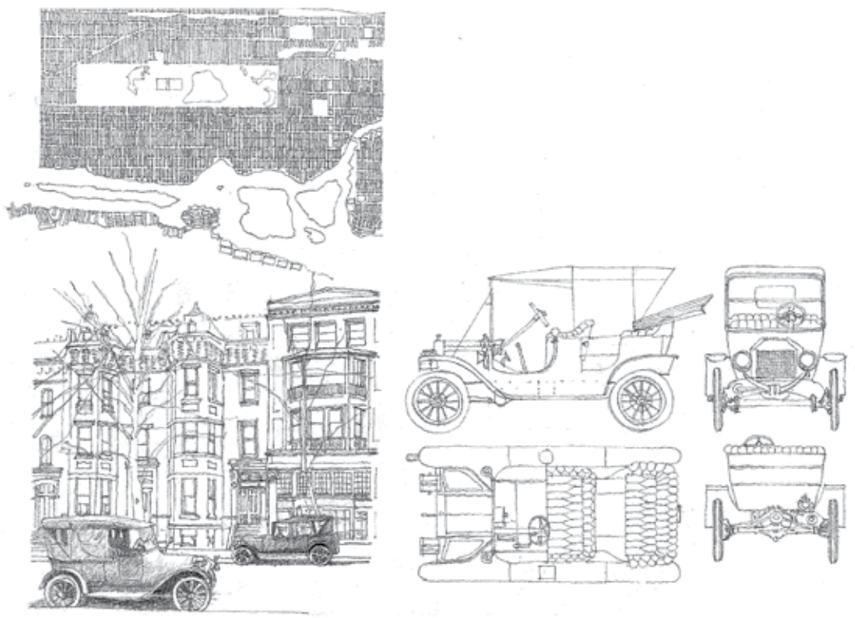


Figure 47: Sample, composite drawings of the vehicle and the city 1900 New York.

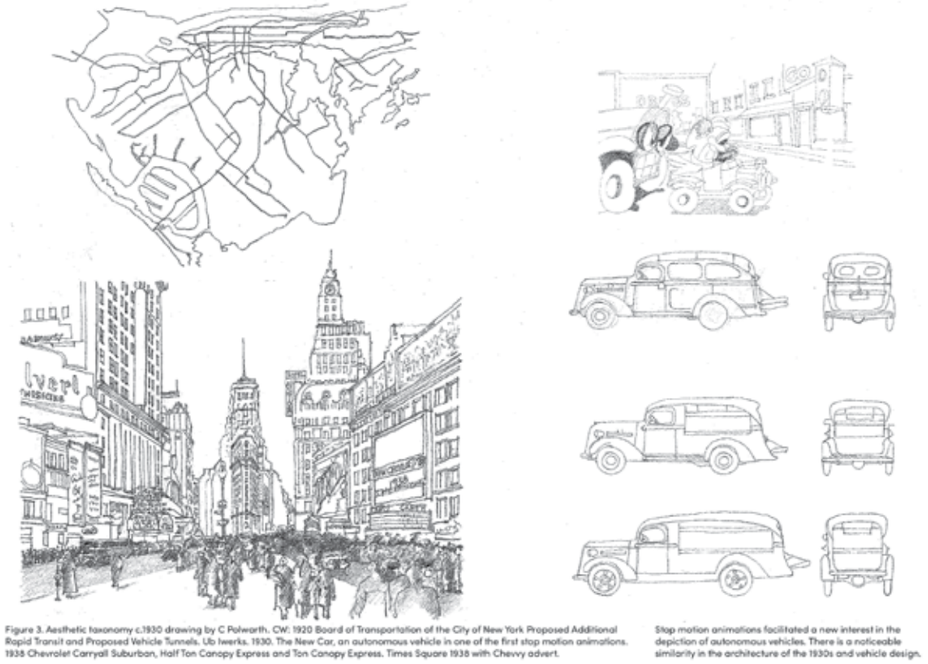


Figure 48: Sample, composite drawings of the vehicle and the city 1920 New York.

The chronology and taxonomy of vehicles, cities and semiotics: a series of composite drawings commencing in 1800 and ending in 2020. They form a taxonomical visual assessment of the evolution and are useful tools in understanding the slow evolutionary process of vehicle and city design.

2.8 Practice method (mapped to the technology theme and symposia)

In Chapter 1.6, I discussed the symposium method, including its structure, tools and the aims of the individual symposia. This section delves into the specific data generated during Symposia 1 and 2 and the responses elicited from the participants. It highlights how the research questions were addressed through the symposium method and provides an analysis of the insights gained and the discussions that took place. The conversations were intentionally flowing, organic and dynamic to encourage participation. This section demonstrates how, by employing this methodological approach, the research objectives were effectively achieved, as well as how the symposium method facilitated a comprehensive exploration of the subject matter.

2.8.1 Symposium 1 – Communications for the future AREV in the urban context

During the symposium, I presented the drawings that can be seen in Appendix D – the Composite taxonomy of the cities, vehicles, semiotics and AV film drawings. The six drawings present a chronology arranged in 30-year intervals from 1800 to 2020 of the aesthetic patterns that exist between vehicles, cities and people. The aesthetic patterns have similarities and differences in the stylistic and linguistic conventions of the period and demonstrate fashion trends in globalisation. The drawings assist in identifying specific 30-year periods across multiple disciplines of research as a systemic approach, including planning, AV literature, typical streetscapes and vehicle design. The trends in architecture, vehicle design and planning demonstrate architectural and design influences across the world as part of globalisation. Sample drawings are shown in Figures 47 and 48. The full set of six drawings can be viewed in detail in Appendix D – Composite taxonomy of cities, vehicles, semiotics and AV film.

My research findings from this symposium were based on the literature and visual evidence of the taxonomy of vehicles, the city and semiotics. They are shown in Figures 47 and 48, and Figure 49 is the large-format composite photography taxonomy, refer also to Appendix C. This taxonomy and a chronology of technology development as a visual tool include visual case studies of several cities including London, Sydney/Melbourne and New York the Hong Kong, Paris and Sao Paulo. The vehicle, city and semiotics taxonomy is a visual tool to understand the evolution of vehicles, the city and semiotics as an aesthetic contribution. It provides a holistic appreciation of a selected view of the evolution of the combined effects, the rhythms of the evolution of city vehicles and semiotics. It was used throughout the research as part of the Capra–Luisi framework to appreciate systemic evolution.

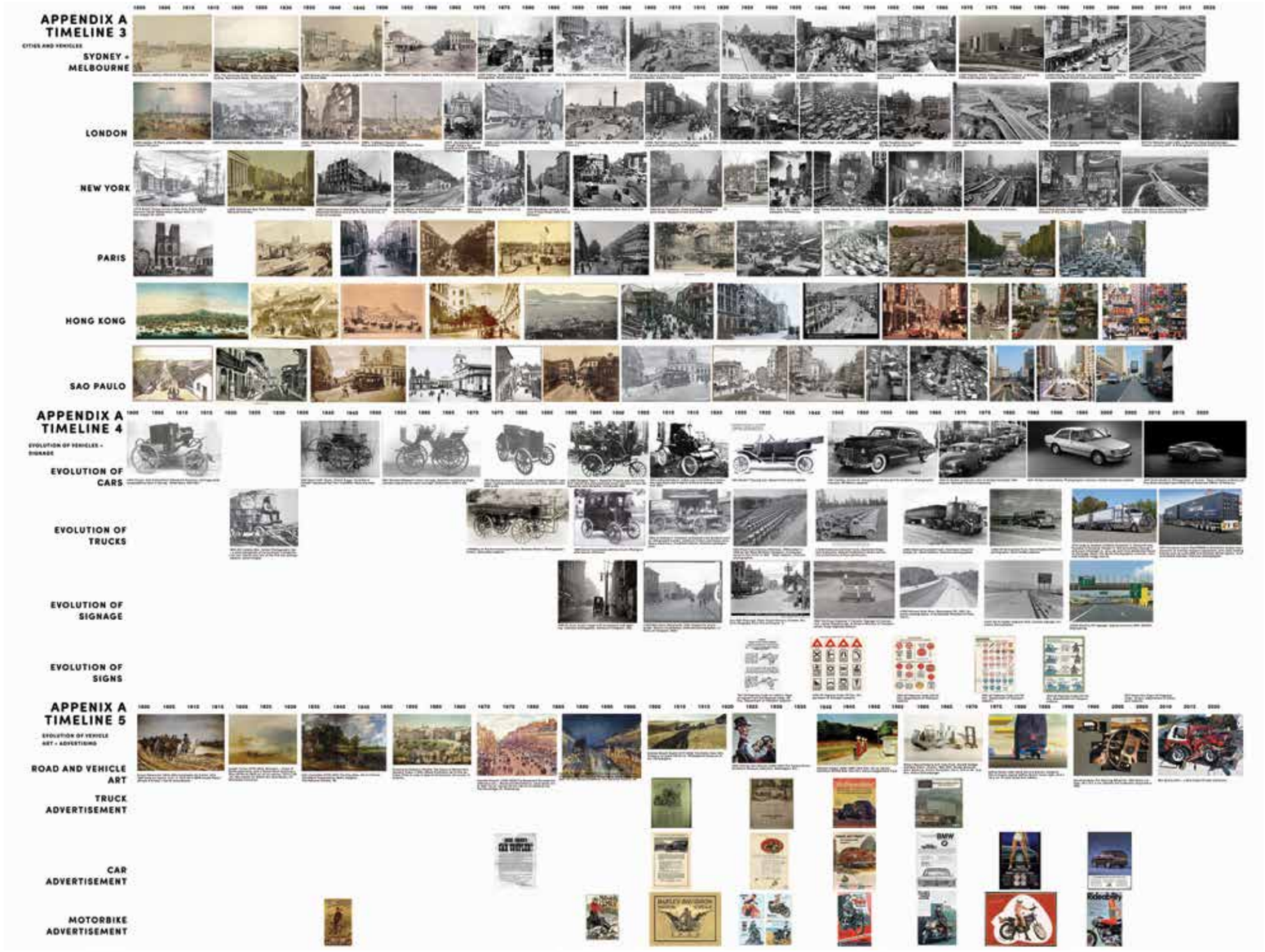


Figure 49: Aesthetic taxonomy of vehicles, semiotics and the city with a chronology.

The drawing was prepared as an A0 size poster for Symposium 1. The taxonomy may be viewed at a larger scale in the Appendix C. Criticism in an early review of the taxonomy was that it did not include a social and cultural history. This led to the creation of the selected social and cultural history of AV.

While the speaker criteria had not been developed for this symposium, the symposium method was developed from the output of the diversity of voices from the cross disciplinary (SoC, SoA and IMDC researchers) as well as a guest representative from industry at this symposium. The speaker criteria included participation of representation for the three theoretical framework fields of technology, semiotics and the environment. The attendees had a diversity of views, relevant to the symposium aim, and their enthusiasm assisted with the exciting extended discussion.

During the cross disciplinary discussions, the participants emphasised the importance of the automotive industry and focused on strategies to achieve zero-emission, zero-incident, and zero-congestion goals. Without these strategic qualities, the impacts of vehicles on cities would likely remain unsatisfactory. A zero-emission vehicle is a vehicle that does not emit exhaust gas or other pollutants from the on-board source of power. An interest in exploring the concept of planned obsolescence within the industry was also discussed at length, suggesting that further investigation into this area may yield valuable insights.

Additionally, the attendees provided the following primary data:

1. 'The transdisciplinary nature of the research and its integration with various schools within the RCA'[351] was regarded as valuable research. The dialogue between different fields, such as urban design, communications and intelligent mobility, was discussed as particularly interesting.

2. It was suggested by scholars and the supervisors that 'narrowing the focus of the research to a specific area of interest'[352] could help deepen and refine the data output.

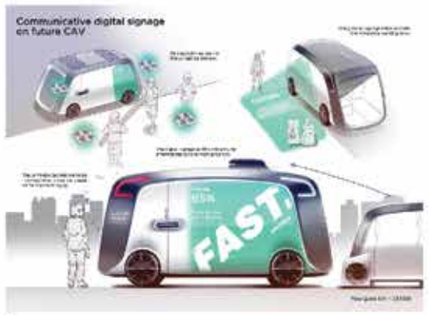
Due to its enormity and complexity of the marketing and commercial advertising semiotics, I was unable in this research to further this specific aspect of study. This is specialised pathway of research for other PhD candidates as noted in the conclusion. A salient insight from the symposium was the importance of interdisciplinary communication and collaboration. Symposium 1 laid the groundwork for formalising the transdiscplinary method used in subsequent symposia.

Overall, this initial symposium method proved effective in generating primary data from *a* 'diversity of opinions and insights'[353], guiding the research towards a more focused and informed direction.

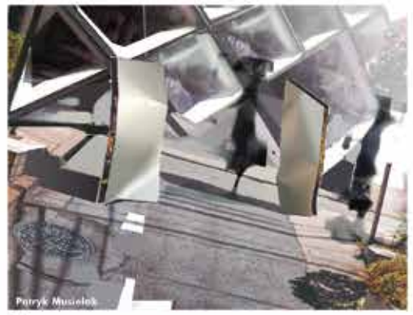
351 De-identified quotation from one of the symposium participants.
352 De-identified quotation from one of the symposium speakers.
353 De-identified quotation from one of the symposium speakers.

1

1. Anna Pittrich - a transhumanist interface



2



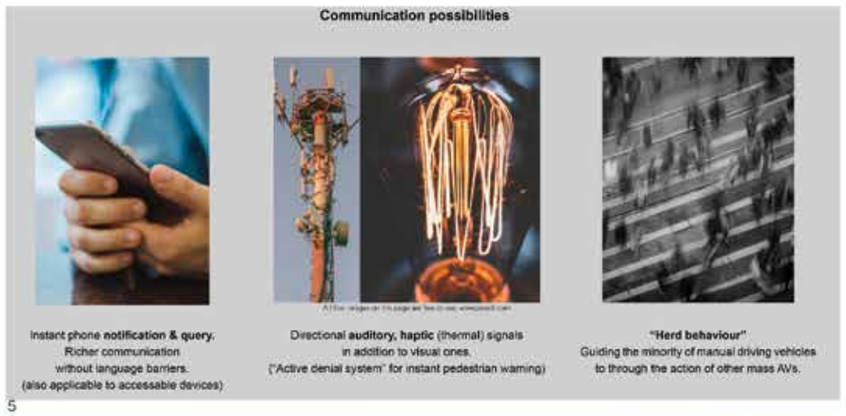
3

2. Young - Jae Kim - AV digital signage

3. Patryk Musielak - a personal AV mobility system

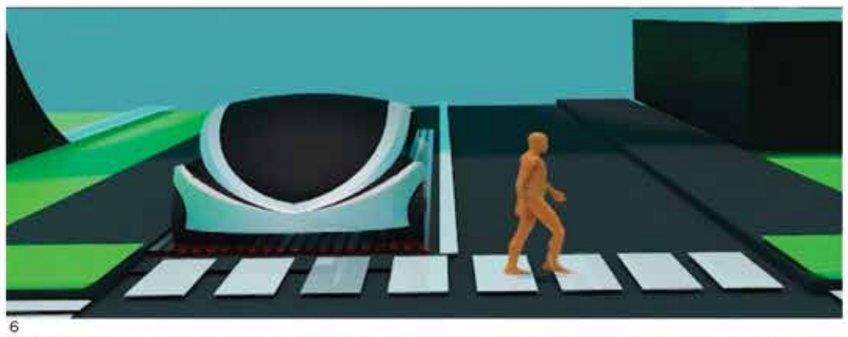
4

4. Tiana WU - a food delivery AV system by gaming



5

5. Choe Seok-woo (Sogu) - a new semiotic system



6

6. Maria Torrens - a road embedded city safety system animation

RCA IMDC Masters students submissions for the Transfiguration or Chaos online symposium, June 2020 (no order)

2.8.2 Symposium 2 – Transfiguration or chaos

Symposium 2, titled 'Transfiguration or Chaos', was an online event focused on CAVs, the right to the city and environmental considerations. The symposium aimed to foster interdisciplinary dialogue to develop transdisciplinary knowledge in this emerging field, the symposium method was structured (refer to Chapter 1.6.1 and 1.6.2), including the general speaker criteria (refer to Chapter 1.6.4).

During the symposium, the discussions encompassed AV technology's social and cultural history, including issues related to urban rights and minority justice sensitivities. One of the speakers initiated discussions on 'the need for spatial studies on AV technology within urban contexts'[354]. This important discussion preoccupied my thinking for many months and resulted in the development of the CAREV spatial investigation.

At its peak, the symposium attracted 46 participants before experiencing a slight drop in attendance during the question-and-answer phase, with about 35 participants remaining engaged. Despite this, the symposium facilitated diverse speakers and viewpoints, with five participants actively joining the discussion. Overall, the event provided valuable insights into the intersection of AV technology, urban rights and environmental concerns. The symposium resulted in a community of researchers and sharing their knowledge of the subject. Various external participants and cross-college PhD researchers joined the symposium panellists.

Symposium 2 included submissions from RCA MA researchers in IMDC to enhance the diversity of inputs and ideas. These submissions, detailed on the website www.transfigcav.com, which I managed under a tutorial system. The student contributions enriched the discussion and PhD research by providing valuable design insights that would otherwise have been unavailable. The contributors were Anna Pittrich, Marie Torrens, Jan Tianyu Wu, YoungJae Kim, Seok-Woo Choe and Partriyk Musiela.

The symposium generated various design contributions related to scenario planning aligned with the PhD research questions. The future scenario method used a mixed method approach that combined brainstorming, trend analysis and scenario development, refer to Figure 50, a compilation of the student contributions.

Figure 50: Symposium 2: Intelligent Mobility Design School MA student scenario contributions.

A composition of the primary images prepared by Anna Pittrich, Marie Torrens, Jan Tianyu Wu, YoungJae Kim, Seok-Woo Choe and Partriyk Musiela. Permission to reproduce images of the submissions in the thesis is granted by the authors.

354 The CAREV spatial study developed from this de-identified primary data input.

Figure 51: Symposium 2 online screen-shot.
This was the first symposium held online and in response to the pandemic.

The framework for synthetic-based autonomy, particularly in AVs, was validated as a suitable research field. However, one of the panellists noted 'the need for clearer definitions and outcomes related to safety, environmental impact, communication and moral/ethical issues in developing AV technology for future cities.'[355] This is an example of primary data collected through the symposium method. Refer to the Principles in Chapter 1.5 and Chapter 5.5 for definitions.

The symposium addressed complex issues regarding autonomy, ethics and safety in AV technology. The need to incorporate ethics and morality into machine learning (ML) systems, as well as the challenges of algorithmic transparency and synthetic consciousness, were addressed. Additionally, one of the speakers highlighted 'the importance of considering social justice and equity in the development and deployment of AVs, particularly concerning the impact on minority and disenfranchised communities'[356], this is another example of primary data collected through the symposium method.

Overall, the symposium provided valuable insights into the interdisciplinary aspects of broad AV research and emphasised the need for ethical, inclusive and sustainable approaches to developing future transportation systems, a screen shot of the online symposium is shown in Figure 51.

The speakers reiterated that the city is a complex and contested space with inherent paradoxes and challenges, presenting numerous research opportunities. In relation to ensuring the safe and sustainable operation of AVs in such environments, one of the public participants discussed a 'dynamic systemic framework that can effectively respond to the diverse needs of the community as a process rather than an object'[357]; this was valuable data collected through the symposium method.

The project supervisors, Jon Goodbun and Artur Mausbach, highlighted the effectiveness of gathering new data through the discursive nature of the symposium. Data collection involved presentation materials and interviews conducted by me with each speaker prior to the symposium. This approach allowed the speakers to adjust their positions and refine their discussion, ensuring that the symposium addressed pertinent issues and stimulated meaningful dialogue.

355 The primary data input from this comment led to questioning current definitions of AV and resulted in the glossary of AV research terminology.

356 The de-identified primary data led to deeper research into social justice and just transport research found in Chapter 4 and 5.

357 The systemic environmental approach had already been established for the research, however the dynamic nature and responses to the diversity of communities was primary data that emerged from this insight.

The discussions in the symposium highlighted one of the speakers insights necessity f*or* 'clear definitions of autonomy and its beneficiaries in the context of AVs.'[358] The participants questioned whether 'autonomy holds different meanings across various societies and proposed developing a comprehensive framework to encapsulate diverse perspectives and guide strategic thinking.'[359] While the discussions initially revolved around safety and environmental sustainability, attention shifted to cultural and ethical factors shaping behavioural and ethical considerations, indicating a need for further exploration.

One speaker raised the intriguing question of 'whether machines can surpass human capabilities and expressed scepticism about this notion.'[360] Despite safety being a primary justification for AV deployment, concerns were raised by a scholar attending the symposium regarding the industry's 'lack of emphasis on ethics and morality.'[361] The discussion emphasised the importance of imbuing ML with empathetic ethics, particularly concerning vehicles, cities and societal behaviour. The question arose about whether public ownership of technology is necessary to clarify its functionality and ensure acceptability.

During Chris Thorpe's presentation, the invisibility of algorithmic intention sparked debate by the speakers on 'the significance of synthetic consciousness and embodiment.'[362] This suggested that some form of synthetic consciousness is crucial for achieving ethical outcomes in AV operations, not only within vehicles but also in urban settings, was consensually acknowledged. The discussions extended to the rights to the city, complexity, resilience and the interplay between human movement and natural systems and highlighted the importance of considering justice issues, particularly concerning social inequality and the impacts of AV technology on marginalised communities. There was a collective inquiry into whether *AVs would weaken or strengthen the rights of such communities in urban environments.*

358 See footnote 355.

359 De-identified data collected at the symposium.

360 De-identified data collected at the symposium.

361 De-identified data collected from a general public insight at the symposium.

362 De-identified data provided by one of the speakers at the symposium.

The writings of David Harvey were cited by one of the speakers:[363]

> *The right to the city is far more than the individual liberty to access urban resources: it is a right to change ourselves by changing the city. It is, moreover, a common rather than an individual right since this transformation inevitably depends upon the exercise of a collective power to reshape the processes of urbanization. The freedom to make and remake our cities and ourselves is, I want to argue, one of the most precious yet most neglected of our human rights.*[364]

This underscores the importance of individual liberty and human access to urban resources, framing them as fundamental rights. A speaker emphasised that the right to access and shape the city is not merely an individual entitlement but a collective endeavour, highlighting the transformative power of communities in reshaping urbanisation processes.

One symposium participants, a scholar, 'acknowledged the reality of transhumanism' (*H+).*[365] They advocated for research f*ocusing on H+ tendencies, tools and integration with the human mind, emphasising the emotional and spiritual dimensions of ML*. For example, Anna Pittrich's submission explored the emotional and spiritual aspects of human–AV communication through wearable technology and urged further interdisciplinary research to understand the implications of embedding AI technology in the human brain or body.

The symposium method was discussed in terms of its ability to generate new data and insights, particularly in exploring AVs' social and cultural history. This subject had previously needed more academic attention. There was a group discussion with participants recognised *the importance of interdisciplinary research in probing hypotheses and identifying avenues for strengthening research in this field.*

363 Applying Harvey's *rights to the city* approach to AV was new data at this stage of the research development.

364 David Harvey, 'The Right to the City', *New Left Review*, 53 (2008), 23–40, p. 23.

365 The notion of H+ agendas being a validated part of a social and cultural history approach was new data for the project.

Addressing questions of aesthetics and spatial and redistributive justice in mobility design, the participants highlighted 'the need for post-colonial research into the effects of AV technology on developing economies and communities.'[366] Key inquiries include examining whether the technology exacerbates inequality and colonial attitudes, identifying which communities benefit or suffer injustice from technological advancements and assessing how diverse societies leverage or are impacted by AV technology.

These questions underscore the complex socioeconomic implications of AV deployment and the need for ethical considerations in technological development. I identified research into the adoption of CAREVs in developing economies as a research limitation and an opportunity for future research by others (refer to Chapter 5.7 – Research limitations and assumptions). The orthodox debate about motor vehicles and the city is further developed in Chapter 4.4, as it is associated with the CAREV spatial investigation.

366 AV research for developing economies was later regarded as a research limitation due to the scale of the research input, being beyond an individual researcher's abilities.

2.8.3 Answering the research sub-questions

The following are a summary of the answers to this chapters sub-questions.

SQ2.1: In the evolution of vehicles, semiotics and the city, what are rhythms and patterns that can be seen?

Arrhythmic contradictions arise because vehicles generally have a shorter lifespan than urban structures, leading to different rates of evolution. This mismatch is further complicated by the presence of older vehicles, heritage cars, and the historic multi-layering of urban conservation areas and new development. The timing conflicts create debates about how vehicles impact cities, resulting in complex patterns of evolution and consumption. These obstacles, combined with commercial interests and the constant production and consumption of the automotive industry, make the relationship between vehicles and cities increasingly complex.

SQ2.2 Can the pace of vehicle technology change and urban evolution be visualised?

The vehicle, city, and semiotics taxonomy used in this research is a visual tool designed to explore how vehicles, urban environments, and semiotics (the study of signs and symbols) evolve together, contributing to aesthetics (the combined contribution). A visual taxonomy offers a comprehensive perspective on the interconnected development of these elements, focusing on their shared rhythms and interactions. It was utilised in the research within the Capra–Luisi framework, which emphasises understanding systemic evolution, to analyse and appreciate these dynamics holistically.

The sub-questions are expanded upon in Chapter 5.6 - Answering the research questions.

2.8.4 Discussion

The selected social and cultural history of AVs establishes historical, cultural and social aspirations for a magical transport modality – one that is safe, efficient, flexible, intelligent, reliable, comfortable, just and socially trusted and, by implication, also has impacts on the public realm as an environmental response. These cultural aspirations challenge the automotive industry's approach to the safety, public health and environmental outcomes of AVs.

The definition of the SI city emerges throughout all of the chapters of this thesis. The notion of the SI city has a long history through the smart city concept. The notion of the CAREV city, one in which this vehicle technology is the dominant road-based transport modality, is a shared system used by various vehicle types networked to the city and human intelligence. The CAREV SI city is a system that intertwines human and synthetic intelligence to increase city liveability. It expands the established notion of a city and its vehicles evolving together.

Through quantifiable scientific output, research in architecture and urban design has demonstrated the human-centric approach in environmental sciences, linking mental and physical health to the environment. In Chapter 4.7, I discuss this issue in greater detail, linking the UHI study to human health outcomes due to CAREVs.

2.9 Findings

The chapter presented the findings by addressing the research sub-questions related to the technology semiotic, and city/environmental themes as discussed in the symposia (refer to Chapter 2.8). Taxonomical research on vehicle evolution, semiotics and urban development underscored the necessity for further exploration in this field due to its complexity and multifaceted nature (for example Figures 47, 48 and 49). Transdisciplinary insights are required to understand the interplay between technological advancements, urban planning and cultural shifts.

The social, cultural and philosophical manifestations of AVs historically encompass various themes, including safety, communication, sustainability and anthropomorphism. These manifestations, rooted in myths, science fiction and philosophy, reflect society's evolving perspectives on technology and its relationship with humanity (refer to the research sub questions in Chapter 2.2). The controversy surrounding fossil-fuelled vehicles and their impact on cities has persisted for over a century, inhibiting research and hindering interdisciplinary collaboration. The dominance of the automotive industry has shaped global economic development and urban landscapes, highlighting the need to understand the complex dynamics between vehicle design, urban planning and societal values, a discussion and insight arrived at through the the symposium method.

The pace of technological change in vehicles and urban development appears disconnected, with advancements driven primarily by safety, legislative and commercial factors rather than urban design considerations. Planned obsolescence in vehicle manufacturing complicates efforts to align technological progress with urban sustainability and intergenerational justice goals, which will be discussed in detail in Chapters 3 and 4.

The evolution of communication systems in vehicles, particularly in the context of AVs/CAVs/CAREVs, presents opportunities to enhance safety, environmental awareness and urban aesthetics. However, complexities in city and vehicle semiotic systems necessitate further research to streamline communication and improve public realm legibility, the subject of the next chapter. The shift towards AVs/CAVs/CAREVs prompts critical inquiries into environmental impacts, communication, semiotic systems and urban design considerations. Addressing these questions requires interdisciplinary collaboration and a holistic understanding of the interdependencies between technology, society and the built environment.

Figure 52: CAREV colour study, CAD animation in Crown Street at night.

The purpose of the colour investigation is to discuss the implications of an aesthetic change that could occur in the public realm as a result of receding and advancing colour systems as system of environmental semiotics to assist people understand CAREV movement in the public realm with an environmental consciousness.

Chapter 3.0 Semiotics: Communications with CAREVs

The man and the external sign are identical, in the same sense in which the word homo and man are identical. Thus my language is the sum total of myself; for the man is the thought.

Charles Sanders Peirce[336]

3.1 Introduction to vehicle and city semiotics and identifying issues

Throughout my practice as an urban designer, I have maintained a continuous and deep interest in semiotics, especially in the public realm. All my projects involve communication, wayfinding, legibility, safety, cognition, signs and semiotics, Figure 52 is an example of my practice approach. It is important to clarify what I mean by semiotics, as it is a large field with multiple facets.

On a purely visual level or pragmatically, as Charles Sanders Peirce clarified, a sign is 'something which stands to somebody for something in some respect of capacity';[337] it is constantly qualified. In the public realm, signs associated with road or active transport safety are semiotic representations of legislation – the legal requirements and conduct of everything within the realm. Road signs in most developed nations (in this study, I broadly refer to Australia and the UK) are governed by local, state and national legislation or by international covenant. I discuss the relationship of the semiotic hierarchies as they pertain to the public realm and the vehicles within.

Semiotics is related to cognition. Peirce asserted that in relation to semiotics, when looking at a sign, the reader undergoes a mental action or process and, through sensing the sign, is then able to respond to its qualifications. I discuss Schneider's LoT[338] as a cognitive science hypothesis, a conceptual system humans may share with SI as a necessary interface to understand CAREVs intentionality as part of living with synthetically intelligent machines in the public realm.

336 Thellefsen and Sorensen, eds., *Charles Sanders Peirce*, p. 7.

337 Ibid.

338 First advanced by Jerry Fodor in the 1970s in *Fodor*.

Figure 53: Mosaic of animation frames CAREV's interaction with humans in the city, refer to Video 2.

In this research, semiotics is limited to visual semiotics in the public realm due to the scale of the field. The semiotics of the public realm is extensive and challenging and has evolved organically. It has become increasingly complex, including both static, digitised and dynamic systems. In addition to legislation, we depend on semiotics to communicate the specific cultural requirements for the safe, legal and appropriate use of the public realm. As a language, signs in this research are systemic in that they are culturally accepted systems by which our rights to the city are maintained. Future systemic research in neuroscientific sensory processing of auditory, olfactory, taste and haptic/tactile signals and systemic and intuitive processing will benefit the field of road-based semiotics.[339]

An early research theme was related to the semiotics of vehicles in the public realm. This emerged from my visual arts studies in the Master of Art capstone project at the University of New South Wales (UNSW). In 2015, with the assistance of the UNSW library, I undertook a search of the data on the semiotics of AVs/CAVs. The global search results on various search platforms, including Google, OpenVerse, Art Index Retrospective, ProQuest, Design Profiles, Philosopher's Index and JSTOR, revealed a gap in the knowledge base regarding AVs and semiotics.

The marketing and commercial aspects of AV/CAV/CAREV and semiotics is another field of inquiry which systemically impacts the industry and public realm. Due to the scale, nature and depth of this field, this subject area could form a separate PhD's or post doctoral research by others.

If designed with artistic intent, the transition from the current traffic semiotics to CAREV semiotics can be dramatic. I argue that a dramatic public realm transfiguration is a desirable outcome and a necessity for CAREVs. This approach is likely to achieve community acceptance, as discussed in Symposium 3, and may be the basis for testing improved public realm functionality (refer to Figure 53). The system should be designed to create positive environmental and safety responses.

Broadly, national roads, such as motorways, utilise national and international sign standards (e.g. speed, stop and directional signs). State roads use combinations of international, national and state standards; they may also use specific state-legislated sign systems. Local roads use local road signs, such as parking and no stopping signs, in addition to state signs. Local roads also

339 Referring to driver's manuals (UK) and road rule books (Australia), all signs have a hierarchy of meaning and direction, which is essential to understand and obey for safe operation.

provide active transport-related signs for cyclists, pedestrians and disabled persons. Importantly, vehicle standards, including semiotic systems, use national standards stemming from international standards. The public realm's semiotic system is complex and requires considerable administrative and engineering input and iterative modification.

Holistic teams focused on environmental and safety outcomes are necessary as a transdisciplinary response to public realm semiotics. For too long, this visual field has been regulated by traffic management alone. The limitations of the hegemonic (current) traffic engineers and authorities, as well as the signage engineers deploying red, white, orange and green primary colour systems tied to the Vienna Convention on Road Signs and Signals, inhibit a more systemic and culturally nuanced approach to understanding environmental safety mechanisms in the public realm. Stated differently, the field needs artistic input. The field can also benefit from deeper research to assist people with the various forms of colour blindness, a cohort of approximately 8% of the population.[340]

Furthermore, the increased requirements of the Vienna Convention and the proliferation of signs and their deployment have had a dramatic visual effect on the public realm, often with a high order of confusion and bombardment of informatics. The current systems are designed for everybody, but especially for sighted drivers. CAREVs can use visual systems, but the legislated requirements may also, and preferably, be communicated to the vehicles through non-visual digital systems (such as GPS).

This chapter reveals a selected social and cultural history of AV semiotics. The history of vehicle and human communication in the public realm is a rich area of research. This is fertile territory for future research by others. The role of embodiment and communications between machines and humans is discussed in this chapter, as these are fundamental to how we navigate the public realm. From this cultural and social history, the expectations for AVs/CAVs/CAREVs are clarified and defined. Through this, the limitations of the current SAE automation taxonomy are examined.

Figure 54: Mosaic of animation frames CAREV's interaction with humans in the city. Refer to Video 2.

The animation is shown in Video 2. Red and blue colours may be easily recognisable, but may not be suited to all vision types.

The mosaic of frames in Figure 54 is from the animation 'CAV's communications along with the CAV's interaction with humans in the city' (refer to Video 2). Animation is a visual tool in scenario planning for spatial and semiotic research.

340 National Eye Institute, *Types of Color Vision Deficiency*, 2024 <https://www.nei.nih.gov/learn-about-eye-health/eye-conditions-and-diseases/color-blindness/types-color-vision-deficiency>.

A new semiotic system for CAREVs will be required, and it should be a city-wide requirement by necessity. Synthetically intelligent vehicles will depend on more than road signs. Other road users will require signal systems and signage to assist them with non-AV mobility (see Figure 53 and 54). By necessity, a new semiotic system would be part of the social education platform for CAREVs. This is related to the research dissemination objective.

The interaction between CAVs and actors in the public realm will be a profound change, as confirmed in the RCA's GATEway publication and discussed in this chapter. Some policy work in this field is underway in the EU and the USA. In 2019, at CES, the leading technology exhibition in the USA, vehicle manufacturers, such as Mobis, a subsidiary of Hyundai, demonstrated external CAV semiotics, which is also discussed in this chapter.

The research suggests that CAREVs' SI must understand, appreciate and respond to diverse cultural phenomena, including semiotics. People in the streetscape will need to be able to communicate and understand the intentions of CAREVs so that CAREV communication systems can be conceptualised as forms of intelligent transport ecology.

A fully CAREV environment will require a new communication and semiotic system to improve safety because this will allow vehicles and the public to communicate and safely interact. This must include aesthetics and semiotics in the public realm. Semiotics affect the way we think and behave regarding the environment. The cognitive, semiotic, technologically based and integrated approach has its foundations in combining Schneider's LoT hypothesis with the Capra–Luisi framework to increase environmental consciousness.

3.2 Research sub-questions related to the semiotics theme

Research sub-questions emerged through the public realm, vehicle and semiotic research. The research sub-questions are answered in this chapter (Chapter 3.8):

SQ3.1 How will a change in the fleet to CAREV allow for deeper combined changes in the city fabric, its semiotics and communications?

SQ3.2 How will a *systemic semiotic technoecology* arise, and what will it look like?

3.3 Identifying knowledge gaps in the social history of road-based semiotics

A substantive amount of literature on AVs' social and cultural history is associated with developing signs and signals, the semiotics of the vehicle and the public realm. In this chapter, I focus on semiotic development: vehicle direction and movement intentionality associated with indicator lights. Indicator lights as safety features are some of the earliest semiotic systems related to driving vehicles and actors in the public realm; their origins lie in social history. During this selected social and cultural investigation of AVs, it became evident that the industry-accepted definitions of automation, as defined by the SAE, required further consideration. To what extent the SAE On-Road Automated Driving Committee, deliberated on the historical, cultural and social literature regarding AVs is not evident from its classification system.

The cultural research revealed that the SAE levels of automation require further consideration of safety, interaction with the city and people's behaviour in the public realm. This is discussed in this chapter in section 3.6. The SAE automation classification for on-road motor vehicles should be revised. Some authors such as Paret and Rabaine[341] and Walker Smith[342] have confronted parts of the SAE's classification of automation. I question the entire classification system based on its failure to acknowledge AVs' social and cultural expectations[343] in the public realm and their environmental impacts.

341 Dominique Paret and Hassina Rebaine, *Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Internet,* trans. by Benjamin A. Engel (John Wiley & Sons Ltd., 2022)

342 Bryant Walker Smith, 'Deep in the Weeds of the Levels of Driving Automation Lurks an Ambiguous Minimal Risk Condition' (Stanford Law School 22_January_2022) <https://cyberlaw.stanford.edu/blog/2022/01/deep-weeds-levels-driving-automation-lurks-ambiguous-minimal-risk-condition> [accessed 1 April 2023]

343 I refer to the cultural expectations of AV as discussed in the social and cultural history of AV in Chapter 2 for AV as safe, convenient, reliable, flexible, sustainable, magical, just, and a comfortable transport modality.

3.4 Literature review of a selected cultural and social history of vehicle semiotics

Architecture, which has for so long thematised our historical social relations to nature, might therefore today have a renewed task in contributing to thinking space, matter, energy and time, as a materialist form of semiotics that encompasses both human and natural orders.

Dr Jon Goodbun[344]

Semiotics, semaphores, vehicles and the public realm

Semiotics is the formal study of signs in a broad sense – not only signs that are artificial, linguistic or symbolic but also signs that are semblances and causal reactions. Charles Sanders Peirce held that 'all this universe is perfused with signs, if it is not composed exclusively of signs', along with their representational and inferential relations.[345]

According to Fernando Andacht, Peirce's semiotic theory describes signification, representation, reference and meaning and, more broadly, the classification of semiotics as part of cognition as a general theory of signs. The main research source relating to semiotics is Torkild Thellefsen and Bent Sorensen's[346] 'Charles Sanders Peirce in His Own Words: 100 Years of Semiotics Communications and Cognition'. Andacht suggested that Peirce's arguments are distinctive and innovative for their breadth, complexity and logical, mathematical approach.

My research revealed that recent thinkers, such as Susan Schneider, with her approach to LoT – specifically, her modes of presentation (MOP) hypothesis – have followed Peirce's semiotic path into the new computational field. Schneider hypothesised that the 'LoT is a computational cognitive process utilising symbols';[347] that is, the LoT is constructed through symbols rather than through syntax or grammatical structure.

344 Jon Clendenning Goodbun, 'The Architecture of the Extended Mind: Towards a Critical Urban Ecology' (unpublished PhD Thesis). *University of Westminster*, 2011, p.10, <https://westminsterresearch.westminster.ac.uk/item/8zy32/the-architecture-of-the-extended-mind-towards-a-critical-urban-ecology> [accessed 20 January 2022].

345 *Charles Sanders Peirce*, Wikipedia, 2023, <https://en.wikipedia.org/w/index.php?title=Charles_Sanders_Peirce&oldid=1150227121> [accessed 29 April 2023]. Refer to 'The Collected Papers of Charles Sanders Peirce', 5.448 footnotes, from *The Basis of Pragmaticism* (1906).

346 Thellefsen and Sorensen, eds., *Charles Sanders Peirce*, p. 13.

347 Schneider, *The Language of Thought*, pp. 28–63.

Peirce's century-old theory[348] presents limitations associated with technological advances, and Schneider's more recent research on semiotics, the LoT and the MOP provides a contemporary view on the subject.

Eduardo Kohn provided key anthropological insights into communication systems and semiotics between humans and the environment in his landmark research 'How Forests Think'.[349] An abstraction of this research provides links between the city and CAREVs through semiotics (signs and signals) and communications (cybernetics) and is related to the research question regarding the semiotics and communications of a future CAREV environment. Kohn linked language and symbols as a cognitive process through observations of cultural practices.[350]

Several technical writers in the AV space, such as Paret[351] and Lui,[352] and videos by various technology suppliers, such as Hyundai,[353] have demonstrated how vehicle sensors view the context and use symbols to understand the environment. This is a semiotic approach to thinking and provides an important link to understanding SI as a common process. These vehicular visual concepts can perhaps bring us closer to SI and make it less onerous and overwhelming conceptually. In a 2019 article for *IEEE Access*, Chunsheng Liu, Shunang

348 Ibid., Thellefsen. 2014.

349 Kohn, *Forests*.

350 Ibid., p. 9.

351 Dominique Paret and Hassina Rebaine, *Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Internet*, trans. by Benjamin A. Engel (Chichester: John Wiley & Sons Ltd., 2022).

352 ibid. Xie and Liu.

353 'Hyundai MOBIS', *Hyundai Motor Group*, 2019, <https://www.hyundaimotorgroup.com/group/CONT0000000000000670> [accessed 23 June 2022].

Figure 55: Hyundai Mobis semiotics. Computer Exhibitions Sciences exhibition in California in 2019.

Korean vehicle design and manufacturing firm Hyundai explores the semiotic responses between AV and an instantly changing environment which is projected in this concept vehicle exhibition. Image from youtube: https://www.youtube.com/watch?v=VFTB1glKPmI.

Li, Faliang Chang and Yinhai Wang[354] of Shandong and the University of Washington assessed the ML capabilities of AV systems based on a review of sign detection methods. Their article confirmed that advanced driver assistance systems and automated driving systems (ADS) systems are semiotic. Their research included an assessment of commonly used AV sensor technologies. Laura Bliss, writing for Bloomberg Hyperdrive, concurred.[355] Johnathan Roberts and Michael Milford, writing *for* The Conversation,[356] noted that Mobileye, an Israeli AI firm, has developed deep learning software for sign recognition being used in AVs.

Other deep learning organisations, such as Google and Alphabet, are currently involved in similar sign recognition software development.

Vehicle indicator lights form part of the intricate UN Convention of Road Signs and Signals[357] and the United Nations Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts.[358] These documents form a significant history in developing road-based semiotics. The development of indicator lights, one of vehicles' primary safety semiotic systems, has a social history. The literature on this subject suggests that in the field of AVs, more work needs to be published on the semiotic requirements associated with AVs. This research gap was identified in the project's early stages and formed the detailed experimental response, including a symposium dedicated to this issue, in the thesis. Clements and Muster experimented with animated vehicle semiotics for Aladdin's magic carpet, shown in Figures 38 and 39, which allowed diverse audiences to fully understand and appreciate the human and emotional framework of the flying carpet through the animated semiotic processes.

354 Chunsheng Liu, Shuang Li, Faliang Chang, and Yinhai Wang, 'Machine Vision Based Traffic Sign Detection Methods: Review, Analyses and Perspectives', *IEEE Access*, 7 (2019), 86578–96 <https://doi.org/10.1109/ACCESS.2019.2924947>.

355 Laura Bliss, 'How Autonomous Vehicles Recognize Traffic Signs,' *Bloomberg*, 2017, <https://www.bloomberg.com/news/articles/2017-02-10/how-autonomous-vehicles-recognize-traffic-signs> [accessed 13 January 2023].

356 Jonathan Roberts and Michael Milford, *How to Make a Driverless Car "See" the Road Ahead*, *The Conversation*, 2017, <http://theconversation.com/how-to-make-a-driverless-car-see-the-road-ahead-74529> [accessed 13 January 2023]

357 Transport and Communications United Nations, *United Nations Treaty Collection: 20. Convention on Road Signs and Signals* (New York: United Nations, 2014), <https://treaties.un.org/Pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XI-B-20&chapter=11&Temp=mtdsg3&clang=_en> [accessed 4 August 2021].

358 Transport and Communications United Nations, *United Nations Treaty Collection: Agreement 'Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of These Prescriptions* (2014), <https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XI-B-16&chapter=11&clang=_en> [accessed 4 August 2021].

Figure 56: Model T Ford advertisement c. 1914, The Saturday Evening Post, Detroit, USA.

The drawing of the vehicle shows headlamps located near the vehicle door on the bonnet, however there are no indicator lights. Vehicle direction intention was by hand signal of the driver at the time. Image from https://www.saturdayeveningpost.com/sep-keyword/ford/

The first international road sign convention was signed in Geneva in 1931. In 1968, the UN Economic and Social Council developed the Vienna Convention on Road Signs and Signals. This multinational treaty was designed to increase road safety and international traffic safety by standardising the signs system. It included road signs, traffic lights and road markings. The convention emerged from the Geneva Protocol and was formed from the need for consensus on road traffic signs and the ubiquitous traffic light that evolved in twentieth-century Western Europe in response to the increase in road vehicles post-WWII.

According to Cole, in 1924, an ophthalmologist in Tasmania – R. Stewart – argued for improved primary colour recognition for drivers. People with deuteranomaly colour blindness (red–green recognition) depend on light intensity and positional luminance[359] as an alternative to colours in traffic light recognition.[360] Figure 56 of the Model T Ford in 1914 shows there were no indicator lights on vehicles at the time.

A short history of the development of road traffic signs by Senka and Andelko[361] provides insights into the development but is inconclusive in assessing the Vienna Convention's success. Most UN members have not signed the treaty.

The USA uses its own Manual on Uniform Traffic Control Devices (MUTCD), while Canada and Australia follow the UN protocols. Many countries in Central America use the 'Manual Centroamericano de Dispositivos Uniformes para el Control del Transito', a Central American integration system and an equivalent system to the US MUTCD.[21] Articles on the success or failure of the convention

359 Colour blind people depend on the position of the brightest lights on the traffic light panel as an alternative to the (red-orange-green) colour system which they are unable to see. Refer to Barry L. Cole, 'Colour Blindness and Driving', *Clinical and Experimental Optometry*, 99 (2016)

360 Barry L. Cole, 'Colour Blindness and Driving', *Clinical and Experimental Optometry*, 99 (2016), 484–87 <https://doi.org/10.1111/cxo.12396>.

361 Senka Pašagić and Anđelko Ščukanac, 'Historical Development of Traffic Signs', *Promet - Traffic & Transportation*, 10 (1998), 309–13, <http://traffic.fpz.hr/index.php/PROMTT/article/view/779> [accessed 13 January 2023].

are few. In 2018, the UN produced an article titled *50 Years On*[362] about the Vienna Convention for its fiftieth anniversary. It recounts the importance of the convention in constantly evolving the road safety sign system internationally. The International Driving Authority[363] has two articles on international traffic light and sign regulation systems advising road users about national and local conditions, for multiple nations and in multiple languages, which revealed the inconsistent use of signs.

In the 2018 YouTube video by the UN[364] titled *50 Years On,* which was a supplement to the article, a variety of participants, such as Mr Edwin Nas (Msart Mobility, the Netherlands) and Dr Bryant Walker Smith (University of South Carolina) stated that 'the convention is a wonderful example of how the international community comes together to safety and continues to develop the dynamic systems'. Various speakers reiterated the benefits of the convention. However, its success is difficult to measure, as there are no comparative systems. In the same conference, Dr Bryant Walker Smith identified the conventions used in CAV and AV technologies and how these will develop together internationally in the future. Smith has authored many leading articles on CAV and AV technologies and ethics.

The first edition of the UK's 1931 Highway Code[365] includes hand symbols regarding driving. Page 17 contains the first drawn symbol instructions with 13 symbols: a policeman using hand signals (five signals) and drivers using hand signals (8 signals). There are no fixed signs for roads. It has a total of 27 pages, including the cover. The 1959 Highway Code has approximately 40 symbols;[366]

362 UN and UNECE, *50 Years On, the 1968 Conventions on Road Traffic and Road Signs and Signals Are Still at the Core of Road Safety Efforts Worldwide,* UNECE (2018), <https://unece.org/transport/press/50-years-1968-conventions-road-traffic-and-road-signs-and-signals-are-still-core> [accessed 13 January 2023]

363 International Driving Authority, *Strange Road Signs in Different Countries* (2023), <https://idaoffice.org/posts/strange-road-signs-in-different-countries/> [accessed 13 January 2023]; International Driving Authority, *Traffic Lights in Different Countries*, <https://idaoffice.org/posts/traffic-lights-in-different-countries/> [accessed 13 January 2023]

364 UNECE, *50 Years of Safer Roads: The 1968 Conventions on Road Traffic and Road Signs and Signals,* online video recording, YouTube, 2018, <https://www.youtube.com/watch?v=TSX_1iCV5CA> [accessed 13 January 2023]

365 Ministry of Transport and UK Government, *The Highway Code 1931* (1931), <http://archive.org/details/the-highway-code-1931> [accessed 13 January 2023]

366 Ministry of Transport and Civil Aviation, *The Highway Code (1959)* (Sir Joseph Causton & Sons Limited, 1959), <http://archive.org/details/thehighwaycode1959> [accessed 13 January 2023]

it has a total of 27 pages, including the cover. The 2022 Highway Code[367] has 17 authorised person signals and links to hundreds of signs in various categories; it has a total of 186 pages, including the cover. The increasing number of road rules and symbols in the Highway Code over 63 years of development is overwhelming.

In 1968,[368] the Vienna Convention included some 25 pages of symbols. In the 2022 amendment, an 80-page convention, there are 50 pages of symbols, with dozens of signs on each page. As of 2023, the website links hundreds, possibly thousands, of signs. It is almost humanly impossible to understand and comprehend all of the symbols. The complexity of these symbols and their deployment, maintenance and control require sign engineers and specific sign engineering. This is a research field within itself that is beyond the scope of this research.

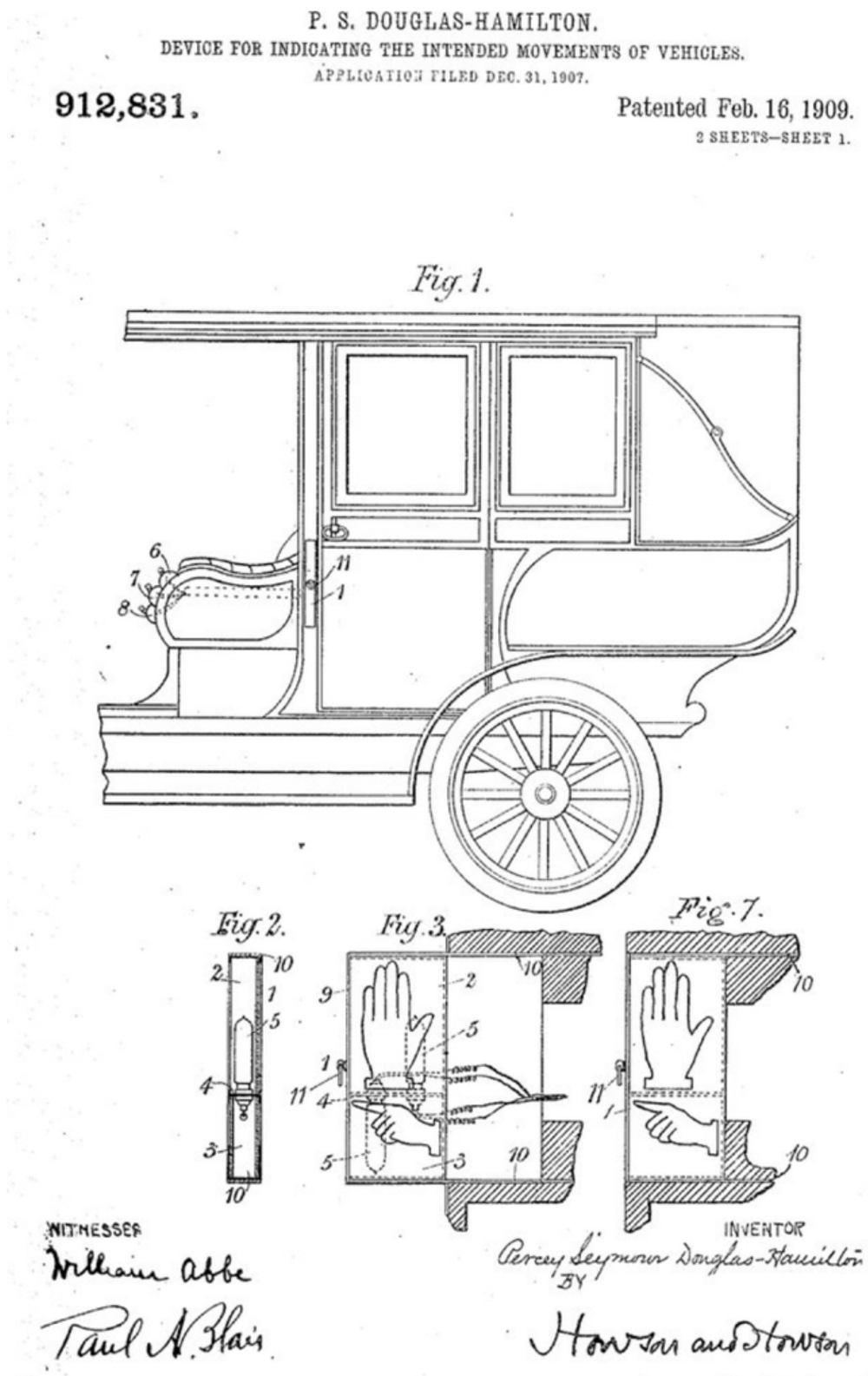
SI is likely to provide compliance and algorithmic appreciation of the legal attributes of road-based symbols, which are the semiotics of the public realm. The symbols are effectively a semiotic representation of the legal requirements. The complexity of the road semiotic system is likely to be disrupted significantly in a fully AV/CAV/CAREV environment, as the road rules, speed zones and yield and stopping provisions are likely to be more effectively promulgated through digital systems. Contemporary vehicle indicator and brake lights comprise combinations of lighting and signalling devices mounted or integrated with the front, rear, sides and, in some cases, on the top (roof) of a motor vehicle.[369] These locations are important for viewers of the vehicles in the public realm. The corner of a vehicle is especially important, as it affords a wider viewing angle of the vehicle's intention. This physical attribute applies to CAREV. In a future CAREV environment, signs will only be required for actors in the public realm who are using other modes of transport, such as cyclists, pedestrians and people using personal mobility devices, during their interactions with AVs.

The Vienna Convention on Signs is in urgent need of simplification. An AV/CAV/CAREV environment will require a semiotic system designed to assist active transport and non-AV users as a first-order shift in the current design, which is focused on the human driver.

367 UK Government Highway Code, *The_official_highway_code_-_27-07-2022.Pdf*, 2022, <https://www.highwaycodeuk.co.uk/uploads/3/2/9/2/3292309/the_official_highway_code_-_27-07-2022.pdf> [accessed 13 January 2023].

368 UN, *Sign Convention, Treaty 20.*

369 Under the UN agreement on vehicle prescription, indicator lights are mandatory devices.



P. S. DOUGLAS-HAMILTON.

DEVICE FOR INDICATING THE INTENDED MOVEMENTS OF VEHICLES.

APPLICATION FILED DEC. 31, 1907.

912,831. Patented Feb. 16, 1909.

2 SHEETS—SHEET 1.

Fig. 1.

Fig. 2. *Fig. 3.* *Fig. 7.*

WITNESSES

INVENTOR

ATTORNEYS

Figure 57: Percy S. Douglas Hamilton 1909 Patent for the first vehicle indicator light, drawing 1.

USA Patents Office

https://patentimages.storage.googleapis.com/23/fb/e2/16209b0cf99ada/US912831.pdf

Pre-1850 vehicle communications

Horse-driven carts and horse riders in the nineteenth century did not use specific systems for indicating direction or change of direction. Drivers used their hands, voices and hooters. A Model T advertisement from 1914 shows no indicator systems available, refer to Figure 56. The advent of signalling vehicle direction change can be traced to naval and rail systems rather than road systems in the late nineteenth century and early twentieth century.[370] According to Eckermann, drivers of early road vehicles indicated direction and speed with hand gestures and a hooter.[371]

1907 – The first indicator light patent

In 1907, Percy Douglas-Hamilton applied for a US patent[372] for a device 'indicating the intended movements of vehicles'. The lights were shaped like hands so that other drivers, accustomed to reading hand signals, would understand their meaning, refer to Figures 57 and 58. The invention was not realised.

The social history of the development of vehicles' indicator lights has a direct relationship to the semiotics of the project and the use of hand gestures as a response to embodiment. According to the Lemelson-MIT Program[373] and Merna Forster,[374] Florence Lawrence (1886–1938) the 'first movie star' and motor enthusiast, is credited with designing the first auto signalling arm,[375] a predecessor to the indicator light. In the 1930s, the first indicator lights on vehicles must have seemed like magical inventions when they first appeared. They were semiotic abstractions of gestural movements – twinkling lights embedded in the vehicle. In many ways, they retain their magical qualities. They are responsible for a major advancement in road safety that has saved countless lives. Seen en masse, they form a stream of magical communication lines across cities into an international semiotic.

370 Erik Eckermann and Peter I. Albrecht, trans., *World History of the Automobile* (Warrendale: Society of Automotive Engineers, 2001), p. 25.

371 Ibid., p. 27.

372 Percy S. Douglas-Hamilton, 'US Patent 912831 Device for Indicating the Movement of Vehicles', *US Patent Office*, 1909, <https://patentimages.storage.googleapis.com/23/fb/e2/16209b0cf99ada/US912831.pdf> [accessed 29 April 2023].

373 MIT Lemelson, 'Florence Lawrence Vehicle Turn Indicator Lamp; Full-Stop Signal', 2023 <https://lemelson.mit.edu/resources/florence-lawrence> [accessed 29 April 2023].

374 Merna Forster, *100 More Canadian Heroines: Famous and Forgotten Faces*, The History Education Network, 2011, <http://thenhier.ca/en/content/100-more-canadian-heroines-famous-and-forgotten-faces-merna-forster.html> [accessed 16 October 2023], p. 221.

375 MIT Lemelson, *Florence Lawrence Vehicle.*

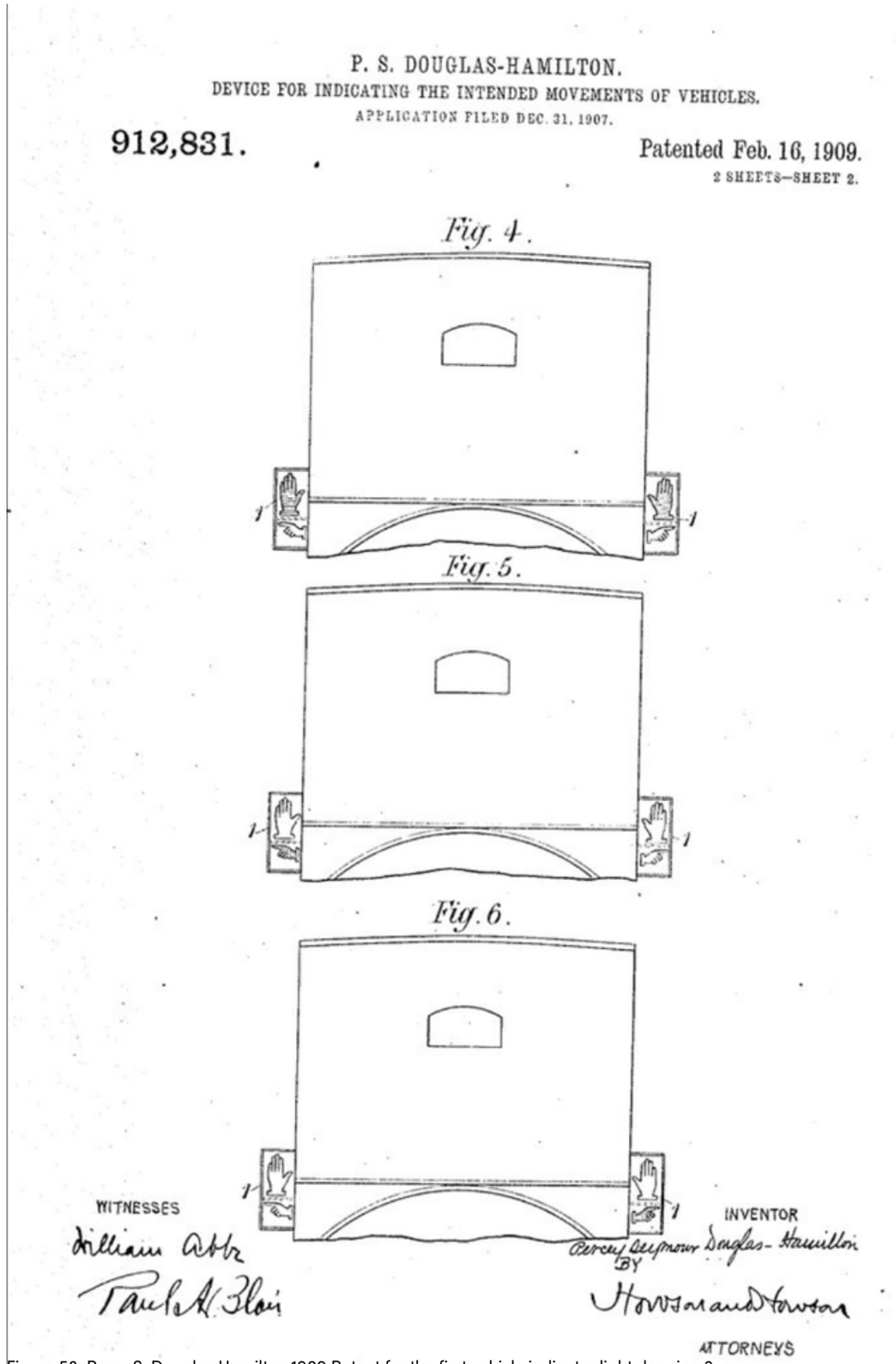

P. S. DOUGLAS-HAMILTON.
DEVICE FOR INDICATING THE INTENDED MOVEMENTS OF VEHICLES.
APPLICATION FILED DEC. 31, 1907.
912,831. Patented Feb. 16, 1909.
2 SHEETS—SHEET 2.
Fig. 4.
Fig. 5.
Fig. 6.
WITNESSES
INVENTOR
Percy S. Douglas-Hamilton
BY
Howson and Howson
ATTORNEYS

Figure 58: Percy S. Douglas Hamilton 1909 Patent for the first vehicle indicator light drawing 2.

The patent is for 'a device to indicate the intended movement of vehicles. The hand gestures in the patent are a form of semiotic embodiment.

USA Patents Office

https://patentimages.storage.googleapis.com/23/fb/e2/16209b0cf99ada/US912831.pdf

I return to the anthropomorphisation of vehicle signal intentions in the design experiments later in this chapter (3.7), as they form an experimental visual system that was assessed in Symposium 5 and provoked transdisciplinary dialogue.

In 'Shaping Autonomous Vehicles', Diels and others commented on the design features of the exteriors of AVs, noting that 'current trends towards increasingly small lights were thought to result in faceless vehicles, lacking the anthropomorphism that vehicle design has historically relied on to connect with the customer'.[376]

Current vehicle communications are limited in their range of complexity. Figure 58 is an abstracted and reductionistic form of current vehicle semiotics. An analysis of the image shows the red (danger), white (visual field/headlights) and amber (warning intention such as indicating or road elements) colour scheme that has dominated the visual semiotics of vehicles for over 150 years and of which road users are universally aware. The system is a visual communication for users outside the vehicle. Such a visual system is unlikely to have the same importance in the CAV/CAREV context, as the data of each vehicle are shared between vehicles. This means that this visual system is of less importance, as SI would not reply on visual semiotics alone. The importance of the future CAV/CAREV semiotic system is therefore for other road users, who would need to understand SI intentionality.

376 Cyriel Diels and others, 'Shaping Autonomous Vehicles: Towards a Taxonomy of Design Features Instilling a Sense of Safety', *in 24th International Conference on Human-Computer Interaction HSII, Virtual Event, June 26–July 1, 2022, Proceedings, Part I: Communications in Computer and Information Science* (2022), <https://doi.org/10.1007/978-3-031-06394-7_24>.

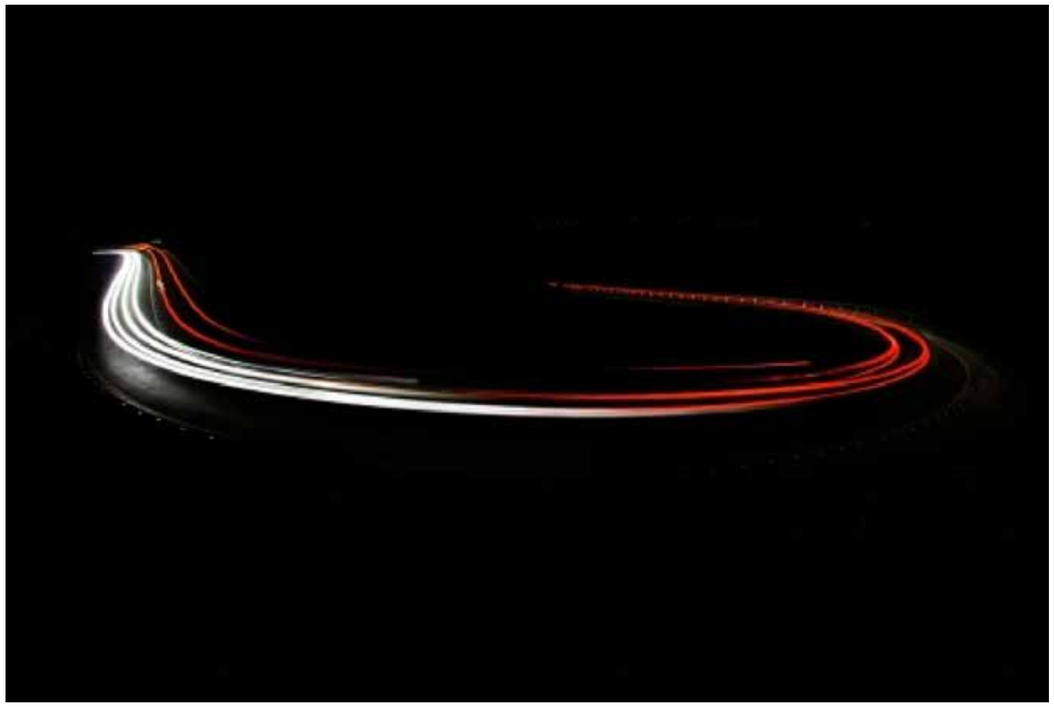


Figure 59: Felix Tchvertkin, 2013. Trailing lights photography. Copyright released. https://therainbowlightpictures.wordpress.com/2013/02/05/car-light-trails/ and https://www.facebook.com/FelixTchvertkinPhotography/

The trailing lights from a semiotic communication of roads and traffic vehicles, in this image it can be deduced to be a human driven vehicle as white lights are required for vision and the red trailing light is for the rear vehicle lights at night as prescribed by the UN Vehicle Prescriptions.

Figure 60: Fiat Centroventi unveiling in 2019.

Note the vehicle digital panel stretched across the rear of the vehicle, including the rear break lights in red. The implication is that all viewers would be required to understand English. However the digital panel could be used to communicate vehicle intentionality if it was reformatted to stretch around the vehicle corners allowing 360 degree views of the digital panel from the context. Image from film: https://www.youtube.com/watch?v=AIP0MoQeXoc

Understanding vehicle SI intentionality in the public realm is critical to human safety. Importantly, the major factors in understanding the cultural and social aspects of road transport include language, local conditions and national identity, as demonstrated through the international misalignment and non-ratification of treaties. Localised conditions, such as driving on the left or right side of the road, alphabets, existing road symbols, refer to Figure 59, and nationalistic tendencies, will need to be addressed with a deeper understanding of contemporary cultural awareness of vehicle intentionality. The experiments conducted as part of this research in AV/CAV/CAREV communications (refer to Symposium 3) aimed to deepen our appreciation of the intentions of a non-human-driven vehicle.

Semiotic systems can be misused as well. As seen in the Fiat Centroventi unveiling in 2019, the vehicle's display panel, refer to Figure 60, is used for commercial purposes, not safety. Even though the intention may be for mixed purposes, the advertising may further confuse the semiotic intention. This raises consumption, safety and public messaging issues, indicating that road authorities must intervene in the appropriate development of vehicle and city semiotic systems.

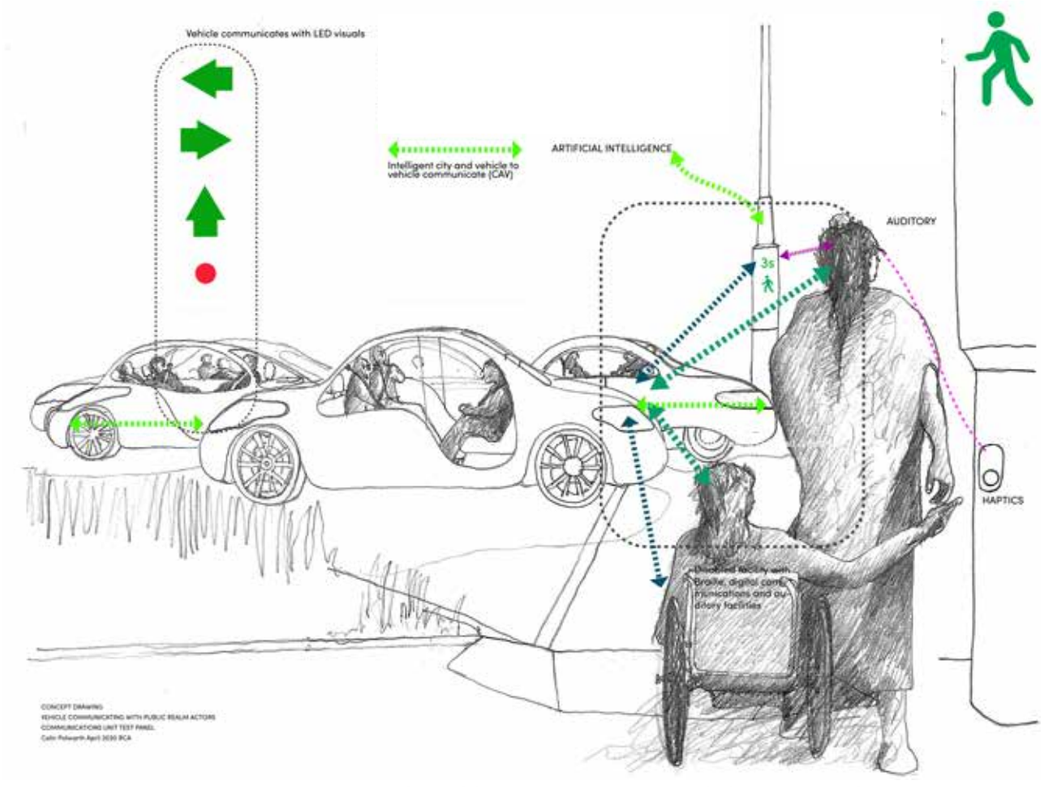


Figure 61: Analysis of the communication networks between people at an intersection.

The sensory systems of the city and the vehicles could be provided in real-time and predictive information to assist the logistical responses. Advanced communications suggests a core objective to reduce confusion and increase safety. City communications could be integrated with personal devices.

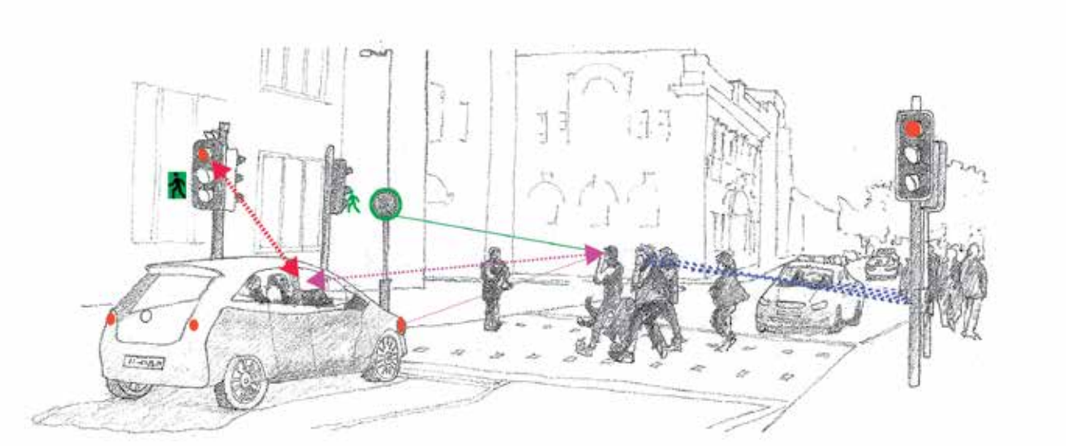


Figure 62: Analysis diagram of the communications between people in the public realm, at a pedestrian crossing.
The analysis assesses the communication between drivers and actors in the public realm. This led to a deeper understanding of the relationship between vehicle communications, city communication and actors in the public realm. The critical role of traffic lights and vehicle indicator lights in combination with driver behaviour, led to further research into vehicle and city communications, including multiple senses and intelligences.

3.4.1 What are we teaching the machines? Semiotics and ecologies in road transport

Actors in the public realm respond to vehicles with drivers in control. Driver intentions are delivered through indicator lights and hand and auditory signals, refer to Figures 61 and 62. Drivers and the public respond to the city system through signs, signals and semi-automated traffic management systems. This is an integrated system that has evolved with the technology and has cultural connections. Increasingly advanced city management systems will augment human intelligence with SI systems.

The Sydney Coordinated Adaptive Traffic System (SCATS)[377] is an area traffic management system consisting of hardware, software and a control philosophy for real-time operations. It adjusts signal timings in response to variations in traffic demand and system capacity as they occur. It manages groups of intersections called 'subsystems', the system's basic unit. In Sydney, the system controls approximately 55,000 traffic lights. The system has been commercialised for use in more than 150 cities worldwide. The commercial and functional success of SCATS in city operations can be regarded as a platform for future AV and SI city systems.

Smart cities utilise sensors and SI to assist with city operations. Simulated models of city operations, such as the digital twin city, and other systems, such as SCATS, are increasingly assisting with multiple transport interface operations for the city. Overall, the semiotic system provides interacting bodies with the legal requirements of the public realm. Safety in the public realm will remain one of the major public health issues, as its implications for society are far-reaching. In Chapters 1.2 and 4.4, I discuss the SCATS system used in Sydney's traffic management, which is also operating in multiple cities worldwide, as an early form of an intelligent city management system.

Systems theory suggests that complex systems, such as a city-wide SI system, require resilience and redundancy built into the system to assist with potential catastrophic failure or simply a particular failure of the system. Redundancy and resilience are also necessary in the application of the planning and predicting models. As noted by Meadows,[378] planning and predicting through simulation are essential aspects of any systemic operations, as well as a

377 The Sydney Coordinated Adaptive Traffic System is an intelligent real-time traffic management platform that monitors, controls and optimises the movement of people and goods in the city. See SCATS Home: https://www.scats.nsw.gov.au/home [accessed 3 November 2023]. 'Sydney Coordinated Adaptive Traffic System', *Transport for New South Wales*, 2023 <https://www.scats.nsw.gov.au/home> [accessed 16 October 2023]

378 Donella H. Meadows, *Thinking in Systems: A Primer* (New York: Chelsea Green Publishing, 2008), p. 275.

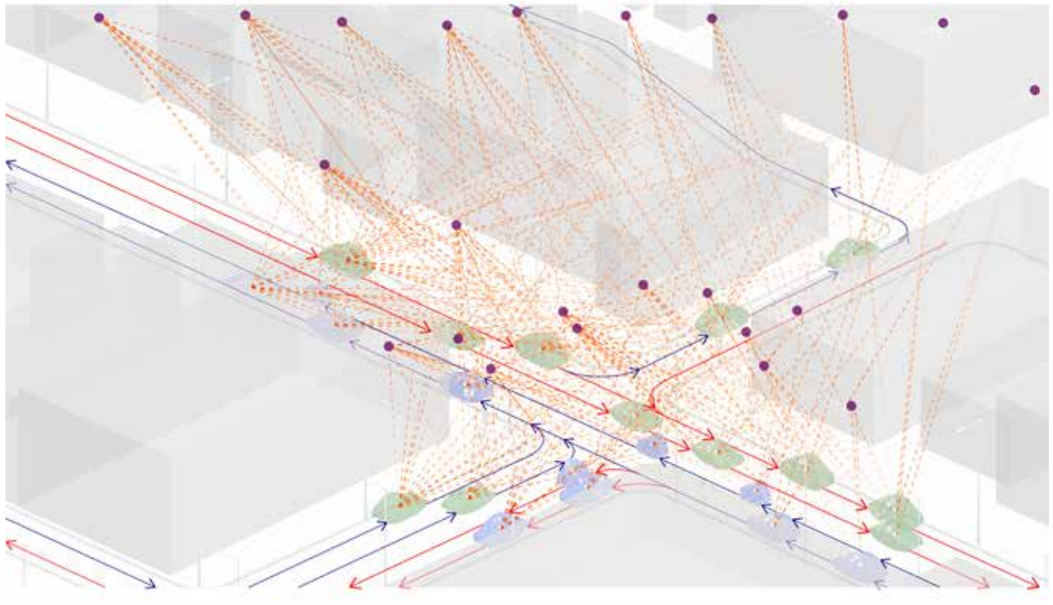


Figure 63: Oblique view of an abstraction of the data and communication pathways between CAREV and city infrastructure as a cloud based system in daylight conditions.

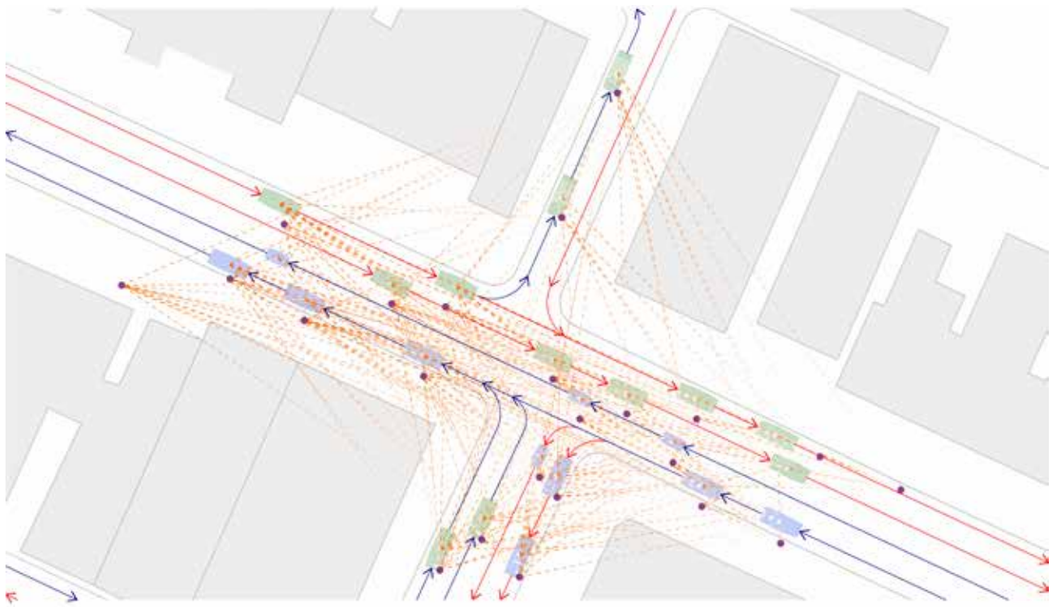


Figure 64: A plan view of an abstraction of the data and communication pathways between CAREV, city infrastructure as a cloud based system in daylight conditions.

The diagram shows vehicle-to-vehicle and vehicle-to-city communications, as well as the sharing of data between vehicles and the city. The dotted lines represent the flow of data between the vehicles, city and actors in the public realm. Refer to Video 1 for the animation..

balancing feedback loop, the result of which either amplifies or moderates the outcomes. Principle 5 covers testing and assessment with transparency of all SI systems.

The body of knowledge and literature about the digital twin city is extensive.[379] The digital twin city is a machine-based simulation of the physical city. It matches the real city's data with dynamic monitoring, real-time diagnosis and accurate prediction of the state of the physical city entity in the real environment. In this process, the city and the model may be calibrated and work together. As a planning tool, its machine-based simulations allow for systemising and assessing impacts in the model, facilitating city design and planning before real-time deployment. The digital twin city was discussed in Symposium 5. In a CAREV environment its semiotic and operational requirements will require super or quantum computing to assist with the huge amounts of data it will need to process to be an effective tool. Refer also to Chapter 1.2, where I introduced the subject.

CAREVs will change current systemic city operations. These are vehicles that operate without human driving and are connected with city operations through SI, computing and algorithms. Pedestrians, cyclists, children, people with disabilities or aged persons in the public realm and people with multiple linguistic requirements in contemporary cities will need to understand the intentionality of CAREVs and vice versa. Abstractions of current communications networks are diagrammatised in Figures 63, 64, 65 and 66.

In *Autonomous and Connected Vehicles,* Paret and Rebaine provided substantial network and communications technical data on this complex area. Their examination of the SAE taxonomy is an important contribution.[380]

Applying complex system theory to integrate predictive models and SI into planning and testing processes in a future CAREV and SI city is important.[381] Dynamic systems are in constant flux, and introducing new elements, such as a new transport mode or climate change, can significantly impact the system. SI can help develop predictive tools to manage these impacts by modelling and assessing potential changes before implementation.

379 World Economic Forum, 'Advancing Urban Development - Digital Twin City', 2024, <https://initiatives.weforum.org/digital-twin-city/home> [accessed 27 February 2024].

380 Paret and Rebaine, p. 16.

381 Fritjof Capra and Pier Luigi Luisi, *The* Systems *View of Life: A Unifying Vision* (Cambridge: Cambridge University Press, 2014), pp. 154–155.

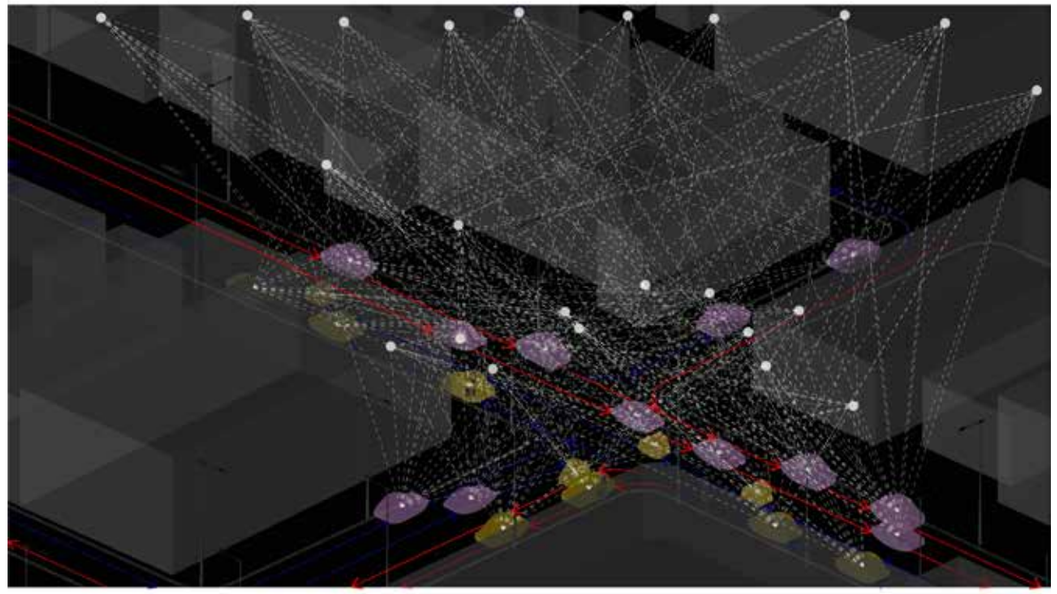


Figure 65: Oblique view of an abstraction of the data and communication pathways between CAREV and city infrastructure as a cloud based system - night time conditions.

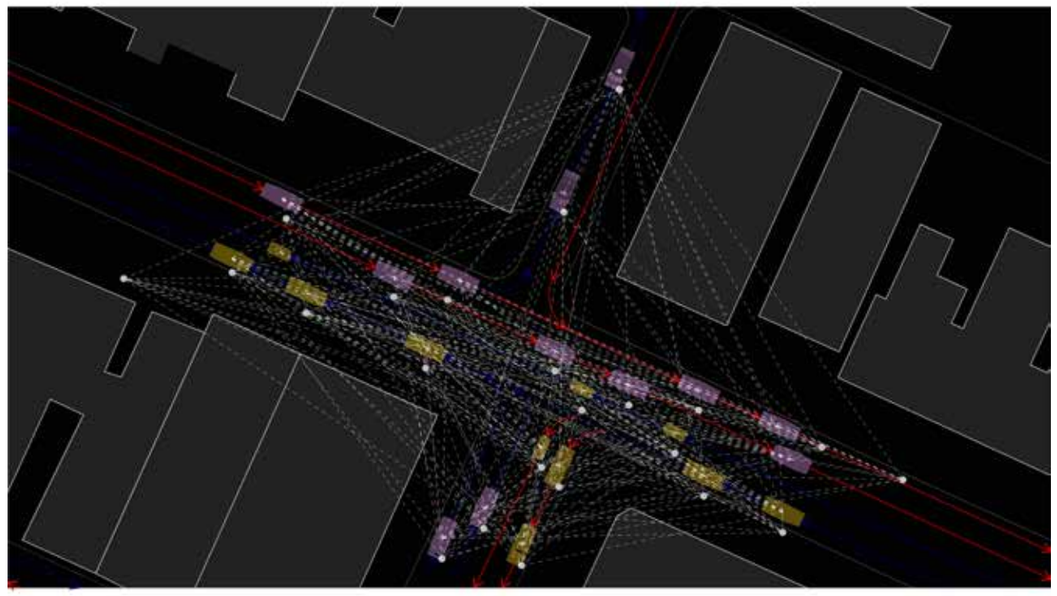


Figure 66: A Plan view of an abstraction of the data and communication pathways between CAREV, city infrastructure as a cloud based system - night time conditions.

In complex systems theory, a practical approach involves dynamic responses that neither strictly adhere to top-down nor bottom-up methods. Instead, it considers responses through a dynamic, complex systems approach. This approach involves modelling, testing and assessing various scenarios to determine optimal results before implementation.[382] In 'Networks Architectures', Paret and Rebaine noted that in 'AI's there are at least 60 families of algorithms available, each of which has an average of 10 sub-groups.'[383] Principle 5 identifies that SI must continuously consult with human intelligence throughout this process and emphasises the significance of transparent testing and assessing of SI systems. It suggests a comprehensive approach to ensuring the effectiveness and reliability of SI systems in managing complex, dynamic environments.

The reductionistic diagram Figures 63, 64, 65, and 66 can be thought of as systems diagrams. The communications network suggests that the sensory information of each vehicle is shared with the next one and with the city. In 'Network Architectures', Paret and Rebaine dedicated Chapters 2.7 to 3.4 - how AVs sense the world through their systems – effectively, how they see the world, including through platooning – and how this information is shared with the city and other vehicles. I concur with their concluding thoughts:

> *The vehicle should now be viewed as a holistic platform, and we should explore the most effective ways to capture data and then safely send those data to the central brain in real time, so as to create a whole vehicle that becomes one huge ADAS (advanced driver assistance system), in which drivers are not obsolete, but are still decision makers.*[384]

Refer to Chapter 1.5, Principle 5 regarding CAREV systems sharing of de-identified data, which this research accepts as a core privacy and confidentiality systems. In Chapter 1.2 the commercial interests of data sharing as part of surveillance capitalism is discussed through the writings of Bratton.

CAREVs must be thought of as integrated with human life and the city environmentally as a holistic system.

382 Jan C. Schmidt, 'Challenged by Instability and Complexity...: Questioning Classic Stability Assumptions and Presuppositions in Scientific Methodology', in *Philosophy of Complex Systems* (North-Holland, 2011), pp. 223–54 <https://doi.org/10.1016/B978-0-444-52076-0.50008-0>.

383 Paret and Rebaine, p 169.

384 Paret and Rebaine, p. 144.

3.5 Understanding AVs and the SI city through Schneider's LoT

William F. Dietrich Distinguished Professor of Philosophy of Mind Susan Schneider, who is also a founding director of the Center for the Future Mind at Florida Atlantic University,[385] is a leader in AI, cognitive science, astrobiology, philosophy, writing and education. In 2019, she presented her most recent book, *Artificial You,* to the US Congress.[386] Schneider's writings provide scholarly and accessible cognitive science and SI approaches to this complex field, which is relevant to SI driving and the relationship between human and SI shared intelligence. I consistently reviewed Schneider's writings throughout the development of the research. The following section reviews Schneider's LoT to understand the role of cognitive sciences and semiotics in the AV/CAV/CAREV field and to answer the research questions about the systemic nature of semiotics through the Capra–Luisi framework and the application of environmental consciousness in semiotics.

In 2011, Schneider published *The Language of Thought: A New Philosophical Direction*.[387] The original LoT hypothesis remains highly influential in cognitive sciences and the philosophy of the mind. Originally published in 1975 and subsequently revisited in 2008 by the philosopher Jerry Fodor, the LoT theory offers a conceptual framework for the computational manipulation of mental symbols.[388] According to Schneider, the established theory had run into self-inflected pessimism. She suggested that the Fodor LoT cognitive program became depressingly futile through its own arguments. Schneider used a reimagined LoT program to find a pathway to argue out of the futility.

ML is the method by which computer systems develop AI. An essential quality of learning to live together requires appreciating the interface between human and synthetic vehicle intelligence. The LoT interrelationship is critical in AV operations in the public realm. Humans in the public realm must understand machine intentionality in multiple vehicles' computational, logistic movements. Schneider's practical, accessible and novel approach reinvigorated the LoT argument. Her approach was revealed through her theory of symbolic MOP, and she took issue with the concept of the brain as only computational. She argued that consciousness includes mindfulness, which steps beyond the algorithmic computational process.[389]

385 Susan Schneider's website is https://schneiderwebsite.com/index.html.
386 Schneider, *Artificial You*.
387 Schneider, *The Language of Thought*.
388 Fodor, *LOT 2*.
389 Schneider, *The Language of Thought*, p. 1.

She clarified her insights by noting that 'numerous cracks have emerged in LoT's conceptual foundation. Its theory of meaning conflicts with its theory of computation; its theory of concepts is too emaciated – too nonpsychological – to be a satisfactory theory of concepts'.[390]

The LoT's program holds that our brains are extraordinarily sophisticated symbol-manipulating devices. The symbols are strung together with an inner grammar.[391] Schneider argued that the three main problems with Fodor's LoT concept were as follows: i) cognitive processing is sequential and ignores biological underpinnings (alluding to consciousness), ii) Fodor did not clarify what is meant by 'symbolic', and iii) the representation model undermines the LoT's ability to explain thought and behaviour.

The LoT program holds that conceptual thinking occurs as an internal language-like representational medium. Furthermore, the mind has numerous mental 'words' called symbols that are combined through metal sentences. Schneider argued that mental pictures of meaning form the grammatical principles of language.[392] Schneider laid out the complexity of the various classical philosophical arguments that have arisen during the 30 years of development of the LoT theory.[393] In the literature on LoT, the relative importance of the complexity has been subject to considerable debate. The wounding arguments about meanings and a propensity for complex computational models have led to a broad philosophical questioning of the whole theory, hence the pessimism she wrote about.[394] Schneider reinvigorated the field and, in so doing, provided a conceptual, theoretical framework to investigate combined human and synthetic intelligence.

In Chapter 2 of the *Language of Thought*,[395] Schneider detailed the relevance of the computational model and opened the chapter with a provocative statement: 'The language of thought program has a suicidal edge'.[396] She then systematically constructed an argument to 'overturn Fodorian pessimism'[397] by pointing out flaws in the argument.[398] She reconstructed her neurological argument, of which she is a leading proponent. The neurological argument is a biological argument for AI consciousness.

390 Ibid., p. x.
391 Ibid., p. 9.
392 Ibid., p. 68.
393 Ibid., pp. 1–25.
394 Ibid, p. 28.
395 Ibid., p 27.
396 Ibid., p. 27.
397 Ibid., p. 28.
398 Ibid., p. 29.

Schneider constructed for the reader an understanding of the nature of algorithms as computational. She discussed the fundamental mechanistic processes. The mental picture of the LoT and its linguistic construct resulted from computational semiotics, which Schneider referred to as the theory of symbolic MOP. Schneider reconstructed the proposal that symbols may be individuated algorithmically as a pragmatic approach in the theory of symbolic MOP.[399] MOP was essentially the core of her new direction. She identified this process as a new direction that she reimagined from the ground up.[400]

In my view, Schneider's LoT establishes an important position about the commonalities of human and synthetic intelligence. It provides clues about how we can build bridges between the apparent chasm of knowledge and a common platform for understanding. In this concept, the LoT is not alien, strange or incomprehensible and becomes familiar, humanistic or even warm. As a key philosophical concept in this semiotic research, it helped guide this aspect of human and machine intelligence interfaces.

Semiotics associated with vehicle rules in the public realm, such as street signs, are pictorial and meaningful.[401] Symbols, semiotics and meaning have specific human and non-human interfaces in AVs and the public realm. The symbols need to be understood, as signified in Peirce's notions of semiotics. The specific symbols, the semiotics of the road and the public realm represent the legal framework of the public realm and its streets.[402] They require a computational appreciation for meaning and responses to occur. While Schneider did not reference semiotics or AVs/CAVs/CAREVs, her insights have provided a granular understanding of human intelligence as computational and semiotic. Through this, we can gain an appreciation of the computational method AVs/CAVs/CAREVs utilise.

In 2020, I wrote to Susan Schneider and asked whether she would participate in a symposium about AVs. She politely replied she had not thought about AVs before. AV technology is nearing reality; therefore, understanding relational interfaces is critical for safety in the public realm. A leading transhumanist made other techno-cognitive and neurological revelations in the same year. Elon Musk, in his infamous hubris-oriented appearance on Computer Network (CNET), a media website in the USA, was asked by the moderator 'if the

399 Ibid., p. 92.

400 Ibid., p. 232.

401 UK Government and Highway Code, *The Highway_code_2022*, 2022, <https://www.highwaycodeuk.co.uk/uploads/3/2/9/2/3292309/the_official_highway_code_-_27-07-2022.pdf> [accessed 13 January 2023].

402 This research focuses on road-based semiotics, signs line markings, variable messaging, and vehicle indicator systems.

Neuralink[403] chip in your brain can be used to summon the future Tesla'.[404] Musk emphatically said yes. Neuralink Corporation is a neurotechnology company that develops implantable brain–computer interfaces. Musk has invested heavily in research at Neuralink and Tesla, which are leading advanced neurological engineering companies.

What emerged from this research was the proposal that we are teaching machines a human-based intellectual system. Schneider wrote:

> *In short, the super-intelligent AI's processing may make some sense to us, and developments from cognitive science may yield a glimmer of understanding into the complex mental lives of certain BISAs (biologically inspired super-intelligent aliens).*[405]

In this context, BISAs are essentially transhumanists.[406]

In Schneider's LoT model, an approach is presented to understand SI intentionality as an algorithmic model. Within it is the computational and semiotic process by which AVs and the SI city and its people can operate and have agency. What is evident from Schneider's LoT is that superintelligence (i.e. SI) utilises semiotics and symbols computationally. In the case of AV technology, it utilises semiotics algorithmically – that is, AVs utilise symbols to assist with synthetically intelligent driving and the hope of advanced safety. This is the essential safety mechanism, the promise of a holy grail of road safety, and it lays the groundwork for human and synthetic intelligence sharing.

A central question for the research is how we will learn to live with AVs in the public realm. The LoT proposes that SI computationally uses the same symbols, syntactical processes and road rules that humans understand. We share the same computational process and semiotics. It is conceivable that we will understand SI intentionality through the commonality of intellectual processes as a systemic approach. A deeper understanding of the two intelligences, human and machine, is necessary to create an appreciation of how the public realm can be made environmentally safer due to a combined synthetic and human intelligence as SI is shared and understood. It is an encouraging, illuminating and optimistic prospect.[407]

403 Play Studio and Elon Musk, *Neuralink Approach: Interfacing with the Brain*, Neuralink, 2021, <https://neuralink.com/approach/> [accessed 5 August 2021].

404 Ibid.

405 Schneider, *Artificial You*, p. 113.

406 Ibid. BISA brains are inspired by those of the original species. Their algorithms may depart from their original biological models at any point.

407 I am aware that a substantial body of research concerning biased optimism exists. This topic was recently discussed by AI leaders in the USA and Europe.

The semiotic technoecology referred to in the hypothesis illuminates the systemic and cognitive approach of leveraging technology to realise positive environmental outcomes. To realise positive ecological outcomes, semiotics is critical to appreciating the environment. I also referenced the notions of ecological oneness between humans and forests by discussing Edward Kohn's *How Forests Think*.[408] The focus of this research is that ML will require a deep appreciation and methods to realise positive environmental outcomes. This includes ML in AVs and their associated city.

Kohn drew on significant novel ethnographic research about Indigenous people, the Avilia of the Upper Amazon, and their functional and spiritual interaction with the forest and its inhabitants.[409] It is deeply insightful research into semiotic systems' potential beyond the human, with relevance to understanding human interaction with the environment. Kohn positioned his research as uniquely semiotic, cognitive and spiritual, with insights into the interdependent and networked relationship between the human and non-human. Kohn discussed the process of thinking about the human and non-human, as well as how forests think and what it is to be human and to think beyond ourselves in emergent terms:

> *Emergence is a technical term I used to trace linkages across disjuncture; beyond is a broader, more general, one. That beyond human language lies semiosis reminds us that language is connected to the semiosis of the living world which extends beyond it. That there are selves beyond the human draws attention to the fact that some of the attributes of our human selfhood are continuous with theirs.*[410]

In my opinion, there is a direct semiotic and cognitive link to Capra and Luisi,[411] who noted that:

> *This spontaneous emergence of order at critical points of instability, which is often referred to simply as 'emergence,' is one of the hallmarks of life. It has been recognized as the dynamic origin of development, learning, and evolution. In other words, creativity – the generation of new forms – is a key property of all living systems.*[412]

408 Kohn, *Forests.*

409 Kohn, *Forests*, p. 33.

410 Ibid., p. 226.

411 Capra and Luisi, *The Systems View of Life,* Chapter 12 Mind and Consciousness p. 252–273, and Chapter 13 Science and Spirituality pp. 275–295.

412 Fritjof Capra and Ugo Mattei, *The Ecology of Law: Toward a Legal System in Tune with Nature and Community* (Oakland, Berrett-Koehler Publishers, 2015), p. 97.

Capra and Luisi discussed the relationship between organisms and the environment, which is based on co-emergence.[413] They commented, 'The great shock of twentieth-century science has been that living systems cannot be understood by analysis. The properties of parts are not intrinsic properties but can be understood only within the context of the larger whole.'[414] This is a significant concept in ecological cognition. Organisms adapting to their environment and the environment adapting to the organisms can be extended to understand the relationship between vehicles, the city and semiotics.

Currently, a high proportion of road users are drivers and, therefore, understand road signs. In the future AV city, over time, cyclists, pedestrians and private mobility users (i.e. non-AV users) will not have any need for or be required to understand road signs associated with vehicles, such as AV trucks and CAREVs.

I now return to the co-evolution of city semiotics. As previously discussed, the evolution of the Highway Code and other similar semiotic-legal road rule frameworks is evident between the 1930s and contemporary times, as seen in the development of the examination procedures that road users are required to undergo to attain a driver's licence. Professor Bryant Walker Smith wrote in the conclusion of his 'Ethics of Artificial Intelligence in Transport' that vehicle manufacturers and operators require community trust to operate in the public realm.[415]

There is a cognitive link between thinking about the environment and acting to assist, which can be found in semiotics. In Barthes' *Elements of Semiology*,[416] he defined signs and meanings that shape our understanding of the world and, by implication, the environment. Thinking about environmental issues creates an understanding or representation of ecologies and the environment. The desire or motivation to take action in response to the representation leads to one addressing the problem or not – this is consciousness.

413 Capra and Luisi, *The Systems View of Life*, p. 143.

414 ibid. Capra and Luisi, p. 44.

415 Bryant Walker Smith, 'Ethics of Artificial Intelligence in Transport', in Dubber, Pasquale, and Das, p. 681.

416 Roland Barthes, *Elements of Semiology*, trans. by Annette Lavers and Colin Smith (New York: Hill and Wang, 1967), p. 41. Refer to the raincoat discussion.

In Symposium 3 – Synthetic chatter or lifesaving semiotics, I asked the attendees whether they thought AVs/CAVs/CAREVs were philosophically transhumanist – that is, part of an intellectual movement advocating for the enhancement of the human condition by developing advanced technologies. The symposium attendees responded that researchers have accepted and moved beyond the notion of transhumanism and that it is an accepted principle of the human condition. The transhumanist agenda about future AVs/CAVs/CAREVs was developed by IMDC MA student Anna Pittrich, refer to Figure 50. The concept of leveraging technology to assist with positive environmental and beneficial social (transport) outcomes, including SI, is essentially transhumanist.

3.6 How does the SAE automation taxonomy limit the technology?

In 2014, the USA-based SAE established its classification systems for vehicle driving automation (updated in 2021/3). The SAE automation taxonomy includes definitions by the SAE committee and the joint working group. During Symposium 3, a panellist suggested that classifications and definitions of AV technology are essential to understand what AV/CAV/CAREV technology can achieve. In Chapter 5.6, I provide a definition that was developed in response to the discussion.

In the SAE international standard J3016 (SAE 2016), vehicle autonomy ranges from 0 (no automation) to 5 (full automation), with the driving system controlling all aspects and modes of driving. A distinction in the taxonomy is between levels 2 and 3, when the automated system takes over an entire dynamic driving task. However, at level 3, the human driver still has a responsibility to intervene at the request of the system. In levels 4 and 5 – high and full automation, respectively – human intervention is no longer required. SAE Level 5 automation (full driving automation) and beyond, is the subject of this research. Refer to the Appendix A for details on the SAE automation taxonomy.

The SAE automation taxonomy classifications are:

- 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 technological definitions are generally internationally accepted by industry and academia. The SAE levels of automation[417] define level 5 vehicle automation as 'an automated driving system (ADS) on the vehicle [that] can do all the driving in all circumstances'. Ellen Edmonds noted that there is also confusion among the definitions of advanced driver assistance technology.[418] Kampshoff and Asutosh[419] provided accessible definitions in the McKensey review of AVs, and Paret and Rebaine provided detailed technical descriptions of the problems with the taxonomy.[420]

The SAE technical report states:

> *Level or Category 5 – Full Driving Automation*
>
> *The sustained and unconditional (i.e. not Operational Design Domain ODD-specific) performance by an ADS of the entire Dynamic Driving Task (DDT) and Dynamic Driving Task (DDT) fallback*

Professor Bryant Walker-Smith noted his concerns with the SAE automation taxonomy in his 2022 critique *Deep in the Weeds of the Levels of Driving Automation Lurks an Ambiguous Minimal Risk Condition*.[421] In the conclusion of his detailed assessment of the stopping and, therefore, safety risks in the SAE taxonomy, he wrote:

> *I hope that the next version also recognizes the difference between a feature's aspirational level of automation and its functional level of automation – a difference with legal significance.*

The focus on driving and driving systems is evident in this taxonomy.

The SAE definition sets out the limitation of automation associated with vehicle performance being equated to human driving: what kind of driving – advanced, good, poor, courteous or rash? As Reed identified in the methodological assessment of Waymo, a quality issue is involved here, which leads to CAV

417 SAE, *Taxonomy*. Refer to Appendix A.

418 Ellen Edmonds, *Clearing the Confusion Coalition Unveils Expanded, Updated Recommendations for Universal Terms for Advanced Driver Assistance Technology*, AAA Newsroom, 26 July 2022, <https://newsroom.aaa.com/2022/07/clearing-the-confusion-coalition-unveils-expanded-updated-recommendations-for-universal-terms-for-advanced-driver-assistance-technology/> [accessed 16 October 2023].

419 Kampshoff and Asutosh, 'Autonomous-Driving Disruption'.

420 Paret and Rebaine, *Autonomous and Connected Vehicles*, pp. 5–19.

421 Bryant Walker Smith, 'Deep in the Weeds of the Levels of Driving Automation Lurks an Ambiguous Minimal Risk Condition' (Stanford Law School, 2022), <https://cyberlaw.stanford.edu/blog/2022/01/deep-weeds-levels-driving-automation-lurks-ambiguous-minimal-risk-condition> [accessed 1 April 2023].

systems.[422] Will we become accustomed to the norm that one manufacturer has polite and excellent driving algorithms, while others are impolite or clumsily rush their tasks but advertise they are advanced systems? It would be appropriate to define excellence in vehicle and city operations and a taxonomy based on excellence in driving and its levels of courtesy with other vehicles and actors in the public realm. Establishing automated driving based on human driving limitations is a severe limitation because human driving has to be the low mark, as evidenced by statistics of death and incidents. AV systems must surely exceed current safety standards (i.e. human-driven safety standards) or not be accepted. I expand on AV driving quality and scenario testing later in this discussion.

In Section 7.1 of the report, the SAE taxonomy also addresses the use of the terms 'autonomy,' 'driverless,' and, 'self-driving,' 'unmanned,' and, 'robotics'. It argues that the term 'automation' is based on the definition in the Oxford English Dictionary. Automation (modified by 'driving' to provide context) is the appropriate term for systems that perform part or all of the dynamic driving task. Using other terms can lead to confusion, misunderstanding and diminished credibility.

The SAE automation taxonomy states: 'In this sense, also, "autonomous" is a misnomer as applied to automated driving technology, because even the most advanced *ADS*s are not "self-governing". Rather, *ADS*s *operate* based on algorithms and otherwise obey the commands of *users*.'

The report suggests the author's preference for not using the popular term rather than clarifying the issues around autonomy. Culturally appropriate terminology is clearer than jargon-laden terms, acronyms and overly technical language.

3.6.1 Assessing the SAE automation taxonomy

It is worth noting that the SAE classification refers to the public domain, cities, streets and regional areas, with the enormous spatial, functional and operational complexities of these areas designated as the ODD. This needs to be improved in the strategic approach to the taxonomy. The ODD is highly complex and requires a deep cultural and social appreciation for technological integration. The ODD classification includes the complex city, the regional

422 UK Department of Transport Centre for Connected & Autonomous Vehicles and others, 'A Review of CAV Safety Benchmarking and a Proposal for a "Digital Commentary Driving" Technique', BSI CAV Programme, June 2021, <https://www.bsigroup.com/globalassets/localfiles/en-gb/cav/bsi-cav-safety-benchmarking-report-2021.pdf> [accessed 15 January 2024]. p. 20.

area, public and private domains, decayed public realms, recreational areas, motorways, feeder routes and local roads. It includes a wide variety of footpaths, cycleways, landscape strips, people, animals, semiotics, communications, traffic management systems, emergency management systems and parking – in short, everything that makes up the public realm and everything within it. The space we communally share is precious.

Therefore, I challenge the SAE taxonomy in the following ways:

1. Overall, the SAE taxonomy is entirely focused on driving systems only. It needs to acknowledge the complexity of the public and private operational realms – the space it calls the ODD. The flaw here is associated with a reductionist approach to the complexity of the natural and built environments. The history of the relationship between vehicles, the environment and the city is dominated by the driving system, which is a pattern of vehicle-oriented dominance at the heart of society's deepest concerns about vehicles and the city.
2. The SAE taxonomy fails to acknowledge the extensive cultural and social literature on AVs developed through myth, fiction, literature, film, animation and oral history and how this has developed aspirations for its use in the public realm. The SAE taxonomy relies on a bland dictionary definition of automation to describe what a global community has been dreaming, writing about and imagining for centuries. The popularly known term 'autonomous vehicle' is culturally understood. I argue that the cultural expectation for the technology is well above what the SAE has classified as automation at level 5. Rather, the cultural expectations of the technology are limitless. For these reasons, the classification system is flawed.
3. The SAE taxonomy focuses solely on the driving task. It fails to acknowledge the quality of the AV's driving ability, its cultural responses, the quality of its interaction with its environment, our complex and treasured public realm. It is as if the driving system operates only from within its reality, a siloed inward-looking driving taxonomy. The SAE automation taxonomy predetermines vehicle-driver dominance, which is a feature of vehicle evolution that has had significant, historic impacts on the public realm, human health, safety and the environment.
4. From the viewpoint of a systemic approach, the taxonomy is flawed by not acknowledging the complexity of its systemic nature. As discussed in this research, siloed specialisations within the vehicle, city and environmental semiotic and behavioural fields will likely lead to systemic flaws.

I return to the Venn diagram of the three research themes in the theoretical framework of the research and its relevance to understanding how the SAE classification system is viewed. The SAE taxonomy needs to meaningfully address the aspects in the semiotic or environmental themes and especially the urban interface. The SAE classification is wholly focused on the technological theme.

In summary, in relation to the three theoretical framework themes in this thesis (refer to Figure 67):

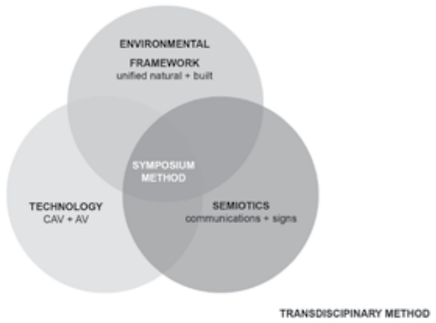


Figure 67: The three research themes and the symposium method as a Venn diagram

1. **Environmental (built and natural)**: the SAE taxonomy fails to respond to complex environmental outcomes. It needs to be more environmentally sustainable, as it fails to address this field. The combined impacts of the current classification system will not achieve desirable outcomes, as the taxonomy fails to acknowledge there will be aesthetic impacts, such as congestion.
2. **Technology:** the SAE taxonomy is an inward-looking, driver-focused classification system. It fails to acknowledge the sociocultural expectations of autonomous systems that developed historically through film, literature, fiction and the collective imaginings of the technology. The classification is focused on the driver and the purchaser of the vehicle rather than wider community concerns with the urban impacts of the vehicles, which may be AVs/CAVs/CAREVs in the future. The potentialities of the technology should be considered limitless (beyond driving), the classification of the autonomy system should be expansive, creative and emergent and should respond to the historic social and cultural desire or 'cultural dream'.
3. **Semiotics:** the classification system fails to acknowledge the public realm user beyond the vehicle and the way SI intentionality communicates with the diverse actors in the public realm. It needs to acknowledge the substantive communications that are required between an AV-driven vehicle and its complex urban interrelationship systemically. It fails to respond adequately to the hugely complex public realm context and its rich diversity. Failing to acknowledge the complexity of the city as one of the great achievements of humanity is a serious oversight. I argue, therefore, that the SAE taxonomy in its current form is unsafe.

I argue that the SAE taxonomy needs to be revised. In its current form, it is unsafe and environmentally unsustainable. The SAE should ensure that multidisciplinary teams are involved in revising the definitions and classification systems and acknowledge how these vehicles are likely to impact our lives and cities.

3.6.2 A limitless AV classification system

The notion of a limitless level of AV classification should be considered in response to the social and cultural expectations of AVs. Systemic integration of CAREV technology with traffic management on city-wide or regional networks may require supercomputing or quantum computing to achieve simulations and modelling to test the systems and establish redundancies. Quantum computing is a type of computation whose operations can harness the phenomena of quantum mechanics, such as superposition, interference and entanglement.

In 2020, Ondrej Burkacky, Niko Mohr and Lorenzo Pautasso from McKinsey wrote an article titled 'Will Quantum Computing Drive the Automotive Future?'[423] From this publication and others (e.g. Roberts[424]), it can be deduced that city-wide communication systems and supercomputing or quantum computing will be necessary components for future CAREV technology deployment to fully realise the benefits of SI in systemic traffic management. This is a key issue, as a systemically operated city- or region-wide traffic management system with a diversity of vehicles can have the features of a public transport modality; that is, it would be a scaled shared platform and may be a disruptor in the orthodox debate about vehicles and the city.

423 Ondrej Burkacky, Niko Mohr, and Lorenzo Pautasso, *Will Quantum Computing Drive the Automotive Future?*, McKinsey, 2020, <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/will-quantum-computing-drive-the-automotive-future> [accessed 11 February 2021].

424 James Roberts, *Hyundai Explores Quantum Computers for Autonomous Driving*, Autovista24, 25 April 2022, <https://autovista24.autovistagroup.com/news/hyundai-ionq-quantum-computers/> [accessed 1 April 2023].

This assessment opened up a research field and presented a hitherto unknown research gap. This thesis defined the technology in response to the Symposium 3 feedback to understand the relationship between humans, AVs, semiotics and the city as a systemic approach.

Associated with quantum computing are mass data systems, such as environmental management systems, air quality modelling, hydrology modelling and traffic, transport and heat island modelling. In 2022, James Roberts, writing for Autovista, confirmed that Hyundai, the Korean vehicle innovator, has invested in quantum computing research to drive the AV platform.[425]

Goodbun wrote in his 2022 publication about ecological semiotics:[426]

> *The ecological wisdom required to understand our relations with eco-mental systems such as Αθηνα[427] asks that we engage with both metabolic and semiotic understanding, remembering that if Αθηνα is driven insane through heat and pollution, its insanity will also be incorporated into the larger system of our thought and experience.*

I argue that the SAE automation taxonomy perpetuates a vehicle/driver-dominant attitude that prioritises the vehicle and disregards broader societal and environmental concerns. I suggest that the SAE automation taxonomy overlooks the historical views of urban design professionals and the ongoing concerns communities raise regarding the impact of vehicles on the public realm. Therefore, I call for a re-evaluation of the SAE automation taxonomy to address the social, cultural and environmental dimensions of AVs.

A transdisciplinary examination of the SAE taxonomy is imperative for policymakers to ensure the social acceptance, safety and ecological sustainability of AVs/CAVs/CAREVs. A new, liberalised AV taxonomy can align better with historical societal and cultural expectations, necessitating community involvement in its development. Such a taxonomy should address various aspects of AV responsiveness, including:

425 Ibid.

426 Jon Goodbun, 'The Ecological Semiotics of Air Pollution and Heat in Athens', in *Taking Action: Transforming Athens' Urban Landscapes*, ed. by N. Kling, A. Roidis, and M. Michaeli (Berlin, 2023), p. 265.

427 Αθηνα tr. Athens, the capital of Greece.

- Communication abilities with diverse users of the public realm and vehicle occupants to enhance safety and environmental outcomes
- Responses to various incidents, encompassing everyday situations and major emergencies, including how CAREVs support emergency services and assist individuals with daily tasks
- Levels of safety, comfort and consideration for both occupants and individuals outside the vehicle and environmental responsiveness
- Modes of communication (e.g. voice, semiotic and haptic) between CAREVs, city infrastructure and users, including backup systems in case of failures
- Ethical, legal and moral considerations guiding CAREV behaviour in different contexts
- The prioritisation of safety, environmental sustainability and social justice in design, manufacturing and operations
- The prioritisation of communication between vehicles, city infrastructure and users to ensure safe and effective interactions in the public realm.

Such a classification system, informed by AVs' social and cultural history, will foster trust and understanding of CAREVs' capabilities.

3.6.3 Recommendations to reformulate the SAE classification system

The following is an approach to re-imagining and restructuring the SAE vehicle automation classification system.

Objective: The current SAE classification system for vehicle automation needs to be updated to provide clearer definitions of automated vehicles (AVs). The goal is to align these definitions with cultural and social norms, regenerative environmental and safety advances making the system more relevant and comprehensive.

Proposed approach: The research method suggests using a transdisciplinary framework—an inclusive and multi-perspective method. The method involves three main steps:

1. Selecting specializations and disciplines: Identify and involve experts from various fields (e.g., technology, social sciences, environment etc,. refer to the diagram) to ensure diverse viewpoints contribute to the updated classification system.

2. Systems filter: The recommendations should be assessed through a filtering mechanism that balances three criteria: A. Environmental: for regenerative ecological outcomes. B. Technical: How practical and feasible the system is from a technological standpoint. C. Semiotic/cognitive: How the system aligns with human behaviour understanding, cultural norms, and communication standards in the public realm.

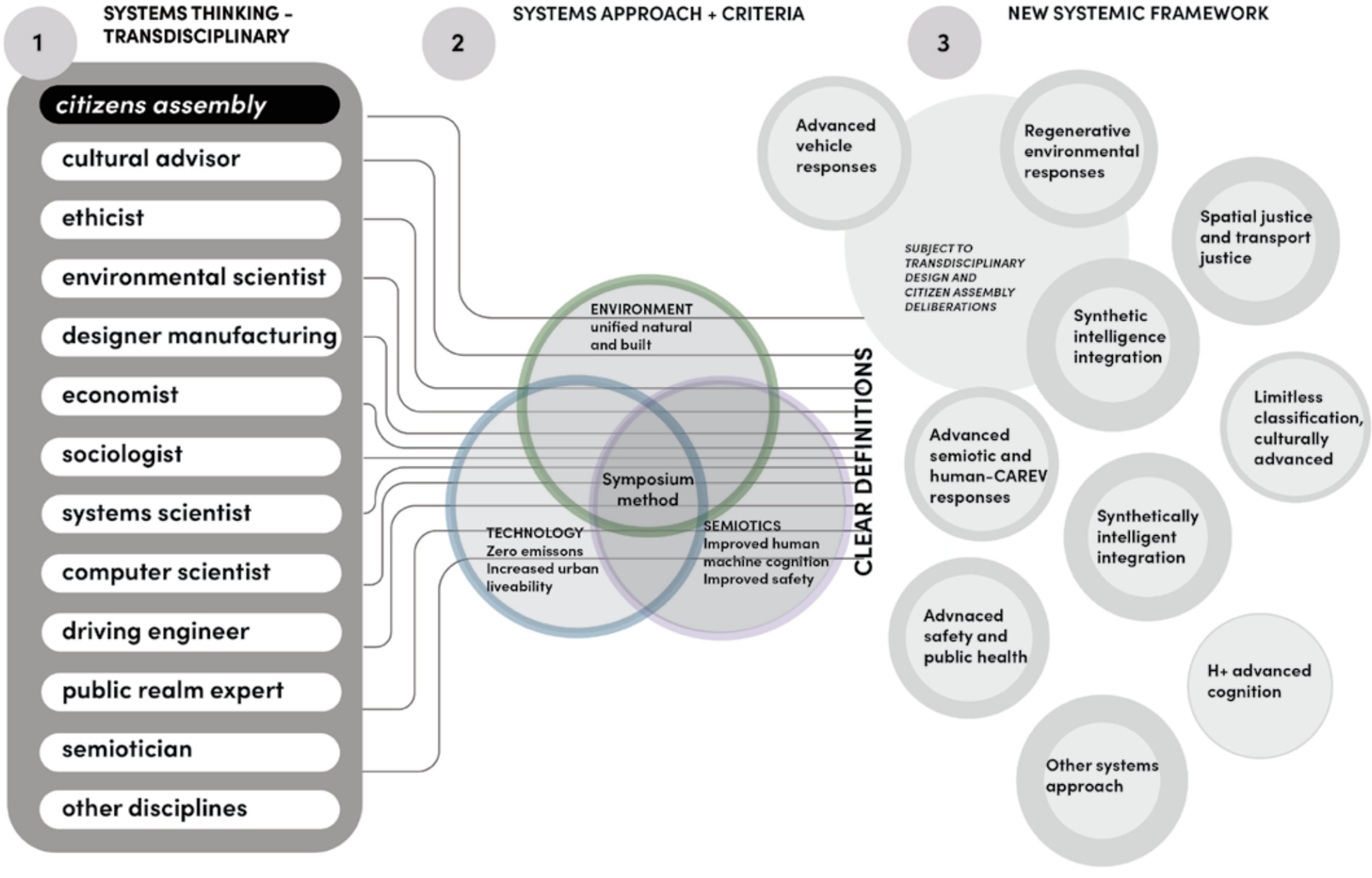


Figure 68: A diagram of a possible framework to assist with the reclassification of SAE vehicle autonomy

3. Holistic Outcome: Develop a new classification system that integrates these perspectives to achieve a balanced, comprehensive framework. The new classifications system must respond to the current concerns of the community at local, state and national levels. These current concerns may change over time and therefore the classification system must be regularly re-assessed. the final filter that is a requisite of the framework is to deliberate the outcomes through a citizens' assembly process,[428] especially in relation to a). environmental (urban and natural), b). technology and c). semiotic and cognitive responses systemically.

Scope limitation: Designing a new classification system is beyond the scope of this research scope. A new classification system would require extensive collaboration with leading experts and stakeholders, underscoring the complexity of the task. In essence, the research emphasises the need for a transdisciplinary, balanced and holistic approach to update the SAE classification system.

Figure 68 is a diagram of a proposal for a framework to assist in restructuring the autonomous vehicle classification system. Part 3, the new systemic framework should be defined by consensus through the transdisciplinary approach and finalised though a citizen assembly process.

428 A Citizens' Assembly is a representative body composed of randomly selected citizens from the population. Its members are tasked with learning about, discussing, and making recommendations on a specific issue or set of issues. The decision to act on these recommendations ultimately rests with elected officials.

'Citizens' Assembly', UK Citizens' Assemblies <https://citizensassembly.co.uk/> [accessed 18 January 2025]

'Citizens' Assembly', Extinction Rebellion UK, 2024 <https://extinctionrebellion.uk/decide-together/citizens-assembly/> [accessed 18 January 2025]

Figure 69: Auslan hand filming with greenscreen for CAREV semaphore display.

3.7 Practice method (mapped to the semiotics theme and symposia)

The research sub-questions and the data to support the symposium method were developed iteratively.

Design experiments in architectural multimedia, drawings and animations, and prototypes were developed between 2018 and 2022. They underwent revision, refinement, redesign, examination and various feedback processes during that period. The inclusion of palimpsest stop-motion animation required patience to repeatedly draw, erase, photograph, draw, erase and photograph and was a contemplative process. For example, at 24 frames per second, five seconds of film required 120 drawings, and most animations required more than 300 drawings each. The introduction of the hand into the process as a thread of knowledge that winds through this research was an important practice statement.

The architectural multimedia practice was influenced by Robin Evans' 'Architectural Projection in Architecture and Its Image.'[429] Anna Hougaard's PhD[430] writings influenced the animated studies. William Kentridge's[431] *Transformation with Animation* influenced the practice. In this context, an inherent quality of the research was animation as spatial, time- and motion-oriented design. As the semiotic requirements of the research became increasingly complex, I adopted computer software to assist with the animations. The animations were developed using AutoCAD, Rhino, 3DSMax and a variety of rendering software.

The purpose of the design experiments, prototype communications panel and animations was to deepen my understanding of how society can learn to live with machines in the public realm through displays and provocative discussions in the symposia. The animations started as one film linked to the research questions. During the process, I mediated the individual animations. The process was not linear or sequential but iterative. The symposium discussion was flowing, unconstrained and culturally sensitive. The symposium method allowed me to examine, re-examine and answer the research questions. Through this exploration, I was able to affirm the circuitous feedback process

429 Robin Evans, 'Architectural Projection', in *Architecture and its Image*, ed. by Eve Blau and Edward Kaufman (Montreal: Canadian Centre, 1989).

430 Anna Katrine Hougaard, 'The Animate Drawing' (PhD dissertation, Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conversation, 2016), <http://annahougaard.com/wp-content/uploads/2017/06/The_Animate_Drawing_web_small.pdf> [accessed 20 January 2022].

431 William Kentridge, 'William Kentridge: Transformation with Animation', SFMOMA, 2005, <https://www.sfmoma.org/watch/william-kentridge-transformation-with-animation/> [accessed 6 August 2021].

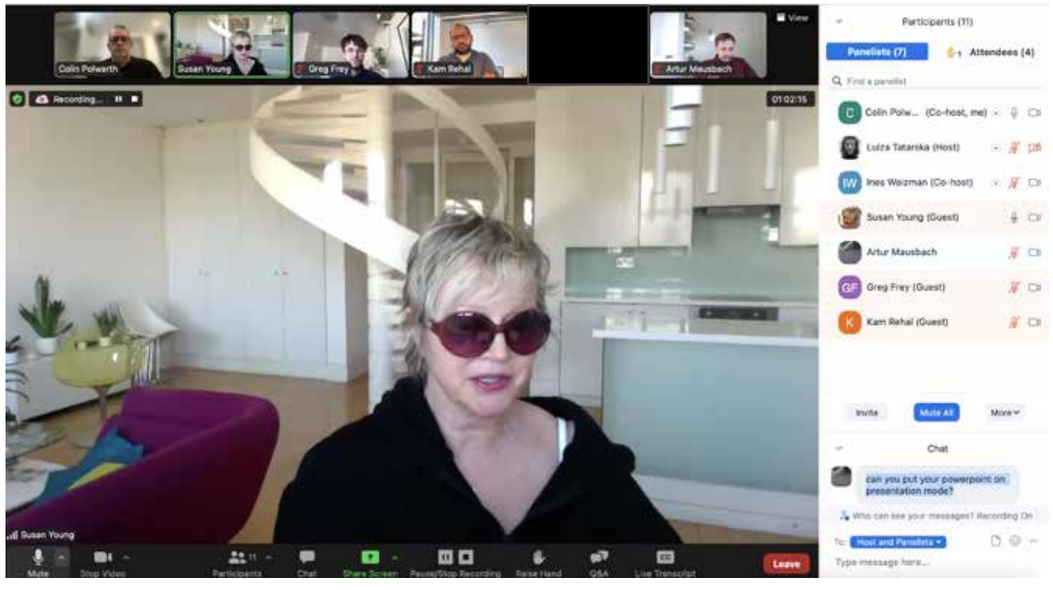


Figure 70: Symposium 3 (4th March 2022): a screen-shot of the online symposium.

seen in the method diagrams as an essential process.

3.7.1 Symposium 3 – Synthetic chatter or lifesaving semiotics

Symposium 3, titled 'Synthetic Chatter or Lifesaving Semiotics', was supported by the RCA SoA and aimed to provide insights into the relationship between humans, AVs/CAVs/CAREVs and the SI city. Recognising the potential for information overload in longer symposia sessions, Symposium 3 was split into two sessions to allow for an open and participatory process with organic and fluid dialogue and to encourage engaging discussion. Previous long symposium sessions appeared to exhaust participants.

The speaker and participant selection process for this symposium was highly detailed and structured as discussed in Chapter 1.6.4, as the subject and symposium was specialised and required relevance to the aim of the symposia. The symposium attracted environmental activists and researchers from within the RCA School of Communications, along with representation from the public. A total of 15 people attended, including speakers, a PhD supervisor and the head of the school program. They were intimate and detail oriented symposia and achieved the aim of being engaging, refer to Figure 70.

Despite the academic subject, this symposium was designed to be creative, direct and warm. The symposium featured animations, experiments and discussions on semiotic communication between vehicles and the people in public realm, captured in Video 2. The design experiments demonstrated the diverse sensory and intelligence-providing information communicated from vehicles and the city to actors in the public realm. The experiments emphasised the importance of effective semiotic systems in future transportation networks and the interrelationship with environmental consciousness. The multimedia provided interest and assisted with the time-based and motion based aspects of the field.

During Symposium 3, the concept of hand signals as a semaphore system for CAREVs was presented. The hand signals were developed in consultation with an Auslan/British sign language interpreter to ensure cultural sensitivity and inclusivity, refer to Figure 69. The idea highlighted the importance of balancing universal semiotic systems with local cultural nuances and meaning. It emphasised the need for an intuitive and culturally sensitive approach to semiotics that is adaptable to local conditions while maintaining message integrity for a globally accepted system as an environmental approach.

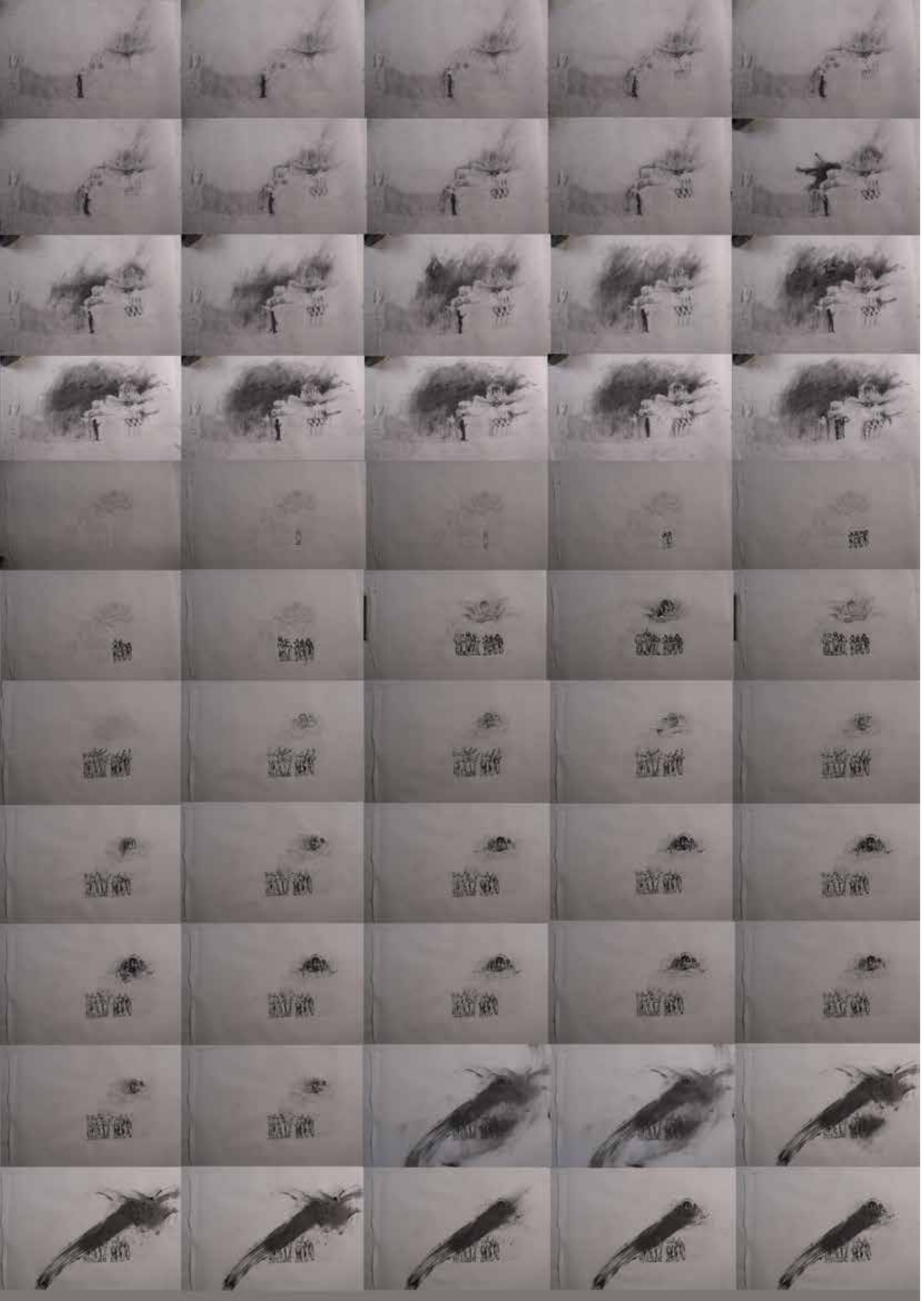


Figure 71: A mosaic of frames from the palimpsest Vimana animation.

This animation was regarded by symposium panellists as too abstract and difficult to understand. The animation is on the www.transfigcav.com.au research interface.

3.7.2 Summary of the various design experiments associated with the research questions

As refining the sub-questions was an iterative process, I frequently had to rewrite the research questions to make them clearer or specific to the meta-question and the responses to cognitive and semiotic considerations. Videos 1 and 2 with their animations and time based content are a mediated form of the animations used in this symposium. The use of animation is part of my practice method as it assists readers to understand the significance of movement in the public realm.

3.7.3 Summary of the animations by the research questions

Animation 1 – Vimana animation

Research question: SB1.6 Do current industry definitions of autonomous vehicles fall below historical, cultural and social expectations?

The speakers discussed the historical field and social expectations of AVs setting up conditions for the industry, and there was a 'sense that the breadth of the literature and history is being glossed over in the race to deploy AV technology.'[432] The audience added that significant safety and social licence concerns appeared associated with AV/CAV/CAREV expectations. During the discussion, a speaker commented that the Vimana animation was 'the least successful of all of the animations, despite its artistic qualities'[433], because of its overtly abstracted content, refer to Figure 71. The speakers noted the flowing and naive quality of the animation as an appreciation of its creative output.

432 This de-identified data validated a position that the research had developed. Validating primary data was a valuable outcome from the symposium process.

433 Feedback from one of the speakers also assisted in providing primary data for the project development.

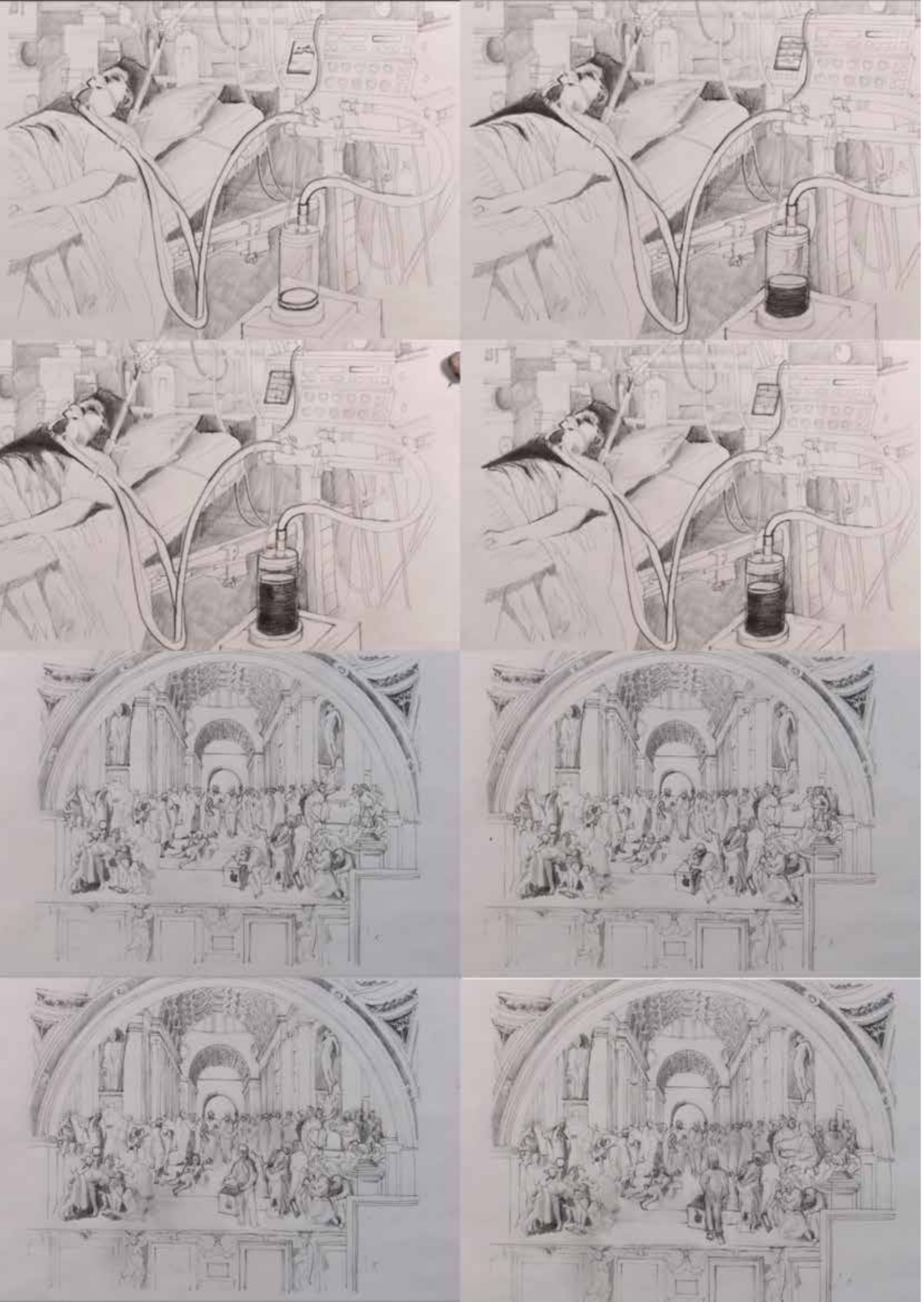


Figure 72: Mosaic of frames from the palimpsest animation 'our relationship with machines' from 'Defining vehicle autonomy'.

The animation is of human dependency on life support ventilators. The animation was displayed online during a Covid lock down in Sydney, it drew strong reactions from the audience and speakers in Symposium 3 related to human dependency on machines.

Animations 2 and 3 – Ethics and synthetic intelligence

Research question: SQ1.6 Do current industry definitions of autonomous vehicles fall below historical, cultural and social expectations? Are the current definitions appropriate?

The animation 'Defining Vehicle Autonomy' was created to stimulate discussions about the definitions of vehicle autonomy, AVs/CAVs/CAREVs, driverless vehicles, SI, algorithms and ethics. This animation aimed to reveal the complexities of challenging the SAE taxonomy through animation. In this animation of an appropriation of Raphael's 'School of Athens,' which is a hypothetical forum of major philosophers, an Apple computer is brought into the school as a metaphor for AI, changing the philosophical discussion, refer to Figure 73.

In the second part of the animation, an intubated person is attached to a life-supporting ventilator and kept alive through artificial means, including the monitoring of breathing utilising SI, refer to Figure 72. Referencing Tomaso Marintetti's *Manifesto of Futurism*, our common dependency on machines is the subject of the animation.

Figure 73: Mosaic of frames from the palimpsest animation 'our relationship with machines' from 'Defining vehicle autonomy'.

An appropriation of the scene from Rubens' School of Athens. An Apple computer is brought in by a philosopher, the synthetic intelligence disrupts the philosophical debate. Refer to Video 1 for the animation.

These two animations provoked a substantive discussion about the fundamental change that SI will cause in society. The speaker commentary linked 'society's inherent need to be involved in the transparent development of the technology and its role in the public realm.'[434] The speakers appreciated the link between the philosophical nature of ethics and CAREVs being elevated in the discussion, especially in relation to society's expectations of the role of SI in the public realm. The animation assisted in the appreciation of the importance of ethical questions, the definition of technology and the role of SI in the public realm.

The animation of the life-support machine was identified by a speaker as *provocative*: 'The reliance of humans in their most fragile state on machines has ethical and environmental implications.'[435] This animation was designed and posted on the interactive website during the pre-vaccine era of the COVID-19 pandemic. During the early stages of the pandemic, computerised ventilators were, for many, the last line of defence against the virus. Making a critical conceptual link between humans, machines and the environment, the animations helped to make ethics a visceral issue.

434 I have paraphrased this conversation as it was lengthy discussion.

435 De-identified data from one of the speakers.

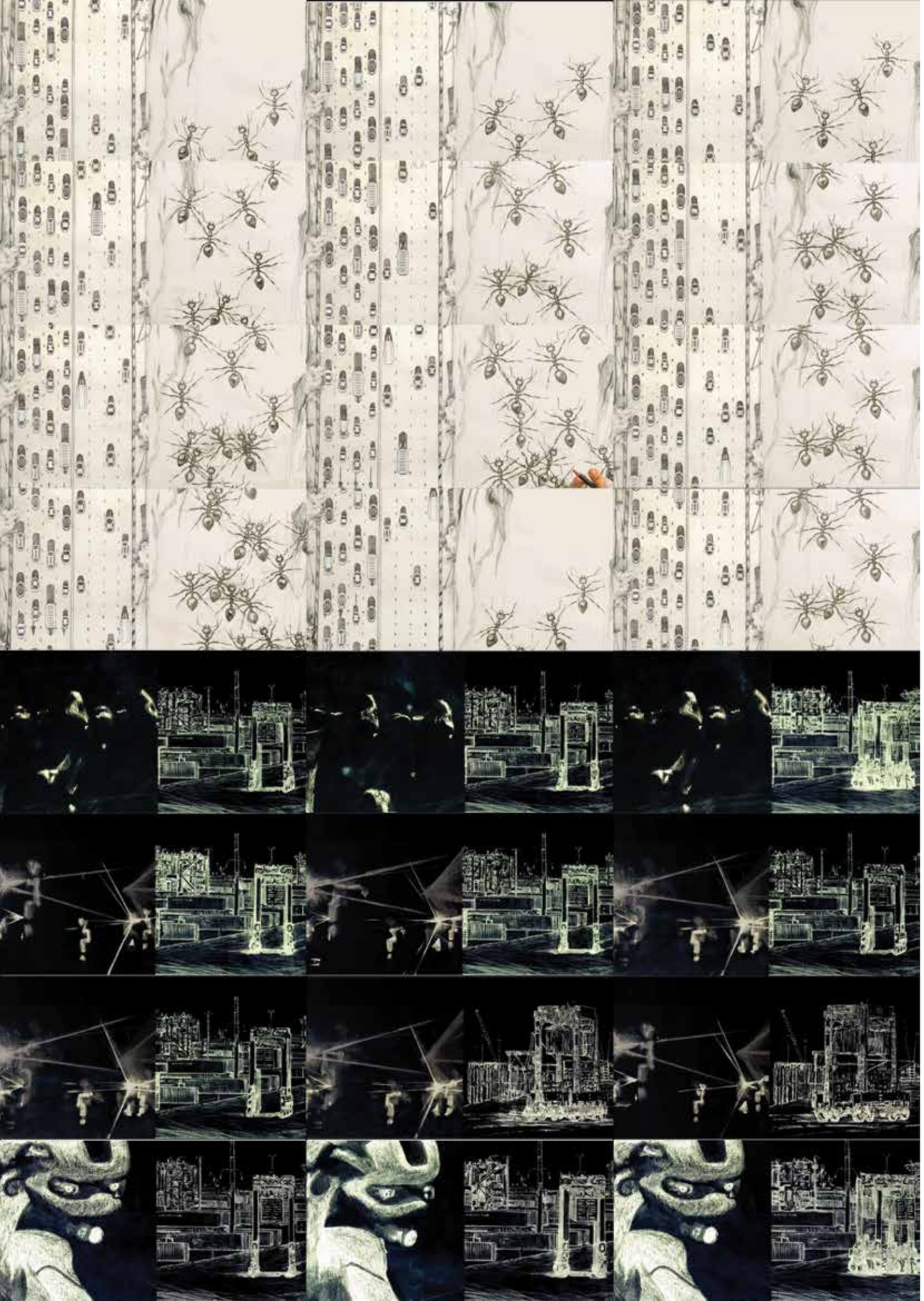


Figure 74: Mosaic of frames from the palimpsest animation of (top) ant colony movement and bottom (robot dancing) similarities.

The top eight frames from the animation compare ant movements to the movements of vehicles on a highway. The bottom eight frames are from the comparative analysis of robotic movement which compares Autostrad cranes at Port Botany with the dancing robots in Mylene Farmer's 2013 concerts. Refer to Video 1 for the animation.

Animations 4 and 5 – Movement similarities

Research question: SQ1.2 Can we co-define an ecological framework in which CAREV and SI technology positively influences the environment?

In Animation 4, the movement systems of the natural world, in the form of an ant colony, are compared with the movement of vehicles on a motorway. This introduces the ideas put forward by Capra and Luisi that upend the notions of a Cartesian divide between the so-called natural world and the man-made world.[436]

Comments by one of the participants were made during the symposium that 'biophilic movement and transport responses, including choreographed and vehicle movement, are areas for future research at the RCA IMDC.'[437] Biophilic movement references Dr Chris Thorpe (RCA) and his work about bird murmurings, which was presented in Symposium 2.

The animation of the ant colony originated from Marco Dorigo and Gianni Di Caro's *Two Ant Colony Algorithms for Best-Effort Routing in Datagram Networks*.[438] Dorigo commented, 'AntNet is a distributed multi-agent system inspired by the stigmergy model of communication observed in ant colonies.' The notion is that human–machine movement and ant movement are part of a holistic system of movement, refer to Figure 74.

In Animation 5, the choreographed movements of the robots used by Mylene Farmer in her 2016 concerts are visually compared with the dance-like movements of the AutoStrad cranes and AVs of Port Botany. The cranes appear to pirouette, as do Mylene Farmer's programmed robots. These emerging intelligences about movement demonstrate that machines and the natural world are integrated. In the context of the Capra–Luisi framework, AVs are environmentally unified, refer to Figure 74.

The speakers identified the ant/motorway animation (4) as 'the strongest of all the animations'[439] in Symposium 3. Animation 4 provoked the most discussion about how ants and vehicles move, as well as their similarities and differences.

436 Capra and Luisi, *The Systems View of Life*, p. 55.

437 Validating research and cross college research undertakings was an essential component of data collection.

438 Di Caro and Dorigo, 'Two Ant Colony', p. 6.

439 De-identified primary data, validation of the animation process as a data tool, and feedback as part of the symposium method.

Figure 75: Mosaic of frames from the palimpsest animation of (CAREV) and city semiotics.

This animation was the initial sketch set of CAREV-S with a digital panel communicating vehicle intentionality with people in the public realm.

The sketching process is a thinking and designing process, and in Symposium 3 this was also used to provoke discussion with the speakers about embodiment as a process of assisting us understand machine intelligence.

The notion that CAREV movements are likely to be choreographed, resulting in an aesthetic change in the public realm, was a novel quality for most panellists or something they had not previously considered. That a CAREV system could be designed to be environmentally friendly was also regarded as a novel or unrealised notion. The attendees agreed that a 'change in vehicle movement (between current vehicle and CAREV movements) will likely provoke a cognitive awareness of environmental conditions and the costs of human movement for the environment more broadly.'[440]

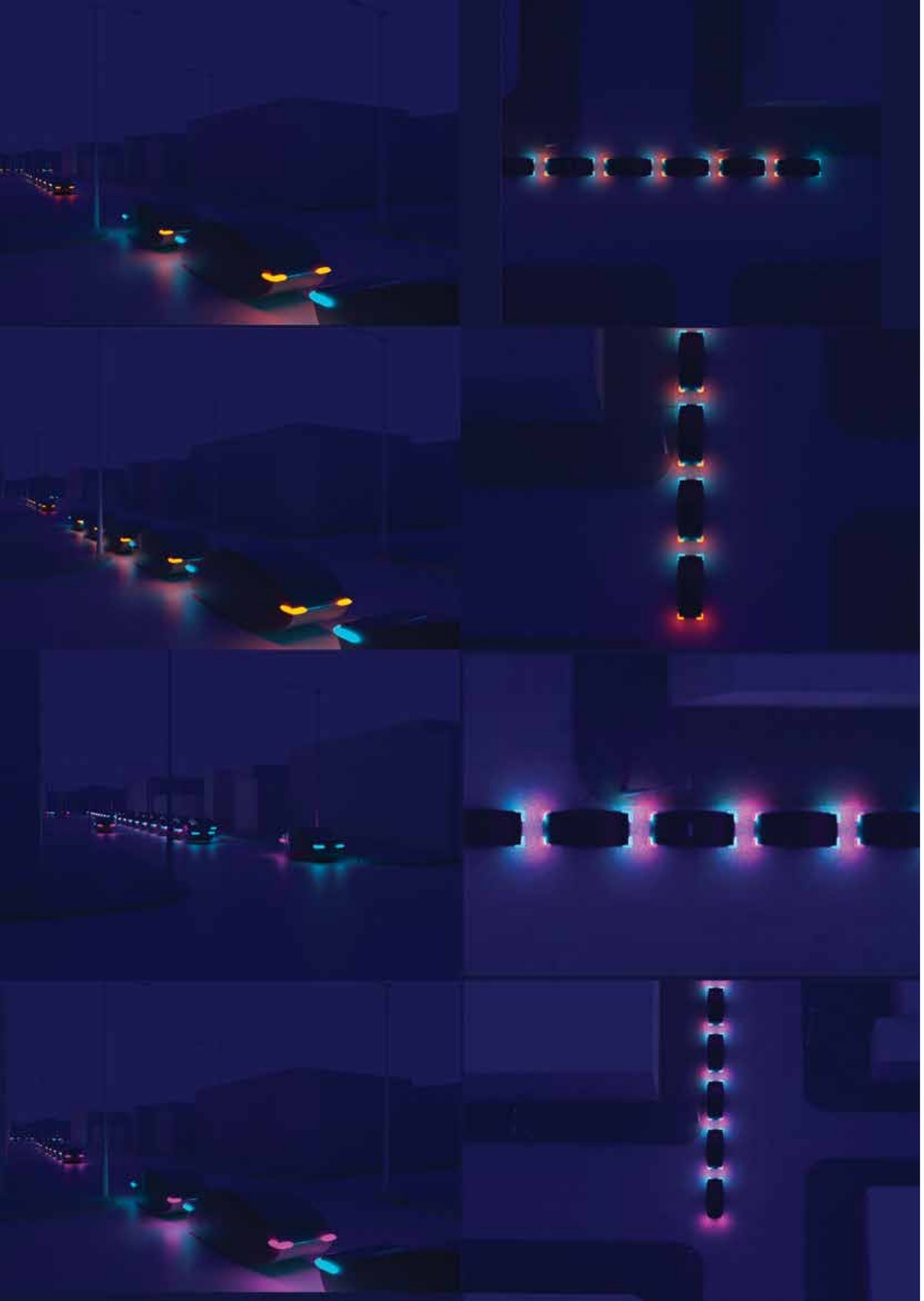
A noteworthy comment from the symposium was that the involvement of communities, choreographers and artists in designing the transport system (i.e. a CAREV system) would make the notion of AVs in the public realm more appealing. The environmentalists discussed nature being in constant conflict and renewal with itself; a continuous battle or a dance of the biological and material emerges.

The animations aimed to provoke and communicate ideas and concepts, refer to Figure 75. The animations were discussed in the symposium with the speakers as experimental design and not intended as final filmmaking. One of panellists suggested 'that the stop-motion drawings enhanced the idea of the experimental design and their quality enhanced the discussion,'[441] achieving the objective of provoking discussion rather than defining an outcome. As experimental tools, the hand-drawn stop-motion animations performed their task and a personalised the presentation. The most crucial aim of the animations in the symposium was to facilitate interesting conversations that evolved from the viewing. The role of the animations in the symposium discussion was identified as critical. I regarded them as part of the tradition of animating as a rehearsal site for AVs as contemplative tools.

This study confirmed that society and specialists can intervene in and co-define an ecological framework for future CAREVs. This process may interest the industry in developing co-design or collaborative dialogue. Communities and leaders must assert their aspiration for CAREV technology to be ecologically sustainable and to positively influence the environment.

440 I have paraphrased this primary data as it was a open-ended discussion between a number of participants.

441 De-identified data collection, validation of the experimental aspects of the data tools and resulting dialogue.



Animation 6 – CAREV communications and the city

Research question: **SQ1.2** Can society intervene? Can we co-define an ecological framework in which CAREV and SI technology positively influences the environment? Can CAREVs reverse current pollution levels and lead to improved public health and safety? Does a change in the fleet from human-driven vehicles to CAREV-S allow for deeper changes in the city fabric, its semiotics and communications. Can a 'systemic semiotic technoecology' arise?

The CAREV-S colour study animations present a CAREV-S that is focused on improved environmental outcomes. 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 Figure 76. Refer to Appendix F.10.1 Colour study. The colour study animation facilitated the symposium discussion and reaction to the prospect of CAREV-S. The approach was seen as beneficial, although concerns were raised about current vehicle consumption practices focusing on larger vehicles as status symbols and for convenience. I return to this discussion in the spatial investigation in Chapter 4, as it forms a major discussion in Symposium 5. The animations used in the symposium facilitated and provoked discussions about 'designing the future transport system with the community, artists, industry and urban designers in a transdisciplinary and integrated manner'[442] to realise the historic cultural aspirations of AVs. As a systemic approach, the semiotic system is a critical component of a future positive ecological outcome that is ethical and cognitive.

Figure 76: Mosaic of the colour study of CAD animation of (CAREV) semiotic animation at night. Refer to Video 1 for the animation.

The purpose of the colour investigation is to understand the aesthetic changes that could occur in the public realm as a result of receding and advancing colour systems as system of environmental semiotics to assist people understand vehicle movement in the public realm.

The discussion in Symposium 3 was related to understanding human interaction with machines as an environmental and semiotic approach.

In the investigations into CAREV communications, the colour systems of the semiotics refer to Figure 76, combined with environmental outcomes are an inherent component of semiotic technology. 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. The animations led to the philosophical approach that semiotic systems should be designed to assist with environmental consciousness. The semiotic systems must respond to the dynamic qualities inherent in complex systems thinking. Making the cognitive link between semiotic systems and positive environmental outcomes can lead to changes in behaviour. A bottom-up approach to the developed system is an important component but needs technical leadership.

442 De-identified data about the animation and experimental design process.

Animation 7 - CAREVs, embodiment and cultural semaphores

Research question: SQ 3.2 How will a systemic semiotic technoecology arise, and what will it look like?

The experimental CAREV communications unit was presented in Symposium 3 as part of the approach to the anthropomorphising of semiotics between SI and humans in the public realm, refer to Figures 76 and 77. The communications unit, refer to Figure 77, is an experimental semaphore display panel designed to be located on the four corners of a vehicle, roughly in the locations specified for vehicle indicator lights. The communication unit aims to advance novel knowledge about dynamic communications between CAREVs and actors in the public realm. My observations of human drivers in their vehicles and actors in the public realm revealed considerable passive and active communication. In 2018, my analysis of hand signals between drivers and actors in the public realm at an intersection revealed several repeating instructions, such as 'left,' 'right,' 'go,' 'stop,' 'thank you' and 'slow down.'

The CAREV communications unit looks back to the history of indicator lights. The first patent by Percy Hamilton-Douglas included the use of the human hand as a semaphore (refer to Chapter 2.5 Social and cultural history of AVs). The communications unit experiments expand this notion of hand uses in signalling as a humanising element. The hands are displayed on the organic light emitting display (OLED) screen as a moving display. This also references the anthropomorphic tassels, refer to Figures 38 and 39, on the corners of Aladdin's magic carpet (refer to Chapter 2.5 Social and cultural history of AVs), which provided precise AV–human communications. Universal hand signals created in consultation with an Auslan actor, whose hands were covered in white hand cream, were filmed on a green-screen background and formed the basis of the digitised experimental semaphores, refer to Figure 69 and 78. The films were run on software for the OLED screen display, and I filmed the results, as shown in Figure 77.

Figure 77: A mosaic of animation frames, from the communications and digital panel showing experimental hand signals as a semiotic animation.

These frames are of semaphores are displayed on the digital communications unit. The semaphores in this mosaic are 'thank you'.

Refer to Video 1 for the animation.

Refer to the Appendix E for the full set of semaphores.

The next step in a more extensive and detailed study is to increase the participation of industry, designers and artists. For example, future studies can include research into colour blindness,[443] as 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.[444]

443 Antonio Tagarelli and others, 'Colour Blindness in Everyday Life and Car Driving', *Acta Ophthalmologica Scandinavica*, 82 (2004), 436–42, <https://doi.org/10.1111/j.1395-3907.2004.00283.x>.

444 National Eye Institute.

Figure 78: Photograph of the magnetic back digital communications unit on a curved galvanised steel backing plate. Test colour display.

The RGBW digital panel is flexible, 12 volt with a controller and DC transformer with connection to a vehicle. The prototype was designed to display dynamic semaphores on the four edges of a vehicle to communicate SI intentionality and cultural awareness to people in the public realm.

The experimental digital unit was manufactured by a specialist lighting engineering firm in Sydney for Australian conditions. It proved to have insufficient illumination in Australian daylight conditions and the software was challenging to operate. The photographs in Figure 78 and Appendix E, are of the semaphores displayed and photographed on the communication unit. The hand signals were first filmed on green screen, converted to data for the digital panel to read and then displayed through the micro-computer that drives the RGBW LED array, the animation is shown in Video 1.

The semaphores allow the CAREV algorithm to communicate vehicle intentionality to the actor in the public realm. Figure 77 shows a photographic mosaic of three display semaphores; the animation may be viewed in Video 1. As an experimental design and communication device, the communications unit was also envisaged to be a teaching unit, refer to Figure 78. Designers can test different displays to achieve optimised or alternative outcomes. However, this was not taken any further at this stage, as it would require additional resources and time to structure detailed experimentation and testing.

This experimental study intended to test the potential uses of such a communications unit for CAREV to understand the role of digital semiotics in the public realm and the aesthetics that may arise. The communications unit was magnetised to bend at the corner of a vehicle, and the sequence of semaphores may be controlled from inside a vehicle. The panel size was 180 mm high x 800 mm wide, established for visibility standards for 50-m viewing (normal optics) in daylight conditions in Australia. In real-life testing, the panel was inadequate in full sunlight and required re-engineering to achieve full daylight visibility. The prototype testing and experimentation stage achieved its aims. Future simulation and understanding of the complexities of visual outcomes in a local context need to be undertaken by specialist lighting and vehicle engineers.

The design experiments were discussed with the speakers during Symposium 3. There was an appreciation for the anthropomorphisation of the CAREV semiotics. One of the speakers commented on the 'romantic cultural link'[445] to the original indicator light patent, which was appreciated as a historical and cultural notion. Culturally appropriate signals can be expanded on a digitised panel and assist with multicultural communications. The speakers also noted an appreciation that the semiotic link to vehicle intentionality could be established through the anthropomorphisation of SI intentionality. This opened a field of communications research that others may investigate. The cognitive link to Schneider's MOP and LoT argument was noted and the 'link between philosophical and practical design based outcomes'[446] established through the audience discussion. There was an appreciation that these semiotic experiments could combine cognitive and aesthetic changes to the public realm that the experiments explored.

445 De-identified primary data provided through the symposium method, the nature of these insights reinforced the cultural and social history approach for the research.

446 Validation comments assisted me with the development of the synthesis of the data.

I bring to this semiotic investigation a reflection. In 2022, Goodbun wrote in 'The Ecological Semiotics of Air Pollution in Athens':[447]

> *Thus Bateson argued that we should think of cities as ecological beings which we are both a part of and which are also a part of us, and he suggested various paradigms for observing, working with and thinking about such extended eco-mental assemblages. Perhaps most well-known, albeit indirectly via Felix Guattari (1989), is the Three Ecologies model. I have shown elsewhere (Goodbun, 2022a) how Guattari, in his 'ecosophy' project, played with and developed Bateson's aesthetico-epistemological framing of three interacting ecological systems: the cognitive organism, that organism's relationship to its collective social ecology, and both of those systems' relations to each other and to the wider web of life.*

447 Goodbun, 'The Ecological Semiotics', p. 256.

3.7.4 Discussion

The participants in Symposium 3 expressed interest in the animations and design experiment, which compared CAREV and ant movements. This was a biomorphic consideration of CAREV semiotics. Its foundations can be found in Dr Marco Dorigo's[448] and Dr Chris Thorpe's research.[449] Re-establishing a philosophical position that humans are part of the ecological system requires that we think and act with environmental consciousness. To act and respond environmentally, we need a constant supply of data that reinforces behavioural responses to the environment. A semiotic system communicating with actors in the public realm is an essential component of changing behavioural responses. An environmental semiotic system can be seen in waste management systems: red, green and yellow waste bin lids form an environmental semiotic system that results in behavioural outcomes.

The speakers at the symposium discussed and assessed whether a fully CAREV environment would require a new communication and semiotic system. The research remains agnostic to the CAREV technology selection (the selection of software/hardware), as this is likely to develop over time. The transition from driver- to machine-driven vehicles is a functional change. A new semiotic system was agreed upon to improve safety. This would allow vehicles and the public to communicate and interact with the SI of the vehicles and the city. The anthropomorphisation of the SI and human interface design experiment showed a pathway – but not the only pathway – to a new semiotic system that assists human and SI intelligence through humanising processes. I expand upon the novel aspects of the semiotic investigation in the conclusion of the thesis and the combined effects of these experiments as part of the synthesis of the semiotic aspects of the research.

448 Gianni Di Caro and Marco Dorigo, 'Two Ant Colony Algorithms for Best-Effort Routing in Datagram Networks', Université Libre de Bruxelles, 11 June 2000, <https://www.researchgate.net/publication/2328604_Two_Ant_Colony_Algorithms_For_Best-Effort_Routing_In_Datagram_Networks> [accessed 15 December 2022].

449 Ibid., p. 6.

A point in the discussion during Symposium 3 was that semiotic, cultural and environmental sensitivities are key components assisting communities to live with AVs/CAVs/CAREVs. The symposium attendees agreed that a semiotic system for AVs/CAVs/CAREVs that communicated ecological information would be desirable. Environmental semiotic data may include distance, availability, congestion, flexibility of routes and multimodal connectivity.

The research highlighted the rich cultural history surrounding AVs depicted in various forms, such as myth, fiction, philosophy, literature, art and film. It underscored a collective image of AVs as imaginative, partly magical, ethical, humanistic, just, ecological, convenient, comfortable, resilient and flexible. Despite the depth of this cultural knowledge through literature, the automotive industry and academia often overlook or downplay the significance of AVs' social and cultural history.

The industry tends to rely on the SAE taxonomy of automation, which categorises AVs based solely on their driving ability without considering social and cultural expectations or environmental impacts. This taxonomy diminishes the importance of public spaces in cities and fails to address the complex cultural aspects and environmental responses associated with AVs. As a result, the classification is deemed unsafe and requires revision.

Future CAREVs should integrate a range of sensory inputs, such as GPS, LIDAR and digital mapping, as well as visual, auditory, haptic and other sensory systems, to increase safety and flexibility. The integrated approach accommodates diverse users and environmental factors and enhances safety and communication effectiveness. To coexist safely and harmoniously in shared spaces, SI and human intelligence must develop interfaces and deepen cultural understanding. This includes acknowledging social justice principles and ensuring effective communication between CAREVs and individuals in the public realm. Overall, a transdisciplinary approach involving experts from safety, engineering, communications, visual arts, environmental studies, cognitive sciences and semiotics is essential for advancing research and development in this field.

Chapter 3 delves into the semiotics of AVs/CAVs/CAREVs and highlights the need for further exploration of the public realm and vehicles as an integrated

system at the international, national, state and local levels. A systemic, integrated and environmentally conscious approach to semiotics may enhance visual and communication outcomes for fixed and movable semiotics in the public realm. An example of this environmentally conscious approach is the concept of a 'green' Uber, where users can select EVs powered by RE, fostering environmental consciousness and responsible decision-making.

Reliable environmental data and effective communication are crucial for promoting ecologically positive behaviours. The transition to responsible environmental management requires a deep understanding of ecological impacts and clear data communication with users, emphasising the importance of environmental considerations in transport, vehicle and city semiotic systems.

Experimental communication and semiotic concepts pave the way for reimagining semiotic systems for future AV/CAV/CAREV realms, as they focus on safety, environmental outcomes and aesthetic integration. By sharing data and integrating logistics and traffic management, CAREV systems can become more flexible and resilient, resulting in positive environmental outcomes through reduced energy use.

Envisioned with circular economy models utilising RE, CAREVs aim to be considerably safer than human-driven systems while facilitating meaningful communication between vehicles and individuals in the public realm. Understanding the human and synthetic intelligence interface is crucial for designing culturally sensitive systems that foster trust and operate ethically.

Future research should explore cultural sensitivities in different cities and leverage transhumanist potential to produce positive environmental outcomes. This involves reimagining the relationship between humans, vehicles and cities to achieve intergenerational equity and ecological improvements. Ultimately, societal agreement on environmental targets and transparent measurement throughout the life cycle of AVs/CAVs/CAREVs is essential for their social licence to operate in the shared public realm.

Synthesising my practice-based knowledge of the impacts of vehicles on the environment, along with insights from the literature reviews in Chapters 2 and

3, and understanding the environmental impacts on cities from Newman and Jennings' 'Cities as Sustainable Ecosystems,'[450] and CAV environmental impacts from Taiebat et al.[451], as well as the varied discussions from symposia 1, 2, and especially the environmental discussions in symposium 3, I have compiled a summary of human and machine behavioural insights about possible direct and indirect benefits that could be achieved through the adoption of AV/CAV/CAREV:

- **Improved safety**: reductions in human error and traffic congestion through enhanced communication between vehicles and city infrastructure
- **Increased mobility**: accessibility for minority groups, such as the elderly and disabled
- **Energy efficiency**: optimisation of logistics through SI systems
- **Productivity and time savings**: decongestion and lifestyle improvements by shifting from driving to other activities
- **Enhanced transportation systems**: improved city and regional mobility and intermodal sharing
- **Potential for shared mobility**: using CAREV systems as a shared transport modality
- **Reduction in parking demand**: decreased need for parking spaces due to more efficient utilisation of vehicles
- **Infrastructure cost reduction**: lower infrastructure spending associated with CAREV-S systems
- **Increase in active transport**: encouragement of walking and cycling, leading to healthier and more environmentally friendly transportation habits.

However, the adoption of CAREVs also raises potential issues and indirect impacts:

- **Employment disruptions**: job displacement in the transportation sector due to automation
- **Ethical and legal challenges**: determining liability in incidents involving SI-driven vehicles
- **Cybersecurity and privacy concerns**: ensuring the security of AV systems to prevent cyberattacks

450 Peter Newman and Isabella Jennings, Cities as Sustainable Ecosystems: Principles and Practices (Island Press, 2008) p. 18–19.

451 Morteza Taiebat, Austin L. Brown, Hannah R. Safford, Shen Qu, and Ming Xu, 'A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles', Environmental Science & Technology, 52 (2018) <https://doi.org/10.1021/acs.est.8b00127> [accessed 5 August 2021], Table 1 p. 11451.

- **Infrastructure changes**: modification of existing infrastructure to accommodate AV technology
- **Capital costs**: initial high costs that may limit accessibility to some users
- **Transportation impacts**: more vehicle movements, additional demands unoccupied vehicles, congestion
- **Dependency on technology**: concerns about resilience and over-reliance on technological systems
- **Regulatory challenges**: addressing ethical and legal implications of technological advancements.

The indirect benefits of CAREVs, especially in terms of environmental outcomes, include:

- **Reductions in air pollution**: decreased emissions of pollutants, such as particulate matter and greenhouse gases
- **Reductions in ozone depletion**: mitigation of ozone-depleting substances used in vehicle systems
- **Reductions in water pollution**: prevention of oil spills and pollutants from roadways into water bodies
- **Reductions in noise pollution**: decreased urban noise pollution from fossil fuel-powered vehicles
- **Reductions in light pollution**: minimisation of light pollution through optimised lighting systems
- **Reductions in global environmental impacts**: lower contribution to climate change and biodiversity loss
- **Systemic health benefits**: improvements in public health due to cleaner air and fewer incidents.

Potential negative impacts, such as land degradation and resource depletion, also need to be addressed.

3.8 Answering the research sub-questions

The following are a summary of the answers to this chapters sub-questions.

SQ3.1 How will a change in the fleet to CAREV allow for deeper combined changes in the city fabric, its semiotics and communications?

A systemic approach to semiotics and urban transformation is crucial for effectively harnessing the benefits and addressing the problems associated with AVs/CAVs/CAREVs. This entails the development of new semiotic interfaces to facilitate communication between humans and SI systems to ensure safety, cultural sensitivity and environmental consciousness. Collaboration among diverse stakeholders, including industry experts, technocrats and visual artists, is essential for designing aesthetically pleasing and environmentally sustainable transportation systems. Moreover, robust regulatory frameworks and international conventions backed by monitoring assessment and continual improvement are necessary to govern the implementation of AV technology and ensure societal acceptance and safety.

The advent of SI driving systems, both at the vehicle and city levels, will significantly reshape urban communication and usage patterns. As humans become accustomed to a future assisted by SI and human intelligence, traditional human-driven signage systems must be updated. This transformation will require individuals to become increasingly aware of their environmental footprints associated with transportation, with SI offering the computational power to assist in this task. Consequently, the urban environment is poised to undergo substantial changes, and communities must deliberate on the extent and nature of these changes.

For example, Sydney's transport authority pioneered the development of city traffic management systems in the 1970s, with the commercialisation of SCATS being a notable achievement. SCATS operates as a demand-driven system using in-ground sensors, cameras and intelligent traffic light systems. Despite their technological advancements, current traffic management systems primarily focus on vehicle management and are developed in tandem with city infrastructure. In a future dominated by CAREVs, these systems would need to integrate seamlessly to navigate the complexities of urban environments and cultural nuances.

SQ3.2 How will a *systemic semiotic technoecology* arise, and what will it look like?

Society's involvement in co-defining and positively influencing the urban environment is imperative and requires techno-political leadership, especially in the realm of AV/CAV/CAREV technologies.

Developing a *systemic semiotic technoecology* that integrates advanced technology with environmental consciousness to enhance the public realm's safety, functionality and environmental sustainability was discussed in the Symposium 3, as a rich and novel research contribution. Such an approach can lead to higher environmental awareness and contribute to creating more resilient and adaptable urban environments with human health and safety benefits. Understanding SI may also reveal insights into human consciousness.

In summary, a systemic approach to semiotics and urban transformation, guided by collaboration, regulation and societal engagement, is essential for realising the potential benefits of AV/CAV/CAREV technologies while addressing their associated challenges and ensuring a sustainable and equitable future.

In Chapter 5.4 - the conclusion, the research vision is presented as a method to understand the future visual implications of CAREV-S, it is not the only solution but rather a pathway to visualising a systemic semiotic technology hypothesis.

The sub-questions are expanded upon in Chapter 5.5 and 5.6 - Answering the research questions.

3.9 Findings

This chapter critiqued the industry definitions of automation within the AV sector and argued that the reductionist SAE automation taxonomy overlooks broader cultural and historical aspirations related to AV technology. The potentialities of the technology should be classified as limitless, responding to cultural aspirations. The AV classification system should appropriately respond to the environment, the climate crisis as well as to its ability to respond to the public realm and everything in it. I assert that acknowledging specific cultural and social events in the history of AV literature can help better understand and define social aspirations for technology. Moreover, it suggested that the SAE automation taxonomy focuses solely on the vehicle's driving abilities, resulting in maintaining the status quo and more of the same creeping, obscure evolution of vehicle technologies impacting humans, cities and the environment.

The discussion delved into the potential role of combined human–synthetic consciousness in shaping future research inquiries, particularly regarding the human–machine interface. Drawing on Susan Schneider's cognitive science research, it proposes a framework for examining the philosophical and semiotic aspects of the human–machine interface, facilitating a deeper understanding of human intelligence and its interaction with machine cognition practically. As demonstrated historically in vehicle design, embodiment is highlighted as a crucial mechanism, but not the only option, for conveying synthetic intelligence intentionality and achieving safety outcomes in the public realm.

The chapter also explored the notion of environmental semiotics and suggested that future semiotic systems should be designed to be aesthetically pleasing, environmentally conscious and responsive to user actions to realise positive environmental outcomes. It drew inspiration from anthropological research on Indigenous tribes' environmental and cultural responses and emphasised the importance of integrating environmental consciousness into urban semiotic systems. The chapter integrated the Capra–Luisi framework and Schneider's reimagined LoT process of human–machine cognitive interfaces through computational semiotics in a practical manner.

Through experimental design and symposium discussions, the importance of creative feedback processes and transdisciplinary approaches in generating new data and expanding knowledge was discussed in an open, positive manner.

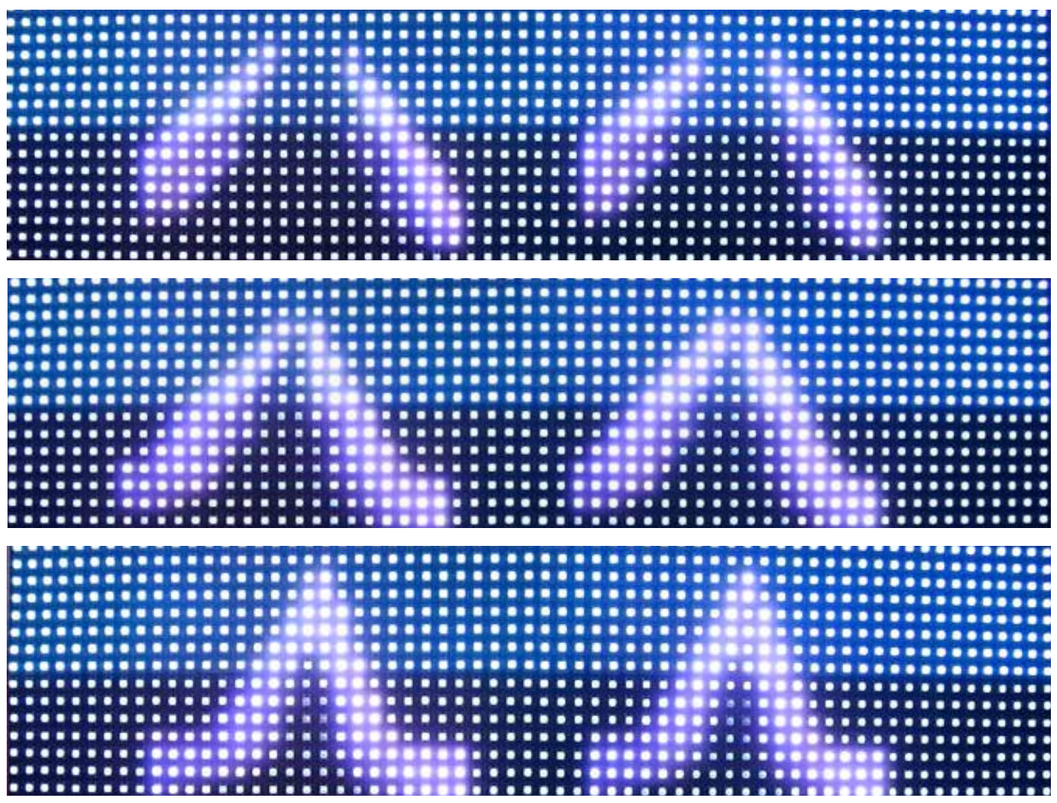


Figure 79: A mosaic of animation frames, ‘Thank You’ on the communications and digital panel

The communication unit with digital display of semaphores as a semiotic animation. These are three frames from the the ‘Thank You’ semaphore. It is a double display as the digital unit wraps around the corner of the vehicle to optimise viewing. Refer to the Appendix E for the full set of semaphores, and Appendix F.10.1 for the colour study.

The symposium method provided invaluable data, controversy, validation and critical assessment through flowing, respectful dialogue for the research. The dialogue process underscored the significance of understanding and integrating cultural aspirations into technological advancements to enhance the resilience, functionality and liveability of urban environments, refer to Figure 79. It also underscored the value of architectural multimedia in assisting in the development of dialogue and supplying new data for research.

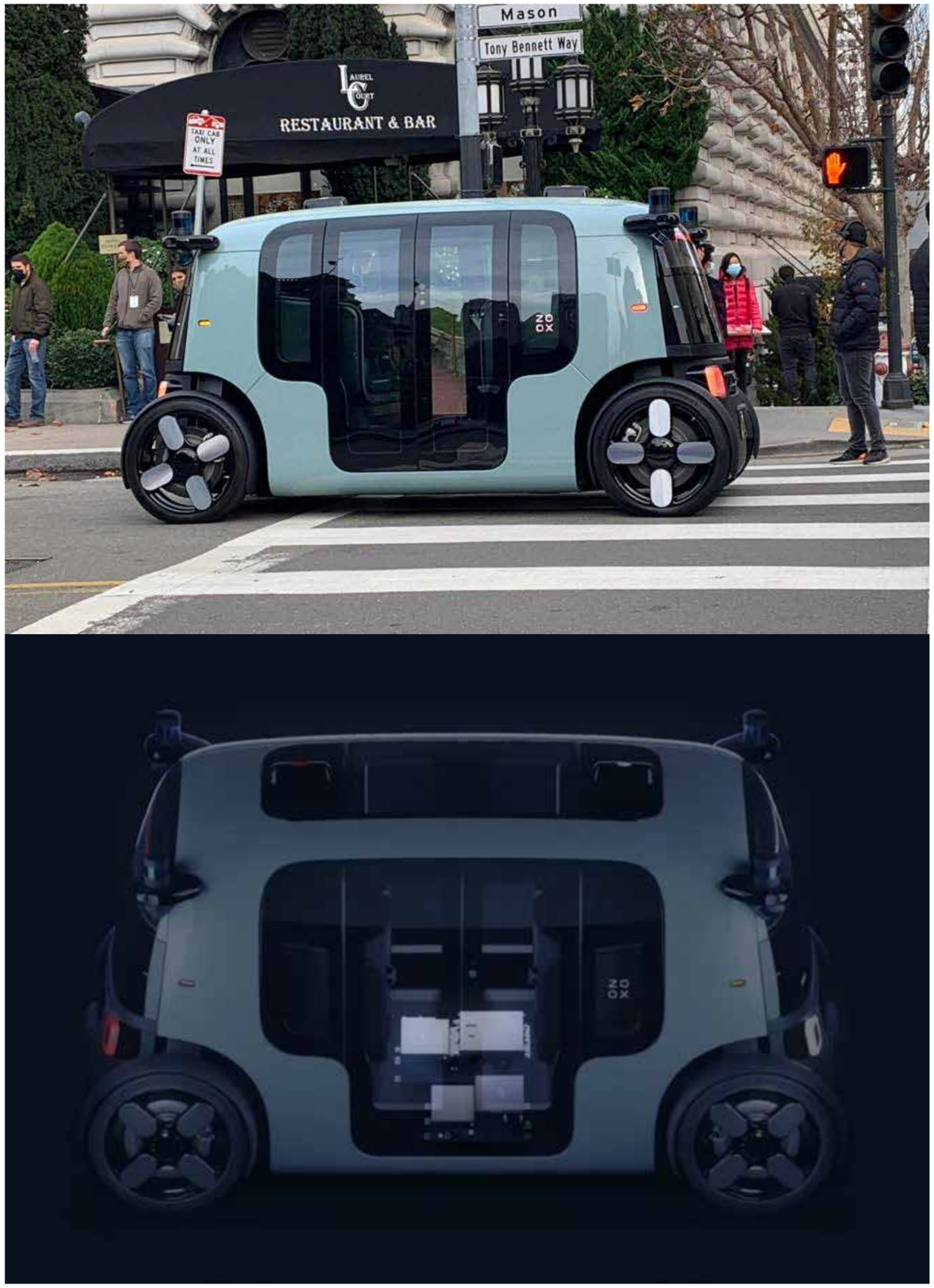


Figure 80: Zoox is an AV design and manufacturing company purchased by Amazon.

Zoox is an example of a robotaxi / MaaS rideshare vehicle. Top image prototype in operation in San Fransisco and bottom image from the Zoox website. Images from Forbes article by Brad Templton in 7 December 2020, supplied by Reddit Lakailb87.

Chapter 4.0 Environmental: Spatial justice with CAREVs

4.1 Introduction and identifying issues

CAREV spatial and environmental justice investigation

This research module aims to investigate and understand how a social and environmental framework should mediate the development of AV/CAV/CAREV technologies and how society can shape future cities, semiotics and mobility concerning evolving and increasing demands for spatial, urban, climate and social justice. This spatial justice investigation is part of a module of research that makes up a larger study that delves into the future of a fully CAREV environment.

During the literature review and symposia, especially symposium 4, it became evident that a considerable amount of research was undertaken by academia and industry worldwide on shared mobilities, refer to Figure 80, and less on privately owned vehicles in the context of city design. It became evident that systemic spatial investigations into the relationships between vehicles, semiotics and their cumulative impacts on the city are needed to respond to urban, climate and social justice demands.

4.2 Research sub-questions in the spatial and environmental justice theme

The spatial investigation research sub-questions included in this chapter are:

SQ 4.1: How can autonomous mobility be beneficial for cities, people and the environment?

SQ 4.2: How can shared mobility promote a fair, equitable and inclusive city?

SQ 4.3: Can regenerative principles in CAREV guide more ecologically and socially just mobility?

SQ 4.4: What are the impacts (negative and positive) of CAREV-S on the public realm?

SQ 4.5: Do spatial studies assist with social and environmental assessments of CAREV and the SI city?

The research sub-questions are answered in this chapter (Chapter 4.9.)

4.3 Identifying knowledge gaps in CAREV spatial studies

Current vehicle agendas, such as larger vehicles, SUVs, trucks and four-seat utilities, which evolve to meet commercial and planned obsolescence agendas of consumption are unsustainable. Vehicles should be designed for environmentally sustainable cities of the future. This requires that the city set spatial and environmental policies for vehicle design and manufacturing.

An example of this approach is the Japanese Kei car,[434] a light vehicle category specified (since 1949 and updated) by the Japanese government in agreement with manufacturers to stimulate vehicle consumption, offering owners lower tax and insurance rates. The light vehicle results in lower fuel consumption. Spatial studies of vehicles and the city need to address these issues.

This research provides tools and strategies for other wider city-related studies, as this is a limited local case study. The road capacity study and UHI study, with their limitations, link vehicle design to the environmental outcomes of the city. This systemic study reveals a new way of measuring climate change impacts and linking vehicles to city impacts.

Smaller vehicles may seem a self-evident spatial statement. Surprisingly, similar systemic studies that take a small vehicle spatial study approach are lacking. Architects and urban designers are ideally located to argue issues of a spatial nature, and they require many tools of their practice to help change the current paradigms.

Policymakers at the local, national and international levels need to be involved in developing this type of research to understand and assess the beneficial and complex implications of the systems approach comprehensively, as there is a lack of knowledge and advocacy in this field.

Applying the Capra–Luisi framework to spatial studies of CAREVs is one of the contributions of this research to the field.

434 'Kei Car', Wikipedia, 2024 <https://en.wikipedia.org/w/index.php?title=Kei_car&oldid=1260968369> [accessed 27 December 2024]

4.4 A spatial justice review of the orthodox debate about vehicles and the city

The literature review is thematically arranged as follows:

1. The orthodox debate about vehicles and the city
2. General research context about AV/CAV/CAREV spatiality
3. Ergonomic and smaller vehicle typology research
4. Spatial justice, vehicles and the city
5. UHI study – increasing active transport or environmental space through CAREVs.

Deepening research into the orthodox debate about vehicles and the city

The orthodox debate about vehicles and the city feels interminable, varied, complex, polemical and heated. Central themes include banning vehicles, providing more public transport and active transport provisions to reduce road congestion and improve environmental conditions, and pedestrianisation. Active transport is self-propelled human movement, including walking, running, cycling and non-motorised transport, including associated transport infrastructure. Since the 1930s,[435] anti-vehicle[436] movements have advocated for increased living densities in city centres, congestion taxing, pedestrianisation, shared zones in which vehicles share space equally with active transport users[437] and excluding vehicles completely from the city.

Counterarguments are similarly dialectical, including those advocating for new road infrastructure to reduce congestion, increase safety and improve productivity. The cited advantages of new road infrastructure include tolling, decongestion and increased productivity and economic opportunities.[438] The principal economic arguments focus on using public funds to improve roads or public transport systems.[439] The arguments are politically and economically oriented due to the magnitude of the economics of construction, operations and tolling opportunities of motorways in urban areas.[440]

435 Jacobs, *Cities*.

436 Adriana Ortegon-Sanchez and Cosmin Popan, 'Car-Free Initiatives from around the World: Concepts for Moving to Future Sustainable Mobility', *Transport Research Board*, (2016), <https://www.researchgate.net/publication/318040518_Car-free_Initiatives_from_around_the_World_Concepts_for_Moving_to_Future_Sustainable_Mobility> [accessed 19 February 2023].

437 Peter D. Norton, *Fighting Traffic: The Dawn of the Motor Age in the American City* (Cambridge: MIT Press, 2011). This book provides information on a variety of approaches to anti-car movements in the USA.

438 Adrian Dwyer, 'The journey towards a fairer road toll system,' *Sydney Morning Herald*, 25 November 2021, Roads edition. This is a recent example of the typical newspaper debate on road tolling systems.

439 Giulio Mattioli and others, 'The Political Economy of Car Dependence: A Systems of Provision Approach', *Energy Research & Social Science*, 66 (2020), <https://doi.org/10.1016/j.erss.2020.101486>.

440 Australia Department of Transport and Regional Services and others, *Estimating Urban Traffic and Congestion Cost Trends for Australian Cities* (Canberra: Bureau of Transport and Regional Economics, 2007).

Governments of various persuasions swing between policies and opportunities and exploit local issues as suited to the peculiarities of the location and community.

Some community action groups in Australia are vehemently opposed to new motorway projects.[441] These stakeholder groups have influential dissenting voices. For example, the Public Transport Users Association (Victoria, Australia) wrote an article on 22 February 2022[442] titled 'Myth: Self-Driving Cars Will Cut Congestion and Make Public Transport Obsolete'.[443] Pressure from local communities for low-traffic neighbourhoods suggests that car space will be dramatically reduced in many cities in the coming years. However, there are counterarguments to the low-traffic environment movement, including reduced connectivity and rat running.[444] In 2021, McKinsey and Company produced a report on 25 global cities and their assessments of the increased quality of urban transportation systems and the liveability measurements of cities with higher public transport offerings. They noted that efficiency, safety and environmental outcomes are the benchmarks for sophisticated transport.[445]

Unexpected outcomes are also the subject of much debate and discussion among transport journalists and urban planners. Adam Mann's article 'What's Up with That: Building Bigger Roads Actually Makes Traffic Worse'[446] notes the unreasonable outcome of building more infrastructure to resolve congestion. The spatial investigation in this research discusses the adverse outcomes of CAREV-Ss, as there are potential advantages, disadvantages and paradoxes. However, the research's approach is that a novel technology and novel spatial investigation can shift thinking and, therefore, the orthodox debate. Presenting new opportunities and discourse does not resolve the issues but perhaps provides opportunities to learn from and improve the current circumstances and to open dialogue in siloed fields.

441 Transport Action Network, Our Transport, 2023, <https://ourtransport.org.au/community-action-groups/> [accessed 21 March 2022].

442 *Myth: Self-Driving Cars Will Cut Congestion and Make Public Transport Obsolete*, Public Transport Users Association, 2022, <https://www.ptua.org.au/myths/robotcar/> [accessed 22 February 2022].

443 Summarising the Public Transport Users Association Victoria's position: 'It's almost certainly untrue that robot cars will have any positive effect on urban traffic congestion.'

444 *Rat Running*, Wikipedia, 2024, <https://en.wikipedia.org/w/index.php?title=Rat_running&oldid=1193499911> [accessed 12 January 2024].

445 McKinsey and Company, Detlev Mohr, Vadim Pokotilo, and Jonathan Woetzel, 'Elements of Success Urban Transportation Systems of 25 Global Cities', McKinsey, 2021, <https://www.mckinsey.com/~/media/mckinsey/business%20functions/operations/our%20insights/building%20a%20transport%20system%20that%20works%20new%20charts%20five%20insights%20from%20our%2025%20city%20report%20new/elements-of-success-urban-transportation-systems-of-25-global-cities-july-2021.pdf> [accessed 12 January 2024].

446 Adam Mann, 'What's Up with That: Building Bigger Roads Actually Makes Traffic Worse', *Wired*, 17 June 2014, <https://www.wired.com/2014/06/wuwt-traffic-induced-demand/> [accessed 22 March 2004].

Two decades ago, in 'The Tragedy of the Highway: Empowerment, Disempowerment and the Politics of Sustainability Discourses and Practices', Guy Baeten[447] commented on similar issues[448] in relation to a Flemish study of a highway in Ypres and Furnes. In his article, he noted a critical reflection regarding the pacifying words 'sustainable transport'.

He argued that this phrase is part of the orthodox vision that leads to the established empowerment of technocratic principles and elitist groups in society. The pacification aids the de-legitimisation of minority social groups, including environmental groups. 'Sustainability' is increasingly used in greenwashing discourse.[449] However, the climate crisis has worsened and made the debate poignant. An example is the Conde Nast article about Greta Thunberg's guide to being climate-positive.[450] As David Smith of *The Guardian* pointed out, there are 'anti-Greta' trends in response.[451]

I argue that CAREV-Ss and the intelligent city may shift thinking through design by introducing new variables. There is considerable academic research and focus on MaaS and shared AV transport mobilities (refer to Symposium 4, Karmargianni,[452] Nikitas,[453] International Transport Forum[454] Fagnant and Kockelman).[455] The behavioural disruption of technology, business practices and environmental politics offers an opportunity to reimagine the spatial debate if developed systemically and through careful, thoughtful design. The research and design spatial investigation of smaller vehicles (i.e. CAREV-Ss) and the future intelligent city introduces three new variables into the debate, as discussed in the spatial study.

447 Baeten, 'The Tragedy of the Highway'.

448 Ibid., p. 70. 'There are, so to speak, as many definitions of "sustainability" as there are authors publishing on the topic (see, for instance, Franks, 1996; Basiago, 1995; Naess, 1995)'.

449 Nadira Razzhigaeva, *What Is Greenwashing and Why Is It a Problem?*, UNSW Sydney, 2022, <https://newsroom.unsw.edu.au/news/art-architecture-design/what-greenwashing-and-why-it-problem> [accessed 26 August 2023].

450 Condé Nast, *Greta Thunberg's Guide to Being Climate Positive*, CN Traveller, 2022, <https://www.cntraveller.com/article/greta-thunberg-on-how-we-can-be-climate-positive-travellers> [accessed 12 January 2024]

451 David Smith, '"Anti-Greta" Teen Activist to Speak at Biggest US Conservatives Conference', *The Guardian*, 25 February 2020, section US news <http://www.theguardian.com/us-news/2020/feb/25/anti-greta-teen-activist-cpac-conference-climate-sceptic> [accessed 28 February 2024].

452 Maria Kamargianni, Weibo Li, Melinda Matyas, and Andreas Schäfer, 'A Critical Review of New Mobility Services for Urban Transport', *Transportation Research Procedia*, 14 (2016), 3294–3303, <https://doi.org/10.1016/j.trpro.2016.05.277>.

453 Nikitas, Alexandros, Ioannis Kougias, Elena Alyavina, and Eric Njoya Tchouamou, 'How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-as-a-Service Shape Transport Futures for the Context of Smart Cities?', *Urban Science* 1, (2017), 36, <https://doi.org/10.3390/urbansci1040036>.

454 International Transport Forum, *Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic, International Transport Forum Policy Papers, No. 6* (Paris: OECD Publishing, 2015, <https://doi.org/10.1787/5jlwvzdk29g5-en>.

455 Daniel J. Fagnant and Kara M. Kockelman, 'The Travel and Environmental Implications of Shared Autonomous Vehicles, Using Agent-Based Model Scenarios', *Transportation Research Part C: Emerging Technologies*, 40 (2014), 1–13, <https://doi.org/10.1016/j.trc.2013.12.001>.

As Christine Ro of the BBC pointed out in 'How to Make Cars Less Dangerous for Pedestrians', 'So one thing we have to do is think about how we design vehicles, and one way to do that is through regulation'.[456]

Several studies, such as the OECD report[457] and the work of Wadud and others,[458] identified energy efficiency benefits that range from 15% to 40%, depending on various parameters, with modelling studies based on fossil-fuelled CAVs. Philippe Crist and Sharon Masterson, coordinators of the related OECD AV publication, provided modelling for two traffic data sets and a summary acknowledging that policy choices will change outcomes. They stated, 'In all cases examined, self-driving fleets completely remove the need for on-street parking'[459], while the model ignores social needs and desires, which may include the convenience of parking outside of residences. Industry coalitions, such as Partners for Automated Vehicle Education[460] and the ADVI[461] among others, cited the multiple benefits of CAVs/AVs.

In his 2012 publication *Flexibility and Ecological Planning: Gregory Bateson on Urbanism*, Goodbun wrote:[462]

> *Equally, while today there is a growing body of design research theorising cities as urban ecologies and metabolic systems, much of our thinking around environmental sustainability and the politics of resource allocation remains problematic, especially when based upon narrow quantitative and technocratic methods. Developing a critical socio-ecological understanding of global urbanism remains a key challenge. Perhaps we might develop out of Bateson's thinking some new tools and suggestions towards a new kind of learning process, an experimental socio-ecological practice in which we recognise that 'the ecological ideas implicit in our plans are more important than the plans themselves, and it would be foolish to sacrifice these ideas on the altar of pragmatism.*

456 Christine Ro, *How to Make Cars Less Dangerous for Pedestrians*, BBC News, 10 October 2023, <https://www.bbc.co.uk/news/business-66912123> [accessed 4 November 2023].

457 International Transport Forum, *Urban Mobility System Upgrade: How Shared Self-Driving Cars Could Change City Traffic*, OECD Library, 2015, <https://doi.org/10.1787/5jlwvzdk29g5-en> [accessed 19 January 2023], p. 28.

458 Zia Wadud, Don MacKenzie, and Paul Leiby, 'Help or Hindrance? The Travel, Energy and Carbon Impacts of Highly Automated Vehicles', *Transportation Research Part A: Policy and Practice*, 86 (2016), 1–18, <https://doi.org/10.1016/j.tra.2015.12.001>. They stated, 'We explore the net effects of automation on emissions through several illustrative scenarios' (p. 1).

459 ibid. Crist (p. 5)

460 Partners for Automated Vehicle Education, 2016, <https://pavecampaign.org>/ [accessed 19 January 2023].

461 Australasian Driverless Vehicle Institute, <https://advi.org.au/> [accessed 19 January 2023].

462 Goodbun, *Flexibility*, p. 55.

The key point here is that a system that may be considered highly efficient and stable in conventional terms quickly becomes unsustainable and non-robust, as it cannot change and adjust to environmental shifts. Adaptation and learning require flexibility and movement – a lesson that speaks to the design of everything, including software, buildings, cities and global economies.

General research context of AV/CAV/CAREV spatial justice

In this research, spatial justice is both a product and a decision-making process. The contested public realm, and especially road space, references John Rawls' *A Theory of Justice*[463] regarding the redistribution of geographies. David Harvey in 'Social Justice and the City', writes 'Social justice is a particular application of just principles to conflicts which arise out of necessity for social cooperation in seeking individual advancement.'[464] Harvey illuminates in the 'Right to the City.'[465] The decision-making justice provision references Iris Marion Young's *Justice and the Politics of Difference*,[466] which is a book on transportation policy and how to set targets and goals that redistribute space justly. The public realm is a highly contested space, and the rights to the space are of interest to all sectors of society.

The EU is a leading international authority on road transport systems. Its leadership partly stems from the high use and manufacturing of vehicles in Europe and its long history of urbanisation. The EU stands in contrast to the United States of America and Asian authorities in its approach to road transport systems, notably on questions of social justice.[467] According to a report by Raposo and others published for the EU titled 'An Analysis of Possible Socioeconomic Effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe',[468] various CAV studies show that this technology promises to contribute to fewer negative impacts from road transport while generating new mobility paradigms and transport governance opportunities. The EU report sets out environmental outcomes (e.g. cleaner systems and decarbonisation) and equitable/sharing such as that shown in Figures 80 and 81 (e.g. social justice-related issues), commenting, 'It is expected that EU transport activity will continue to grow in the coming decades, *with road transport maintaining its dominant role*'.[469]

463 John Rawls, *A Theory of Justice* (Cambridge: Harvard University Press, 1971).

464 David Harvey, Social Justice and the City. London: University of Georgia Press, 2009. p97

465 David Harvey, 'The Right to the City.' New Left Review, no. 53 (2008) p. 23.

466 Young, *Justice and the Politics of Difference*, pp. 73–89.

467 European Commission, *The Future Development of the Common Transport Policy: A Global Approach to the Construction of Community Framework for Sustainable Mobility* (Luxembourg, European Commission, 1993), https://op.europa.eu/en/publication-detail/-/publication/67d2cd43-9740-42b0-8ba8-e759d36f3109 [accessed 18 October 2021], p. 15. 'Settlements have very diverse demographic structures, requiring mobility systems that can be adapted to become more inclusive and accessible to everyone.'

468 Maria Alonso Raposo and others, *An Analysis of Possible Socio-economic Effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe - Effects of Automated Driving on the Economy, Employment and Skills* (Luxembourg: Publications Office of the European Union, 2018), p. 150 <http://dx.doi.org/10.2760/777>

469 Ibid., p. 42.

Figure 81: Vehicle designer/manufacturer Cruise's concept vehicle 'Origin'.

Photographer: David Paul Morris/Bloomberg. This is a typical example of a MaaS-type AV, effectively in minibus format. 'Waymo, Cruise and Zoox Inch Forward Ahead of Tesla Joining Robotaxi Race', Bloomberg.Com, 15 April 2024 <https://www.bloomberg.com/news/newsletters/2024-04-15/waymo-cruise-and-zoox-inch-forward-ahead-of-tesla-joining-robotaxi-race> [accessed 13 May 2024]

As Raposo and others asserted:[470]

Vehicle automation will act as a transformational technology in the freight transport sector by diminishing operating costs and allowing more efficient logistics. These benefits would justify the idea that this sector becomes one of the early adopters of CAV technologies. The two most costly elements in commercial vehicle operation are fuel and drivers, both of which can be reduced through truck automation.

The report also states that 'inequality between low-skilled and high-skilled workers will widen as a result of CAV, this is due to the increases in the technological advancement of the system'.[471] Furthermore, economic effects across industries have been tabulated,[472] and various authors have made assumptions about the magnitude of the CAV industry in Europe, ranging from US$51 billion to US$1.2 trillion annually, highlighting uncertainty in the field.[473] Raposo and others indicated a likely significant change in the economy and markets because of CAVs.

One such disruption is MaaS.[474,475] The key concept behind MaaS is to offer travellers having access to multiple transport modes, the traveller can select the form of transport that suits their needs, essentially as a vehicle-sharing system (refer to Figure 81 for a typical autonomous MaaS vehicle[476]). Specialist urban mobility applications are also expanding their offerings to enable MaaS, such as Waymo, Transit, Uber, Amazon[477] and Lyft. Extensive research is being undertaken on MaaS, including that of the RCA. This formed a third of the day's proceedings during Symposium 4 – Mobility metamorphosis.

470 Ibid., p. 107.

471 Ibid., p. 146.

472 Ibid., pp. 34–35. A tabulation of economic industries.

473 Ibid., p. 38.

474 Miloš N. Mladenović, 'Mobility as a Service', in *International Encyclopedia of Transportation*, ed. by Roger Vickerman (Oxford: Elsevier, 2021), pp. 12–18 <https://doi.org/10.1016/B978-0-08-102671-7.10607-4>.

475 Göran Smith, *Making Mobility-as-a-Service: Towards Governance Principles and Pathways* (Gothenburg: Chalmers University of Technology, 2020), <https://research.chalmers.se/en/publication/516812> [accessed 18 August 2021].

476 Christofer Dawson and David Welch, Driverless Cars Have Arrived, and They All Look Like Loaves of Bread, Bloomberg, 2020, <https://www.bloomberg.com/news/articles/2020-03-13/driverless-cars-have-arrived-and-they-all-look-like-loaves-of-bread> [accessed 9 October 2023].

Edward Ludlow, *Amazon's Zoox Unveils Robotaxi for Future Ride-Hailing Service*, Bloomberg, 2020, <https://www.bloomberg.com/news/articles/2020-12-14/amazon-s-zoox-unveils-robotaxi-for-future-ride-hailing-service> [accessed 9 October 2023].

It is worth noting that MaaS systems in Sydney had a modest uptake in 2016[478] and that private vehicle ownership remains a dominant force in road vehicle economics. One of the most contentious issues in the orthodox debate about vehicles and the city is related to the amount of space private vehicles occupy in comparison to buses. Leading researchers, such as Giulio Mattioli, have noted that vehicle ownership is a core capitalist and commercial agenda,[479] hence the importance of addressing its fundamental complexity and conflict. Central to my thinking is that more research in this contentious field is required. MaaS is attractive from a distributive justice point of view; however, it is unlikely to address the issue that individuals in democratic capitalist cultures believe they have the right to move around privately and in the comfort of their own vehicles. I argue that private vehicle ownership, as complex as it is for increasing populations in advanced economy cities, will likely remain in some form in the future CAREV context.

It is difficult to see why CAREV technology would be more attractive as a shared ownership pattern. The enormous uptake of Tesla's 'Full Self Driving', driving assistance program partially supports this argument.[480] The relationship between AVs/CAVs/CAREVs and the city is associated with the technological development of AV systems, such as lane assist, global positioning, LIDAR, prediction algorithms and V2V. CAV/CAREV systems are likely to be highly technological, complex and multifaceted, as discussed by Hossam Abdelgawad and Kareem Othman in *Connected and Autonomous Vehicles in Smart Cities*.[481] LIDAR (light detection and ranging) is a remote electronic and computerised sensing method used to examine the surface of the Earth. Their research revealed substantive complexity surrounding the consumption, patterns of ownership and use of privately owned vehicles, as well as urban capacity, and this is likely to remain the focus of economists and traffic planners. The vehicle manufacturing industry dependence on private vehicle ownership as an economic model is unlikely to change, despite MaaS research.

Potts, Harwood and Richard's *Relationship of Lane Width to Safety for Urban and Suburban Arterials* 'investigates the relationship between lane width and safety for roadway segments and intersection approaches on the urban and suburban arterial':

478 Statista. "Most Common Modes of Transportation for Commuting in Australia 2023." Accessed March 11, 2024. https://www.statista.com/forecasts/1188000/most-common-modes-of-transportation-for-commuting-in-australia.

479 Mattioli and others, 'The Political Economy of Car Dependence'.

480 Fred Lambert, *Tesla Confirms 285,000 People Bought Full Self-Driving*, Electrek, 2022, <https://electrek.co/2022/12/29/tesla-people-bought-full-self-driving-north-america/> [accessed 26 August 2023].

481 Hossam Abdelgawad and Kareem Othman Mouftah and others, 'Chapter 3 Multifaceted Synthesis of Autonomous Vehicles' Emerging Landscape' in *Connected and Autonomous Vehicles in Smart Cities*, ed. by Mouftah, Erol-Kantarci, and Sorour (pp. 67–114). See Section 3.2.4.

> *The research found no general indication that the use of lanes narrower than 3.6 m (12 ft) on urban and suburban arterials increases crash frequencies. This finding suggests that geometric design policies should provide substantial flexibility for lane widths narrower than 3.6 m (12 ft). Narrower lanes should be used cautiously in these three specific situations unless local experience indicates otherwise.*[482]

The report is associated with human-driven vehicles, which require additional lane width for vehicle 'driver drift'. According to Lily Elefteriadou in *An Introduction to Traffic Flow Theory,* 'lane width is a design outcome based on physics, comfort and acceptable safety risks (driver drift) perceived by the community and culturally based attitudes'.[483] AVs, CAVs and CAREVs utilise SI driving and require less vehicle drift space in normative operations. However, CAV metrics are unavailable, as the technology is still in trial. Mohamed Elshiek and Aboelmagd Noureldin discussed emerging technologies and accuracy in 'Multisensor Precise Positioning for Automated and Connected Vehicles' in Mouftah, Erol-Kantarci and Sorour's *Connected and Autonomous Vehicles in Smart Cities*. They commented that new sensor technologies are being developed and invented constantly in the development of AVs and that this is likely to continue to increase accuracy.[484] They pointed out that higher levels of autonomy will require higher levels of accuracy and robust positioning,[485] including the systemic precise point positioning (PPP) technique, which in its current calibration and testing is suited to level 5 automation (Table 13.5 p.389), as it recorded a maximum error of 2.6m.

Despite the availability of major publications on traffic, such as Peter D. Norton's *Fighting Traffic: The Dawn of the Motor Age in the American City*,[486] data on the implications of the sizes of vehicles in blocking roads are lacking. It appears to be accepted engineering and cultural practice that vehicle sizes are rarely questioned in major spatial and technical studies.

482 Ingrid B. Potts, Douglas W. Harwood, and Karen R. Richard, *Relationship of Lane Width to Safety for Urban and Suburban Arterials*, (Kansas: Transport Research Board, 2007), p. 27.

483 Lily Elefteriadou, *An Introduction to Traffic Flow Theory* (New York: Springer, 2014), pp. 61–91, <https://doi.org/10.1007/978-1-4614-8435-6_3>.

484 Elshiek and Noureldin, p. 351.

485 Ibid., p. 352.

486 Norton, *Fighting Traffic*.

Figure 82: Harald Belker's model of an autonomous vehicle design model for Minority Report.

This concept vehicle format explores a narrow one-seater Maglev autonomous vehicle.

Image: Petersen Museum Hollywood Dream Machines https://www.motorworldhype.com/2019/05/hollywood-dream-machines-exhibit-opens-at-petersen-museumpetersenmuseumhollywooddreammachines_39/

Harald Belker,[487] a renowned vehicle concept designer, provided the design for a narrow one- or two-seater vehicle for *Minority Report*.[488] A feature of and important difference between this concept vehicle and other small vehicles, such as those in *Kleinwagen*[489] or Mitchell's CityCar,[490] is its luxurious quality. In this concept, Belker designed a super-luxury one-seater AV, as shown in Figures 29, 30 and 82.

This research asks whether existing vehicles are larger than they need to be and why they are getting bigger. A current EV paradox is related to range anxiety associated with EVs. Martine Paris discussed this in Future[491] and challenged the weight of vehicles rather than seating and ergonomic or spatial formats. A smaller and lighter EV format would require fewer battery and energy storage systems. A systemic approach can unlock this paradox.

Norton,[492] an authority on traffic in the USA, noted that 'traffic engineers' studies resort to wider roads and flow increases, ITS and other congestion-relieving strategies'.[493] Congestion begins with chokepoints in terms of network performance. Road network refers to the entire road network, including in hierarchical order the motorway, feeder route, federal roads, state roads, freeways, arterial roads, local roads, alley and lanes. Chokepoints are demand areas that are exceed the capacity of the road at any point in the road network. As a result, congestion grows throughout the network until the chokepoints are removed by reducing demand or increasing capacities in current congestion models.

487 Image from Car Body Design website. https://www.carbodydesign.com/gallery/2013/11/harald-belker-on-his-career-and-design-industry/4/. Accessed 21 February 2024.

488 Dir. by Steven Spielberg.

489 Hans-Ultrich von Mende and Mattias Dietz, *Kleinwagen: Small Cars. Petits Voitures* (Cologne: Benedikt Taschen, 1994).

490 Mitchell, Borroni-Bird, and Burns, *Reinventing*, p. 64.

491 Martine Paris, *Electric Vehicles: Can "Lightweighting" Combat Range Anxiety?*, BBC, <https://www.bbc.com/future/article/20240108-electric-vehicles-can-lightweighting-combat-range-anxiety> [accessed 12 January 2024]

492 Norton, 'Fighting Traffic', p. x.

493 I asked local engineers in traffic and infrastructure whether they knew of studies on congestion that included smaller vehicles. The answer was typically no.

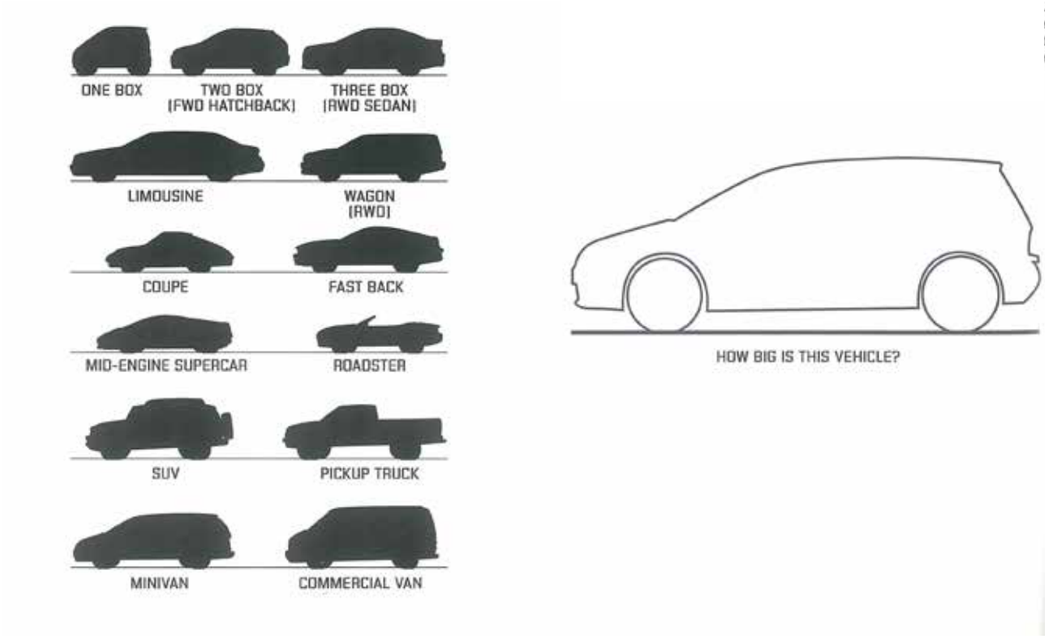


Figure 83: Taxonomy of vehicle proportions from H-Point: vehicle proportions. p. 100.

A comparative analysis by silhouette of vehicle passenger and commercial van sizes. Unfortunately, the comparative analysis is limited to smaller vehicle typologies. Large trucks and road trains are not included. The dimensional analysis as a spatial investigation is limited.

That vehicles appear to be increasing in size is a subject not frequently discussed in traffic studies. Recent sport utility vehicle (SUV) developments may influence research in this field. Form Trends,[494] a motor vehicle website, noted that historically, smaller vehicles have been less desirable as 'conspicuous value'. This suggests that society does not value smaller vehicles as much as larger ones. Recent research on crash testing and highway safety has noted the adverse safety outcomes of SUVs.[495] Keith Bradsher wrote a comprehensive book on SUVs, *High and Mighty*,[496] but did not suggest why this trend arose or whether a relationship existed between passenger vehicle size increases. Large truck size increases are a subject that requires further insights. *H-Point*,[497] a reference vehicle pattern book, has a single page on the matter and stops short of a comparative analysis of trucks and vehicle footprints. Refer to Figure 83, H-Point: Vehicle Proportions.[498]

494 Less Is More – The Biggest Drivers for Smaller, Simpler Cars, Form Trends, 2020, <https://www.formtrends.com/less-is-more-biggest-drivers-for-smaller-simpler-cars/> [accessed 20 January 2023].

495 New Study Suggests Today's SUVs Are More Lethal to Pedestrians than Cars, IIHS-HLDI, 2020, <https://www.iihs.org/news/detail/new-study-suggests-todays-suvs-are-more-lethal-to-pedestrians-than-cars> [accessed 20 January 2023].

496 Keith Bradsher, *High and Mighty - The Dangerous Rise of the SUV* (New York: PublicAffairs TM, Perseus Book Group, 2003).

497 Stuart Macey and Geoff Wardle, *H-Point. The Fundamentals of Car Design and Packaging*, 2nd edn (Pasadena: Design Studio Press, Art Centre College of Design, 2014).

498 Macey and Wardle, *H-Point.*

Figure 84: Image from 'Kleinwagen': ACCE Mazda, Switzerland, 1991. p. 141.

This is a typical example of smaller vehicle typology. This illustration represents an example of a design exercise from students at Art Centre for a small concept vehicle. The seating arrangement (one or two seat) and internal spatial configurations are not clear in the illustration.

Recent research by the Insurance Institute for Highway Safety suggested that SUVs have increased lethal outcomes for pedestrians.[499] Safety advocates, authorities and manufacturers are complicit in not attending to larger high-speed (i.e. sport) vehicles, such as SUVs, worsening pedestrian road fatalities. The consumer of the vehicle is the hegemonic decision-maker in consumption and use. According to Kim Willsher, writing for *The Guardian*, Paris has acted to stem the uptake of SUVs.[500]

Cars can be status symbols. Car manufacturers – especially car manufacturing centres, such as the USA – have rarely accepted the sensible and necessary smaller vehicles seen in European vehicle manufacturing.

Hans-Ulrich von Mende and Matthais Dietz published *Kleinwagen* in 1994, a compendium of small vehicles and their development, with examples such as the Citroen 2CV,[501] the Italian Fiat 500 and the Renault Twizy. An example of the Mazda ACCE from *Kleinwagen* is shown in Figure 84.[502]

Recent European/UK vehicle manufacturing attempts include the Mercedes A1 Smartcar, the UK's Mini Wizy, the Citroen AMI and the Fiat Topolino.[503] The small vehicle typology has had limited uptake in USA vehicle consumption. In 2007, Segway and GM (USA) developed the Personal Urban Mobility and Accessibility[504] prototype in New York, a rickshaw-like electric vehicle.

499 *New Study Suggests Today's SUVs Are More Lethal to Pedestrians than Cars*, Insurance Institute for Highway Safety, 2020, <https://www.iihs.org/news/detail/new-study-suggests-todays-suvs-are-more-lethal-to-pedestrians-than-cars> [accessed 5 January 2023].

500 Kim Willsher, 'Paris to Charge SUV Drivers Higher Parking Fees to Tackle "Auto-Besity"', *The Guardian*, 12 July 2023, <https://www.theguardian.com/world/2023/jul/11/paris-charge-suv-drivers-higher-parking-fees-tackle-auto-besity?CMP=Share_iOSApp_Other> [accessed 4 November 2023].

501 *Citroën 2CV*, Wikipedia, 6 March 2022, <https://en.wikipedia.org/w/index.php?title=Citro%C3%ABn_2CV&oldid=1075487050> [accessed 21 March 2022]. Anthony Madaffari, *Seven Tiny Cars to Easily Navigate City Car Parking*, Carsales.com.au, 26 July 2020, <https://www.carsales.com.au/editorial/details/seven-tiny-cars-to-easily-navigate-city-car-parking-125107/> [accessed 21 March 2022].

502 Von Mende and Dietz, *Kleinwagen*.

503 Several low-volume manufacturing vehicle companies have explored small vehicle formats.

504 Corey Rueth, 'New GM/Segway PUMA and Other Personal Mobility Vehicles', *Winding Road Magazine*, 7 April 2009, [accessed 20 January 2023].

Figure 85: Image from Near to Far by Dan Sturges. p 178.

Dan Sturges refers to a narrow format vehicle, called a Tango lane-split format, in Near to Far. These vehicles are designed as human-driven vehicles, which accounts for their appearance as uncomfortably narrow.

A potential desirability issue is that some tiny vehicles are not classified as cars, thus avoiding safety standards and other issues. MIT held a vehicle seminar and competition in 2006 on personal mobility vehicles (PMVs).[505] In 'Paradigm Shift',[506] Mausbach noted that the two-seater vehicle configuration has not had mass adoption despite the rationality of the proposal. The low uptake may be associated with the perceived cramped and uncomfortable format of these vehicles (see Figure 85) and their size and spatial relationship to larger vehicles on the road.

505 Massachusetts Institute of Technology, *Vehicle Design Summit*, online video recording, Infinite MIT, 2006, ,<https://infinite.mit.edu/video/vehicle-design-summit> [accessed 10 January 2023].

506 Mausbach, 'Paradigm Shift', p. 101.

In 2023, Dan Sturges published *Near to Far*,[507] an exploration of new mobility with small vehicles compiled from 25 years of research on the subject. He provided a taxonomy of personal mobility to shared mobility vehicle typologies. The 'Tango' format human-driven vehicle is shown in Figure 85. in *Near to Far*, Dan Sturges referred to a narrow format vehicle, called a Tango lane-split format. These vehicles are designed as human-driven vehicles, which accounts for their appearance as uncomfortably narrow.[508]

4.4.1 Ergonomics and small vehicle typology research

Design publications recommending a fleet of small vehicles include those of Mitchell, Borroni-Bird and Burns,[509] Burns[510] and Sturges.[511] The benefits of small vehicles include lower energy use, less embodied energy, improved spatial outcomes, optimised parking, smaller batteries and environmental benefits. In short, multiple benefits arise. However, controlled studies that compare the differences of narrow-format vehicles in investigated capacity and spatial benefits in the road space of the city are needed – a research gap that this study fills.

Research on large and mass transport vehicles includes 'Spaces on Wheels'.[512] The spatial injustice of passenger vehicles is summarised by Brad Plumer in 'Cars Take up Way Too Much Space in Cities'.[513] These AV studies include robotaxis[514] by companies such as Uber, Waymo and WeRide and focus on large mass transport vehicle typologies. There is an attempt to fit more into a vehicle or in speculative design processes, such as those discussed in *Forbes* by Nargess in the article 'Tech Start-Up Pix Moving Uses Self-Driving Ideas To Make Flexible Cities'[515] using modular vehicle types. 'Moving Space' is a concept vehicle that moves office space.

507 Dan Sturgess, *Near to Far* (Dusseldorf: Zora Identity and Interaction Design, 2023).

508 Sturgess, *Near to Far*, p. 173.

509 Mitchell, Borroni-Bird, and Burns, *Reinventing*, p. 52.

510 Burns, *Autonomy*, p. 142.

511 Sturgess, *Near to Far*, p. 172.

512 Simon Caspersen, 'Spaces on Wheels: Exploring a Driverless Future', *SPACE10*, 17 September 2018, p. 10, <https://space10.com/project/spaces-on-wheels-exploring-a-driverless-future/> [accessed 21 March 2022].

513 Brad Plumer, *Cars Take up Way Too Much Space in Cities. New Technology Could Change That*, Vox, 26 September 2016, <https://www.vox.com/a/new-economy-future/cars-cities-technologies> [accessed 9 August 2021]

514 *Robotaxi*, Wikipedia.

515 Nargess Banks, 'Tech Start-Up Pix Moving Uses Self-Driving Ideas To Make Flexible Cities', *Forbes*, 9 February 2020, <https://www.forbes.com/sites/nargessbanks/2020/02/09/autonomous-drive-pix-moving/> [accessed 21 March 2022].

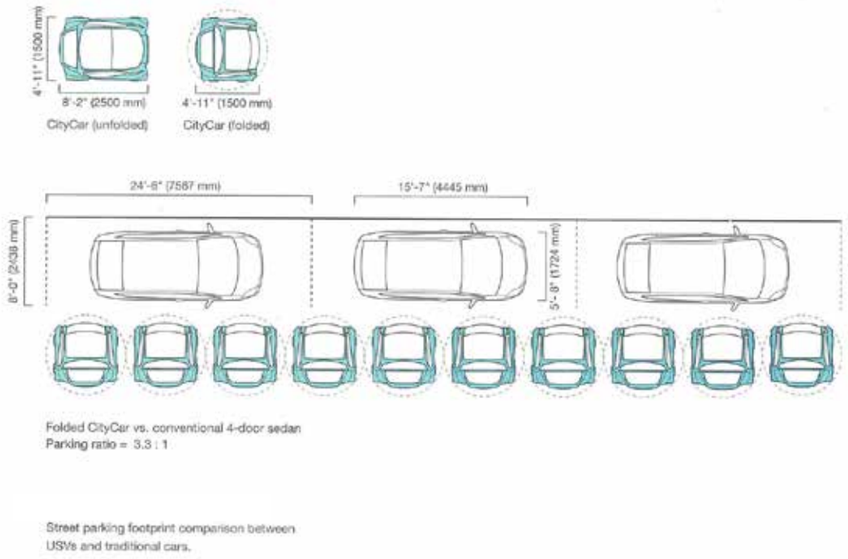


Figure 86: Drawing from 'Reinventing the Automobile: The City Car' parking savings. Figure 9.20, p.180.

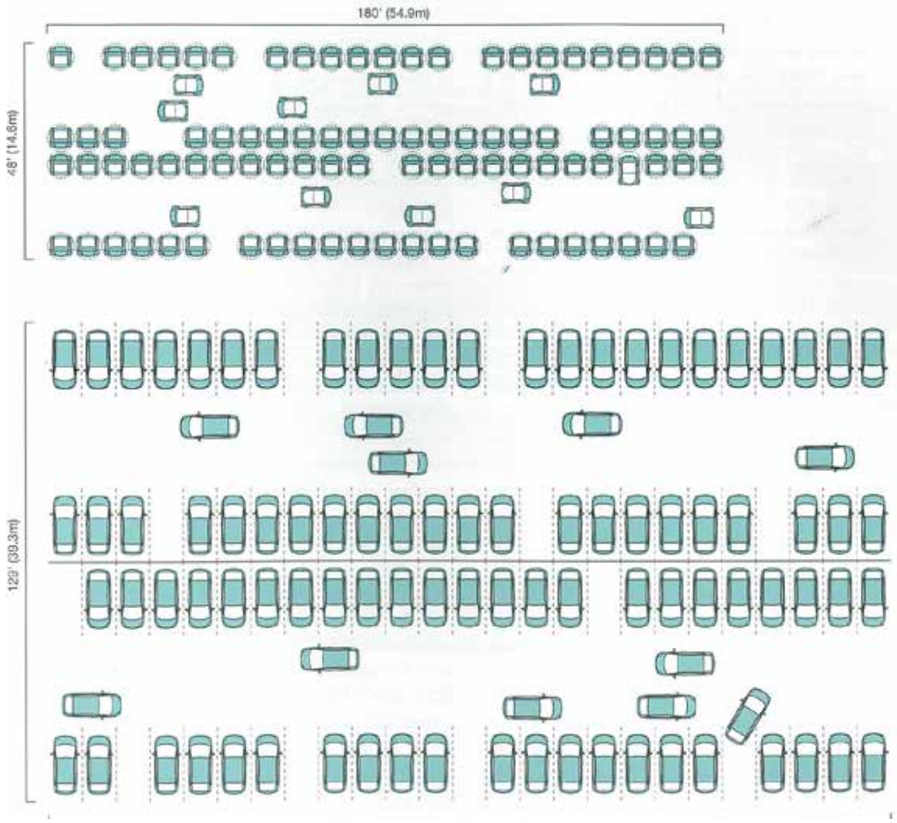


Figure 87: Drawing from 'Reinventing the Automobile: The City Car' parking savings. Figure 9.21, p.181.

Parking arrangements show the space-saving outcomes for the MIT 'CityCar'.

Figure 88: 'The Folding City Car' in Reinventing the Automobile for Urban Use by Mitchell and Burns. p. 67

Large vehicle formats have been outlined by local engineers, such as Stephen Taylor. In a newspaper opinion piece titled 'Time for NSW to Get a Scoot on E-scooters', he wrote, 'Australians want bigger electric vehicles.'[516] A counterargument is that research on CAV delivery and freight vehicles exists, such as that Aarian Marshall discussed in *Wired*.[517] However, these are generally not passenger-transporting vehicles.

A leading design publication, Mitchell, Borroni-Bird and Burns' *Reinventing the Automobile: Personal Urban Mobility for the 21st Century*,[518] focuses on small vehicles designed for the city. Mitchell was a leading scholar at MIT.[519] The book presents the benefits of small vehicles, but the reference research does not investigate the traffic effects or decongestion of small vehicles in the city. The authors argued that the small-vehicle typology requires less embodied energy for manufacturing and less operational energy to move the vehicles and occupants, thereby reducing overall energy consumption.

Figure 88 of the small vehicle format is taken from 'Reinventing the Automobile': The CityCar.[520] Figures 86, 87 and 92, taken from 'Reinventing the Automobile: parking savings' the parking arrangements show the space-saving outcomes for the MIT CityCar.[521]

In *Reinventing the Automobile,* Mitchell, Borroni-Bird and Burns also explored the positive impacts of parking small vehicles have spatial benefits. They did

516 Stephen Taylor, 'Time for NSW to Get a Scoot on E-Scooters', *Sydney Morning Herald*, 25 October 2021, <https://www.smh.com.au/environment/climate-change/time-for-nsw-to-get-a-scoot-on-e-scooters-20211020-p591lp.html> [accessed 26 October 2021].

517 Aarian Marshall, 'These Small Cars Can Help Drive the Autonomous Future', *Wired*, 5 October 2018, <https://www.wired.com/story/small-cars-help-drive-autonomous-future/> [accessed 21 March 2022].

518 Mitchell, Borroni-Bird, and Burns, *Reinventing*.

519 Regarding Mitchell, Wikipedia notes 'Starting in 2003, he created the Smart Cities program within the MIT Media Lab. Projects that Mitchell developed as part of the Smart Cities program included the MIT Car (also called the "CityCar", and developed into the Hiriko' another small vehicle format.

520 Mitchell, Borroni-Bird, and Burns, *Reinventing,* p. 67.

521 Mitchell, Borroni-Bird, and Burns, *Reinventing,* p. 180.

Figure 89: Analysis of vehicle occupancy and spatial requirements of four seat vehicle from a typical motorway scene in Australia.

Vehicle occupancy with one or two people for a four-seater passenger vehicle. The driver sway space and wasteful energy use of vehicles with empty seats has a major environmental impact.

not explore the social justice implications. Importantly, in the publication,[522] visions of small vehicles for personal mobility are presented. Small vehicles provide a redistributed equity of spatial use within the broader public realm. This key spatial concept may partly explain the broad popularity and use of vehicles, along with comfort, convenience, privacy and cultural practice.[523]

Large cars are popular with a wide demographic, including lower-income cohorts, some of whom depend on them for access to places of work and recreation and are essentially elitist. This is also true where there is limited public transport or because of location, and it raises the issue of inequalities. Matt Wade discussed this subject in an opinion piece on 'How Our Cities Work: Essential Lessons from Lockdown'.[524]

522 Burns, *Autonomy*, p. 145. Burns co-authored *Reinventing the Automobile*. His later publication, *Autonomy*, did not make a link between small vehicles and AVs.

523 This comment references the cultural research: Peter Wollen, *Autopia: Cars and Culture*, ed. by Joe Kerr (London: Reaktion Books Ltd., 2002) and Stephen Bayley, *Cars: Freedom, Style, Sex, Power, Motion, Colour, Everything* (London: Conran, 2009).

524 Matt Wade, 'How Our Cities Work: Essential Lessons from Lockdown', *Sydney Morning Herald*, 09 October 2021, <https://www.smh.com.au/business/the-economy/how-our-cities-work-essential-lessons-from-lockdown-20211109-p597gn.html> [accessed 21 March 2022].

The 2017 Australian Census[525] revealed that about 68% of daily private vehicle trips were undertaken by the vehicle driver only, while 5% of trips to work included a driver and one passenger.[526] In 2023, the University of Michigan Center for Sustainable Systems produced a mobility fact sheet that confirmed USA statistics for 2019 in which the average car occupancy was 1.5 people per vehicle (62% occupancy)[527]. Refer to Figure 89 for a visual analysis of a typical motorway scene in Australia emperical data suggesting that vehicle occupancy with one or two people for a four-seater passenger vehicle is the dominant occupancy rate. The driver sway space and wasteful energy use of vehicles with empty seats has a major environmental impact.

Comparative studies on traffic management with small vehicle types or reduced seating configurations are not available, which is a research gap. Joshua Dowling noted in 'Gone in 70 Seconds', his Drive article on Citroen's 'My Ami Buggy', that the small vehicle sold out in 10 hours in Europe after its launch: 'The vehicle is too small and too slow to be eligible for registration on Australian roads.' This is a size-related bias for a vehicle with a maximum driving range of 75 km and a top speed of 50 km/h.[528] Refer to Figure 90, Citroen's 'My Amy Buggy', an electric runabout special release in 2023 in France.

525 *More than Two in Three Drive to Work, Census Reveals*, Australian Bureau of Statistics, 2017, <https://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbyreleasedate/7DD5DC715B608612CA2581BF001F8404> [accessed 2 December 2022].

526 Therefore, logically, a spatial design investigation should include an ergonomic study of one, two- and other seat combination vehicles that are directly related to current transportation trends.

527 University of Mitchigan. "Personal Transportation Factsheet." Center for Sustainable Systems, 2023. https://css.umich.edu/publications/factsheets/mobility/personal-transportation-factsheet.

528 Joshua Dowling, *Gone in 70 Seconds: Citroen's Tiny Electric Runabout Sells out in Record Time*, Drive, 24 June 2023, <https://www.drive.com.au/news/citroens-my-ami-buggy-sol-sales/> [accessed 26 June 2023].

Figure 90: Citroen's 'My Amy Buggy', a special series electric runabout released in 2023 in France. From Drive article by Joshua Dowling 24 June 2023.

Joshua Dowling, *Gone in 70 Seconds: Citroen's Tiny Electric Runabout Sells out in Record Time*, Drive, 24 June 2023, <https://www.drive.com.au/news/citroens-my-ami-buggy-sol-sales/> [accessed 26 June 2023].

4.5 A review of spatial justice and vehicles in the city literature

Spatial justice in transportation is important to our understanding of how the public realm functions. Karel Martens wrote authoritatively on transport justice in 'Transport Justice: Designing Fair Transportation Systems'.[529] He said that 'First, this definition of a fair transportation system as a system that provides a sufficient level of accessibility to all under most circumstances may not seem radical in character, its consequences for transportation planning could not be more radical'. Pertaining to the leading luminary Iris Young's analysis in *Justice and the Politics of Difference*,[530] it can be argued that transportation planning based on the principles of spatial justice that ignore the powerful processes of domination and oppression that systematically disadvantage groups in society, such as ethnic minorities, women and LGBTQIA+ persons, is inherently socially unjust.

Kara Kockelman, a USA transport authority, and her team argued in their 2017 study *An Assessment of Autonomous Vehicles: Traffic Impacts and Infrastructure Needs*[531] that under certain conditions, CAVs can have decongestion effects on various road systems with time- and demand-based modelling, which includes spatial effects. This is a qualified assumption that other CAV authors in this field have made, such as Sha.[532] However, arguments that congestion may increase as a result of CAV are also prevalent, such as the heavily qualified findings in the the UK Department for Transport National Road Traffic Projections 2022[533]. and Kockelman's study[534] on simulated modelling took the assertion further into a deeper appreciation of the impacts. For this reason, it appears to be a unique and significant study.

529 Karel Martens. 'Transport Justice: Designing Fair Transportation Systems', Transport Reviews, 37 (2017), 245–46, <https://doi.org/10.1080/01441647.2016.1258599>. p. 151.

530 Young, *Justice and the Politics of Difference*, pp. 92–110.

531 Kockelman, *An Assessment of Autonomous Vehicles*, p. 130.

532 Ibid, Sha. 'Investigating'

533 'National Road Traffic Projections 2022', Department for Transport (UK), 2022 <https://assets.publishing.service.gov.uk/media/63975bcfd3bf7f3f7d1cf440/national-road-traffic-projections-2022.pdf> [accessed 26 March 2024]

534 These include Carlino and others (2013), Andersen and others (2016), Bajpai and others (2016) and Stiogios and others (2019).

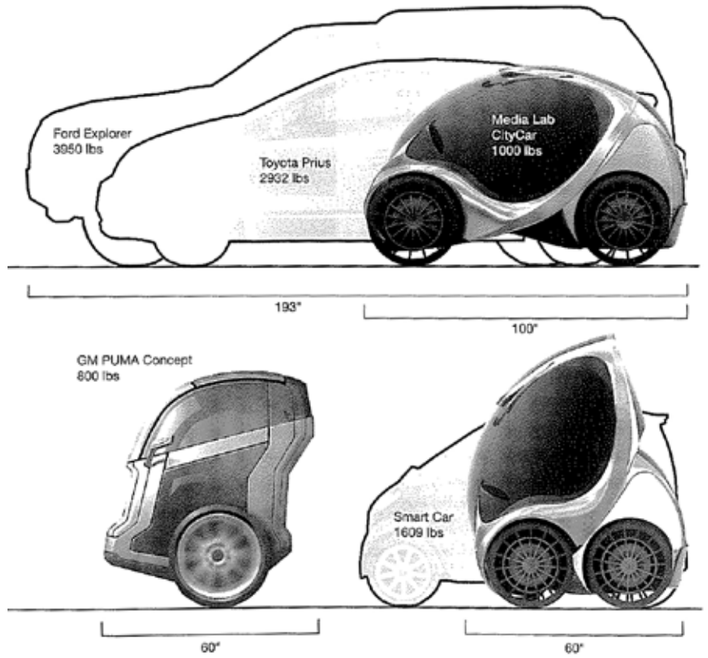


Figure 92: MIT CityCar - 'Folding and balancing to reduce the vehicle footprint', from Reinventing the Automobile for the city. Mitchell and Burns Figure 2.12 p. 30.

MIT CityCar comparative analysis with Toyota Prius and Ford Explorer

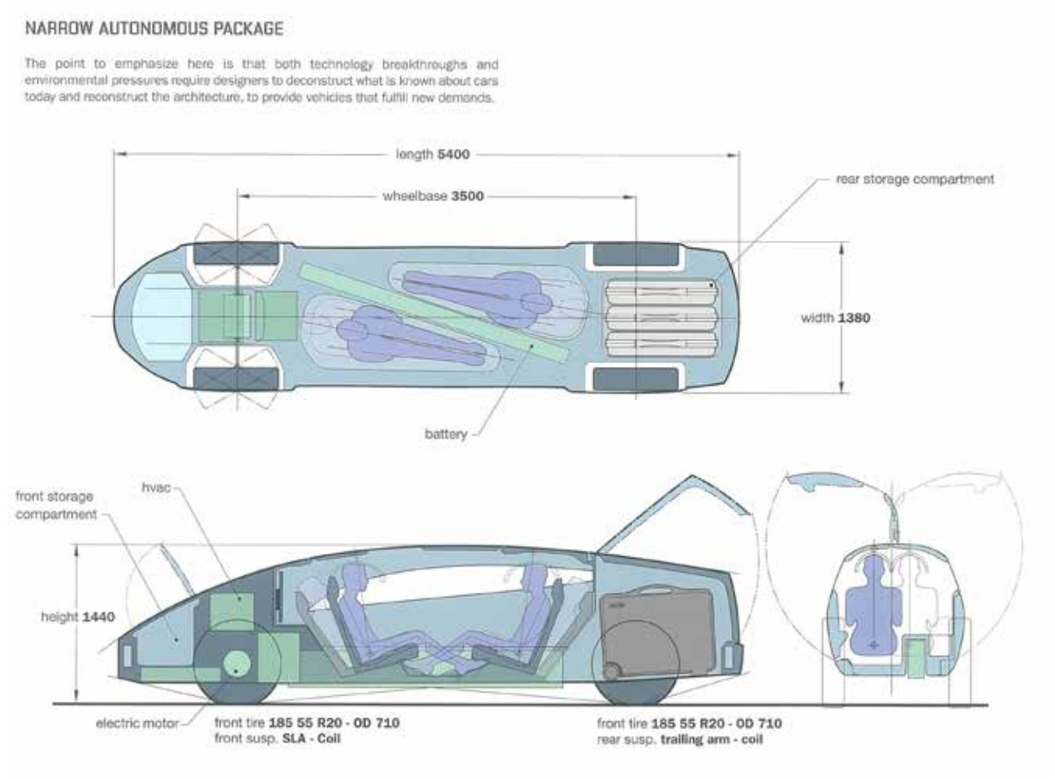


Figure 91: Drawing from H-Point: a 'Narrow Autonomous Package'. p. 264

A figure in the H-Point pattern book which investigates the seating and layout composition of a two-seater narrow autonomous vehicle. These dimensions are approximately consistent with the spatial study in this research.

One study assumption that Kockelman and others made in an otherwise rigorous model is that AV sizes and configurations will remain consistent with existing human-driven vehicle sizes. A critical review of the modelling immediately raises the question of why this assumption is made. Based on the ergonomics of AVs/CAVs/CAREVs, it is evident that no driver is required, and therefore, the internal layout and ergonomic formation of AVs/CAVs should change to assist with congestion modelling. This realisation was a central spatial question of my research and led me to develop a conceptual ergonomic study for CAREVs.[535] The *H-Point* pattern book references small vehicle typologies for future AV/CAV/CAREV ergonomics (refer to Figure 91).

Minority groups interested in AV mobility options will be interested in spatial justice issues concerning equitable access and just movement, including aged persons[536] and those with disabilities. This assertion was reinforced during Symposium 4 – Mobility metamorphosis and summarised later in this chapter (4.8.1) in the AV shared mobility research presentations. In their 2012 report 'People with Disability: The Forgotten Road User Group',[537] Haning, Gazby and Woolmer noted that the preferences of their research cohort of people with disabilities[538] for road-based transport were associated with improved privacy and accessibility.[539]

535 A spatial investigation that addresses environmental justice using small vehicle formats and advanced technology is therefore a research aim.

536 *Ageing and Health*, World Health Organization, 2022, <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health> [Accessed 20 January 2023]. These are WHO statistics of interest with respect to people living with disabilities and age-related issues.

537 Alice Haning, Cathy Gazey, and Jillian Woolmer, 'People with Disability: The Forgotten Road User Group', *Australasian Transport Research Forum, 2012 Proceedings. Perth, WA (28 September 2012)*, 18.
According to Haning, Gazby and Woolmer, 92% of the respondents were either a passenger or a driver of a private vehicle at least once per month with the majority (51–60%) preferring to use private road transport to access services.

538 Ibid., p. 5. In 2009, approximately 80% of people with disabilities reported being either the driver or a passenger in a car on the last trip prior to the survey (ABS 2009b).

539 Ibid., p. 5. The reasons given for the use of private transport were mainly convenience and that it is quicker and/or easier to use than other modes of transport.

The WHO noted in 'Ageing and Health 2021' that in 2020, 22% of the world's population was over the age of 60. In 2020, 15% of the world's population (i.e. ~1 billion people) were living with a disability, regarded as the world's largest minority.[540] In 2018, 17% of the population of Australia were regarded as persons living with a disability, comprising 4.4 million people.[541] Furthermore, due to socioeconomic constraints,[542] these groups tend to be associated with lower-income urban settings[543] and live on the periphery of major cities, where public transport is unavailable.

The AV industry makes strong representations to the aged and people living with disability groups regarding the potential of the technology to respond to their private and public transport needs.[544] The economic aspects and the cost of travel in the AV/CAV/CAREV system are, according to Kogelmann,[545] 'affordable' at scale. AVs/CAVs/CAREVs will assist with mobility options for people living with disabilities and the aged, as these cohorts will not be reliant on human drivers. Vehicles will be able to adapt to the requirements of the disabled person. This has been identified by the National Highway Traffic Safety Administration (USA) in its policy statement on AVs.[546]

540 'Ageing and Health', World Health Organisation, 2021 <https://www.who.int/news-room/fact-sheets/detail/ageing-and-health> [accessed 28 April 2022].

541 Australian Bureau of Statistics, 'Disability, Ageing and Carers, Australia: Summary of Findings', Australian Bureau of Statistics, 2018 <https://www.abs.gov.au/statistics/health/disability/disability-ageing-and-carers-australia-summary-findings/latest-release> [accessed 28 February 2024].

542 Haning, p. 14. People with disabilities are at higher risk of transport disadvantage compared with people without disabilities due predominantly to the impact of their disability on the capacity to access a range of transport modes but also low income and age (Disability Rights Commission, 2003).

543 Ibid., p. 3. 'People with a disability have lower labour force participation and educational attainment than people without a disability.'

544 I have attended ADVI summits in Australia since 2017. Each congress has at least one session dedicated to minority and special use groups.

545 Kockelman, *An Assessment of Autonomous Vehicles*, p. 56.

546 Automated Vehicles Policy Statement Concerning Automated Vehicles from 2013, National Highway Traffic Safety Administration, 2013, <https://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf> [accessed 5 August 2021].

In their consultation across a wide interdisciplinary USA spectrum on 'Planning for Walking and Cycling in an Autonomous-Vehicle Future',[547] Bryan Botello and others noted:

> *Several respondents suggested that cities should set strategic priorities for transportation and land use. These priorities should be formulated independently of technology—and focus on the communities' vision is for the future. CA/Vs and other technological innovations should then be integrated in this overall strategic vision. For example, a city could decide to prioritise liveability and active travel. Such a city would then allow the deployment of C/AVs as long as they further that goal. In essence, the suggestion is to not allow technology to set the strategic agenda, but to employ technology to achieve strategic goals.*

Hua Sha's doctoral thesis 'Investigating the System-Level Performance of Connected and Autonomous Vehicles against Transport and Broader Societal Impacts' evaluated and quantified the potential impacts and benefits of AVs/CAVs based on various traffic conditions in urban and suburban environments.[548] He demonstrated that standard-sized CAVs 'improve the efficiency of the road network, reduce emissions and conflicts' and suggested 'that policymakers will need to make some tough decisions in future as to how these new technologies will be implemented'. This technical study assumed standard vehicle sizes, the

547 Bryan Botello and others, 'Planning for Walking and Cycling in an Autonomous-Vehicle Future', Transportation Research Interdisciplinary Perspectives, 1 (2019), 100012, <https://www.academia.edu/40396389/Planning_for_walking_and_cycling_in_an_autonomous_vehicle_future> [accessed 9 August 2021].

548 Sha, 'Investigating', p. 293.

replacement of the human driver with SI spatially, and had a cause–effect approach to environmental outcomes. It did not set environmental targets or principles. The deep investigation did not pursue small-vehicle spatial outcomes to benefit the environment.

Both Kockelman's and Sha's studies lacked systemic environmental approaches to vehicles and the city and accepted standard vehicle sizes a priori. Neither questioned the sizes of vehicles nor their impacts on the contested public realm spatiality. Refer to 'PRINCIPLE 4 – Social justice, rights to the city and sustainability'.

4.5.1 Spatial justice, complexity, contradictions and consumption

In this complex field, spatial justice is unlikely to be resolved through spatial, technological or behavioural changes; it requires systemic change. Several reasons drive private vehicle purchases and use patterns, such as style, comfort, performance, safety and practicality. This was discussed in detail by O'Connor and others[549] and Mausbach.[550] Consumption and marketing research by motor vehicle manufacturers is a continuously evolving, dynamic, complicated and brutal system that includes manufacturing systems, fashion, comfort, status, design, safety and commercially driven outcomes, as leading authors attest. This is additionally complex due to the specialised nature and siloed approach to fields of knowledge. Leading authors and theorists tend to focus only on their fields and avoid the inevitable complexity of systemic thinking, which integrates planning, economic, behavioural, fashion, ideological, technological, environmental, safety and politically motivated areas of knowledge.

The field is also influenced by social licence. We see use changes because of emissions scandals and how clean air and public health issues drive consumption patterns, new emissions standards and legal and environmental outcomes.[551] Lou Shipley, a Tesla shareholder and senior lecturer in Entrepreneurial Management at Harvard Business School, suggested a direct relationship between the VW emissions scandal and the rise of Tesla.[552] These complex, interrelated fields of vehicle purchase and consumption are classified under the commercial category of planned obsolescence for simplicity. Research in this field requires deeper research than this thesis was able to undertake.

At the heart of planned obsolescence is a policy of producing goods that become obsolete and so require replacing. Production is increased through frequent changes in design, function and materiality. Ever-changing products (e.g. vehicles) require huge archives and stores of spare parts, which are often vehicle-model specific. The planned obsolescence of materials with limited lifespans and low durability increases the necessity for consumption. In this research, consumption is the driving force behind capitalist economics.

549 Peter J. O'Connor and others, 'What Drives Consumer Automobile Choice? Investigating Personality Trait Predictors of Vehicle Preference Factors', *Personality and Individual Differences*, 184 (2022), 111220, <https://doi.org/10.1016/j.paid.2021.111220>.

550 Mausbach, 'Paradigm Shift', pp. 47, 81, 96, 116, 131, 246.

551 Silva and others.

552 Lou Shipley, *How Tesla Sets Itself Apart*, Harvard Business Review, 28 February 2020, <https://hbr.org/2020/02/how-tesla-sets-itself-apart> [accessed 27 August 2023].

In *Capitalism, Socialism, Ecology*,[553] Andre Gorz noted:

> *The quest for maximum economic productivity, by contrast, consists of selling at as high a profit as possible the greatest possible quantity of goods produced with maximum of efficiency, all of which maximisation of consumption and need. Only by such maximization is it possible to obtain a return on growing quantities of capital. As a consequence, the pursuit of maximum productivity at the enterprise-level leads to increasing waste in the economy as a whole.*

They set out the capitalist agenda in which planned obsolescence is complex and significant. In the same chapter, Gorz and Chalmers[554] clarified:

> *In the long term, that which is ecologically unreasonable cannot be economically rational … Ecological necessities have become the basic principles of economic activity. If we set about ecological modernisation in time, we shall improve our chances of conquering tomorrow's markets and improve the competitiveness of our economy.*

Joe Kerr wrote in 'Trouble in Motor City' about the 'The Cars That Ate Detroit'[555] – the insatiable production and consumption that ultimately led to that city's urban decay after the 1960s vehicle boom. *Autopia: Cars and Culture* includes a revealing compilation of some 25 authors. The book also includes an extract from Jane Jacobs, who noted, 'But we blame automobiles for too much.'[556] She commented, 'Good transport and communication are not only among the most difficult things to achieve, but they are also basic necessities.'[557] Jacobs argued that the city needs to be activated with pedestrians and motor vehicles to ensure the city has life. Despite the contested footpath and road space, which pedestrians and vehicles share, preventing vehicle access to areas leads to a city with no life and no vehicles – what she called 'city vacuums',[558] alluding to the urban decay of cities with low urban and economic vitality seen in the USA in the 1960s.

553 Gorz and Chalmers, *Capitalism*, p. 32.

554 Ibid., p. 33.

555 Joe Kerr, 'Trouble in Motor City', in *Autopia: Cars and Culture*, ed. by Joe Kerr and Peter Wollen (London: Reaktion Books Ltd., 2002), p. 32.

556 Jacobs, 'Erosion of Cities or Attrition of Automobiles' in *Autopia,* p. 259.

557 Jacobs, 'Erosion of Cities or Attrition of Automobiles', in *Autopia*, p. 259.

558 Jacobs, in *Autopia*, p. 260.

Jacobs' challenge to Robert Moses' expressway plans for Manhattan centred on protecting neighbourhoods from so-called urban renewal through new road infrastructure. An important aspect of understanding the orthodox debate is appreciating how the automotive industry responded to urban and lifestyle issues. There is little evidence that the automotive industry responded meaningfully to the Jacobs/Moses discourse. The battle for the industry did not focus on how vehicles and the city coexist or how they benefit society. The industry's focus remained on how to sell more vehicles.

As Jacobs alluded, the automotive industry knows that human movement is a necessity of urban living. The industry's exploitation of individual vehicle sales and company growth are their lifeblood. The global vehicle manufacturing workforce comprises millions of people who depend on the continued financial success of automotive companies. We realised through the 2011 global financial crisis and the emissions scandal that the automotive industry includes companies that are too large to fail, as they have political and international employment significance.

Surveillance capitalism is a concept in political economics that denotes the widespread collection and commodification of personal data by corporations. While an area of extensive research inquiry by Bratton[559] and others[560] the exploitation of data for commercial purposes is another areas of ethical inquiry to which the automotive industry and policy makers must pay attention. The continued focus on individual vehicle sales and the production of more vehicles are more important to automotive companies than the production of vehicles that respond to the common good and the needs of the community or the city in which the community lives. The VW emissions scandal is a prime example of this, and it will have long-lasting brand, economic, industry and environmental impacts.

The automotive industry should refocus its approach on framing its manufacturing and sales platforms by taking a balanced community and environmental perspective. This will require both bottom-up and top-down approaches and preferably a systemically oriented approach to the community, the individual and the environment. The industry will gain a social licence in the process. For a change in the fleet to CAREVs, the combined effects of individual ownership must be moderated at the level of broad community desirability.

To achieve acceptable social justice, the automotive industry, which will

559 The Stack: Design and Geopolitics in the Age of Planetary-Scale Computing, Simon Fraser University, 2014 <https://www.youtube.com/watch?v=EA1jbm-Jcul> [accessed 4 August 2021].

560 Tiziana Terranova, *Network Culture: Politics For the Information Age* (UK: London: Pluto Press, 26_June_2004).

develop AVs/CAVs/CAREVs, must respond to the needs of urban and regional communities. All levels of governance (i.e. international, national, state and local) have their parts to play, as vehicles are found in all of these jurisdictions, and industry operates across all of these levels of governance. This subject was discussed during Symposium 5, and the speakers agreed that a systemic approach with community welfare and environmentally positive outcomes as an aim would effectively be a systemic change in thinking about spatial justice.

AV/CAV/CAREV technology presents an opportunity to change the fleet. A change in the fleet provides an opportunity to realise a systemic and designed approach to vehicles and the city, one that can be designed and assessed as a cumulative outcome with multiple benefits.

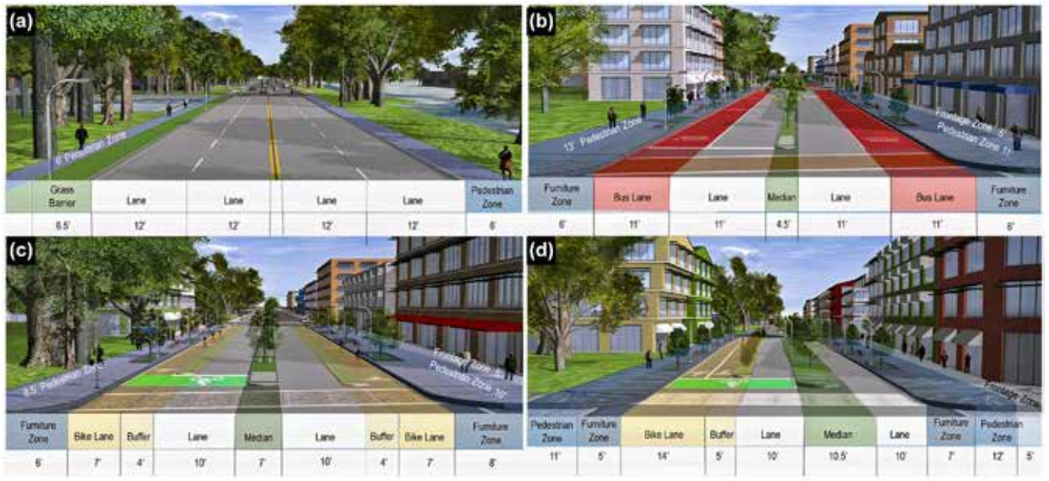


Figure 93: 'Complete Streets Design Scenarios' for streets. Ilir Bejleri and others.

There is a considerable body of visual and spatial research into the adjustment of the contested road space and its conversion to landscape or other uses to make the city more liveable. This is a typical example from 'Using 3D Rule-Based Modeling to Interactively Visualize "Complete Streets" Design Scenarios'. The four images present various road reconfiguration options.

4.5.2 UHI effects in technical literature

One aspect of CAREV-Ss and evolving urban research that will become increasingly important in urban climate change studies is understanding how to reduce UHI effects as cumulative environmental research. Developing a UHI study is an important component of understanding the broader and specific environmental and spatial implications of CAREV-Ss. The UHI study for this research utilised simplified data output and modelling samples using shading from additional trees as the principal variant.

The limited UHI study should be regarded as an initial step in understanding the implications of CAREV-Ss on the urban form and, specifically, the combined effects of UHI. There is an established landscape and spatial design tradition in those professions for transforming streets to improve environmental and public realm improvements. A typical example is shown in Figure 93.[561]

No data regarding the impacts of small vehicles on UHI in cities in Australia were available. This spatial study aimed to provide new knowledge in this field and fill a research gap. As Marando and others discussed in 'Urban Heat Island Mitigation by Green Infrastructure in European Functional Urban Areas',[562] UHI studies measure the cumulative effects[563] on the city. An urban heat island (UHI) is an urban or metropolitan area that is significantly warmer than its surrounding rural/regional areas due to human activities. Hard surfaces, roads and footpaths are major contributors to UHI effects. I utilised the Universal Thermal Climate Index (UTCI) as a baseline measurement system for this UHI research.[564] The universal thermal climate index (UTCI) is an equivalent temperature (°C); it is a measure of the human physiological response to the thermal environment. I also referred to Goodbun's publication 'The Ecological Semiotics of Air Pollution and Heat in Athens',[565] where he explored semiotics, ecological thinking, heat island effects and pollution in Athens via a systemic approach.

UHI data for CAREV-Ss were unavailable, and it was only possible to argue for the transformation of the urban environment through CAREV-Ss with the necessary data. I undertook this limited UHI study to provide UHI data for CAREV-Ss as a speculative vehicle typology as part of the systemic approach to the spatial study.

561 Ilir Bejleri and others, 'Using 3D Rule-Based Modeling to Interactively Visualize "Complete Streets" Design Scenarios', *Sage Journals*, 2675 (2021), <https://journals.sagepub.com/doi/10.1177/0361198121999051> [accessed 9 October 2023].

562 Federica Marando and others, 'Urban Heat Island Mitigation by Green Infrastructure in European Functional Urban Areas', *Sustainable Cities and Society*, 77 (2022), 103564, <https://doi.org/10.1016/j.scs.2021.103564>.

563 Mohammad Harmay and others, 'Urban Heat Island Associated with Land Use/Land Cover and Climate Variations in Melbourne, Australia', *Sustainable Cities and Society*, 69 (2021), 10286,1 <https://doi.org/10.1016/j.scs.2021.102861>.

564 Sajad Zare and others, 'Comparing Universal Thermal Climate Index (UTCI) with Selected Thermal Indices/Environmental Parameters during 12 Months of the Year', *Weather and Climate Extremes*, 19 (2018), 49–57, <https://doi.org/10.1016/j.wace.2018.01.004>.

565 Jon Goodbun, 'The Ecological Semiotics of Air Pollution and Heat in Athens', in *Taking Action: Transforming Athens' Urban Landscapes*, ed. by N. Kling, A. Roidis, and M. Michaeli (Berlin: JOVIS Verlag GmbH, 2023) <https://doi.org/10.1515/9783986120139> [accessed 4 November 2023]. P. 255–271.

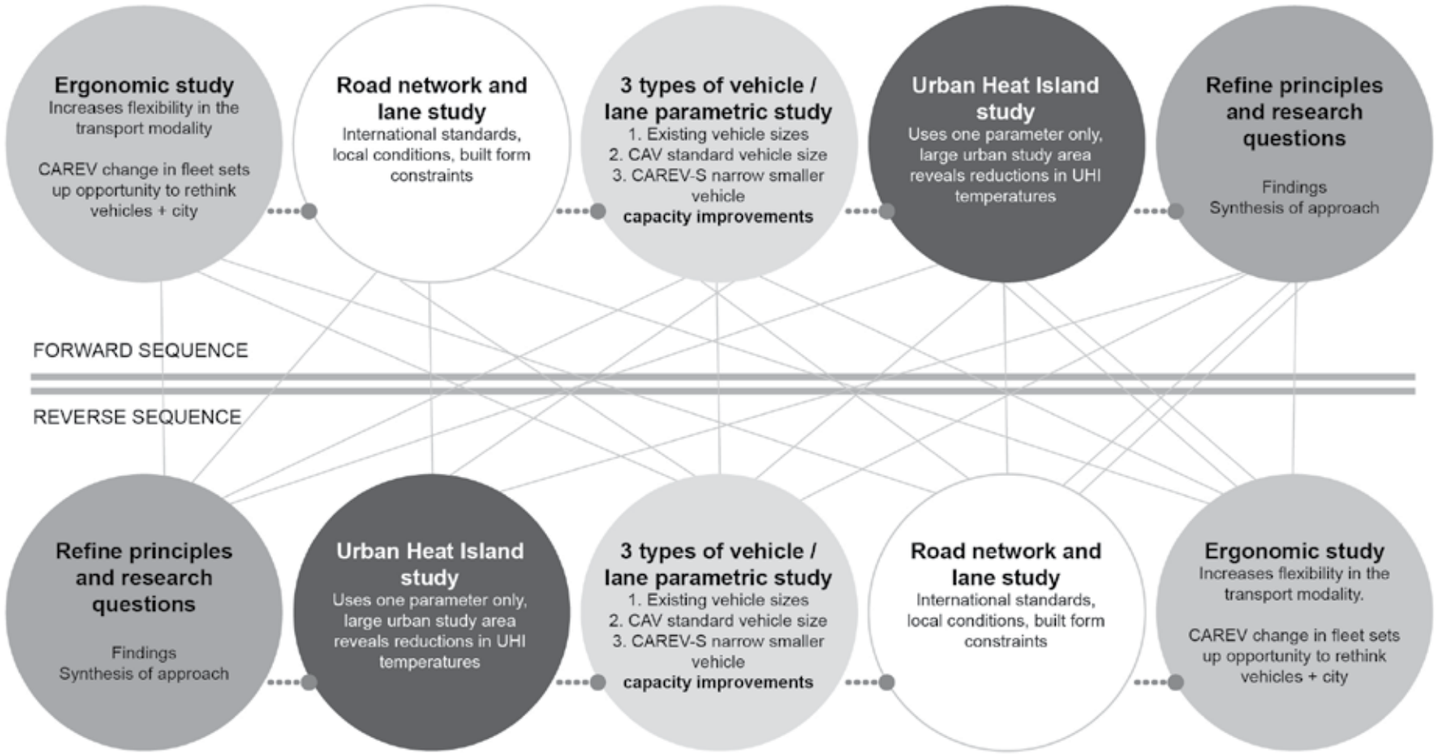


Figure 94: A diagram of systemic approach to the CAREV spatial study.

4.6 Introducing the systems approach for the CAREV spatial study

The spatial justice study aimed to compare current conditions with speculative CAREV and CAREV-S conditions to understand the cumulative effects on the city. As discussed in detail in Chapter 1.6 – Symposium method, the spatial investigation required various systems approaches to understand and compare existing and future CAREV conditions. The development of the spatial study focused on spatial and environmental justice knowledge associated with CAREVs, as follows:

1. **Background**: the study originated from a literature review, which revealed a gap in understanding spatial and environmental justice concerning CAREVs.
2. **Study components**: the study encompassed various elements, including systemic approaches to ergonomics, road space allocation, road capacity, a case study and a heat island study, overlaid with research questions and principles.
3. **Systemic approach**: the systemic approach was necessary to respond to the complexity of the research and the need to manage the components effectively. This approach involved breaking down the study into manageable components that could be adjusted systematically as data from each component became available and influenced the others.
4. **Influence**: applying the Capra–Luisi framework and the transdisciplinary method emphasised integration across disciplines, including Meadows' approach to systems complexity,[566] and the recognition of incomplete mental models.
5. **Limitations**: although the study has limitations, such as the inability to undertake traffic or city-wide modelling, it primarily focused on road capacity and related spatial and environmental aspects.
6. **Reflection**: Meadows reminds us of the complexity of the world and the incompleteness of mental models when working with systems and adopting a learning, precautionary and humble approach.[567]

The diagram alongside shows the systemic nature of the spatial study, refer to Figure 94. The final stage of the process was to organise Symposium 5 and its research interface (www.transfigcav.com.au). During Symposium 5, I mediated the literature reviews and the spatial and calculated data to facilitate the dialogue. Refer to 'Principle 2 – Transdisciplinary systems thinking'.

566 Meadows, 'Systems', p. 180. Meadows commented in 'Stay Humble - Stay a Learner' that 'systems thinking has taught me to trust my intuition more and figure out rationality less, to lean on both as much as I can but to still be prepared for surprises'.

567 Meadows, p. 180.

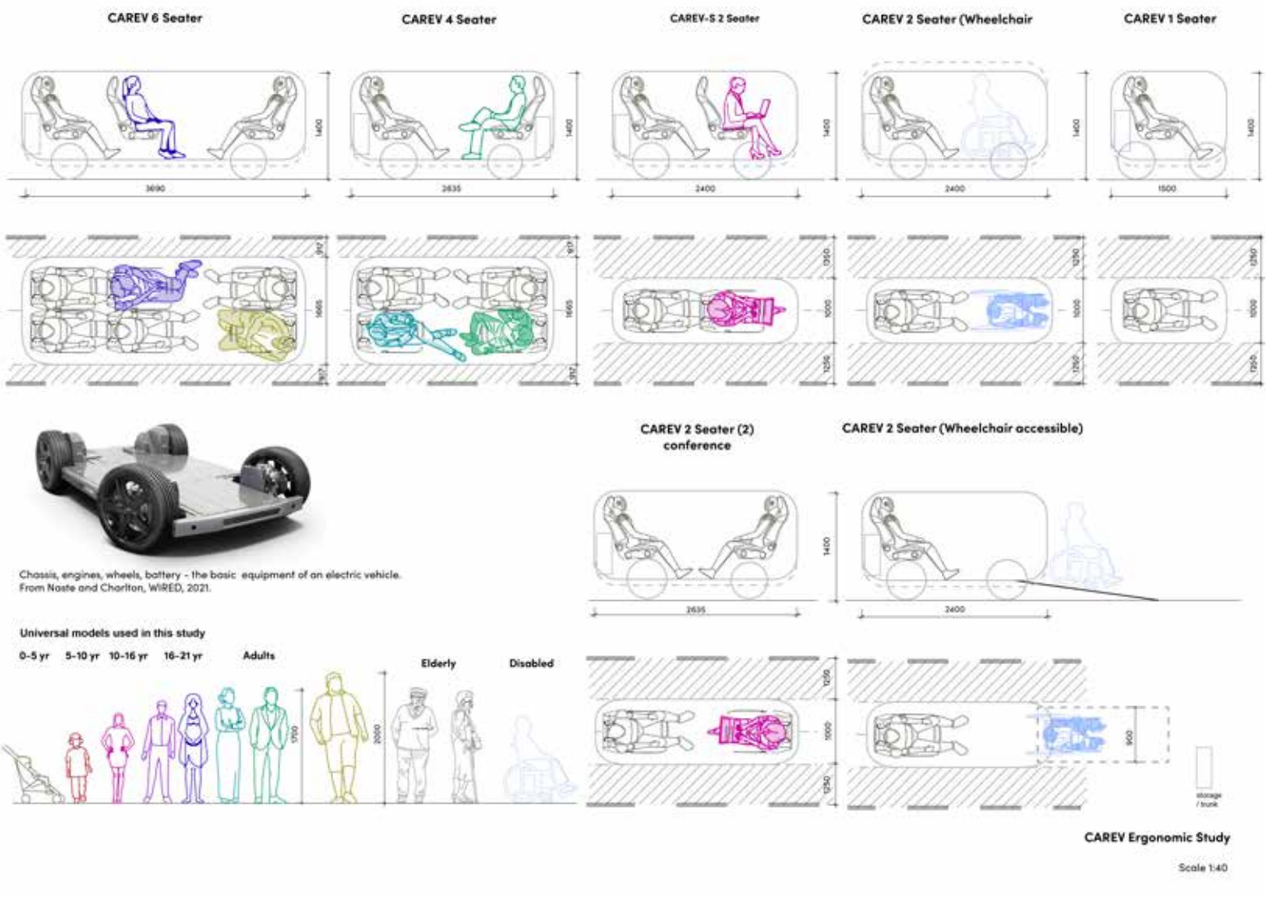


Figure 95: A sample drawing of the vehicle ergonomic study. Refer to Video 2 for the animation. Refer to Appendix E.1. The criteria for the development of the ergonomic study are contained in Chapter 4.6.1.
These drawings were useful for understanding the spatial ergonomic requirements in three dimensions and the limitations of the study, which did not attempt to be a motor vehicle interior or exterior or functional design study. It used a variety of human models in its approach to a universal ergonomic application for the road capacity study of which it is part.

Refer to Video 2 for the animation of the ergonomic study. Refer to Appendix E.1.

4.6.1 Ergonomic and CAREV-S study[568]

The ergonomic study included all age cohorts, from babies to the elderly, a wide variety of body sizes, a diversity of genders and a variety of disabilities. The study was intentionally inclusive to ensure just outcomes. The study used a seated configuration for passenger safety. It focused on passenger vehicles for personal mobility and ranged from one-seat to six-seat vehicles. The study used universal models and also specific modelling for all age groups, diversity models and disabled formats. However, it did not attempt to model all ergonomic formats.

I focused on small-vehicle typologies and specifically one- and two-seat vehicles, which represented statistical vehicle occupancy patterns (63% one occupant etc.). Importantly, small vehicles may suit minority groups, such as people with disabilities, aged groups and LGBTQIA+ cohorts seeking security and privacy, as the vehicles would be designed to suit the individual needs of aged persons and people with disabilities. This was outlined in the literature review with reference to Alice Haning's 2012 report[569] and indirectly to the work of Vitrano and Lindkvist in 2021.[570] One-seat and two-seat configurations represent the current road use pattern of 63% of vehicles with a driver and an additional 7% with a driver and one passenger. The driver in the CAREV system is non-human.

The study focused on the critical ergonomic dimension for small PMVs using CAREV technology (driver sway/driver-assist employed[571]) to allow two vehicles to pass each other within the current road lane format. The dimensional analysis was critical to the research outcomes and showed that CAREV technology will result in an adaptive reuse of the existing public realm's contested space. The lane width drawings can be found in Appendix F.2. The ergonomic study was not focused on vehicle architecture or motor/driving requirements. It was not an interior design study, refer to Figure 95.

I referred to Stuart and Wardle's *H-Point: The Fundamentals of Car Design and Packaging* for vehicle design.[572] However, this reference book does not cover

568 Refer to Appendix F.1 – Vehicle ergonomic study.

569 Alice Haning, Cathy Gazey, and Jillian Woolmer, 'People with Disability: The Forgotten Road User Group', Australasian Transport Research Forum, 2012 Proceedings, Perth, WA (28 September 2012), 18.

570 Chiara Vitrano and Christina Lindkvist, 'Justice in Regional Transport Planning through the Lens of Iris Marion Young', *Planning Practice & Research*, (2021), 1–17, <https://doi.org/10.1080/02697459.2021.1874637>

571 CAREV technologies increase vehicle lane use accuracy – that is, they reduce driver sway, which takes up 15–20% of the current driven vehicle lane space.

572 Macey and Wardle, *H-Point*.

CAREV vehicle typologies. According to the extensive design principles identified by Macey, Stuart and Wardel in *H-Point,*[573] the new design paradigm of an EV will substantively change all aspects. The varied seating arrangements in Figure 95, show some options (forward facing, conference and tandem style seating) for CAREV. The seating arrangements were designed to accommodate a variety of human transportation responses and to accommodate disabilities, and age variations. The ergonomic study includes options for seating arrangements to assist with passenger comfort as riding backwards or both forward facing have limitations. Current passenger patterns in vehicle suggest this could be predicted to be in the order of 7% to 15% vehicle occupancy.

The study is not exhaustive but rather scenarios setting. Articles and videos (Nasté and Charlton[574], Paris[575]and Loh and Liebermann[576]) regarding the fundamental differences between ICE vehicles and EVs show how vehicles' design and manufacturing are developing.

573 ibid.

574 Condé Nast and Alistair Charlton, 'This Is Why All Electric Cars Look Exactly the Same', Wired, 31 August 2021, <https://www.wired.co.uk/article/electric-car-design-engineering> [accessed 14 January 2024]

575 Martine Paris, 'Electric Vehicles: Can "Lightweighting" Combat Range Anxiety?', <https://www.bbc.com/future/article/20240108-electric-vehicles-can-lightweighting-combat-range-anxiety> [accessed 12 January 2024]

576 MotorTrend Channel, Tesla Chief Designer Franz von Holzhausen, online video recording, YouTube, 31 March 2023, <https://www.youtube.com/watch?v=tY37muDxFRI> [accessed 13 January 2024]

This is a fast-moving field due to the technological advances and changes in batteries and storage systems. As noted by Conde Nasté and Charlton in their *Wired*[577] commentary, 'We're approaching a future where car drive platforms will be white-label goods from Foxconn-like suppliers. Differentiation will be much harder.' The issue they raised concerns the fundamental change in vehicle design between ICEs and EVs, including the arrangement and materiality of the chassis, engine, computer and batteries, which also affect the seating and internal vehicle design space. Mark Stubbs from Radford,[578] a significant vehicle design house, commented on EVs' new technology, including the battery, engine and chassis, and said they can provide 'us the freedom as designers to push the boundaries and create unique proportions and shapes'.

The trend for ICE larger vehicles (SUV's) and ongoing concerns about the crash-worthiness of smaller vehicles requires further research and investigations in relation to AV (refer to Chapter 4.4 SUV discussion). The AV revolution would likely usher in systemic speed control. Controls on speed, limiting vehicle mass and energy use as a systemic approach could transform safety outcomes, and therefore revolutionise current consumption patterns and attitudes to smaller vehicles.

Loh and Liebermann[579] suggested that Tesla is a once-in-a-century revolution in automobile design, referencing their interview with Tesla chief designer Franz von Holzthauzen. The design of the Tesla Model 3 shows that EV design is a substantive shift from ICE vehicle design, as the experience is closer to driving a computer than a standard ICE vehicle. Most studies in the field of CAV have only focused on standard four-seater vehicle formats.

577 Condé Nast and Charlton.

578 *Radford - Makers of Fine Automobiles*, Radford, 2024, <https://www.radford.co/> [accessed 14 January 2024].

579 Loh and Libermann.

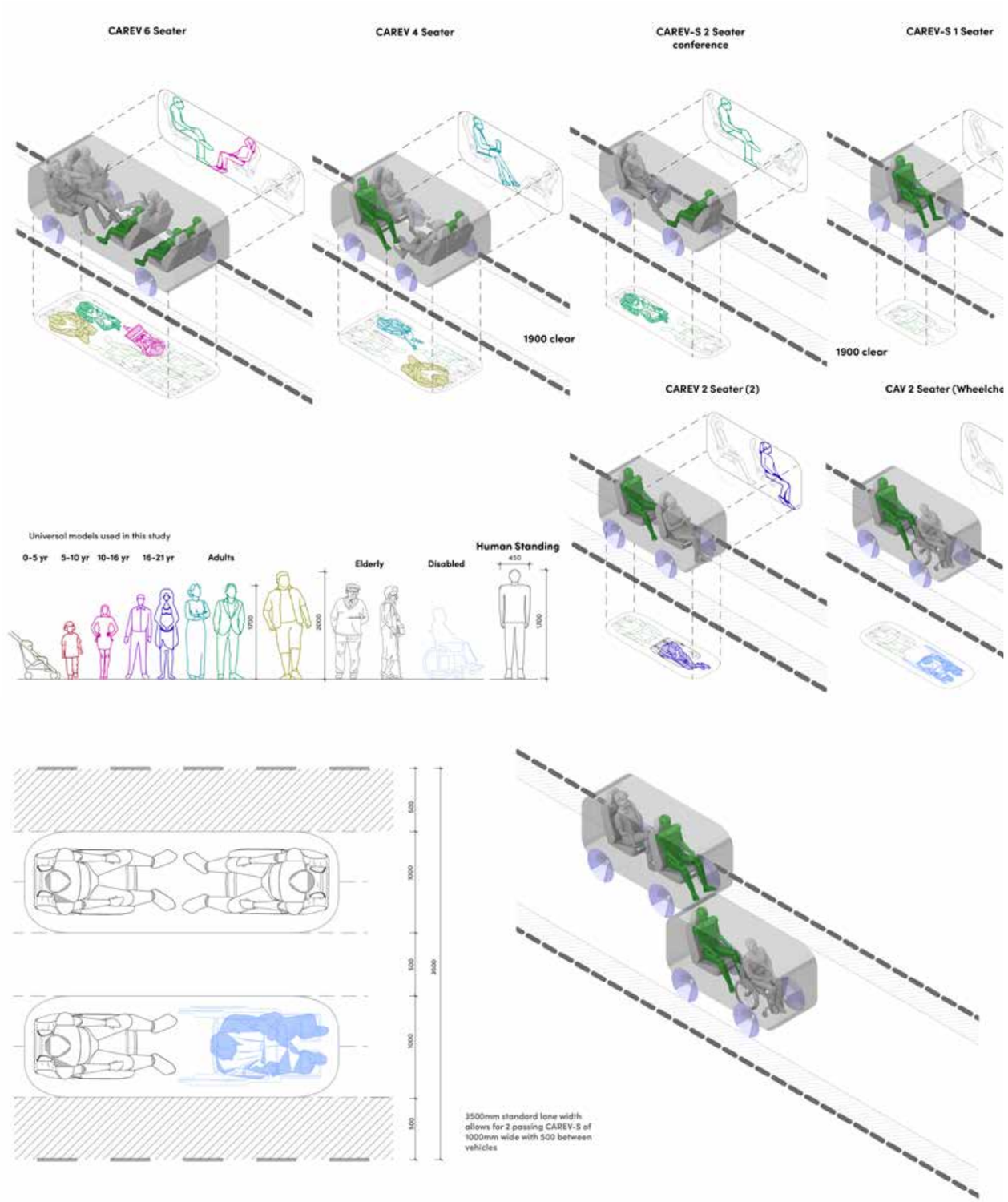


Figure 96: A sample of the 3D drawing of the vehicle ergonomic study. Refer to Appendix E.1. The criteria for the development of the ergonomic study are contained in Chapter 4.6.1.

This study did not intend to discuss in detail the designs of vehicles, engines, batteries, storage, luggage space or wheel locations. These issues will inform future vehicle design investigations. Notwithstanding the limitations, the spatial allocations in the ergonomic study broadly allowed for including all these items. There is an important ergonomic link between CAREV technology and the future SI city. The ergonomic study aimed to understand the spatial implications of a narrow CAREV-S and the relationship of the vehicle envelope to the occupant and road space as an extension of the dimensional implications for the city, refer to Figure 96.

One of the criteria for the parametric modelling was to determine how CAREVs (standard vehicles) and CAREV- Ss (narrow vehicles) can increase the active transport or landscape space within each road typology. The study accepted that a variety of vehicle sizes and formats (refer to the ergonomic study) are required. These include freight, emergency and utility/services vehicles, which may all benefit from CAV systems, according to Cantelmo, Amini, Monteiro and others in 'Aligning Users' and Stakeholders' Needs: How Incentives Can Reshape The Carsharing Market' from *Transport Policy* in 2022.[580] As active transport space will likely result in reduced vehicle-based transport (i.e. more people using passive transport as an alternative), increases in environmental and active transport space in the modelling are a desirable outcome. This is a noticeable feature of many city planning strategies, including that of the City of Sydney.[581]

580 Guido Cantelmo, Roja Ezzati Amini, Mayara Moraes Monteiro, Amnon Frenkel, Ofer Lerner, Sharon Shoshany Tavory, and others, 'Aligning Users' and Stakeholders' Needs: How Incentives Can Reshape the Carsharing Market', *Transport Policy 126*, 2022, <https://doi.org/10.1016/j.tranpol.2022.07.009> [accessed 15 January 2024]

581 'Cycling Strategy Action Plan 2018', City of Sydney, 2018, <file:///Volumes/Studio/RCA/Research/Articles/CyclingStrategyActionPlan2018%20low%20res%20with%20watermark.pdf> [accessed 18 January 2024]

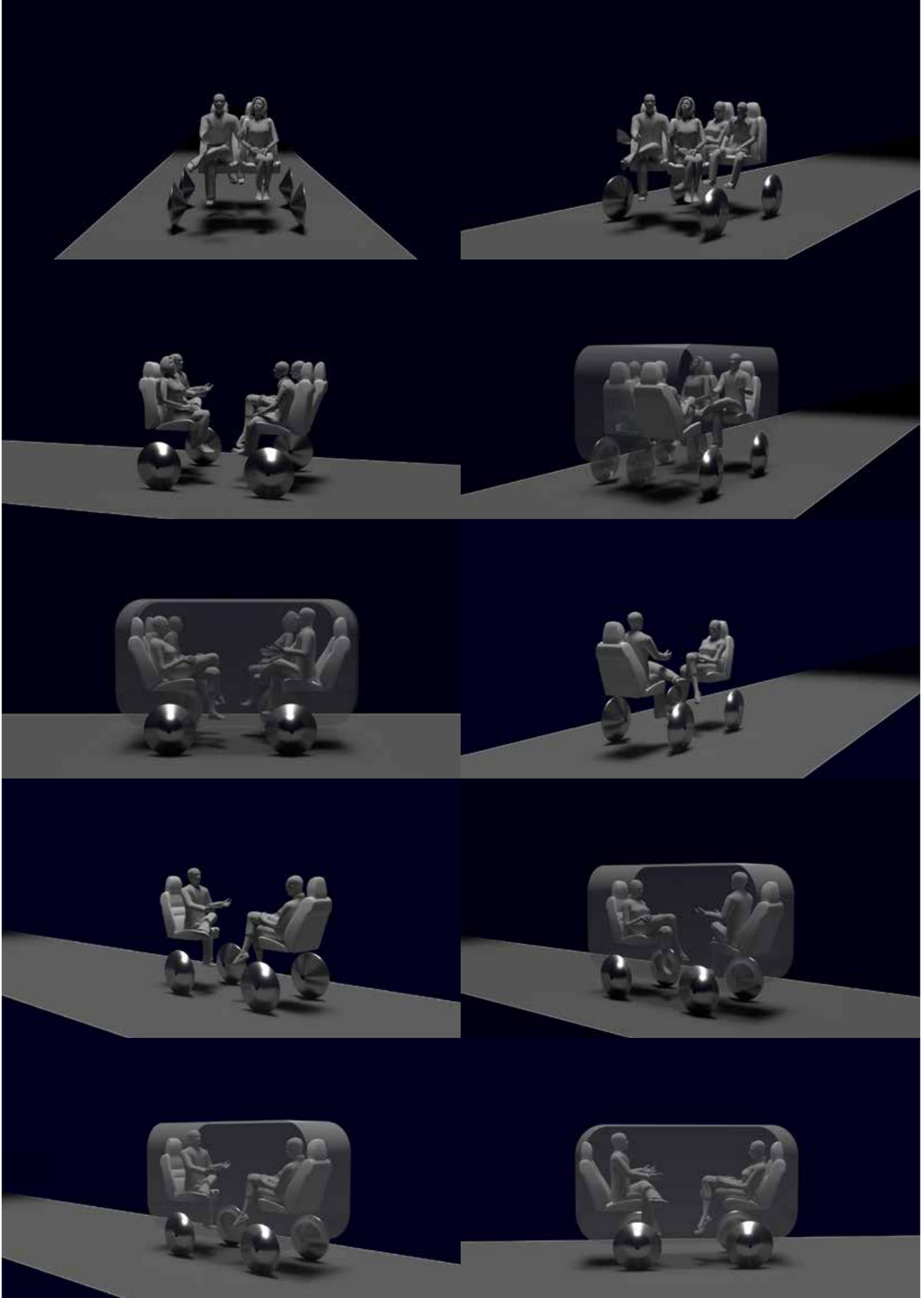


Figure 97: Mosaic of frames from the animation for a two seat CAREV-S. Refer to Video 1 for the animation.

Through a reflective process to understand the limitations of ergonomic outcomes, lane width and vehicle dimensions, a critical dimension for a CAREV-S was found to be 1 m wide so that two CAREV-Ss can pass each other within a 3.5-m lane, refer to Appendix F.2. An assumption the study made was that the space between passing vehicles is 500 mm on each side, which results in an overall 500-mm sway space (i.e. the space between passing vehicles). The study assumed this can be accurately managed by synthetically driven lane assist technology. The study included both two and three dimensional spatial investigations as shown in Figures 95, 96 and 97. Figure 97 is a mosaic of still frames from the animation created for Video 1.

Current road types accommodate typical Australian passenger vehicle use patterns, as follows:

- Sixty-three per cent of passenger vehicles have one person (a driver).
- Seven per cent of passenger vehicles have two people (one is a driver).
- Thirty per cent of the remainder of typical traffic is a variety of other vehicles, including trucks, buses, vans and emergency services, which are large-format vehicles.

The next stage was to apply these findings to a road capacity and case study. Details of the ergonomic study, including its three-dimensional qualities, are provided in Appendix F.1.

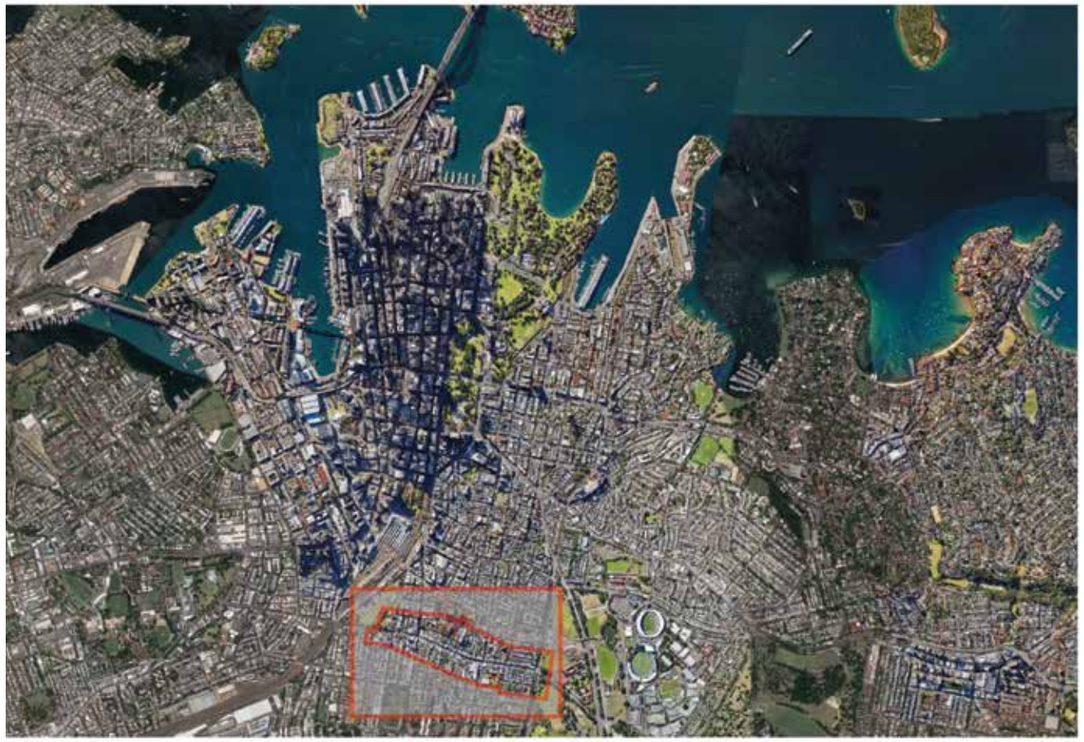


Figure 98: Surry Hills, Sydney, case study area location plan. Refer to Appendix F.3. Aerial photograph by Google Earth.

The study area featured a well-landscaped inner suburb directly linked to the central business district. Both Surry Hills and Redfern are part of the City of Sydney's local government area. The location featured five major road types, an established nineteenth-century urban form and congested roads with parking oversubscription. These qualities are typical for many Australian suburbs. Refer to Appendix E.3 – Case study – Surry Hills, Sydney Australia. Aerial photograph open source 2020.

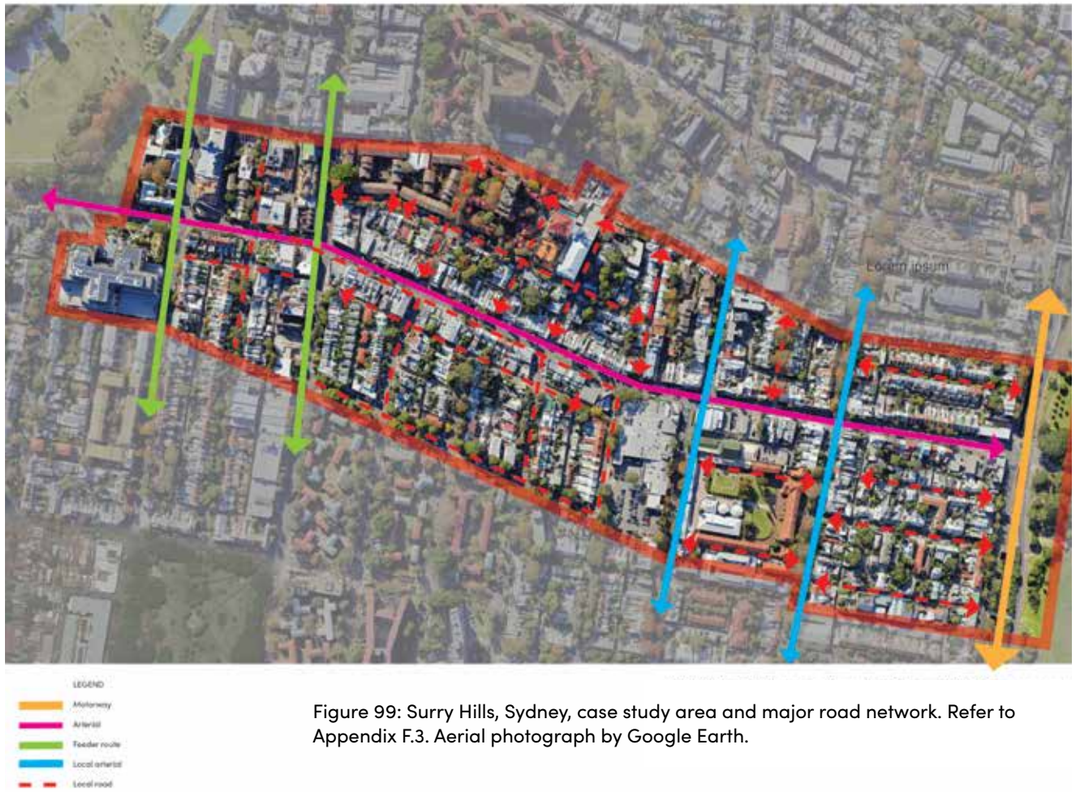


Figure 99: Surry Hills, Sydney, case study area and major road network. Refer to Appendix F.3. Aerial photograph by Google Earth.

The road network in the study area shows the diversity and locations of the road types and how the road network shapes the suburb. The road types influence the types of vehicles that will operate in the road network, the speed environments and resulting vehicle capacities, and the consequential urban form. This is summarised in the photographs of the study area in Figure 95. Aerial photograph open source 2020.

4.6.2 Road space spatial research – Local case study in Surry Hills, Sydney

Surry Hills, a suburb of Sydney, was used as a local case study from which other research could emerge, refer to Figures 98 and 99. The road network and configurations of five road[582] typologies were investigated refer to Figure 96. The road network of the case study was important because, to have realistic outcomes, at least five classes of roads were required to understand the implications of the structures of city road systems. The Transport for New South Wales[583] literature suggests that there are 19 classes of roads in Australia. However, for the purpose of a conceptual study, five road types in Surry Hills were sufficient for this investigation. This is typical for many Australian inner-city road formats. Large format drawings can be found in Appendix F.3.

Road dimension and lane width analyses were required to understand the critical dimensions for a small vehicle (i.e. CAREV-S) to fit into the current format. The assumption was that governments and communities are unlikely to change how urban roads are designed and constructed. The detailed road width analysis is included in Appendix F.2 – Lane widths: Narrower vehicles and existing lane configuration. Road classifications are significant in the management of the public realm, including the legislative management and operations of roads and which authority is responsible at the national, state or local government levels.[584] The road types for this study were as follows:

Table 2: Table of road classifications in Australia

Road type	Authority	Legislated
Class A motorway	Federal government	National Road Act, Commonwealth of Australia
Arterial road	Federal or state government	National (commonwealth) or state act (government of NSW)
Feeder route (no parking)	State or local government	National (commonwealth) or state act (government of NSW) policy legislation
Local arterial road	Local government	Local government (City of Sydney) legislation or policy
Local road	Local government	Local government (City of Sydney) legislation or policy

582 Refer to Appendix F.2 - Lane widths: narrower vehicles and existing lane configuration study.

583 Transport for New South Wales, Practitioners Guide to Movement and Place (Sydney: 2023), <https://www.movementandplace.nsw.gov.au/sites/default/files/guides/pdf/practitioners-guide-to-movement-and-place.pdf> [accessed 18 January 2024]

584 Ibid. Transport.

Each of these legislated road types is co-dependent and has systemic interrelationships with the types of vehicles, the classification of drivers licenced to use the road and the legislated and hierarchical management levels. These legislated functions are essential to the road's operations, maintenance and urban qualities. Legislation, therefore, affects the liveability of the environment where the roads are found. In the Surry Hills case study area, the local government is the City of Sydney. However, the motorway and feeder routes are operated by and function under the NSW Government. In this research, a feeder route denotes an important route in a system of roads, commonly used colloquially in Australian urban design terms as a higher-order arterial road for vehicles. A controlled-access motorway is designed for high-speed vehicular traffic, with all traffic flow, ingress and egress regulated.

Transport for New South Wales is the department managing the road environments for the state. Despite the elected officials, the operations of the suburbs are dependent on each level of government working together with the other levels of government. This highly complex area of land management requires the political, strategic, legal, social and economic efforts of multiple levels of government, as evidenced by the Transport for New South Wales' publication, *Practitioners Guide to Movement and Place*.[585]

This is a complex organisational system developed over decades and inherent in the democratic system of managing the city at the local, state and national levels. It is also a dynamic system that is constantly being reviewed and considered at multiple levels. The impact of AVs on the public realm must be assessed within the existing democratic structures of the city – that is, society must decide to what extent it wishes to accept this technology as part of its future.

585 Ibid. Transport.

4.6.3 Road capacity spatial study

Road capacity and network traffic modelling is a highly specialised and complex field. It has increasingly become the exclusive field of engineering teams, and few studies investigate one- or two-seat vehicles, as evidenced by several publications, including Kockelman,[586] Sha,[587] Reed[588] and Harwood.[589] The spatial investigation diagrammatised the road network to calculate the maximum capacities. The study did not attempt traffic modelling, as it was a capacity study only. Parametric spatial studies in Grasshopper, a plugin for Rhino, were used to interactively develop these spatial calculations along with the ergonomic and case study. The study utilised future scenario planning, with existing worst-case and base-case CAREV and best-case CAREV-S planning. The full set of spatial calculation investigations is presented in Appendix F – Spatial investigation. Figure 97 is an example of the road capacity spatial study using parametric modelling.

The assumptions for the study included the following:

Roads have traffic lights, intersections and pedestrian crossings, which slow down throughput. Typical contemporary fossil-fuelled vehicles are 2,400 mm wide and 5,200 mm long. Braking distance is the distance required by driving regulations and assumed human reaction times during incidents, acceleration and deceleration at normal operating speeds, which affect capacity. Capacities are theoretical – that is, the study did not represent all factors, such as slowing due to SI/human driver reaction times. Traffic congestion is excluded in modelling, as it has dynamic implications that affect capacity and alternate route option selection (i.e. human intervention). Lane changes, overtaking, reactions and on-route decision-making at interchanges and during interactions can impact theoretical capacities, and these were not represented in the study. Traffic network simulation modelling technology is expected to be integrated with SI to help traffic management and regulation and maintain optimum flow and capacities. A lane capacity per kilometre section model does not include network performance considerations.

586 Kara Kockelman, 'An Assessment of Autonomous Vehicles - Traffic Impacts and Infrastructure Needs - Final Report', Center for Transportation Research at the University of Texas at Austin, 2017, <https://library.ctr.utexas.edu/ctr-publications/0-6847-1.pdf> [accessed 20 January 2022]

587 Hua Sha, 'Investigating the System-Level Performance of Connected and Autonomous Vehicles against Transport and Broader Societal Impacts' (unpublished, School of Design and Creative Arts, Loughborough University, December 2020), <https://repository.lboro.ac.uk/articles/thesis/Investigating_the_system-level_performance_of_connected_and_autonomous_vehicles_against_transport_and_broader_societal_impacts/13342064/1> [accessed 3 August 2021]

588 Nick Reed and N. Harwood, 'Modelling the Impact of Platooning on Motorway Capacity', in IEEE Road Transport Information and Control Conference 2014 (RTIC 2014), (2014), <https://www.researchgate.net/publication/289723117_Modelling_the_impact_of_platooning_on_motorway_capacity> [accessed 28 January 2024].

589 Ibid. Reed.

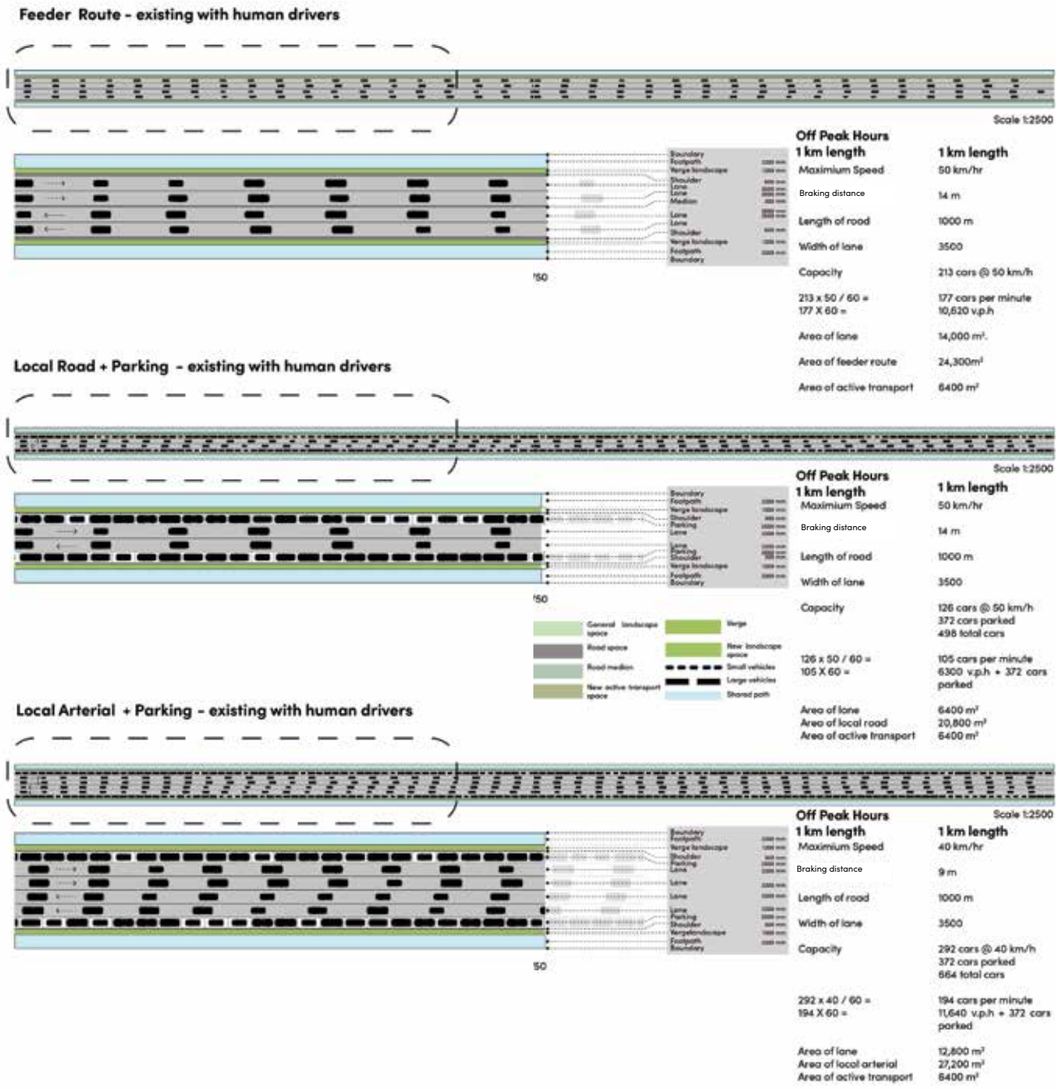


Figure 100: Spatial study sample 1. Parametric modelling of existing vehicle road capacity, sample of feeder and local / local arterial roads. A sample from the control study
Sample drawing of the existing road typology drawing. Refer to Appendix F.4 - Road capacity study existing vehicle size for the full set of large scale drawings.

Control study (existing roads with human drivers and standard size vehicles)

A control study (Figures 100) was developed using current vehicle configurations (i.e. four-seater human-driven vehicles).[590] The distance between vehicles, and therefore the road capacity, was determined by the speed and safe distances between vehicles in each lane. Parametric modelling was performed for peak and off-peak maximum speeds to arrive at the control capacity at peak and off-peak times. The control model was consistent with the published maximum capacity data for motorways in Australia.

590 Refer to Appendix F.4 – Road capacity study existing vehicle size.

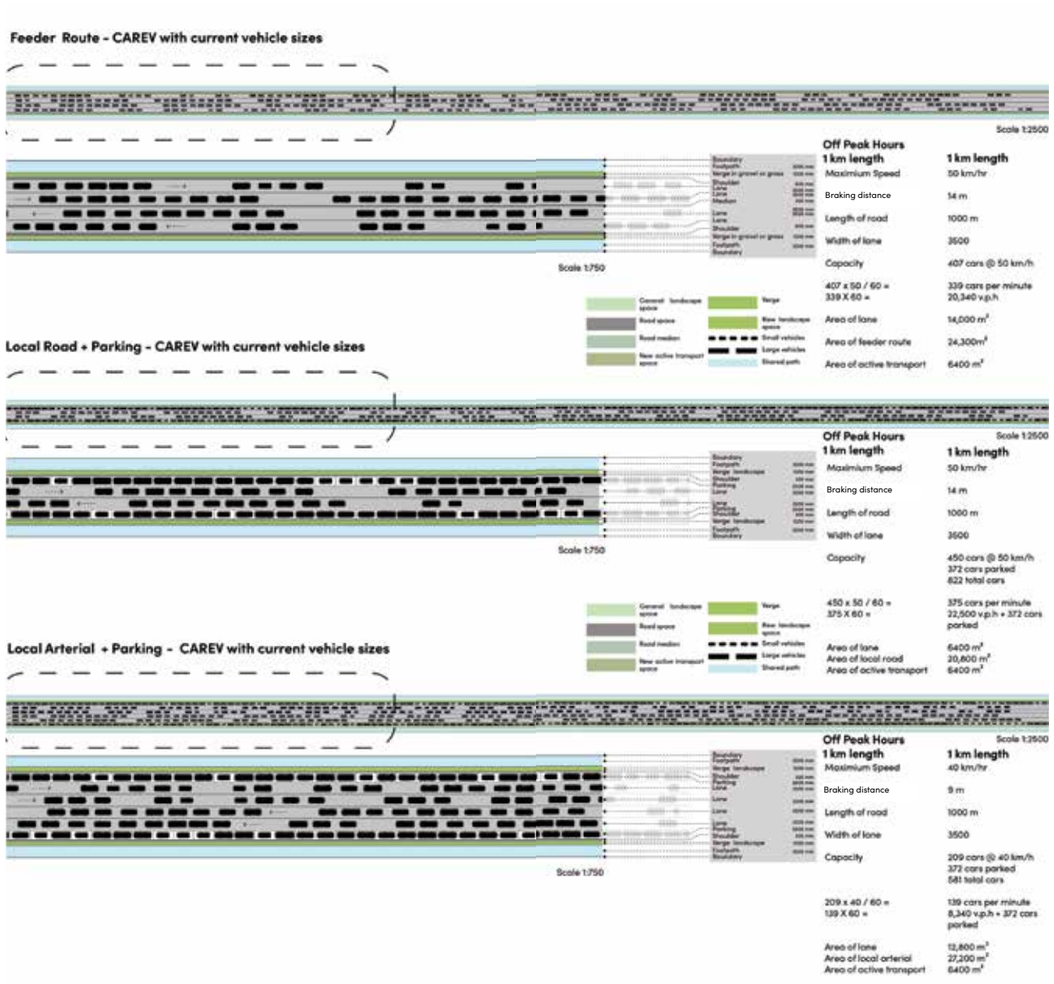


Figure 101: Spatial study sample 2. Parametric modelling of road capacity with standard size CAREV, sample of feeder and local / local arterial roads.
Sample drawing of the capacity study with standard vehicle size CAREV. Refer to Appendix F.5 - Road capacity study existing vehicle size for the full set of large scale drawings.

Spatial study using current standard four-seater vehicles

The second capacity study investigated the road capacity of the five road types with CAREV technology and standard passenger vehicle types (i.e. four seats or more), refer to Figure 101. CAREV technologies permit platooning and other V2V safety systems for vehicles to travel at speed together in convoys or platoons. Thus, CAREVs with standard vehicle sizes will increase the capacities of roads. The findings from this intermediate spatial investigation were consistent with those of other AV/CAVs/CAREV studies that have identified increased vehicle capacities on roads due to the technology. However, as noted by Sha[591] and Kockelman,[592] while the model showed decongestion on some roads, the technology will likely result in more vehicle movements. More CAVs will be moving around, and therefore, the benefits of the technology will not be optimal. Refer to Figure 98 for the parametric modelling of a standard-sized connected autonomous renewable energy vehicle (CAREV) and road capacity.

This spatial study of standard-sized CAREVs provided the following results based on the assumptions listed. In this study, there was no change in the active transport or landscape/environmental area from the existing vehicle modelling as a result of the change from human-driven to CAREV vehicle standard sizes.

The CAREV technologies in this study may increase standard current vehicle throughput capacity by:

- ~200–300% in motorways
- ~150–300% in arterials
- ~200% on feeder routes
- ~200% on local arterials
- ~130% on local roads.

The overall outcome was that CAREVs, due to such technologies as lane assist and computerised logistics and driving, are likely to improve city congestion.[593] Refer to Appendix F.5 – Road capacity study of CAREV using standard vehicle size.

591 Sha, 'Investigating', p. 294.

592 Kockelman, *An Assessment of Autonomous Vehicles*, p. 59.

593 EU and other USA studies that suggest that CAVs are likely to reduce congestion in cities include Fagnant and Kockelman, and European Commission, Joint Research Centre, and others, *An Analysis of Possible Socio-Economic Effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe*, Publications Office: European Commission, Joint Research Centre, 15 May 2018), <https://doi.org/10.2760/777>.

USA studies that suggest increased congestion include Engineering and Technology, 'Autonomous Cars Would Worsen Road Congestion, Study Finds', *E&T*, 2023, <https://eandt.theiet.org/content/articles/2023/01/autonomous-cars-would-worsen-road-congestion-study-finds/> [accessed 23 January 2023]. These studies assumed standard vehicle sizes (i.e. the dominant four-seat passenger vehicle).

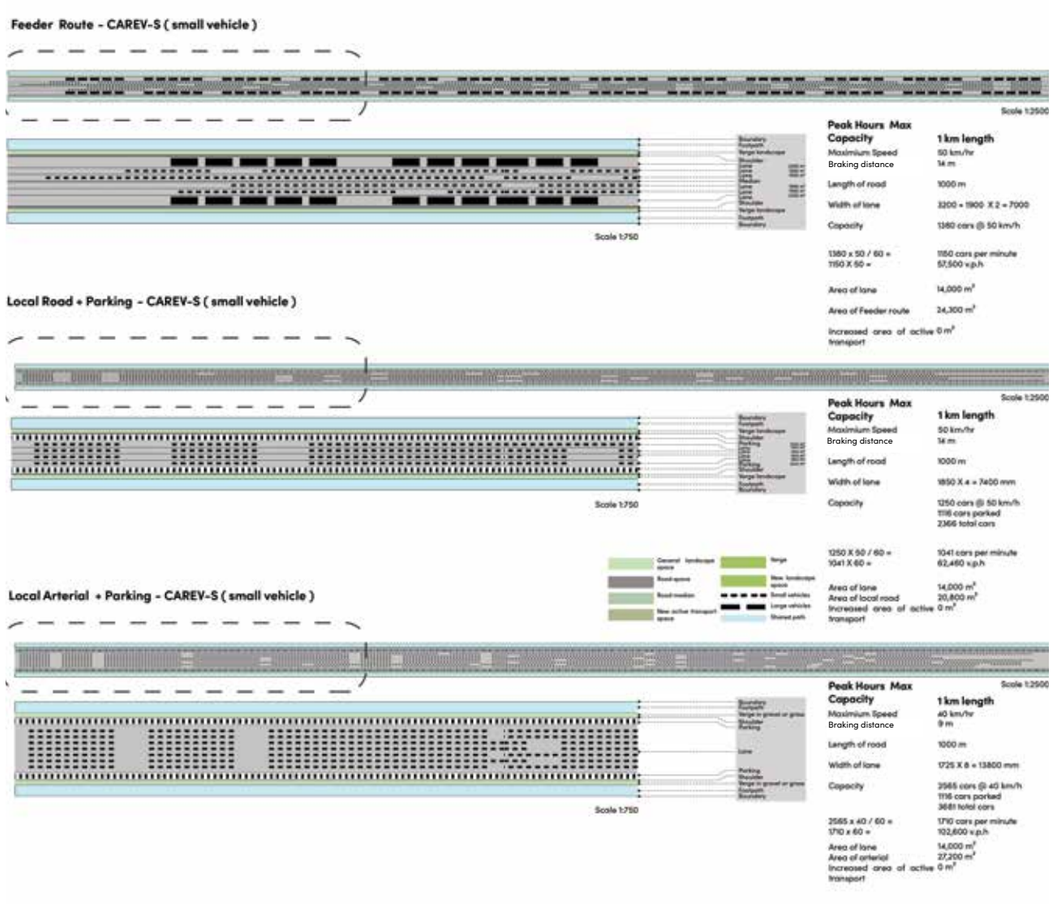


Figure 102: Spatial study sample 3. Parametric modelling of road capacity with CAREV-S CAREV-S and mixed size vehicles at maximum capacity, sample of feeder and local / local arterial roads.

Sample drawing of the capacity study with CAREV-S and mixed size vehicles at maximum capacity. Refer to Appendix F.6 - Road capacity study existing vehicle size for the full set of large scale drawings.

Maximum CAREV–S capacity findings

The results from a CAREV-S in reconfigured lane widths refer to Figure 102, showed an increase in vehicle capacity, as follows:

- ~600–1,000% for motorways
- ~300–680% for arterials
- ~250–541% for feeder routes
- ~600–800% for local arterials.

Local roads introduce frequent traffic conflicts for entering and exiting car parking zones, reducing the potential increase in lane capacity; this was not modelled. Parking could be increased by ~300% on the local and arterial roads if parking was identified as a priority. Large format drawings can be found in Appendix F.6.

The study was developed into animations shown in Video 2 which compare the current road space configuration with that of the CAREV/CAREV-S format in the high street of Crown Street, Surry Hills in the case study.

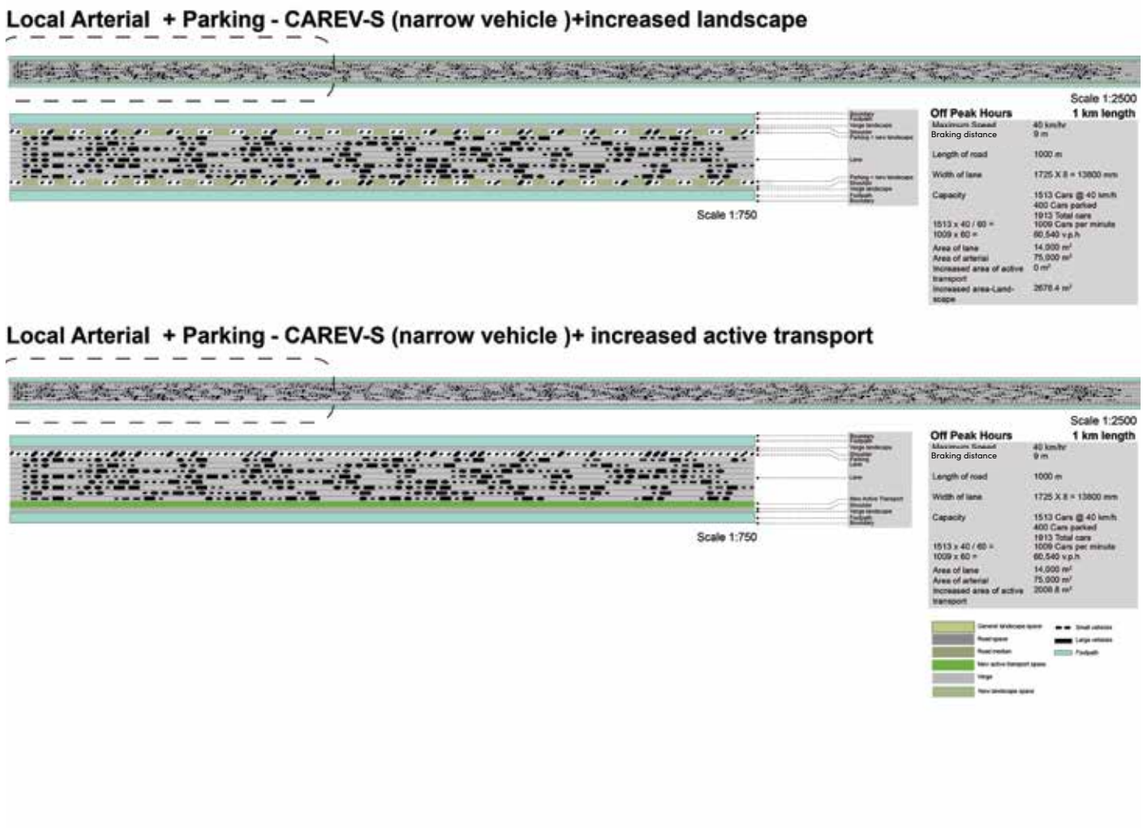


Figure 103: Spatial study sample 4. Parametric modelling of road capacity with CAREV-S CAREV-S and mixed size vehicles with increased landscape area, and local / local arterial roads.

Sample drawing of the capacity study with CAREV-S and mixed size vehicles with increased landscape area. Refer to Appendix F.7 - Road capacity study existing vehicle size for the full set of large scale drawings.

Current criteria used for road and vehicle research

Another portion of the study utilised the same Australian passenger vehicle user statistics to understand the maximum capacities of CAREV-Ss[594] that may be expected to be modelled parametrically from the ergonomic study. CAREV-S technologies permit platooning and other V2V safety systems for vehicles to travel at speed together in convoys. The parametric modelling set an objective for an increase in the roads' environmental and active transport space – that is, the utilisation of space as a preference for environmental outcomes, refer to Figure 103. This redistributive spatial justice provision aimed to rebalance the contentious use of road space by vehicles by increasing the space for active transport or environmental areas. Large format drawing can be found in Appendix F.7.

During Symposium 5, a critical reflection on the study focused on scenario modelling to better understand the implications of the impacts on the public realm. At the time of the symposium, the computer-aided visualisations and animations of Crown Street were incomplete, refer to Chapter 5.3 - 5.8 for the visualisations of a future CAREV Crown Street and SI City.

594 Refer to Appendix F.6 – Road capacity study with CAREV-S.

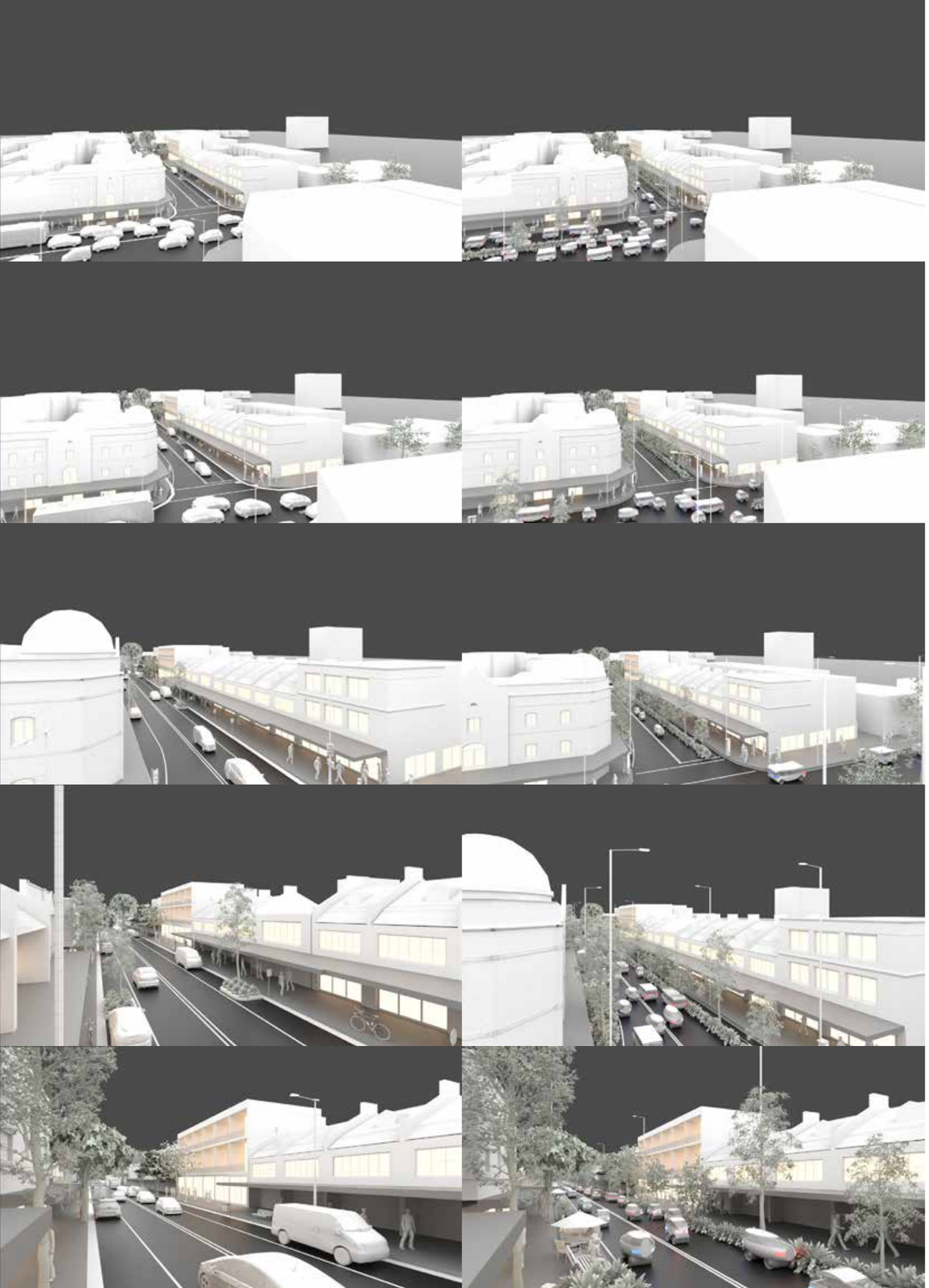


Figure 104: Mosaic of frames from the animation for a two seat CAREV-S day time scenario.

The spatial study demonstrated that deploying a CAREV-S system could result in increased city functionality, decongestion, increased road capacity, reduced environmental impacts, improved resilience, flexibility and spatial justice. The transdisciplinary symposium challenged the usual debates about vehicles and the city by reimagining human behaviour, CAREV-Ss and the city through an environmental lens. Refer to Video 1 for the animation.

The animations supported the spatial study. Taking into account scenario testing, a recommendation during Symposium 5, the comparative visual assessment images were created from the animations. They reveal the visual impacts of synthesising the data from the semiotic study and spatial study applied to Crown Street in Surry Hills, Sydney, the high street of the case study, refer to Figures 104 and 105.

Specifically, the comparative analysis between the existing conditions and the CAREV scenario showed (refer to Figures 101 and 102) an increase in CAREV-Ss due to their narrower footprint, as well as increased environmental areas comprising an active transport (shared path) area on the left and additional trees and landscaping as a result of the redistribution of parking to the left-hand side of the street. A shared path is a mixed-use path designed to accommodate the movement of pedestrians, mobility-disabled persons and cyclists.

The visualisations at night show the new semiotic system's effects on the public realm as mixed-sized CAREVs and the city communicate with each other and the public in the streetscape. The context of the nineteenth-century high street was maintained, the footpaths were widened, and the trees provided additional shade.

The overall environmental benefits were systemic: reduced air and water pollution, less noise, less energy use and zero emissions. The liveability of the city was improved with increased road capacity, smaller vehicles transporting more people, increased active transport and environmental areas for landscaping, reduced temperatures and UHI effects, and increased communications between the city, vehicles and people in the public realm. The modelling was designed to redistribute road space to environmental area as part of the spatial justice investigation of CAREV and CAREV-S. The day and night time animations can be found in Video 1.

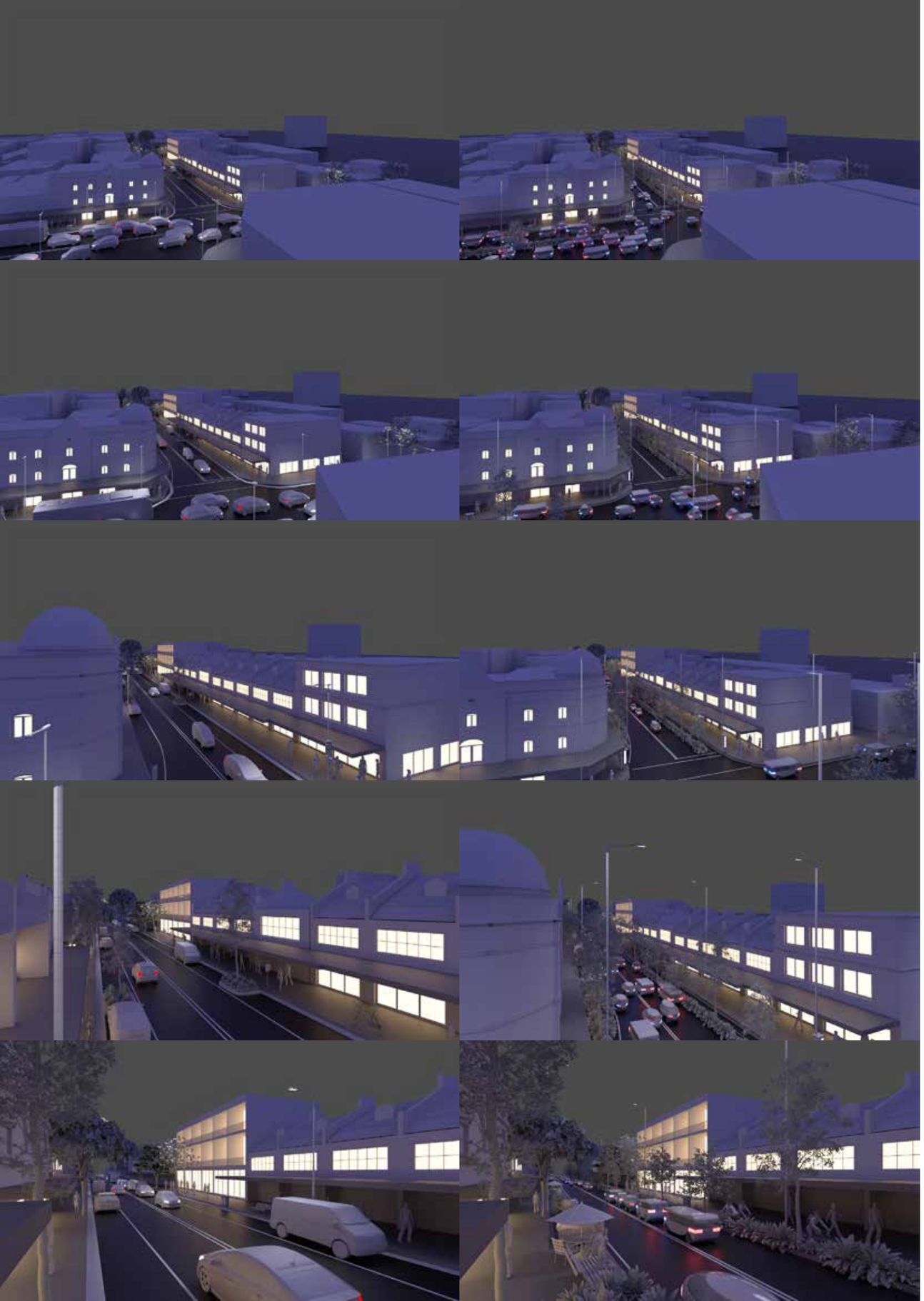


Figure 105: Mosaic of frames from the animation for a two seat CAREV-S night time scenario.

Right: existing Crown Street night-time model of the mixed CAREV/CAREV-S and SI city, with additional landscaping, active transport and CAREV-S semiotics, and city semiotics controlled by synthetic intelligence. Left: active transport signals provide actors in the public realm with real-time information about how to interact with CAREV-Ss. Refer to Video 2 for the animation. Refer to Video 1 for the animation.

The environmental and spatial investigations of CAREV-Ss demonstrated the following:

1. The active transport (shared path) area could be increased by 33% on the local arterials and 40% on the local roads. This equalled a total of 40% of the road corridor area dedicated to active transport on the local arterials and 49% on the local roads.
2. Parking (372 bays) was maintained on local roads at the same level as the existing vehicles. However, the spatial allocation was less as a result of the smaller vehicle size.
3. As an alternative, environmental areas could be increased by 9.8% on the local arterials and 9.8% on the local roads if active transport and parking were maintained at the same levels as the existing vehicles. These increased environmental areas could be used in the UHI study to reduce the impacts.
4. In the next part of the study, the increased environmental areas included trees and landscaping areas, both of which had environmental benefits, including UHI reduction effects.

Still frames from the animations can be found in Appendix 10.

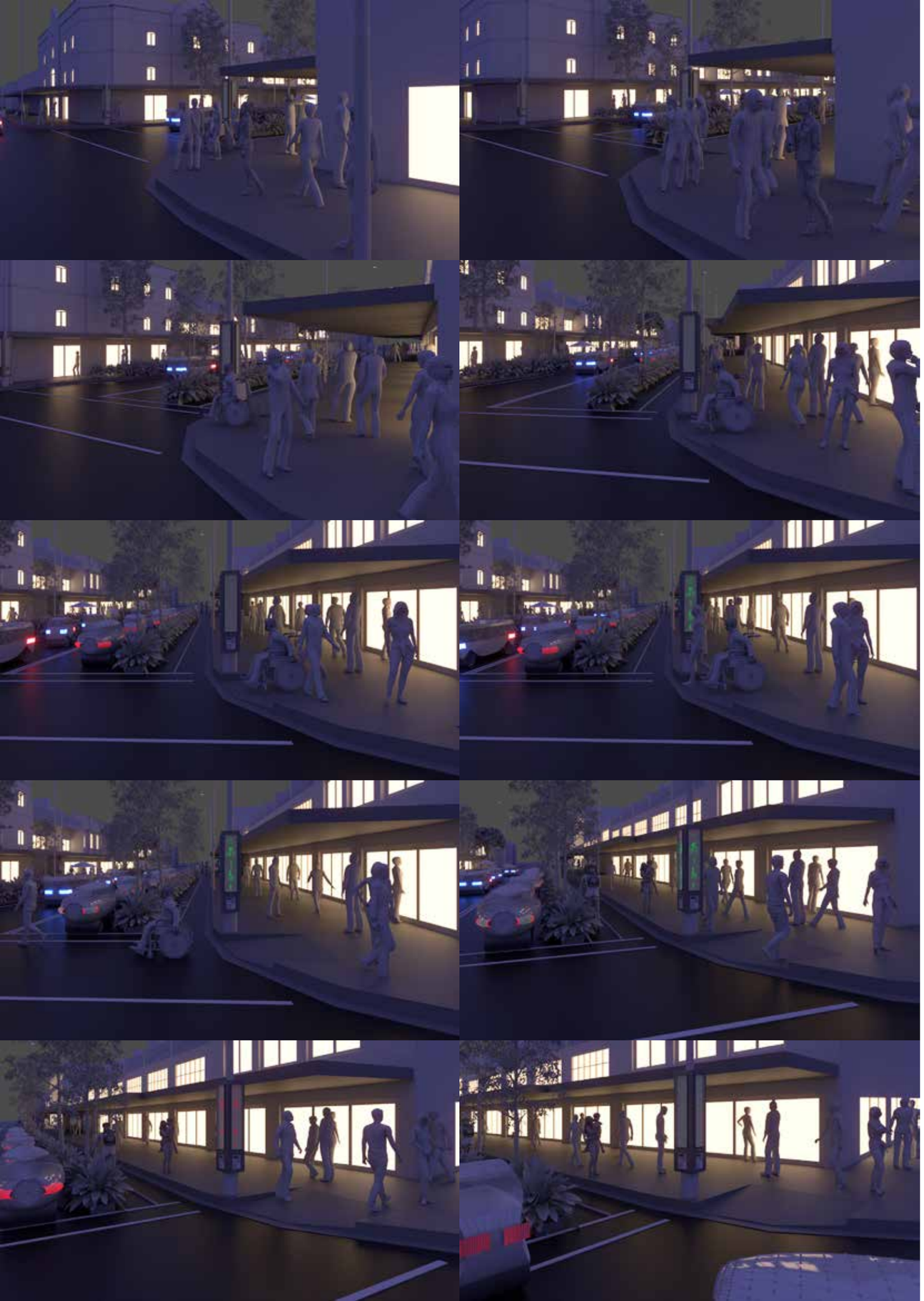


Figure 106: Mosaic of frames from the animation for a two seat CAREV-S at Crown and Cleveland Street intersection night time scenario. Refer to Video 1 for the animation.

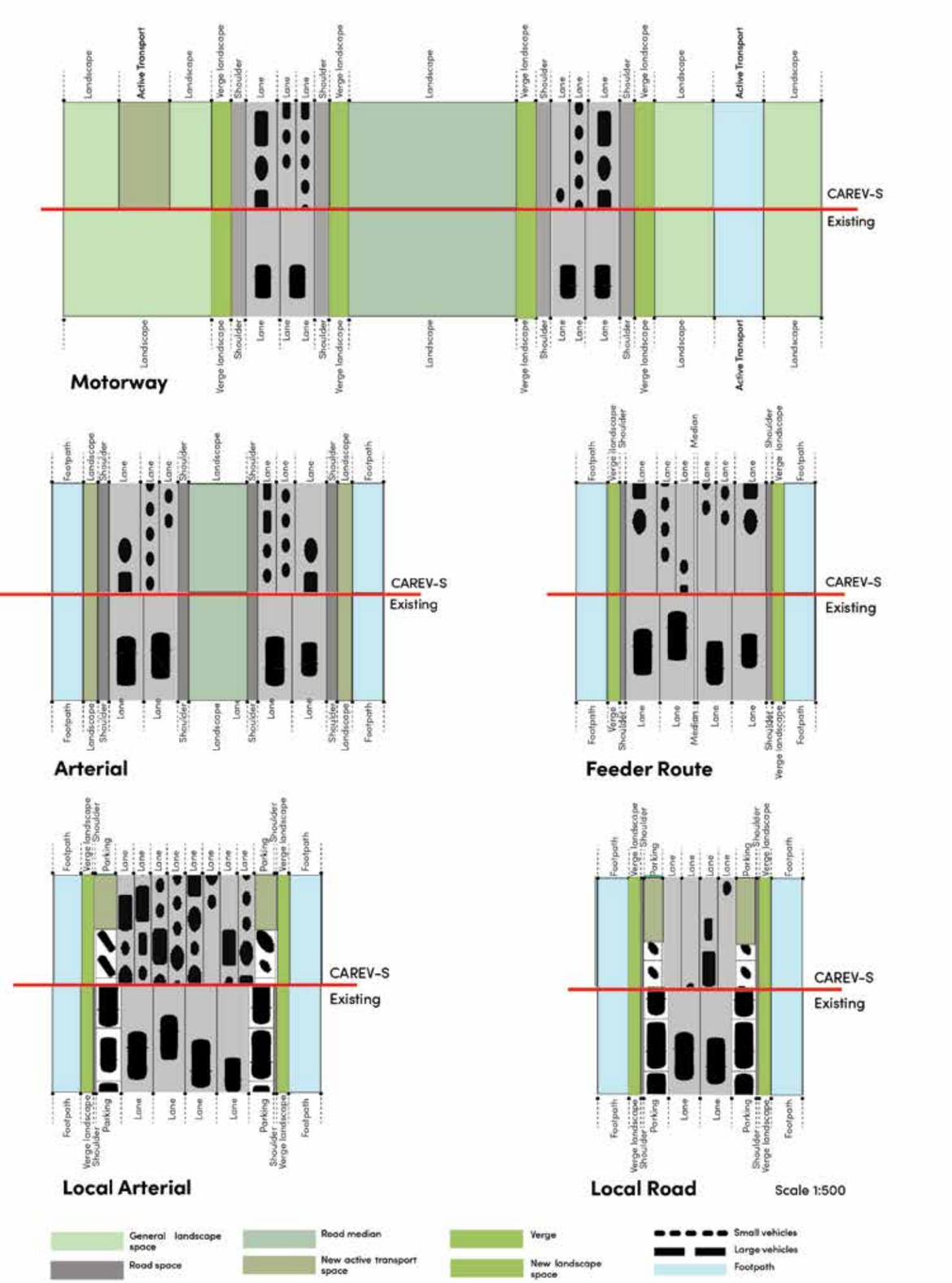


Figure 107: Comparative analysis between CAREV-S mixed road and existing road / standard vehicle type.

The CAREV-S spatial study included a comparative analysis drawing, shown in Figure 107. which shows the road configuration changes between the existing and CAREV-S typologies. The full set of drawings is in Appendix E.8 – Comparative analysis.

4.6.4 UHI study for CAREVs in Surry Hills, Sydney

UHI studies can be used to provide data on the broad impacts of vehicles on cities. The UHI study for Surry Hills, Sydney, was used to assess the implications of setting policies for spatial and environmental outcomes to reduce UHI effects. While increasing shade in urban areas is likely to reduce temperatures, to what extent an increase of 9.8% in landscape areas with mature trees spread across a UHI model would influence the UHI data needed to be clarified. Would this magnitude of change have noticeable effects? The UHI study used scenario planning, with best- (CAREV-S) and worst-case (current) future planning. The study revealed that a 9.8% increase in environmental space in the public realm was a considerable spatial increase. It was not modest, as the public realm is a highly contested space.

Climatic data were supplied by the Australian Bureau of Meteorology for Surry Hills, Sydney, in 2020 using the Ladybug software, a Rhino plugin. The model was run for 2021, as more recent data were not available. The summary results were from a CAREV-S city with 9.8% extra environmental areas and 9.8% areas for mature shade trees approximately equally distributed across the model, in addition to the shade provided by existing trees. Temperature reductions of 3– 4 degrees Celsius at all times of the year in 2021 were found for this limited UTCI model UHI study.[595]

595 Refer to Appendix F.9 – UHI study for CAREV-S.

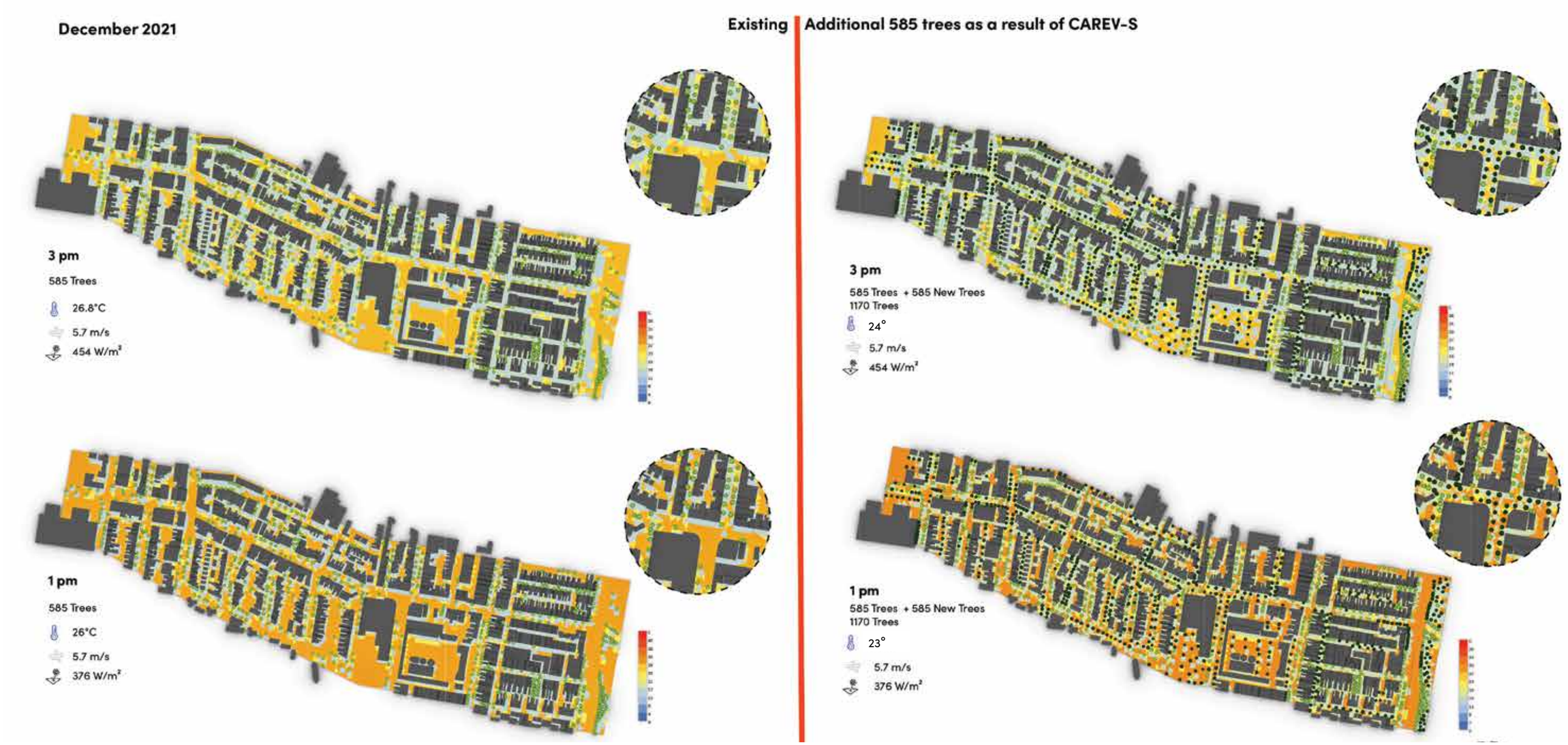


Figure 108: Urban heat island study for Surry Hills case study December 2021, 1pm and 3pm.

Sample drawing existing versus CAREV-S with additional 585 trees (shown as black dots) and 9,8% increased landscape area. Refer to Appendix F.9 for the full set of large scale drawings.

The results were represented graphically in the 24 models run at 8 am, noon and 3 pm as standard UHI modelling (see Appendix F.9 – UHI study for CAREV-S in Surry Hills), a sample of the UHI study is shown in Figure 108. For Australian residential suburbs, such as Surry Hills, a 3–4-degree Celsius reduction was recorded most times during the year's hottest season. Such a reduction is a highly desirable environmental outcome, especially with climate change. UHI effects directly impact human health.

This modelling demonstrated a direct link between vehicle type and UHI effects, which was likely even with increased traffic capacities because of CAREV-Ss and a 9.8% increase in environmental areas to allow for additional tree shading. Consequently, the technology provides city-transforming and improved opportunities for the liveability of the city. In 'How Environmental Neurosciences is Shaping Architecture and Urban Planning'[596] Andrea Cutieru noted that emerging environmental neuroscience studies are used to influence

596 Andreea Cutieru, 'How Environmental Neurosciences is Shaping Architecture and Urban Planning' in Equitable Cities through the Lens of Environmental Neuroscience, ArchDaily, 30 September 2023, <https://www.archdaily.com/969038/equitable-cities-through-the-lens-of-environmental-neuroscience>.

Figure 109: Urban heat island study for Surry Hills case study December 2021, 1pm.
Sample drawing. The black dots represent 585 new mature trees distributed across the model in the public realm based on smaller connected autonomous renewable energy vehicle parametric modelling. Refer to the Appendix for the full set of large scale drawings.

social justice policies related to urban and environmental planning. I presented these UHI and spatial research findings to the Academy of Neurosciences for Architecture in September 2023. This matter was also discussed in detail during Symposium 5 – Beyond justice, which is summarised later in this chapter.

While this study was limited to shading metrics, refer to the enlarged sample drawing in Figure 109, the detailed study in Appendix F.9 (UHI) noted additional variables that researchers can model in future expanded studies. These include reduced temperatures due to changes to the surface of the model (more landscape); reduced vehicle engine heat from CAREVs (omission of ICE, which are considerably less efficient than EVs); reduced urban heat in general, which can further reduce domestic energy and heat output from air conditioning; and transitioning to renewable energy (omitting greenhouse gasses). Multiple benefits appear possible, which is a feature of systemic thinking.

Transforming the city to create more spaces for active transportation, such as walking and biking, can encourage more people to use these modes of transport. Advances in REVs and smaller PMVs can make urban areas more liveable, reduce UHI effects and improve environmental conditions. The limited UHI model showed many benefits for health and the environment. If implemented in more cities and regions, the combined effects can increase positive environmental outcomes systemically. Overall, this approach can potentially transform cities and regions for the better. Critically, it reduces energy waste (the syndrome of empty seats in vehicles), aligns vehicle occupancy with functionality and improves environmental outcomes.

How can SI guide more ecologically and socially just mobility?

A comprehensive technical approach to this question provided an intriguing opportunity. One avenue to follow was to obtain a response from the open-source AI ChatGPT. The full response from the 22 September 2023 interaction is contained in the Appendix G.[597]

ChatGPT suggested that AI can play a crucial role in environmentally sustainable AV development that is socially just. SI can assist humans with emission reduction, energy efficiency, shared mobility, decreasing congestion, integration with public transport, increasing and managing smart city infrastructure, providing eco-friendly alternatives for AV, increasing equity and accessibility for a just future, improving job transition programs, increasing data privacy and security, increasing community engagement, monitoring and accountability, and long-term planning.

Notably, ChatGPT was unable to provide specific cultural nuances for this reply, such as circular economy principles, responses to cultural issues (such as reducing consumption), reducing advertising of ICE and human-SI cognitive processes.

597 ChatGPT (August 3 Version) [Large language model], OpenAI. (2023), <https://chat.openai.com>.

4.7 Spatial study summary

The current road and vehicle system in Sydney, and other similarly sized Australian cities, has been criticised for its spatial and environmental imbalance, leading to claims of inherent injustice. This imbalance is characterised by the dominance of vehicle traffic planning, which prioritises roads and fossil-fuelled vehicles over active transport modes and environmental considerations. Consequently, community groups and society at large often harbour complex and disillusioned attitudes towards roads and vehicles.

In response to this imbalance, a growing discourse advocates for a more equitable distribution of spatial resources, particularly in favour of active transport and environmental spaces, banning vehicles or taxing regimes, such as congestion or parking taxes. The introduction of the CAREV-S model, which reallocated approximately 9.8% of the road space to active transport/environmental space in the study area, was proposed to enhance safety and comfort for cyclists and pedestrians, ultimately encouraging greater use of active transport modes. This approach aligns with the goals of the pedestrian movement in Sydney and international pedestrian advocacy groups, which emphasise the importance of prioritising non-motorized modes of transportation.

A spatially just system aims to rebalance the allocation of road spaces between vehicle occupancy, traffic, active transport and environmental uses. This redistribution of space is expected to yield aesthetic and public health benefits while addressing spatial and ecological injustices. The comparative synthesis conducted in this spatial study explored the potential impacts of reallocating road spaces based on CAREV-S technology, with a significant focus on redistributing spaces for narrow one- or two-seater CAREV-Ss while maintaining adequate lanes for large vehicles.

The full set of the CAREV-S spatial investigation drawings and explanations are located in Appendix F1- F10.

4.8 Practice method (mapped to the symposia)

The spatial study included two symposia: 4 – Mobility metamorphosis and 5 – Beyond justice. A summary of the discussions from the symposia is included below. While the written form of the symposia appears structured, the dialogue was free flowing:

4.8.1 Symposium 4 – Mobility metamorphosis and a summary of the discussions

The 'Mobility Metamorphosis' symposium served as a platform for interdisciplinary collaboration by bringing together researchers from various fields to discuss the evolving landscape of urban mobility. Divided into thematic sections focusing on AVs, shared mobility and environmental considerations, the symposium provided valuable insights into current academic research from around the world.

For the AV theme, the discussions centred on recent developments in the industry, including the relationship between AVs and freight, city planning, and vehicle design in Europe. The shared mobility theme explored such concepts as public versus private vehicle use patterns (e.g. MaaS) and the implications of commercial AVs, with a particular emphasis on road-based public transport and shared ownership models. Shared mobility issues were structured in my research under the environmental section of the PhD framework to integrate natural and man-made environments with mobilities into a holistic system. My research endorses the principle of shared mobility but notes that others have made considerable contributions to this field. Consequently, I chose to focus on private-use and privately owned vehicle systems.

The symposium included speakers who discussed the implications of commercial AVs. Freight and private-use vehicles were intentionally not a dominant theme of the symposium. The environmental theme delved into detailed perspectives on vehicle manufacturing materials, circular economy principles and waste management strategies, highlighting the importance of sustainability in vehicle design and production.

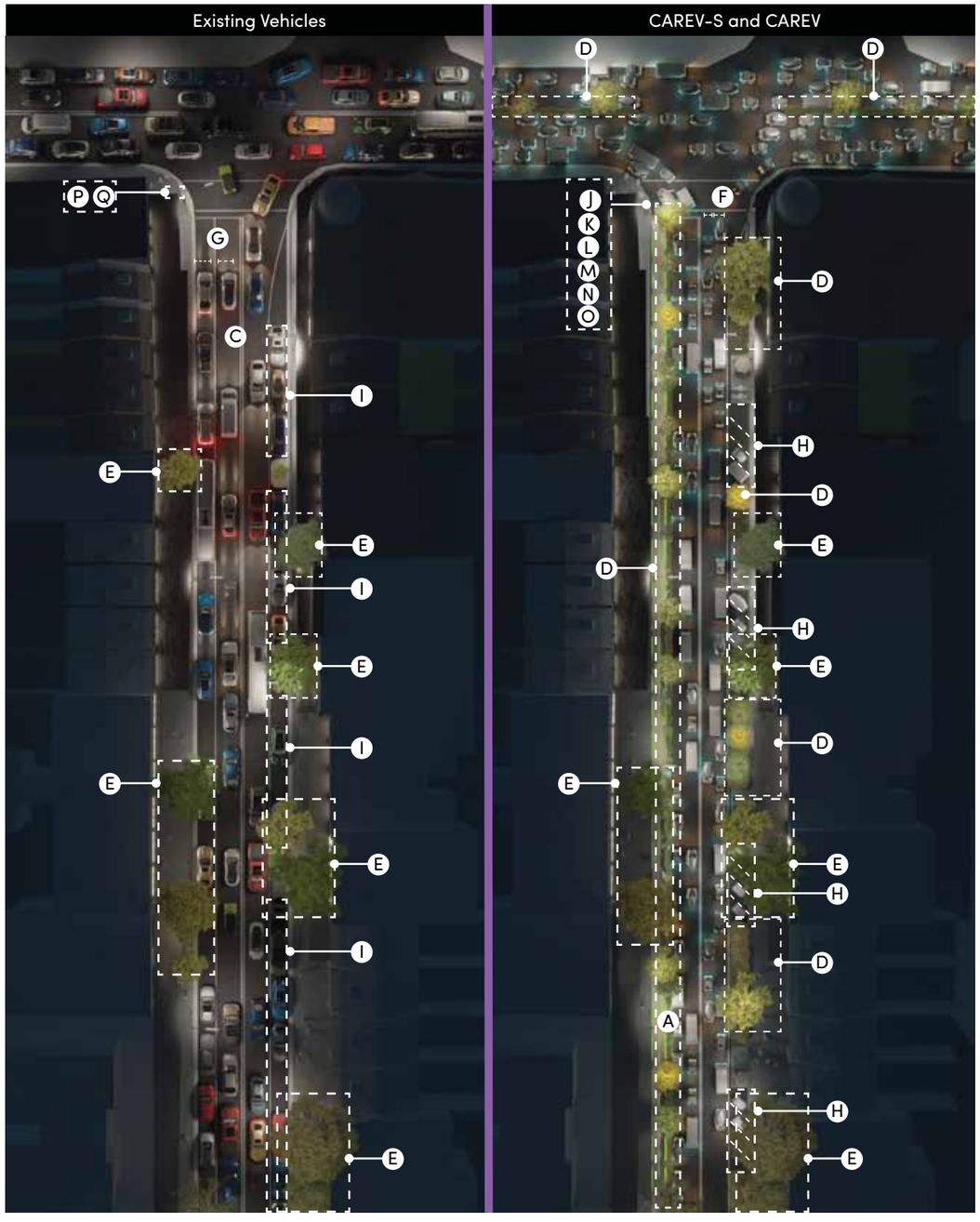
The data from the symposium, which enriched my research, included the following insights:

1. An argument was put forward by a participant for a 'transport currency'[598] that could provide a clear picture to users of the total environmental footprint of the mobility service. This is a major subject itself and requires additional expertise beyond mine.
2. Circular economies as a pathway to balance extraction and environmental waste is an area in which further research could be developed. Circular economy strategies are being developed in other research areas. This research endorsed circular economy principles.
3. Various speakers reinforced the AV/CAV 'sharing for all' mobility strategy. They reiterated how AVs could expand and improve transport justice, especially for minority/disabled cohorts. As previously mentioned, my research focused on private vehicles, as it responded to a research gap.
4. Community engagement strategies were emphasised by some speakers and reinforced through the RCA GATEway study. Examples of case studies, 'scenario modelling and other methods to assist community consultation' approaches were discussed. While the symposium method does not involve specific direct community consultation strategies or methods, these symposia were open to the public, and the general public did attend Symposia 2, 3, 4 and 5.
5. Governance of the public realm, the role of politicians and technocrats such as transport authorities depend on public realm research, such as this, to be able to improve public realm and the liveability of cities to benefit communities and environmental outcomes.

The symposium expanded the participants' knowledge of various academic areas within the field of urban mobility and offered insights from unpublished research from different regions. Discussions on circular economy strategies, community engagement and the potential environmental impacts of increased AV production enriched the research landscape and provided valuable data for ongoing studies.

Overall, the symposium underscored the importance of transdisciplinary dialogue and collaboration in shaping the future of urban mobility. By bringing together researchers, industry professionals and stakeholders, events such as 'Mobility Metamorphosis' facilitate meaningful discussions and contribute to the advancement of knowledge in the field. Moreover, the support and resources provided by the college enable the organisation of such symposia and foster a conducive environment for academic exchange and research dissemination.

598 De-identified data provided by two speakers in dialogue.



Crown Street is modified with additional active transport space, vegetation and trees, CAREV-S vehicles moving more people in less space, the CAREV-S semiotics change the streetscape appearance - a semiotic and environmental transformation through technology advanaces. CAREV-S vehicles move more people using less space, they platoon.

Figure 110: Annotated plan of Crown Street (existing) and CAREV-S) showing the increased landscape areas and modifications.

4.8.2 Symposium 5 – Beyond justice

'Beyond Justice' was held online on Wednesday, 24 May 2023. Supported by the IMDC, it was the fifth and final symposium for the PhD research. Its focus was spatial and environmental justice research on CAREVs and the SI city. The research looked at current vehicle use patterns in the city and the potential for CAREV-Ss to transform cities environmentally. The spatial study was presented at the symposium.

The speakers of the symposium provided feedback that the spatial study was a 'valuable contribution'[599] to the field as a systemic study despite its limitations. Another speaker suggested that a future study could 'investigate the findings through various options, such as scenario testing, assessment processes and traffic modelling.'[600] I used the case study method and animated the spatial investigation in response to the symposium feedback, refer to Figures 104, 105, 106, 110.

In response to the symposium feedback, I created Video 2, which explored the case study and scenario approach to the spatial study as a visual tool. It provided data about road capacities and assisted me in determining which areas could be changed from road spaces to landscaped or environmental areas and which areas could have increased active transport space uses. The discussion in the symposium about the use of a UHI study to understand the cumulative effects of CAREV-Ss with increased tree shading as a case study from which wider environmental findings could emerge was helpful in understanding cumulative impacts in the era of climate change.

The discussion and feedback received from the speakers about the case study method focused on governance and methods of governance in the public realm, which would in the speakers opinion likely remain 'complex due to the democratic and spatial nature of the study area.'[601] Figure 110 is comparative plan of spatial differenced between existing conditions and the future CAREV in the SI city in Crown Street.

Figure 110 uses a typical nineteenth-century high street retail and mixed-use urban form as a background context, which is compared with the existing road photograph. High streets such as Crown Street in Surry Hills are highly desirable urban environments in Australia, and much of Sydney is made up

599 De-identified validation data from one of the speakers.

600 This discussion provided valuable insights and resulted in more animations and scenario testing being undertaken.

601 De-identified validation data from one of the speakers.

of suburbs arranged with the high street forming the major urban spine. The visualisation includes CAREV-Ss with a new semiotic system that provides SI information, such as machine intentionality, to a variety of actors in the public realm. The cyan (recessive colour) lights indicate vehicles moving away from the viewer refer to Figure 52. CAREV-Ss with orange lights (dominant colour) move towards the viewer. Further studies on colour blindness and disability considerations would be desirable. Figure 79 shows the anthropomorphised semaphores on the vehicle, which signal actors in the public realm about the SI vehicle intentionality with culturally appropriate semaphores, such as 'wait', 'thank you', 'stopping' and so on (refer to Video 2).

The reimagined CAREV-S road format includes a new dedicated cycleway separated from the vehicular lanes with a landscaped space and trees, all possible due to the redistribution of parking space and vehicle drift space not required by accurate CAREV guidance systems. The SI city's communications are managed through a cloud-based system that directs and choreographs all traffic (see Video 2). Importantly, SI city information assists actors in the public realm, such as pedestrians, cyclists and people with disabilities, braille/QR code, in managing movement at traffic intersections. The flowing choreographed movements of CAREVs can be seen in Video 2, which shows a subtly orchestrated transition from the current vehicle movement coordinated with the traffic management system. The CAREV transformation is internationally subtle. It respects the built heritage and areas that, through practice, we understand the community wishes to enhance, such as more active transport and environmental spaces, improved city functioning, larger footpath areas and smaller vehicles.

A feature of the model in this spatial study is that road spaces in the existing road infrastructure do not have to change to adopt the new vehicle typology. Any public realm benefits from environmental improvements can be achieved consecutively or after CAREV-S deployment. A significant aspect of the CAREV-S approach is that it specifically aims to reduce expenditure on road infrastructure through the adaptive reuse of existing infrastructure.

The aesthetics used in the video avoid dystopian visions, such as those seen in *Minority Report*, the utopian visions of *Futurama* or *Avatar* and the hyperrealism of the GATEway project. The animation provides the viewer with a realisation that CAREV-Ss and the city are operating to improve safety and environmental outcomes. They improve aesthetic, environmental, lifestyle and public health and safety outcomes.

The symposium speakers agreed that the 'entrenched paradigm of four-seat vehicles was likely to remain,'[602] as decades of development and practice have supported it despite its environmental impacts. Nevertheless, there was an appreciation for the mixed vehicle typology (mixed one- to four-seat vehicles) in the study and the findings that point to a higher functioning city with improved spatial and environmental outcomes from CAREV-Ss. Manufacturers and designers may see the commercial advantage of increased functionality of smaller vehicles in the network operation and market this opportunity to increase mobility opportunities.

One speaker suggested that there was 'great value in understanding CAREV-Ss' implications, which were not evident without design drawings and calculations.'[603] There was criticism that 'not enough scenarios were included in the study,'[604] as I only presented part of the spatial capacity study due to time limitations during the symposium. This led to a discussion about choreographed traffic movement and its potential to change the public realm's aesthetics and functional attributes, noting that communities are unlikely to accept more vehicle movement in the public realm.

The panellists regarded the calculations of increased road/vehicle capacities as 'somewhat theoretical' but raised the importance of studies highlighting complex areas. They agreed that the important aspect was 'not the metrics but rather the demonstration of the potential for further spatial research.'[605] The idea of CAREV-Ss, fewer impacts and higher functionality was identified as a worthy study area. They also noted that this is a highly complex area of research that requires ongoing investigation for the benefit of the community. A capacity study has limitations and vulnerabilities. I return to the commentary by Donella Meadows about futures research by Donald N. Michael: 'Typically we hide our vulnerabilities from ourselves as well as from others. But to be the kind the person that truly accepts his [sic] responsibility … requires knowledge and access to self far beyond that possessed by most people in this society.'[606]

Complex systems theory suggests that there are tipping or leverage points: stages in system change where one system changes and is dominated by another. This study was not a traffic model, and it did not assess efficiency, flexibility or network restrictions, as its focus was spatial. Predictive modelling

602 I have paraphrased this discussion for brevity.

603 De-identified validation data from one of the speakers, rephrased.

604 Feedback is an essential part of developing research and an inherent quality of the symposium method, the comments provided validation of the method.

605 De-identified validation data from one of the speakers, rephrased.

606 Meadows, p. 180. See footnote 9: Donald N. Michael, quoted in 'Futures Research', ed. by H. A. Linstone and W. H. Simmonds (Reading: Addison-Wesley, 1977) pp. 98–99.

of the change point between human-driven vehicles and CAREV-Ss was beyond the scope of this research and would have required traffic, population and network modelling. A traffic model would require supercomputing and/or urban simulation models, such as the digital twin city, to predict outcomes. Future stages of spatial CAREV-S and CAREV modelling at the city and local scales would benefit from advanced computing.

The speakers discussed the 'dominance of large-format vehicles, including trucks, SUVs and public transport vehicles, which cause ongoing difficulties in the urban environment.'[607] Small vehicles can add diversity to a field dominated by four-seater vehicles.

A consensus was reached that urban designers and industry require more design work, thinking and concepts, such as those presented in this research, to make the city more liveable, including changing paradigms, such as the relative monoculture of four-seat vehicles.

The complexity of the industry and its role in impacting the public realm is worth highlighting, and including a paradigm shift of thinking in the field is a worthy pursuit. The speakers agreed that the design output of the spatial study on CAREV/CAREV-s was critical to understanding the research and that information could assist the community and urban designers in understanding their roles in changing the debate about vehicles and the city for policies and governance initiatives.

A source of difficulty was that the field attracted limited participation from the public. Pre-PhD research has its limitations, and student-led symposia exacerbate limitations. Teachers' strikes and other events impact attendance as well. To other researchers, I recommend integrating the symposia with school or college courses and/or school-led and funded symposia. The management of symposia requires considerable resources. However, despite the difficulties in finding speakers and an audience, I obtained the data I needed to complete the research. I did this by asking for answers to the research questions.

607 De-identified validation data from one of the speakers

As mentioned in Chapter 1.6 – Symposium method, one of the difficulties with the symposium method is finding speakers who are interested, have the time and are willing to volunteer their valuable resources. Due to the somewhat narrow academic field of spatial inquiry, considerable effort was required to find speakers to provide specialist insights into vehicle design and manufacturing, public realm policymaking, governance, social justice, environmental justice and communications. I was mostly successful in fulfilling the task and am grateful to the speakers who attended. I could not attract interest from the automotive industry's vehicle design and manufacturing sectors.

The Symposium 5 dialogue and data obtained through the flowing discussion were useful and assessed as the end of several years of practising this research method. By facilitating four of the five symposia and planning and designing all five symposia, I obtained data that allowed me to develop the synthesis and approach further and think about the role of CAREV and CAREV-S in the future city context. As a qualitative method, the speaker dialogue also allowed me to assess the overall aim to improve environmental and city semiotics and achieve cognitive, spatial, social and intergenerational benefits in the process of learning to live with AVs in the public realm.

4.8.3 Discussion

Shared AV mobility focuses on rights to the city, community shared transport, road-based public transport, MaaS and non-private vehicle ownership. This was agreed by most of the participants in Symposium 4 to be a significant beneficial quality of autonomous transport. Programming regular autonomous shuttle services not dependent on human drivers can benefit regional transport, as well as aged and disabled transport. It can facilitate access to the transport system for economically disadvantaged communities, such as those living on the city periphery, while offering environmental benefits through sharing and zero-emission vehicles. Furthermore, it was noted that many AV industry sectors focus on buses, personal mobility pods, mobile offices and other shared AV transport modalities.

The research brought attention to an important gap in the field of AVs, particularly in the context of private AV ownership and its implications for urban transportation patterns. While shared AV mobility models have garnered significant attention and support, the problems posed by the prevailing dominance of private vehicle ownership, especially four-seater passenger vehicles, in many contemporary cities needs to be addressed.

Tesla's fully autonomous vehicle invention (SAE Level 5) is yet to be achieved, it remains the vehicle manufacturer's objective. According to Ben O'Hare, in 2023, Tesla sold more than 250,000 units of Tesla's 'fully-autopilot driving systems,'[608] in the private vehicle market in the USA. Tesla's 'fully-autopilot driving system' (SAE Level 2) requires full control of the human driver over the vehicle, however this technology can be regarded as a step towards full AV. These sales records underscore the rapid evolution of AV technology and its potential impact or desire in relation to private vehicle ownership patterns.

This research does not advocate for a specific vehicle ownership model for AVs. Instead, it acknowledged the diverse range of ownership models that may emerge, including private, corporate, quasi-private–public and publicly owned models.

608 Ben O'Hare, Tesla Reveals How Many Buyers Have Bought FSD, InsideEVs, 3 January 2023. https://insideevs.com/news/629094/tesla-how-many-buy-fsd/.

In the context of this research, while the ownership model of individual vehicles may vary, the overarching SI city system, which encompasses the infrastructure and operations of AVs within the urban environment, should remain publicly owned. I envisage an overarching public ownership model – as it manages the public realm and everything in the public space – acting as a logistical city management system that ushers in the notion of the entire road-based transport ecology as a civically aligned modality.

This model is crucial to ensure equitable access to transportation services and to uphold the rights of all citizens in the public realm, as well as the communal right to change the way the city operates. Privately owned AV spaces, such as those found in industries like mining and ports, often exclude public access, highlighting the importance of maintaining public ownership and accessibility in advanced technology urban transportation systems.

The preference for private ownership and usage contributes to traffic congestion, environmental pollution and other issues associated with car dependency.

This topic also presents an opportunity for future researchers to explore strategies for improving the comfort and desirability of shared and CAREV mobility options. By understanding the preferences and priorities of different user groups, transportation planners and policymakers can design and implement shared mobility services that meet the diverse needs of urban residents while promoting sustainability and reducing reliance on private vehicle ownership.

Integrating ecological and social considerations into the development of AV design for a sustainable and socially just transportation system requires a shift in thinking about various factors that currently make shared mobility unattractive.

During the early stages of the COVID-19 pandemic, public transport was banned in several cities. Emerging from this was isolation and private space. For thousands, even millions, of people across the planet, the private vehicle

was the primary safe mode for accessing medical testing and treatment. A lesson from this is that shared mobility and private mobility platforms provide city transport resilience, and both systems have their place and are necessary for city functioning. However, private vehicle ownership has dominated the road-based transport system for more than 100 years. This trend is unlikely to change due to CAREVs and may worsen. Indeed, the findings indicate that CAREV/CAREV-Ss may increase consumption and traffic movement, as unit cost and accessibility increase access to this type of vehicle.

A notable feature of the current road-based transport system is its relatively monocultural features, the dominance of four-seater vehicles, the dominance of large format vehicles and the current trend towards SUVs and large vehicles despite the safety issues and environmentally impactful nature of these vehicles.

A first step in society intervening in the road-based transport system to realise an ecologically positive outcome is to have a conceptual vision of such a system. The renewable energy (RE) classification is important in the current context of the ongoing misuse of fossil-fuelled vehicles that contribute to climate change. Hopefully, this RE classification will eventually seem quaint and of its time as society transitions to RE sources. Still, it is an important distinction in contemporary thinking and actions.

The conceptual position is where the Capra–Luisi ecological framework of a holistic, integrated and unified system is a significant adaptation for the AV modality. Appreciating the CAREV system, its semiotics and the intelligent city as one interrelated system and adapting the Capra–Luisi framework and Schneider's LoT theory to conceptualise this system with networked sub-systems is this research's contribution to the field.

Society and much of the urban design community appear to have given up on attempting to change the automotive industry, the dominance of four-seater vehicles, consumption and the combined impacts of vehicles on the city. The extended history of the impacts of fossil-fuelled vehicles on the city and public health and the 'too-big-to-fail' industry scandals that have rocked nations and companies have increased the sense of a lost cause.

I argue that a new vision is required to assist systemic change. A new path to an ecologically positive AV transport modality that fulfils the cultural dreams of a magical, safe, sustainable, just, convenient, resilient and flexible system is required to inspire systemic behavioural change at all levels. It is incumbent on society to intervene in the system and to ensure that future generations benefit from this generation's intervention.

The spatial investigation into CAREVs suggested that the whole of society can benefit from a narrower CAREV-S, as multiple systemic benefits arose from the CAREV-S and mixed vehicle modelling. The benefits include reductions in energy use in manufacturing and operations, less extraction if circular economy principles are incorporated, higher levels of flexibility and resilience in city operations, including the capacity and functionality of the public realm, and increased mobility access and use by minority groups. A fully CAREV environment requires a systemic and designed approach for the benefits to be realised. While the whole of society can benefit from a system that redistributes and balances shared and private vehicle ownership and operations, there are minority cohorts who are likely to experience increased opportunities with CAREV, as follows:

1. Aged and young persons utilising CAREVs specifically designed for them and who are no longer dependent on human drivers will experience increased transport access and flexibility.
2. Economically disadvantaged communities – that is, people living on the periphery of the city, where public transport is scarce and rail transport is unavailable – will benefit from no longer being dependent on human drivers. This cohort will have increased transport access and flexibility due to shared mobility.
3. People with disabilities can have vehicles specifically designed for their disabilities. They can have greater transport access through CAREV technologies.
4. Minority groups, such as racially or sexually profiled individuals (e.g. LGBTQIA+), may experience increased transport accessibility if the system is designed to exclude discriminatory and profiling practices. Small vehicles can made more accessible, and security and privacy issues can be addressed in the design and manufacture of CAREV-Ss suited to these cohorts.

5. A range of freight and emergency service vehicles that feature robotic interventions due to CAREVs and that are no longer dependent on human drivers can result in increased safety, resilience and functionality.
6. The adaptive reuse of infrastructure such as bridges, tunnels and dedicated road space, through the deployment of CAREVS as a dominant vehicle form would reduce investment in the network overall, a systemic benefit.

The study accepted the principle that PMVs will have SI management systems integrated into their uses and functionality. For example, motorbikes with autonomous driving capacity will be part of the CAREV system. Urban bicycles will have SI integrated management systems to increase functionality, safety and comfort. Systemic impacts that will require legislative or other controls to manage the outcomes are likely.

1. The research reiterated that there will be an increase in traffic movement as a result of CAREVs. This is a feature that most AV researchers agree upon. It is a system effect and inherent quality of CAREV movement and its desirability, convenience and comfort in moving humans and goods in the city.
2. While the movement is not a major impact, congestion will eventually occur as the system reaches capacity. This research investigated a narrow, bypassing CAREV-S with a one- or two-seater format, which, if redistributed at a percentile matching the existing use patterns of 70% of one- or two-occupancy vehicles on the road, will significantly improve the capacity and operations of the city. There will be an increase in movement.
3. CAREV-Ss will be less costly than larger vehicles to produce and operate, with systemic benefits from lower transport distance costs. An adverse outcome will be that more people can afford less-expensive vehicles, resulting in increased consumption, use and operations. This will need to be mitigated by circular economy principles.

4. Hopefully, MaaS will be able to assist with mass movement strategies. For private vehicle ownership, the CAREV-S will be controlled by the owner and SI city logistical systems, conceivably to maintain control over the city and to manage the space savings gained through the change in vehicle format.

Refer to Principle 4 regarding social justice and Principle 5 for the ethical responses to SI for AVs and the city.

The orthodox debate on vehicles and cities continues. In this debate, the conflicting character of real transport planning is avoided; this includes increasing population growth, rampant consumerism and urbanisation. Furthermore, vehicle sizes and speed, occupancy statistics and road capacities are rarely assessed. This study proposed introducing new variables of CAREV-Ss to change the debate.

4.9 Answering the research sub-questions

The following are a summary of the answers to this chapters sub-questions:

SQ 4.1: How can autonomous mobility be beneficial for cities, people and the environment?

Ultimately, achieving equity and sustainability in urban transportation requires a systemic approach that balances the diverse needs of users, commercial interests and public welfare. By promoting city-wide or civic shared mobility governance and maintaining public ownership of essential transportation infrastructure, cities can work towards creating more inclusive, efficient and environmentally friendly transportation systems for all residents, subject to their licences.

SQ 4.2: How can shared mobility promote a fair, equitable and inclusive city?

In the future, CAREVs can transport aged and young groups and people with disabilities in a shared mobility system. The low cost per transport distance can make the shared mobility platform more inclusive and accessible to minority groups and cohorts requiring specialised transport facilities. In Australia, there is a strong trend of aged persons relocating to regional areas for their retirement to avoid the complex living requirements of the city. Living regionally has broad health and economic benefits. However, a shared mobility detractor is access to specialised medical facilities often being restricted by the limited number of human drivers and emergency vehicles. CAREV-Ss can assist regional communities and minority groups living in regional areas to access specialised care in cities with SI mobility with ease and comfort. People with disabilities can anticipate vehicles being explicitly designed to address their needs with CAREV-S driving facilities. The combined effects of CAREV-shared mobility can promote a fair and equitable city through autonomous driving operations defined by their sophistication.

During Symposium 4, a consideration was brought to light regarding the need to enhance the comfort and reliability of shared mobility services to increase their attractiveness to users. Historically, the road-based transport system has prioritised high capacity and efficiency over passenger comfort, resulting in vehicles with low comfort levels, cramped seating arrangements and limited amenities. While effective in increasing capacity and patronage, this approach has led to a lack of appeal among users who prioritise comfort and convenience. Consequently, many individuals opt for private vehicle use or low-occupancy transportation options, such as renting or using cars, rather than utilising shared mobility services.

SQ 4.3: Can regenerative principles in CAREV guide more ecologically and socially just mobility?

Changing the paradigm and technology benefits the city by introducing a spatial justice investigation into a new vehicle typology and its effects on the city is part of a regenerative ecological principle. As discussed in Chapter 3.6, the SAE taxonomy needs to respond to the complexity of cultural settings and just environmental outcomes beyond the vehicle and the quality of its driving ability. It is a rich cultural setting that CAREVs will find themselves operating in, should they be granted a social licence to operate.

According to numerous scholarly reports, such as Moriarty and Wang[609] and Morteza and others,[610] CAVs will have emission benefits over current ICE vehicles. CAVs are cited[611] as a labour disruptor and will deepen the inequality between low- and high-skilled workers. The commercial interests of CAV manufacturing and industry operations will accentuate this if not managed.[612] The EU publication *The Future of Road Transport* did not address how spatial redistribution could improve cities or labour inequality in the next stage of developing spatial justice in transportation.

This spatial investigation addressed environmental justice using small vehicle formats. Advanced technology, such as CAREV-Ss, filled the research gap. The study used spatial justice principles to further develop the idea of platooning, swarming and traffic-based rhythms as a choreographed system with CAREV-Ss. Choreographed, flowing traffic is the dream of traffic engineers, such as Marques and Silva,[613] and other interesting research that utilises the ant-based algorithms of Di Caro and Dorigo.[614]

The CAREV-S system can also be argued to be a necessary part of the production of space. This approach intends to shift the current orthodox debates on private vehicle use in the city. For many, a private vehicle is an essential transport

609 Patrick Moriarty and Stephen Jia Wang, 'Could Automated Vehicles Reduce Transport Energy?', *Energy Procedia*, 142 (2017), 2109–13, <https://doi.org/10.1016/j.egypro.2017.12.613>.

610 Morteza Taiebat, Austin L. Brown, Hannah R. Safford, Shen Qu, and Ming Xu, 'A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles', *Environmental Science & Technology*, 52 (2018), 11449–65, <https://doi.org/10.1021/acs.est.8b00127>.

611 European Commission, Joint Research Centre, Maria Alonso Raposo, Monica Grosso, Jacques Després, Enrique Fernandez Macias, Maria Cristina Galassi, and others, 'An Analysis of Possible Socio-Economic Effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe', Publications Office, European Commission Joint Research Centre, 15 May 2018, <https://doi.org/10.2760/777>.

612 European Commission Joint Research Centre, *The Future of Road Transport: Implications of Automated, Connected, Low-Carbon and Shared Mobility* (Luxembourg: Publications Office, 2019), <https://data.europa.eu/doi/10.2760/524662> [accessed 3 August 2021].

613 Maria Marques and Rui Neves-Silva, 'A Systems Theory Approach to the Development of Traffic Flow-Density Models', *IFAC Proceedings Volumes*, 39 (2006), 621–26, <https://doi.org/10.3182/20060829-3-NL-2908.00107>.

614 Di Caro and Dorigo, 'Two Ant Colony', p. 6.

modality without which they would not be able to work.

Creating a vision for a flowing, functioning, ecological transport modality for the growing population and consumerism creates an opportunity to approach the field with optimism. It asks the sub-questions, 'How do we want to live with CAREV-S in the public realm?' and 'Can such as system be reimagined aesthetically, that is a combined outcome of ecological and just mobility?'

SQ 4.4: What are the impacts (negative and positive) of CAREV-S on the public realm?

The adoption of CAREVs introduces significant societal benefits, especially for disadvantaged and minority groups, while presenting difficulties that require careful management.

Benefits include:

Enhanced Accessibility: CAREVs provide tailored mobility solutions for aged and young individuals, economically disadvantaged communities, people with disabilities, and minority groups. These vehicles eliminate dependence on human drivers, improve flexibility, and could reduce discriminatory and injustice barriers.

Optimised infrastructure reuse: By repurposing existing infrastructure like road width bridges and tunnels, CAREV-Ss minimise the need for costly new investments. Smaller CAREV-S vehicles, designed for one or two occupants, can reduce congestion and improve road efficiency.

Improved safety and flexibility: SI systems in freight and emergency service vehicles increase safety, resilience, and operational functionality.

Cost-effectiveness: CAREV-S vehicles would be more affordable to produce and operate, lowering transportation costs and broadening accessibility.

Integration with SI: Autonomous PMV, motorbikes and bicycles equipped with safety and comfort features enhance SI urban transport options and functionality.

Traffic and congestion management: While CAREV-Ss may increase traffic movement due to their convenience, redistributing smaller formats aligned with current patterns can alleviate congestion combined with a SI systemic approach. This could significantly enhance urban operations.

Environmental benefits: Incorporating renewable energy and circular economy principles can mitigate potential increases in consumption and resource use from affordable CAREV-Ss.

Potential impacts include:

Increased traffic movements: The affordability of CAREVs may lead to more vehicles on the road, exacerbating congestion and increasing resource demand.

Additional resource consumption: Incorporating renewable energy and circular economy principles can mitigate potential increases in consumption. Strategic measures, such as vehicle redistribution and MaaS (Mobility as a Service) integration, are essential.

Legislative and systemic controls: Effective management of systemic impacts, such as congestion, urban space usage, and traffic flow, will require updated legislative frameworks and control measures.

Dependence on MaaS: Successful implementation of mass mobility strategies depends on seamless integration between CAREV-Ss and MaaS systems, envisoning a shared mobility system with a variety of vehicle ownership models reduces a dependency on MaaS.

Summary:

The transition to CAREV-Ss offers transformative opportunities to enhance equity, accessibility, and sustainability while improving infrastructure utilisation and safety. However, the inherent problems, including traffic growth and systemic management, necessitate strategic planning, regulatory oversight, and innovative solutions to maximise benefits and mitigate impacts.

SQ 4.5: Do spatial studies assist with social and environmental assessments of CAREV and the SI city?

The spatial investigation set environmental and spatial justice objectives as distributive and decision-making processes. This process could result in an increase in environmental areas for roads. It could transform current road space for active transport. The spatial and environmental forms of the city could benefit dramatically. CAREV will assist with mobility options for people living with disabilities and the aged, as discussed by Botello et al.[615]

In essence, the suggestion is to not allow technology to set the strategic agenda but to employ technology to achieve strategic environmental and spatial goals to change the city.

The principles of society, which determine the vision and the technology designed to suit the principles, were an inherent outcome of this research. The overall investigation was focused on providing current data that allowed us to imagine that cities and their communities should set the policy. A designed

615 Bryan Botello, Ralph Buehler, Steve Hankey, Andrew Mondschein, and Zhiqiu Jiang, 'Planning for Walking and Cycling in an Autonomous-Vehicle Future', Transportation Research Interdisciplinary Perspectives, 1 (2019), 100012 <https://www.academia.edu/40396389/Planning_for_walking_and_cycling_in_an_autonomous_vehicle_future> [accessed 9 August 2021] p. 8.

system with CAREV-Ss enabled a system of vehicles that reflected use patterns and the city. The current models of vehicles and cities involve creep and obfuscation by planned obsolescence, which was questioned by this process. Vehicle design was also challenged through a paradigm shift to ensure that vehicles are designed to respond to the city and all of its inhabitants, not just the vehicle owner. This spatial study showed a pathway to a new way of thinking about the city, its vehicles and its communities.

What emerged from the spatial investigation was that CAREVs/CAREV-Ss can be designed to have substantive environmental and city functioning benefits in addition to safety and convenience. This in turn can result in an approach that considers the vehicle, the city and the environment systemically. Policies can improve spatial justice in the public realm, reduce inequalities, assist minority groups and increase environmental justice with flow-on effects on public health and city liveability. These are some of the advantages of a systemic approach.

While the study focused on maximising the capacity results with environmental and functional criteria, this could lead to a dystopian or perverse appearance. Smaller RE vehicles along with larger vehicles filling city roads could be a dystopian urban outcome when used as a single disputing criterion. However, the realities of increasing population growth, urbanisation and consumption are currently, for many, unacceptable circumstances in most similar-scale cities as the case study.

A vehicle transportation system such as CAREV-S will bolster the resilience, liveability and sustainability of the city through environmentally sensitive and just outcomes via a systemic approach. It can be a desirable outcome for the future CAREV city. In this speculative system, there may be more CAREV-Ss on the road, along with designed criteria and policies for increasing trees and shade, cooling effects and less-polluting vehicles (with regard to noise, air and water pollution); reducing manufacturing and operational energy and

costs for the CAREV-S system; and increasing active transport possibilities and enticements along with functional improvement to reduce congestion.

Overall, this speculative study showed CAREV-Ss to be a city-enhancing and transforming proposal with a designed outcome, one that confronts current orthodoxies. Transforming the current congested, polluting and environmentally degrading transport system will be revolutionary, even magical. Increasing opportunities for environmental outcomes and active transport in the existing public realm through spatial justice will rebalance modality justice from current low-capacity-dominated transport with large vehicles.

Such radical intervention requires legislative intervention and activism to change consumer practices in favour of CAREV-Ss. It will certainly require a transformative CAREV computing system to operate safely and efficiently in the public realm and considerable investment in transforming the public realm. In the era of climate action, these seemingly intractable commercial and social interventions may have appeal, especially in such environments as Sydney and other Australian cities, where heat has severe health consequences for the community.

The sub-questions are summarised in Chapter 5.6 - in the conclusion.

4.10 Findings

The chapter presented the CAREV spatial study, the potential benefits and issues associated with the adoption of CAREV-Ss and their impacts on urban mobility, environmental sustainability and social equity. It highlighted the transformative potential of leveraging advanced technology and urban infrastructure to reshape transportation systems and address pressing urban road transport problems.

Some of the study's findings included the potential environmental and social benefits of CAREV-Ss, particularly in terms of reducing overall energy consumption, minimising environmental pollution and increasing access to transportation for economically disadvantaged and minority communities. By introducing smaller (narrow), more efficient vehicles using RE and circular economy principles and adaptively reusing road typologies, the study demonstrated how CAREV-Ss can contribute to an equitable urban transportation system with regenerative environmental outcomes.

However, the study also acknowledged the potential challenges and trade-offs associated with the widespread adoption of CAREV-Ss. These included concerns about increased vehicle movements, potential labour disruptions due to technological advancements and the need for legislative interventions to promote small vehicle formats and environmental concerns. Additionally, the study underscored the importance of considering the broader ethical and policy implications of transitioning to CAREV-Ss, including issues related to economic incentives, social justice and environmental responsibility.

The study envisioned narrow, light vehicles with SI city-controlled speeds that are demand-managed and cognitively semiotic as part of a transport ecology from a city perspective that is civically shared, logistically oriented to platooning and environmentally conscious.

The concept of the SI city emerged as a guiding framework for navigating these complexities and advancing a vision of urban development that prioritises environmental sustainability, social equity and human well-being. By integrating the principles of SI, environmental stewardship and ethical governance, the SI city seeks to harness technological innovation for the collective benefit of society and the environment as an ecologically conscious and civic platform.

Overall, the study provided valuable insights into the potential role of CAREV-Ss in shaping the future of urban mobility and underscored the importance of transdisciplinary research and collaborative policymaking in addressing the complex challenges of urbanisation and transportation.

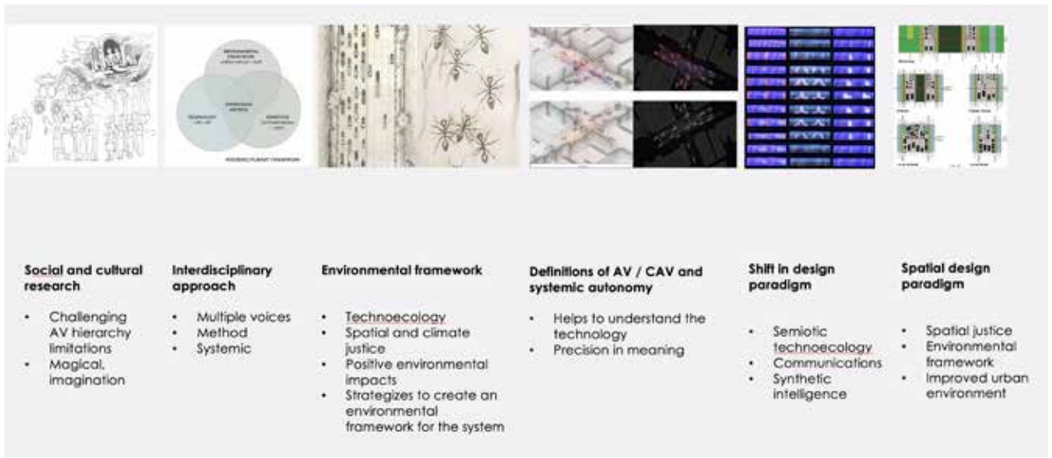


Figure 111: Summary of themes in the thesis as a diagram.

Chapter 5.0 Conclusion

5.1 Introduction

This concluding chapter summarises the transdisciplinary research findings and articulates the outcomes of the practice-based inquiry. I reflect upon the findings and discuss the research hypothesis. The conclusion synthesises the research and is structured to answer the meta- and principal sub-questions.

5.2 Research findings by theme

The research aimed to investigate and understand how a social and environmental framework should mediate the development of AV/CAV/CAREV technologies and how society might shape future cities, semiotics and mobility in the face of evolving and increasing demands for spatial, urban and climate justice. The key findings were developed iteratively using the symposium method, with the five symposia mapped to the research questions and sub-questions. The final section of the research findings related to assessing the aims, objectives, and meta-questions and principal questions. The key findings of this research are arranged through the themes, as follows:

- Technology theme – Designing the systems for CAREVs and the intelligent city (Chapter 2).
- Semiotics theme – Ecological semiotics and living and communicating with machines in the public realm (Chapter 3).
- Environmental theme – Beyond justice: ecological transport and intergenerational justice (Chapter 4).

In the findings, I also reflect upon my practice and its relationship to academic research and the symposium method and summarise the PhD submission. Refer to Figure 111 for a summary of the themes of the research as a diagram.

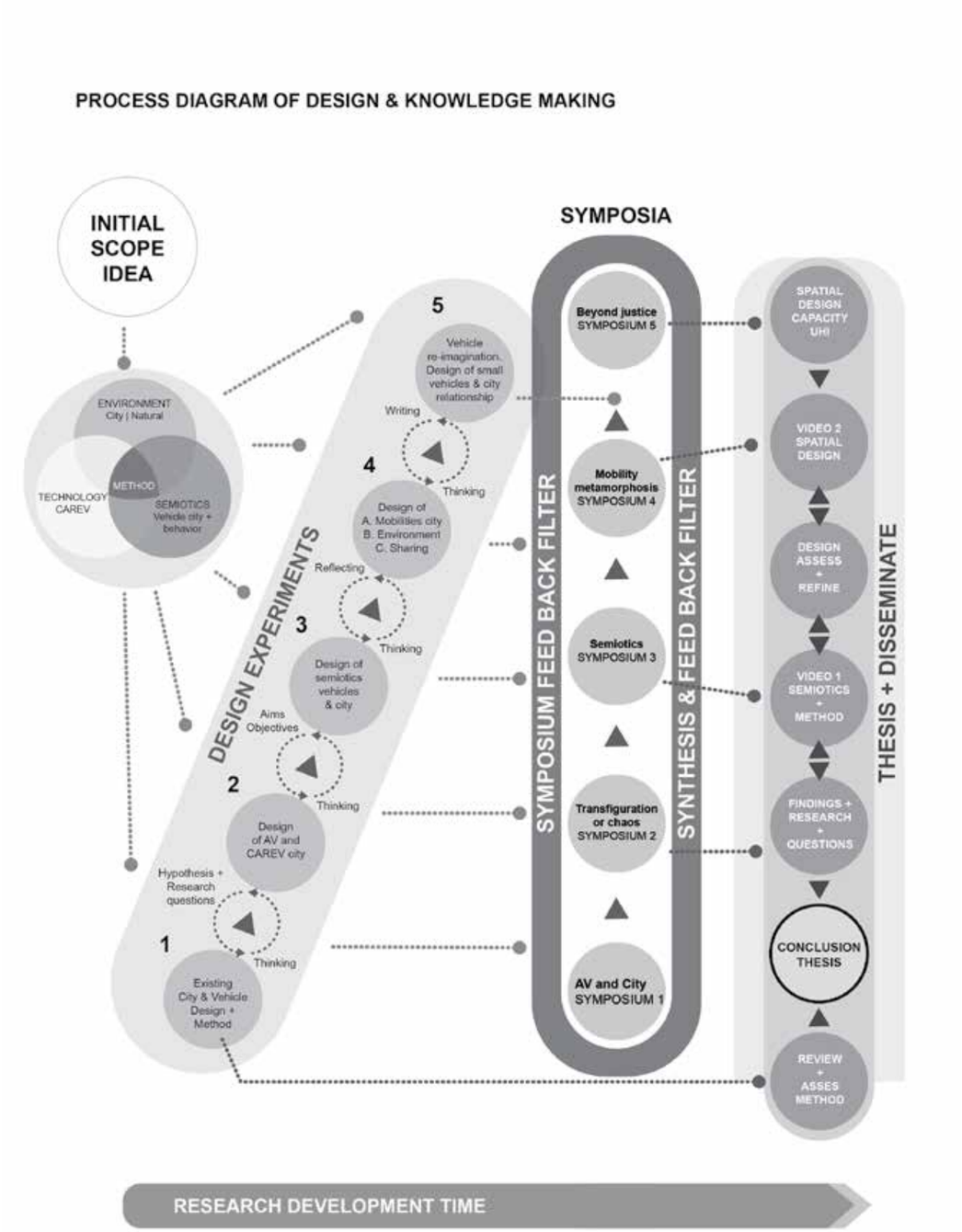


Figure 112: A process diagram of design and knowledge making in the symposium method.

5.2.1 The symposium method transdisciplinary academic and practice-based research

I developed this project's unique approach called the 'symposium method' which involved conducting five symposia where diverse opinions and insights were gathered in response to provocations and design experiments to address complex issues. The research expands knowledge through a combination of practical and academic research methods within a transdisciplinary framework, particularly influenced by the Capra-Luisi environmental combined with Schneider LoT cognitive semiotic frameworks.

The involvement of the Royal College of Art with its expertise in architecture, intelligent mobility design, and communications was crucial to my practice development and developing the research method. The symposium method facilitated diverse dialogue, collaboration and assessment, allowing for a deeper understanding of the research topic and validation of the research and conceptual design approach, qualitatively. The synthesis of findings from the symposia enriched the research output as I responded to the discussions and the feedback throughout the process. Overall, the research demonstrates the value of transdisciplinary approaches and practice-based methods in advancing knowledge in the CAREV field.

5.2.2 Knowledge making through the symposium design method

A feature of the symposium method is the design process integration This process is represented as a flow diagram in Figure 112, as follows:

Investigative design and experimental process: The symposium method incorporates a design process, which is crucial for the development of research and the generation of data. The design process is fundamental to the research's development and data generation. It involves experimentation and investigation to gather information.

Creativity in data output: The data output is viewed as a creative process, where the architect's role evolves as a thinker, strategist, and designer.

Introduction of new elements: Each design module introduces new elements such as drawings, animations, and films, which are integrated into the process. The symposium participants provide validation or critical assessment of these additions.

Design method diagram (Figure 112): The diagram illustrates the chronological development process of design integration with research modules within the symposium method. Each stage of development includes design data output.

Rigour: each module of research was subject to continual review, annual examination, confirmation examination and considered feedback with the supervisors and external examiners. I have identified the primary data collection to assist future researchers and this research development in building, validating and rejecting arguments.

Iteration through symposiums: Each symposium builds upon the previous one, with changes in emphasis and improvements in execution. This iterative and dynamic process allows for refinement and enhancement. Table 1 in Chapter 1.6, provides a summary of the key data collection and dissemination features of the symposium method.

5.2.3 Complexity, paradox and the systems approach

Describing and working within a comprehensive ecological system is complex and challenging. A systematic research approach requires structures an understanding of networks and relationships and the use of transdisciplinary methods.[601] Moreover, this research is set in a contested, paradoxical field with no simple or single outcomes. The potential for CAREV technology to disrupt the transport system provides an opportunity to change the debate and call into question existing practices.[602]

In this research, I have approached systems thinking through a multiscale, complex and dynamic approach, applying the Capra–Luisi systems view but also integrating learnings from Meadows regarding contemporary systems associations and from Bratton regarding multiple interconnected layers for planetary computation. I also reviewed semiotic, linguistic and typology taxonomies.

5.2.4 Technology theme – designing systems for CAREV and SI city

The choice of CAREV technology as the research subject emerged from contextual research into AV/CAV and, specifically, CAREV technology in response to the Symposia 1 and 2 discussions. Reviewing AVs' social and cultural history revealed gaps in knowledge about society's historic aspirations for

601 Capra, *Networks*

602 Capra and Luisi, *The Systems View*, p. 394.

safe, convenient, reliable, flexible, sustainable, magical, just and comfortable transport. I selected CAREV as a technology platform because of its systemic qualities. The ability of CAREVs to communicate with each other and the SI city while sensing the environment while being logistically choreographed is a compelling potential feature of the technology. There are multiple benefits that arise from systems approaches; the focus on CAREV in this research optimised operational, semiotic and environmental outcomes systemically. This approach facilitated a new way of thinking about the transport ecology of the SI city through CAREV.

5.2.5 Semiotics theme – ecological semiotics, living and communicating with CAREV

As discussed in Chapter 2.9, the potential of CAREVs to achieve broad social and urban outcomes appears to outweigh that of other AV technologies, a finding on which other leading technology theorists in CAV. Data management, assessing data and storage of data for CAREV systems will require synthetic intelligence and advanced computing, a major subject area of the Academy of Neurosciences for Architecture 20th anniversary conference, in which it was noted that current sensor data output exceeds the ability of systems to process the data and for the process output to be made useful. A novel approach is the development of systemic and cognitive sciences potential (LoT) with the *systemic semiotic technoecology* hypothesis which sites CAREV as part of a environmentally conscious system

5.2.6 Environmental theme – beyond justice: ecological transport and intergenerational justice

The hitherto missing conceptual aspect of CAVs relates to positive environmental outcomes, which have significance in this era of the climate crisis. An ethical approach to manufacturing and operating CAVs would be to utilise RE; hence the reclassification in this research of CAREVs as part of their definition as a type of vehicle. Environmentally proactive policymakers globally would be well advised to structure future manufacturing policy as part of a circular economy approach as transport transitions from human-driven fossil-fuelled vehicles to CAREVs. Circular economy principles aim to reduce extraction and the environmental footprint of the AV industry at the design, manufacturing, operational and decommissioning stages.

A Redistributed active transport area
B Variety of actors & abilities in the public realm
C Existing street scape and road
D Increased environmental areas, trees landscaping
E Existing trees & landscaping
F CAREV-S & CAREV vehicles 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

This study visually expresses the hypothesis of systemic (V2C) semiotic technoecology. The platooning choreographed movements are seen in Video 1. CAREV communicate with each other, the city and their movement and intentions are understood by people in the city.

Figure 113: Analysis of the components making up the CAREV study of Crown Street.

5.3 Shifting thinking in the field

One significant finding related to the research's aim to shift paradigms. Historically, the motor vehicle industry has adopted a neo-liberal, capitalist approach, with significant environmental and human health impacts (re: safety and pollution). A key research objective was to change how we use technology, deepen our interactions with advanced technology, and recognise CAREVs' potential to leverage positive environmental, spatial and liveability conditions. This is represented in the comparative analysis diagrams of the spatial investigation shown in Figure 107 and 113. The overall aim is to move beyond sustainability and regenerative systems into positive ecological approaches[603] that place intergenerational justice and environmental consciousness as core thinking.

5.3.1 The contribution of the CAREV semiotic approach

The research provides a novel response to developing strategy to assist with CAREV semiotics, to appreciating SI intentionality and machine operations in the public realm, this was the subject of Chapter 3, Figures 116 and 117 provides a conceptual and designed outcome in response to the semiotic investigations.

The selection of CAREVs as a specific technology and the case study in Australia are substantive research upon which other studies could build. The project expanded beyond semiotics into an understanding of AV/CAV/CAREV technologies and the technological capacities and limitations currently present in the technology. The semiotics of AVs/CAVs/CAREVs was one of the three themes in the project. The relevance of semiotics, the data obtained through the multi-voiced symposium, and design experimentation, various architectural multimedia in Chapter 3.7 as part of understanding how to live with CAREV in the public realm.

The systemic semiotic technoecology hypothesis is that the semiotic systems and the way they think about movement and the rules of the road, if carefully designed with advanced technology, are part of a cognitive process. The CAREV spatial study demonstrated a systemic process to research and develop strategies to investigate the relationship between vehicles and the city, to improve spatial and environmental outcomes associated with human health, safety and liveability benefits. Notwithstanding its limitations, this type of systemic research has not been previously undertaken. The findings directly linked vehicle size, operations and urban environmental outcomes, refer to Figure 113.

The visual comparative analysis of existing and CAREV in Crown Street shows combined visual outcome of the CAREV mixed vehicle study. Larger format drawings are located in Appendix F.10.

603 Positive environmental outcomes in this discussion include all types of technological, social and sustainability benefits, while regenerative design lies primarily in socio-ecological domains.

A clear vision for a future modality and its operations, benefits and impacts was linked with semiotic research. This was explored through the narrated animations and writings that make up the project, refer also to Figure 108 and 109 (UHI study), and Videos 1 and 2.

The findings suggest the need for active social intervention in the development of technology such as CAREVs to ensure that social and cultural aspirations and integration with the city are balanced and appropriate before the social licence to operate is granted. This includes leveraging legislative processes to ensure positive environmental outcomes aimed at the common good. To leverage urban lifestyle improvements, urban designers and policymakers must be involved in developments in the AV industry.

Various mechanisms – such as the World Forum for Harmonization of Vehicle Regulations, the UN Conventions on Signage, the Vehicle Accessory Conventions[8] etc. – could be leveraged to steer future technologies to optimise environmental and human health outcomes for the future city. I argue that society's mediation and granting of social licence to operate AVs/CAVs/CAREVs should ensure that our cities and the vehicles within them operate justly, environmentally and safely. It should not be granted too easily, and governments and bureaucracy must be accountable. This field cannot be left to industry to regulate, lobby or develop without community consent.

Community consent for CAREV to operate in the public realm may not be a consistent globally. The requirements (refer to Chapter 2.8.3) that emerged from the selected social and cultural history of AV are that the system should be transparent, trustworthy, safe, environmentally regenerative, convenient, resilient, flexible, intelligent, reliable, comfortable and just to achieve consent.

To achieve meaningful change, systems thinking and adaption are required at the international, national, state and local levels. Individual private vehicle owners also need to understand their role, the part they play in the system and their impacts as individual vehicle owners on the community.

5.3.2 Complexity, planned obsolescence and systems thinking

Planned obsolescence as an economic and consumer strategy was discussed in detail in Chapter 4.4, planned obsolescence is highly complex; it is associated with consumer behaviour, marketing, design, manufacturing, commercial and enterprise outcomes. It is also associated with excessive consumption, pollution and waste. The research found that current industry practices such as planned obsolescence require careful consideration, as this approach will likely result in ongoing environmental impacts. CAREV-Ss present an opportunity for the industry, the design and planning profession, and the community to reconceptualise future transport in the city through the lens of environmental practice.

The current motor vehicle design, manufacturing and consumption system is siloed and fixated on established practices. Rarely do urban design responses factor into the complex picture. The commercial process is directly linked to individual or private vehicle ownership and is not focused on the common good, the community or sustainable environmental practices. Consequently, the motor vehicle industry cannot respond to the broad concerns of the community.

New policy is therefore required to ensure industry practices adapt to make and operate vehicles for the common good, for communities rather then the individual vehicle owners benefit only, and benefit the cities in which we live. Industry and the community have an opportunity to change the frustrating and entrenched orthodox debate by looking at this technology through the lens of an environmentally civic responsibility; a shared and common responsibility. Examples of this approach can be found in Tesla's environmental approach to the design, manufacture and operations of their vehicles or General Motors 'Cruise' approach to shared mobility AV. The suggestion is there are social value considerations which the automobile industry has yet to investigate which have commercial and environmental benefits.

CAREV as a transport ecology for the common good, one that improved urban liveability, safety and environmental outcomes was a finding of the spatial investigation in Chapter 4.6. The CAREV technology allows us to reimagine the future city, vehicles, operations, semiotics and environmental outcomes as an aesthetic and holistic contribution. CAREV technology should not solely focus of the on safety improvements. A magical possibility emerges to use CAREV technology to reduce energy waste and requirements, improve environmental outcomes, re-imagine spatial outcomes and the social licence to operate in our shared common space, the public realm. The magic lies in designing a vision for the system that leads to a socially desirable outcome.

Figure 114: Mixed CAREV-S view at the corner of Cleveland and Crown Streets, Surry Hills aerial view at night.

The CAREV in this visualisation are spatial envelopes with semiotic systems attached. The CAREV are not intended to be representative of vehicle design. CAREV and synthetically intelligent city semiotics as a conceptual outcome, the visualisation shows increase environmental and active transport areas as a result of CAREV-S. Larger format drawings are located in Appendix F.10.

5.4 Conclusion

This section synthesises the research and addresses the principal research questions, followed by supplementary information related to the research sub-questions.

The research field, is complex, speculative in nature, with a substantial history of development and almost intractable safety, ethical, behavioural and environmental concerns. The challenge for researchers is developing methods to question the status quo and find alternative pathways that assist in expanding human knowledge. The symposium method used in this project facilitated transdisciplinary research, investigations and experiments, dialogue, feedback in a methodological, themed and systemic manner. The synthesis stage, in turn, allowed reflections upon and consolidating design thinking with writing about the data obtained during the symposia and them moving to present the findings through multimedia, refer to Figure 114, representing a synthesis of the design output.

5.4.1 Assisting with filling the research gaps

The multi-voiced transdisciplinary symposium method proved to be a pivotal aspect of enriching the study, effectively formalising a robust transdisciplinary tool for advancing research. Its adaptability and transferable benefits extend beyond the confines of this study, promising relevance and utility for future research initiatives. I remain committed to refining and developing this method within my practice, recognising its value in both practical and academic settings. Through the symposium method, I addressed identified research gaps by fostering multi-voiced dialogue to address pertinent research questions.

In Chapter 1, the study illuminated research gaps concerning the evolving relationship between vehicle technologies, planned obsolescence's role, and urban landscape evolution. The study highlighted the discordant rhythms between vehicle design, manufacturing processes, and city infrastructure by employing chronological and aesthetic taxonomies alongside related analyses. These taxonomies served to fill knowledge gaps in the arrhythmic patterns and evolutionary dynamics of vehicles and urban environments.

A key outcome of synthesising this research was understanding the evolution of emergent technologies, particularly autonomous vehicles (AVs) and connected automated road vehicles (CAREVs) and how we will live with these vehicles in the public realm. This research prompts me to reflect on when communities might witness a future CAREV and SI city? Predicting such developments

Figure 115: CAREV-S environmental semiotics colour study. Refer to Video 1 for the animation.

proves challenging, as realising these innovations are intrinsically linked to the unpredictable cadence of technological evolution and societal readiness for change, and which society and which city? Some prefer change at different rates to others. Advanced technologies such as SI and quantum computing and their influence on the city combined with the change fleet from human driven to CAREV, would suggest multiple generations of fleet change before a fully CAREV environment is realised. However, this is a dynamic field, and as seen in recent EV developments, commercial opportunities can accelerate revolution dynamically.

The research also underscores the role of private and public sector investment in shaping the outcomes of AV research and development. A personal observation is that research, such as this, struggles to obtain appropriate research funding. Given the inconsistent nature of research investment, especially in urban research simulations, the study advocates for a transdisciplinary approach involving collaboration between city policymakers and CAREV manufacturers. This collaborative effort, guided by shared principles, offers a pathway towards managing the realisation of CAREVs and SI cities within manageable timelines. Appreciating agreed principles, even if thematically structured, provide an approach to realising a holistic CAREV outcome, it is entirely different practice to that which we are accustomed.

In Chapters 2 and 3, I delved into the cultural and social history of AVs and CAREVs, emphasising the significance of this history in shaping societal aspirations and expectations. By contextualising these historical narratives within contemporary standards and industry practices, the study revealed shortcomings in existing automation taxonomies while highlighting the pivotal role of imagination and innovation throughout history. A holistic approach to emergence fills knowledge gaps, reassess industry standards, and fosters new avenues for research exploration, including philosophical and practice research; this was highlighted in the cognitive research in semiotics (Chapter 3, and Figure 115 for the CAREV semiotic colour study). The research offered approach to increasing environmental consciousness through technology, filling another research gap, and assisted in providing data about a future field of study filled with opportunities for further novel research.

The research adopted principles such as circular economy frameworks, renewable energy platforms, and regulatory measures to address ethical, consumption-related, and transport usage patterns (I refer to the empty seat syndrome). By identifying spatial justice research gaps and providing new insights into the holistic transport ecology of CAREVs, the study offers a

Figure 116: Existing and CAREV-S plan of Crown Street, Surry Hills comparative view at night.

Larger format drawings are located in Appendix F.10.

conceptually systemic approach towards achieving positive environmental outcomes within urban environments. This approach advocates for a departure from traditional cause-and-effect practices towards one centred on principled, ethical actions and collective collaboration.

5.4.2 The research context

The research investigated AVs' social and cultural history and provided insights into the relationship between AVs and our current fossil-fuelled vehicle industry. The selective history of AVs and the discussion about the orthodox debate was intended to assist with a deeper understanding of the phenomena that have caused the current congested, polluting transport system and its anti-dote. Through this social aperture, new pathways to look at the technology and to develop novel methods and research fields to offer alternatives arose. Possibilities that could arise through a change in the fleet from fossil-fuelled vehicles to CAREVs were highlighted, along with clear definitions for the technology aligned with community expectations. Figure 116 for example represents a comparative analysis of current vehicle conditions in Crown Street compared to the CAREV condition, synthesising the combined benefits spatially.

5.4.3 Reflections on the hypothesis

The hypothesis (refer to Chapter 1.3.1) had three parts.

Part 1. A transdisciplinary approach

The project hypothesis was that to achieve the cultural aspirations of magical, safe, efficient, convenient, reliable, just and synthetically intelligent transportation through CAREVs, a transdisciplinary approach to conceptualising the integration of synthetic intelligence with the city, the environment and humanity is required.

While symposium method is time-consuming and effort-demanding it facilitated a diversity of opinions and voices in the experimental, design, writing, feedback and through its synthesis processes. Due to the systemic nature of the issues in the field, a transdisciplinary method offered an important, reverential, multi-view approach that can simultaneously be bottom-up and top-down and can break through the field's historic silos of knowledge and specialisation. A transdisciplinary method also allows us to shift how we approach issues and find pathways to new knowledge and provides a mechanism for us to strive for intergenerational justice.

The study considers macro (city) scale and local scales (streets). The top macro scale image is an example of aerial night time view of the City of Sydney - the road network is visible at night the road network is an environmental consideration). The bottom image is from an animation of a local neighbourhood scales consideration. The bottom image is an animation of the CAREV semiotic systems, Crown Street is managed by the city's synthetically intelligent systems which communicate semiotic controls to a variety of users at an intersection - Crown / Cleveland Street

Figure 117: Existing and CAREV-S aerial view at night over Crown Street, Surry Hills comparative view at night. Refer to Appendix F.10.

Part 2. A framework for achieving environmental, spatial and social justice is required through holistic research practice.

The second part of the hypothesis extended the Capra–Luisi framework into the field. There was a need for an ethical environmental framework to be adapted for this research, responding to the ongoing existential environmental issues from ICE vehicles. Holistic practices and systemic approaches are required to provide integrated responses to these issues and impacts.

The automobile industry has experience in working in interdisciplinary and even transdisciplinary processes. The transition from vehicle concept design to an operating vehicle would require large teams working together for a common goal, and there are naturally qualitative issues here, some teams work better than others which is a source of operational and organisation inquiry.

This research advocates for a wider and deeper holistic involvement of other disciplines in automobile industry teams to include urban designers focussed city and regional issues, social justice advocates, spatial architects, artists, semioticians, and environmentalists and so on. Teams like this will with common goals, and set of ethical principles, assist the industry in achieving holistic outcomes. Systemic solutions by their nature can lead to emergent, innovative outcomes and impacts can be mitigated if carefully managed.

Figures 117 and 118 are examples of data output associated with the spatial study which looks at the relationship of the vehicle and the city environmentally, not as separable study but as a unified systems thinking approach to the city, people, semiotics and CAREV.

Part 3. A living transport ecology, a *systemic semiotic technoecology*, could improve safety, communications, spatial justice and public health.

A systemic approach to CAREVs, semiotics and the city allows us to view the transport ecology in a manner that is likely to have multiple beneficial outcomes, it allows specialist sub-field involvement while maintaining a holistic view. Through this research, I argued that the semiotics, cognitive and communication processes inherent in the CAREV field are essential safety and public realm information and control systems. To live together with CAREVs, to share the public realm with them, everything that operates in the public realm needs to be constantly communicating with the realm and the actors within it. In a synthetically intelligent city, combined human and synthetic intelligence augment each other's wisdom and the city's intentions with logistical and legislated requirements. The environmental and cultural nuances will need a shared cognitive platform – a shared semiotic system.

Figure 117 shows the transformation of the public realm as a result of CAREV/ CAREV-S, refer to the legend to identify the increased environmental and active transport areas, redistributed parking, high-functioning vehicle street space, and SI city systems.

The CAREV semiotic systems and the city SI cognitive systems are networked to assist with environmental and safety improvements which assist and manage mobility for a variety of public realm users such as cyclists, pedestrians of various ages and abilities and disabled persons in the public realm as shown in Figure 116 in the top panel of CAREV and SI city and discussed in detail in Chapter 3 of the thesis.

In Figure 117, CAREV semiotics and semaphores are networked and communicating with SI intelligence to assist everybody fairly. Young and old, and a diversity of people in the public realm are guided by intersection wayfinding pillars which communicate with the SI city logistical programs for on-demand management of safe walking, cycling and other personal mobility modes. The wayfinding pillars coordinate operations with the CAREV to assist with city functionality with active transport prioritised according to the rhythms of the city; this would enhance the city operations and improve liveability and safety outcomes. It is an environmental approach to CAREV and the SI city.

The mixed CAREV/CAREV-S communications and the smaller format vehicles operating and manufactured with renewable energy would be part of the transformational qualities. Human understanding of synthetic intelligence is critical to sharing the public realm, a subject discussed in detail in Chapter 3.

The research suggested that cognitive science's LoT is a theoretical tool that could assist us in understanding CAREVs' intentionality. The LoT is essentially a cognitive semiotic system. To think environmentally, we need environmental signs, signals and cognitive processes to ensure we behave environmentally. Combined with CAREVs' advanced technology, the research's semiotic system aimed to realise positive environmental outcomes through the *systemic semiotic technoecology* hypothesis.

Figure 114, provides a comparative analysis of the existing semiotics of Crown Street with the reimagined CAREV SI city. Larger format drawings are located in Appendix F.10.

5.5 Answering the research questions

5.5.1 The meta question - the combined effects of CAREV on the public realm

The combined effects of CAREV on the public realm is a complex meta-question to answer, primarily as the technology and the city is a complex dynamic environment with no single or simple outcomes. This research's findings are that a systems approach, utilising transdisciplinary methods - inviting multiple voices into the development and implementation of the SI city and CAREV-S in a holistic manner is likely to assist in a positive contribution of CAREV-S on the public realm, on safety and public health and liveability outcomes.

CAREV-S could, if implemented carefully and thoughtfully, lead to significant environmental safety and public health improvements. This will also depend on adhering to guiding principles for the implementation stages and in so doing could leverage social licence, community's trust to operate.

It is important to slow or cease current practices which we know would have detrimental effects, such as fuelling the orthodox debate, cause and effect vehicle deployment, unrestricted consumption of vehicles and limited spatial urban and environmental studies to name a few. CARE provide an unique opportunity for this and future generations to revisit the relationship between humans, the city and their vehicles.

The detailed answer the meta question can be found in Chapter 5.5 and 5.8 - Closing and summary.

5.6 Sub-questions answered

5.6.1 **SQ1.1** How can we live with CAREV machines and synthetic intelligence in the public realm??

To live with CAREV a paradigm shift towards understanding and integrating synthetic intelligence in public spaces through transdisciplinary collaboration for improved safety and environmental outcomes through CAREV integration is required. This suggests a transformative approach to urban design and policymaking in developing CAREV and the SI city.

The research showed that the historical development of vehicles and the city has been incremental and evolutionary, driven by planned obsolescence. This has both negative and positive outcomes. The negative outcomes are that manufacturers are primarily beholden to meeting statutory requirements and consumer behaviours; the evolution of vehicle safety has been secondary. The AV movement offers improved safety, as the human driver is replaced by synthetic intelligence. However, a key step in improving safety is for humans outside of the CAREVs – that is, people in the public realm – to understand synthetic intelligence intentionality. I strongly argue that our future as a society will depend on everything – humans, animals and non-humans – in the public realm understanding how CAREVs interact with them culturally (socially) and environmentally. This is a rich field for urban design involvement.

The semiotic design experiments that make up part of this research, especially those developed to assist with embodiment, hand signals semaphores, universal semiotics and LoT concepts, provided clues for future research into CAREV and inter-modal transport. The principles for the research, which could be further adapted to real-life conditions, were founded in an environmental positive outcome. A future transport modality which has improving safety and environmental outcomes as its objectives – reversing 150 years of environmental and safety impacts – by having regenerative outcomes is another significant contribution to learning to live with CAREVs in the public realm.

The research advocates for a paradigm shift, a new kind of systems thinking that acknowledges its current limitations and actively includes a more diverse

and open approach to multidisciplinarities. A broader and deeper inclusion outside the current boundaries of siloed multidisciplinary vehicle design and manufacturing to include objectors and differences of opinions to enrich the responses. This requires a different kind of systems thinking that acknowledges the nature of the change and is open and transparent about the need to bring other critically important voices into the field. An essential ingredient of the change is to openly address urban impacts through community and policy engagement, to include urban designers, landscape architects, semioticians, artists and environmentalists into the field. This will also require the AV industry and its policymakers broadly changing its brief to itself, the principles in this research could provide an initial scope for a future AV brief.

5.6.2 **SQ1.2** Can society intervene? Can we co-define an ecological framework in which CAREV and SI technology positively influences the environment?

Society must intervene and ensure ethical and environmental principles guide CAREV design and manufacturing, to improve environmental outcomes and public health, emphasising community and a diversity of disciplines' involvement. Through methodologies like symposiums and transdisciplinary frameworks risks associated with future AV systems in the public realm must be mitigated.

The spatial study stepped through the complexity of vehicle ergonomics and vehicle operations in the context of the public realm, the functionality of the road network, a case study and a heat island study. It identified systemic problems, such as the energy and material waste with the monoculture of the large-format (four seat) vehicles, that currently dominate vehicle design and manufacturing. This type of study is useful for community action groups, policymakers and the motor vehicle industry to refocus their vehicle responses, which primarily concern commercial and safety issues, to rebalance to positive environmental and community and city outcomes.

The digital twin city is a simulation that utilises real city data with dynamic monitoring, real-time diagnosis and accurate prediction of the state of the physical city entity in the real environment. As a planning tool, the machine-based simulations allow for systemising and assessing impacts in the model, allowing city design and planning to occur prior to real-time deployment. Simulation systems, beyond traffic planning software solutions are key technological interventions and assessment models to assist with non-invasive positive environmental outcomes of CAREV.

The EV movement and leaders in this commercial space have seen a rebirth of the industry in developing a vehicle system that is focused on RE. This research expanded that approach by setting ethical and environmental principles to guide vehicle design and manufacturing developments to assist with urban and regional environmental outcomes, ultimately benefitting public health outcomes. I argue that society must intervene in the future AV/CAVCAREV field as the community faces the greatest risk from any transport system in the public realm. The symposium method is one tool that could be used to integrate the community into key stages of design, manufacturing, testing and deployment stages of AV/CAV/CAREV.

5.6.3 **SQ1.3** Can CAREVs reverse current pollution levels and lead to improved public health and safety?

The CAREV fleet must increase safety, reduce emissions, enhance energy efficiency, increase shared mobility, reduce extraction and integrate with public transport and city infrastructure to reverse current impacts. The research emphasises the concept of systemic semiotic technoecology, where synthetically intelligent CAREV systems provide real-time environmental data to users, facilitating adjustments in behaviour for improved environmental and public health outcomes through enhanced communication between vehicles, the city, and people leading to a broad environmental consciousness leading to improved public health and safety outcomes.

As discussed in Chapter 4.10, the CAREV fleet, specifically the CAREV-S fleet, could result in significant environmental changes to the city, with benefits including reduced emissions, increased energy efficiency, greater shared mobility, and integration with public transport systems and city SI infrastructure. This will require the automobile industry re-writing its scope of works and its suppliers, a change utilising systemic principles for a balanced CAREV transport ecology is essential to reversing pollution and climate change effects as a result of road vehicle manufacture and operations.

Systemic semiotic technoecology represents a systemic change expected from a shift to a CAREV fleet. The synthetically intelligent CAREV system could provide real-time data about environmental performance to all public realm users, allowing everybody to understand their combined impact on the environment and adjust their behaviours. V2V communications and V2C communications along with SI operations will also assist in improved

environmental and public health and safety outcomes. This is the notion of a systemic semiotic technoecology, this was explored through CAREV semiotic colour systems, semaphore investigations and assessed and reviewed through the symposium method in a transdisciplinary process. The investigation revealed an environmental consciousness can and should arise through semiotic cognitive processes. In summary the CAREV system must be focussed on human and synthetic intelligence communications and the manner in which vehicles, the city and people are able to communicate with each other and assist with positive environmental outcomes. The practical expression of this approach is shown in the comparative analysis of existing and CAREV in the case study area of Crown Street, Surry Hills in Figure 118.

5.6.4 **SQ 1.4** Does a change in the fleet from human-driven vehicles to CAREV-S allow for deeper changes in the city fabric, its semiotics and communications. Can a 'systemic semiotic technoecology' arise?

The CAREV city fabric will change as human-driven fleet relies heavily on visual semiotics in the public realm, whereas CAREV will utilise digital sensors and computing and will not be necessarily dependent on visual systems. Changes to road semiotic systems are inevitable. Future research should explore non-visual semiotic processes for comprehensive understanding and integration into urban environments. The systemic semiotic technoecology arises through leveraging technology and cognitive systems to assist with positive environmental outcomes.

The human-driven fleet is almost solely dependent on the visual semiotic systems for the regulation and management of the public realm. There are additional auditory and haptic systems, but not for driving. The semiotic system of the road provides the legal and cultural framework for the operation of the public realm. In contrast, connected autonomous renewable energy vehicles will use vision-based sensors for driving but will not be dependent on visual systems. One of the advanced features of V2V and V2X communications is that the data shared can be between vehicles that are far apart and in different locations, it is a significant systemic quality of CAREV.

This demonstrates the non-visual aspect of mapping, GPS and other shared data systems for CAREVs. One could anticipate, then, that some of the visually based systems that assist vehicle drivers will become be redundant. Reducing the exhausting amount of road-based signage would be a desirable change to the city fabric, although non-AVs, cyclists, personal mobility vehicles and active transport users will still depend on visual, haptic and auditory semiotic systems.

Figure 118: Existing and CAREV-S view at the corner of Cleveland and Crown Streets.

A comparative view at night, a synthesis of the SI semiotic and environmental and city operations at a local level. Larger format drawings are located in Appendix F.10.

Along with fixed signs, transformations in the digital semiotic systems as they interface with synthetic intelligence would transform the semiotic systems. A research limitation is that this study focuses on visual semiotics in the road environment; other future research would benefit from other semiotic processes such as haptic, auditory, taste, human factor and spiritual research in the same field. The limits of the semiotic vision-based approach were demonstrated in Video 1 of the research, where demand-managed traffic systems at intersections coordinated operations with the vehicles, pedestrians and other road users.

The video explores the environmental, semiotic and functional changes that could occur in a designed and integrated system. Video 1 also explores the aesthetic transitions from current human-driven transport to CAREV transport as a comparative analysis, suggesting a pathway for significant aesthetic improvement to the public realm due to the transformation of the city to a fully CAREV environment. Refer to Figure 118 showing the SI city semiotic systems at a local scale.

5.6.5 **SQ1.5** What opportunities does CAREV hold for spatial or social justice, and which societies are affected?

Leading researchers see potential in AV/CAV/CAREV for traffic management, despite concerns over congestion. Shared CAREV (MaaS) offer solutions for minority groups and logistics and a redistribution of transport justice through sharing. Spatial studies suggest road capacity gains with CAREV and SI city transitions may prompt labour and political shifts especially in sectors employed in road transport. The research advocates for ongoing spatial investigations into CAREV urging shifts towards systemic understandings to assist with transport justice holistically and to improve minority representation.

Several leading researchers have noted the potential for AVs/CAVs to assist with urban traffic management, but it is a complex picture. As the vehicles organise themselves, including their parking requirements, additional traffic movement will result. This will likely lead to the vexing outcome that some of the functional gains the technology offers through lane assist, autonomous driving, choreographed platooning and on-demand traffic management systems will be offset by additional movement and congestion. Transport systems are generally complex, as there are enablers and barriers within systems, the role of simulated modelling, not only traffic management, but all movement

management in the city must assist in a deeper appreciation of how social justice imbalances can be redistributed to improve transport justice. Viewing the CAREV and SI city a shared transport, civic transport ecology could assist with rebalancing existing imbalances, including minority groups forced to live further from sources of employment, at the city periphery for example.

There has been substantial research regarding shared vehicle systems. Worldwide, AV/CAV/CAREV bus / shared / MaaS transport systems, trials and whole precincts are seen as testing sites for a shared driving economy. The technology is well suited to minority groups, such as disabled and mobility-impaired persons, aged persons and underage cohorts, as the technology and vehicles can be adapted to the specific requirements of each group. Broadly, AVs/CAVs/CAREVs are suited to rebalancing social justice outcomes of these minority groups. The shared facility is also attractive for people living on the city's periphery and for inter-modal uses. Commercial freight and trades are also a focus in industry, with an international shortage of public transport and freight drivers.

The spatial study used a control model and a capacity model to show that additional capacity in the road system could be anticipated with AVs/CAVs/CAREVs and, especially, SI. The research also proposed principles for RE vehicles, a technological advance over current systems, and circular economy principles to improve environmental and human health outcomes. These principles would allow the whole road-based transport system to operate on RE for positive environmental and, therefore, human health outcomes.

A striking aspect of the major reference studies on AVs/CAVs/CAREVs is the lack of attention to spatial redistribution and spatial justice in the public realm. Few authors have mentioned, let alone quantified, the effects of a smaller vehicle typology, reflecting 150 years of almost unprovoked praxis in a motor vehicle design and manufacturing industry focused on larger vehicles and a monoculture of four-seater passenger vehicles 67% occupied by one person only, and driven by consumer behaviour.

I argue that CAREV technology present an opportunity to rethink transport paradigms and consumer practices – specifically, the environmentally unsustainable monoculture of four-seater human-driven passenger vehicles. Narrow-footprint CAREV-Ss utilising SI could substantially reduce the environmental impact as well as increasing the functionality of the city through additional capacity and reduced congestion.

Another fascinating change that could occur due to AVs/CAVs/CAREVs is related to human knowledge. As we learn more about synthetic intelligence, we will likely learn more about human intelligence. As discoveries are made in synthetic intelligence and synthetic consciousness, human intelligence and consciousness will also be revealed through comparative analysis and observation. A platform for creating synthetic intelligence, potentially more powerful than human intelligence, must be seen as a tool of the human brain; it is a posthuman outcome. Schneider and others have argued – and I agree – that a combined superintelligence will be achieved; indeed, we might have it already. In the context of the public realm, a balanced and culturally nuanced superintelligence in the public realm may have multiple operational, public health and safety benefits, with impacts beyond our current abilities to foresee if designed correctly.

Likewise, the CAREV system, with a change from a human-driven transport modality to algorithms-driven reality, will likely result in unforeseen changes human behaviour – potentially including the systems' unethical use for disruption, corruption or crime-based purposes. The prospect of a dystopian future may be suggested by previous experience of the misuse of advanced technology in war and military or failed operations. Super-intelligent unethical systems could be a major source of global international friction. These dystopian possibilities are fields in themselves for others to explore, noting the obvious connection that many such futures continue to be developed through science fiction, philosophy and film, a cultural theme that has wound its way through this research.

An obvious and dramatic labour change would also occur with a change in fleet to CAREV as human drivers whose livelihoods depend on road-based transport are replaced by SI-driven vehicles. It is therefore likely that transitions to other industries will be needed to mitigate against labour disruptions. Along with this transformation, hopefully, the debate about the role of vehicles and the city will also change. If it has an environmental underpinning, as opposed to a solely commercial or safety underpinning, it is likely to have desirable discourse and educational outcomes.

In shifting the way we think about vehicles and the city, the education system could shift its thinking to research the systemic benefits of a CAREV system rather than retreating into the established siloed fields of research that limit transdisciplinary design outcomes. Transdisciplinary research and education may benefit from appreciable, measurable physical improvements.

5.6.6 **SQ1.6** Do current industry definitions of autonomous vehicles fall below historical, cultural and social expectations? Are the current definitions appropriate?

Technology definitions

In Chapter 3, I discussed the limitations of the current 'definitions of automation' and recommended a revisiting of the SAE classification system through a transdisciplinary framework which could achieve historic cultural and social expectations, refer to Chapter 3.6.3.

In this concluding chapter, I reflect on the technology definitions; an early recommendation from Symposium 2 was that clear definitions would assist everybody in understanding the uses and capabilities of technology as used in this research, which I have included in the following table.

Table 3: Table of research definitions (glossary) from the synthesised research

Driverless vehicle, robo-taxi, self driving	The terms in this research are colloquially used terms suggesting machine-operated driving. However, some academic papers suggest that the term also intimates a transition to autonomy and a sense of no-driving ability.
Autonomous vehicle	An autonomous vehicle (AV) is an aspirational ethical technology that must be trusted by humans to synthetic intelligence. AV are not necessarily network-connected to each other or the city. AV provide enhanced safety as an advanced transport modality.
Connected autonomous vehicle	**A connected autonomous vehicle** (CAV) shares de-identified vehicle-to-vehicle data and vehicle to city (V2C) or vehicle to everything (V2X) with other connected autonomous vehicles (V2V) as an advanced partially networked transport system. The CAV classification does not specify the type of energy use or circular economy principles.
Connected autonomous renewable energy vehicle (CAREV)	Connected autonomous renewable energy vehicles (CAREVs) are vehicle-to-everything (V2X) aspirational transport technology and advanced transport modality using a systemic synthetic intelligence that society trusts. The V2X systems networked to utilise synthetically intelligent city systems to increase the resilience, flexibility and functionality of a city as a positive regenerative environmental outcome. A distinction of this vehicle type is that it is part of a circular economy, and it uses renewable energy sources in both manufacturing and operational stages. These vehicles can autonomously operate in the public realm, complying with all legislated tasks and cultural aspirations systemically.

5.7 Research limitations and assumptions

One of the difficulties of this field is the enormous breadth and depth of vehicle impacts on human health and the environment, making necessary an appropriate method for limiting the discussion to essential issues (see Chapter 2.8). Increasing the breadth and field of research is a quality of systems thinking. Therefore, the depth and breadth of the field and the PhD requirements imposed limitations on almost every aspect of the research output. In response, one limitation that I imposed on the research was to focus on areas that I perceived needed more attention to fill the research gaps.

This was speculative research, and the field is evolving rapidly in terms of both subject matter (technological advances) and research output. With approximately 250-300 articles being published weekly in the English-speaking world, I was reliant on computer software to keep me abreast of scholarly and related research fields. This limitation was discussed in the Chapter 2.7 literature review.

Likewise, the research field has the potential to be unmanageably broad, encompassing CAREV-based public transport, MaaS and urban active transport, vehicle strategies, pedestrianisation, and integrating the technology with other regional public transport modalities (rail, air, freight, hyperloop, shipping, etc.). I decided to fill a research gap by focusing on private vehicle use patterns, one of the most challenging areas in the polemical and orthodox debate regarding vehicle impacts in the city, and one not receiving enough attention. Similarly, population growth, advanced and emerging economies, the transport economics of developing economies, consumerism and human greed are subjects beyond the scope of this research; all of these factors, however, influence industry and society.

I realised there were a specific avenues of research that would require a substantial investment and more resources beyond my limited means to explore in detail. These areas included:

The ability of developing-economy nations to adopt AV/CAV/CAREV technology. Considering that a high percentage of road deaths and environmental impacts are occurring in developing nations, this is an area of research that will require substantial investment to fully understand. Due to my heritage of being born in Zimbabwe and having been partly educated in South Africa, I felt an emotional obligation to assist in this research field, but this will have to wait for my post-doctoral research phase.

Despite attempts over extended periods and efforts to obtain data regarding the relationship between freight and passenger vehicle sizes, which included various libraries, a databases and private correspondence between me and several leading authorities in this field, I have yet to obtain appropriate data on this subject.

Intermodal research (discussed in Chapter 2.7) is a field that requires more attention. While there is evidence of transport departments undertaking intermodal approaches, it is a research area that requires deeper insights, especially on the intermodal opportunities of CAREV versus other autonomous transport systems, as there are city management and transport solving qualities in this field.

Autonomous vehicle environments, such as ports and agricultural and mining operations, are conducted in largely controlled, privately owned settings. Autonomous military vehicles are beyond the scope of this research. These areas offer rich sources of data and experience for future research.

Development in AVs, cognitive science and synthetic intelligence is an enormous area of inquiry that has dominated the news and ethical concerns. The implications of the ethical and moral issues regarding AVs in the public realm would form a PhD subject on their own.

Likewise, further research is required into the excessive expansion of the semiotics (signs) in the Vienna Convention. This was discussed in Chapter 3.4 as a research limitation, as there are thousands of signs in the current catalogue which make for a overwhelmingly complex system. The marketing and commercial aspects of AV/CAV/CAREV and semiotics is another field of inquiry which systemically impacts the industry and public realm. Due to the scale, nature and depth of this field, this subject area could form a separate PhD's or post doctoral research by others.

Finally, governments and road authorities know that speed is responsible for fatal outcomes of incidents, yet they continue to permit vehicle manufacturers to increase the size, mass and speed of vehicles. This needs more research, as it has adverse outcomes. Vehicle manufacturers have been put on notice about oversized SUV in Paris and some signs emerging in other jurisdictions, the interesting question that arises from this is how quickly policy makers will respond to the phenomenon. The increase in size of vehicles has significant cost implications in infrastructure, safety and construction. Governments and policymakers need to respond to the lack of attention in this field.

5.7.1 Recommendations and future directions

Environmentalists, the vehicle (CAREV) design industry and professional urban designers will be interested in applying the Capra–Luisi framework to this field. The systems thinking approach provides new ways of understanding safety, environmental, commercial, cultural and cognitive responses to CAREVs that need their attention.

Academics and researchers will be interested in the transdisciplinary processes. The transdisciplinary nature of the research and its methods apply the Capra–Luisi systemic approach to research fields and, in so doing, open opportunities for extending fields of knowledge. Applying the Capra–Luisi framework has relevance to institutions that must ensure that all research has positive ecological outcomes.

Architects, urban designers and planners associated with the transport and motor vehicle industries should use the AV transport revolution opportunity to reach across their methodological and ideological silos and listen, respond to and explore new design strategies to achieve social and cultural aspirations. A first step would be to revise the SAE taxonomy to appropriately respond to the environment and humans in the public realm, and to reimagine the AV classification system in order to reflect the ability of the CAREV to communicate its intentions and actions. The SAE should ensure, at least, that multidisciplinary teams are involved in revising the definitions and classification systems that acknowledge how these vehicles are likely to impact our lives and cities.

The community should also adjust its consumptive behaviour. By pointing out environmental waste (the empty seat syndrome) and by improving city functionality and environmental outcomes, and aligning cultural expectations with the CAREV technologies, the community has an opportunity to increase the liveability of the future city.

This research pointed to the adaptive reuse of road based infrastructure by changing the technology and format of the vehicle (ergonomic study) to suit established vehicle occupancy statistics. This opens opportunities for environmentalists and policymakers to re-examine the size, mass and speed of vehicles and their impacts on cities and the people within as a vehicle standards requirement. The community is complicit in consuming oversized, overpowered machines.

The community needs to become active in this field. They must pressure local, state and national transport authorities to achieve social and cultural aspirations, improved safety, and environmental and intergenerational justice outcomes. The community needs to be at the heart of insisting on smaller vehicles in the public realm that have speed and size limits as part of the social licence to operate. The community that drives vehicles must become aware of the waste and ongoing impacts on the planet's energy resources and pressure motor vehicle designers and manufacturers to increase the diversity of vehicles, especially narrow and reduced-seat vehicles. The narrow format CAREV-S vehicle opportunity has multiple benefits including assisting with congestion through increasing road capacity and reducing infrastructure costs if approached systemically

Politicians and community leaders should also become involved in communicating leadership for improved urban outcomes, taxing larger vehicles appropriately and increasing taxes on empty seats in vehicles. As Mitchell comments, 'Our job is to design the future we want, not to predict its predetermined path'.[604]

The predetermined path appears to be more of the same, increased congestion, spiralling road death and injury, confusing public realm semiotics, an evolving picture of omnipresent diminished urban impacts. And, more of the same policy responses; more anti-vehicle movements, car banning, throttling of vehicles in cities through taxes or other prescriptive systems. These insights are reminders of one of how the abnormal becomes normalised.

The research aim of this thesis was to advocate for a changed system – one that is more flexible and addresses the social requirements that, as we know from the research, are embedded in the collective memory. CAREV and the SI city offers a rare opportunity to mediate in current practices and develop systemic strategies that rebalance outcomes justly for future generations, the environment and to make the city more liveable. I do not think of this approach as theoretical, for me it is a practical, empirical and design based response research.

604 Mitchell, William J., *E-Topia: Urban Life, Jim - but Not as We Know It* (London: The MIT Press, 2000), p. 12.

5.7.2 Originality of the contribution to knowledge and its significance

The original contribution to knowledge this research provides has been summarised in the following subject areas.

The significant role of the Capra–Luisi environmental framework, as it is applied to the AV/CAV/CAREV field, is unique to this research contribution as an environmental approach. The Capra–Luisi framework is suitable for the future development of CAREVs. Environmental systems thinking opens new avenues of social inquiry; it shifts paradigms. Importantly, it allows researchers to creatively appreciate planetary-scale systems locally and even at the individual level.

The original contribution of this research is the adaptation of the Capra–Luisi environmental framework and Schneiders LoT cognitive sciences to the field of CAREVs – that is, to design a CAREV system that has multiple, systemically positive environmental outcomes. The future design of the CAREV system, the new semiotic and cognitive opportunities it offers, and its integration with the synthetically intelligent city suggest a pathway to living with CAREVs in the public realm that improves urban liveability through positive environmental outcomes. It is a designed and systemic approach, that improves road safety and environmental outcomes. The significance of this research lies in its ability to frame new discussions about AVs/CAVs/CAREVs as a dynamic transdisciplinary approach. This has implications for the broader community, industry, academia and the design profession, including urban design policymakers.

The research's systemic and transdisciplinary approach questions notions of cities as organisms, machines or smart platforms. It focuses on how CAREV technology can be used to reimagine the city. Using an environmentally systemic framework, synthesises the research through technology, semiotics, cognitive processes and communications. The research advocates for a systemically designed future that assists with transforming itself to assist with positive environmental outcomes. The symposium methods transdisciplinary framework suggests a inclusive, holistic and systemic process that is dynamic

and flexible. The research framework also demonstrates how apparently unrelated fields such as semiotics and ecological, should be researched as inseparable modules of nested sub-systems within a larger system and benefits each others' output.

The research strongly argues that the SAE automation classification system fosters a driver-focused perspective, and thus outcomes, further marginalising urban and safety imperatives. A reimagined AV classification system would ideally focus on the ability of CAREV to communicate intentionality in a diversity of environmental conditions with a variety of users in the public realm as well as the occupants of the vehicle. Communication is essential to everybody and everything in the city, a systemic semiotic ecology is required, it can be achieved through the use of environmentally conscious technologies (the technoecology). The semiotic and communications design assists us in reimagining the sensory platform of the city, including its visual, auditory, haptic and other networked systems, to communicate synthetic intelligence to actors in the public realm.

AV/CAV and CAREVs provide a novel way of looking at the city systemically. This research provides a model of systemic framework that integrates environmental, semiotic and technology as part of a process of holistic thinking and design responses through the transdisciplinary method, the intention is not to limit the transdciplinary fields, rather to shine a pathway into how other disciplines method and inputs enrich and expand design and research and in so doing create unique and significant perspectives that change entrenched practices.

Several peer-reviewed authors have argued that CAREV technology has the potential to positively transform road safety. This research argues that the technology has positive city-changing and multifaceted environmental potential to have positive outcomes. Industry may argue that it already practices inter, trans and/or multidisciplinary process in design and manufacture of vehicles. The intentionally siloed approach of planned obsolescence and continuing urban impacts vehicles on the city are a provocation to industry and its methods.

An ethically responsible transdisciplinary approach would seek to increase safety, human and vehicle interaction and to support positive environmental outcomes. The automotive industry should view this an opportunity to leverage social licence. Environmentally ethical responses should include reducing emissions, increasing energy efficiency, increasing shared mobility, CAREV integration with public transport systems, integration with city SI infrastructure, designing and operating a CAREV system that is based on renewable energy and circular economy principles. Continuously assessing the system under environmental impact assessment processes including monitoring and accountability, increasing ethics, equity and accessibility systemically, transitioning to labour from current to new technologies through transition programs, protecting individual and company data privacy and security, engaging with the community, developing long-term planning strategies, designing the system rather than allowing it to evolve through planned obsolescence if designed correctly and implemented carefully to benefit the environment is necessary.

Such a system would improve urban liveability, public health, city functionality and resilience. While these agendas may seem aspirational, the research presents a vision of the future and how to achieve comfort, resilience, efficiency, and clean and environmentally positive outcomes through CAREVs. Such an approach has broad positive social and environmental outcomes and is therefore significant to the community and its leaders and policymakers.

5.8 Closing and summary

This research has used a combination of practice-based and academic qualitative methods to explore the intersection of positive environmental responses, semiotics and synthetic intelligence in the context of future CAREVs. It integrates the Capra–Luisi environmental systems thinking framework with Schneider's reimagined 'Language of Thought' hypothesis to investigate emerging CAREV technology. The research aims to address the potential impact of future CAREVs on public spaces.

Motivated by the desire to apply the RCA's transdisciplinary expertise to my practice observations in road-based transport and infrastructure, a thread of a selected cultural and social history of AV provides context throughout the writings. The research clarifies the historic cultural expectations for AV as a safe, convenient, reliable, flexible, sustainable, magical, just and comfortable transport modality.

The research utilised a symposium method with three stages: context immersion, experimentation and synthesis, characterised by inquiry, feedback, and multi-voiced dialogue to generate new data. The symposium method incorporated action research and interviews, with continuous improvement through reflection and critique. Diverse voices were encouraged and resourced to enrich the outcomes, with the symposia advertised and open to the public and supporting material provided in advance through an open-source research interface (www.transfig.com.au). The process highlights the importance of allocating adequate resources to enhance participation and diversity and emphasises the iterative nature of transdisciplinary systems thinking.

The research examines the potential of synthetically intelligent driving systems, particularly CAREVs, to address road safety, urban infrastructure costs, public health, and climate change impacts. Despite recent setbacks in emerging AV technologies, due to fatalities, the research underscores the importance of investing in safer, environmental transportation systems. CAREVs could revolutionise road-based transport modalities if designed to focus on social and environmental outcomes rather than traditional consumption and cause-and-effect practices.

The research proposes a systemic semiotic technoecology hypothesis, suggesting that CAREVs can communicate with vehicle occupants and actors in the public realm through environmentally and semiotically conscious technologies. This is the practical application of the Capra–Luisi and Schneider theoretical frameworks. These applications enable CAREVs to provide insights into environmental impacts and utilise a regenerative and positive environmental civic technology approach. A research limitation is that this study focuses on visual semiotics in the road environment; future research could explore auditory, gestural, haptic, linguistic and spatial semiotics.

Hopefully, new questions about other semiotic processes as systemic research into human and non-human interaction would arise. Additionally, the research acknowledges the need for non-human interfaces for CAREVs to interact safely in the public realm, which is another area for future research.

Overall, the research advocates for a transhumanist approach that leverages technology to benefit both humans and the environment, envisioning a future in which CAREVs play a pivotal role in positive environmentally regenerative transportation systems.

During the development of the research several salient decisions were made:

1. Weaving a thread of social and cultural history research throughout all aspects of the research, was an early feedback recommendation, resulting in research questions about learning to live with CAREV in the public realm.
2. Challenging the SAE automation classification on cultural and environmental grounds allowed for reimaginging options and opened questions about the limits of industry ambitions.

3. Applying the Capra–Luisi environmental framework and Schneider LoT hypothesis to the research fundamentally changed the direction of the research. Instead of considering only cause and effect, the Capra–Luisi-Schneider framework applies an environmental framework to the subject as a systemic and semiotic process.
4. Developing a multilevel approach to the research was critical to understanding how personal mobility choices affect macro-level outcomes as part of systems thinking.
5. Systems thinking in this field is complex and necessary; it includes many variables, and multiscale and nested dynamic systems thinking was a critical decision for the research.
6. The symposium method was essential to creating and obtaining new data. Dialogue development through transdisciplinary research facilitated uniting practice and academic processes. This included incorporating design experiments and architectural multimedia into the thinking and philosophical processes.
7. Developing a spatial study and incorporating a diversity of ownership patterns, especially private use/ownership of vehicles, was a crucial research decision as it opened an opportunity in a field with relatively limited insights into CAREV typologies.

These critical decisions contributed to a comprehensive understanding of the field and delineated the research limitations. The research's strength lies in its combined practice-based and academic approach, which systematically applies environmental-semiotic thinking to CAREVs, addressing research questions through the symposium method. This approach facilitated a thorough exploration of the breadth and depth of the subject matter.

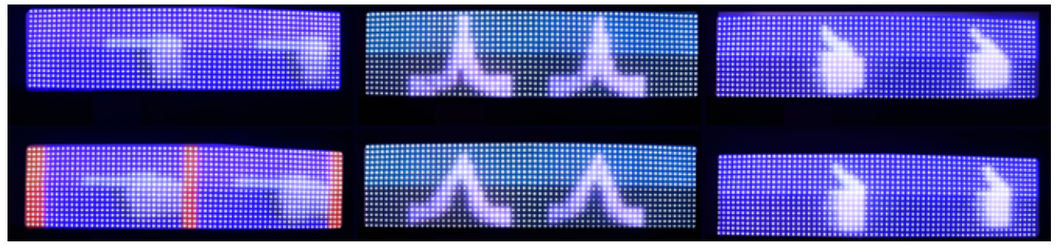


Figure 119: The experimental communications unit and anthropomorphic semaphores.

Figure 120: CAREV-S palimpsest animation frame.

Figure 121: Increases in environmental and active transport area in Crown Street through CAREV.

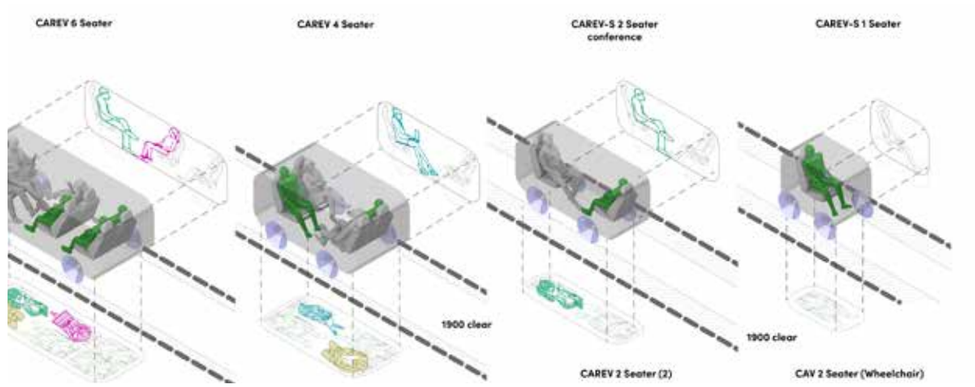


Figure 122: Spatial study: CAREV ergonomic and lane width study.

Culturally sensitive semaphores to assist humans understand SI intentionality with CAREV were explored using the digital communications unit

CAREV and SI city integrated semaphores can assist humans understand SI intentionality in CAREV and the SI city discussed in Symposium 3.

The spatial investigation of CAREV-S and mixed CAREV in Crown Street included an increase in active transport and environmental space.

The CAREV spatial investigation included a review of current vehicle occupancy, linked to lane spatial analysis and transport equity for minority groups such as disabled and aged persons, LBTQIA+ and other minority cohorts.

The research questions evolved iteratively through the symposium method, resulting in key findings:

1. Acceptance of CAREV synthetic intelligence: Successful integration of CAREV synthetic intelligence in public spaces depends on aligning the system with cultural expectations and fostering community trust. Figures 119 and 120 explored a cultural and humanising SI approach to CAREV in the public realm.
2. Applying a positive environmental (Capra–Luisi) framework: The research, guided by the Capra–Luisi environmental framework, aimed to achieve positive environmental outcomes, for CAREVs, emphasising environmental and social justice principles. Figure 121 explored a spatially just and environmental approach for CAREV as a scenario in a case study, Crown Street, Surry Hills.
3. Social justice and CAREV: CAREVs, if designed with a focus on spatial, environmental and social justice, can benefit diverse societal groups, including minority cohorts, the elderly and LGBTQIA+ communities, while still addressing the needs of the majority. Figure 122 investigated diversity and an ergonomic approach that is spatially just for CAREV as a spatial study in CAREV.
4. Flexible vehicle ownership models: Shifting towards a diverse mix of private, collective and public ownership models for CAREVs/ CAREV-Ss could enhance transportation system resilience and flexibility, addressing spatial injustices inherent in the current vehicle ownership landscape. Figures 121 and 122 explored a spatially just and environmental approach for CAREV of a mixed transport modality including MaaS, larger vehicles and CAREV-S.
5. Systemic benefits of CAREV: The spatial study demonstrated systemic benefits of CAREVs and especially the narrow CAREV-S format, such as reduced urban, increased environmental area for the city and aesthetics, leading to a more liveable and equitable urban environment. The CAREV form part of a circular economy model with reduced operational and manufacturing energy. Figure 123 explored the UHI as a combined effect of CAREV in the case study area of Surry Hills.
6. Principles: Principles assist with the development of thinking, to guide the research outcomes; these are arranged thematically to suit the research. The principles used in the research are located in Chapter 1.5.

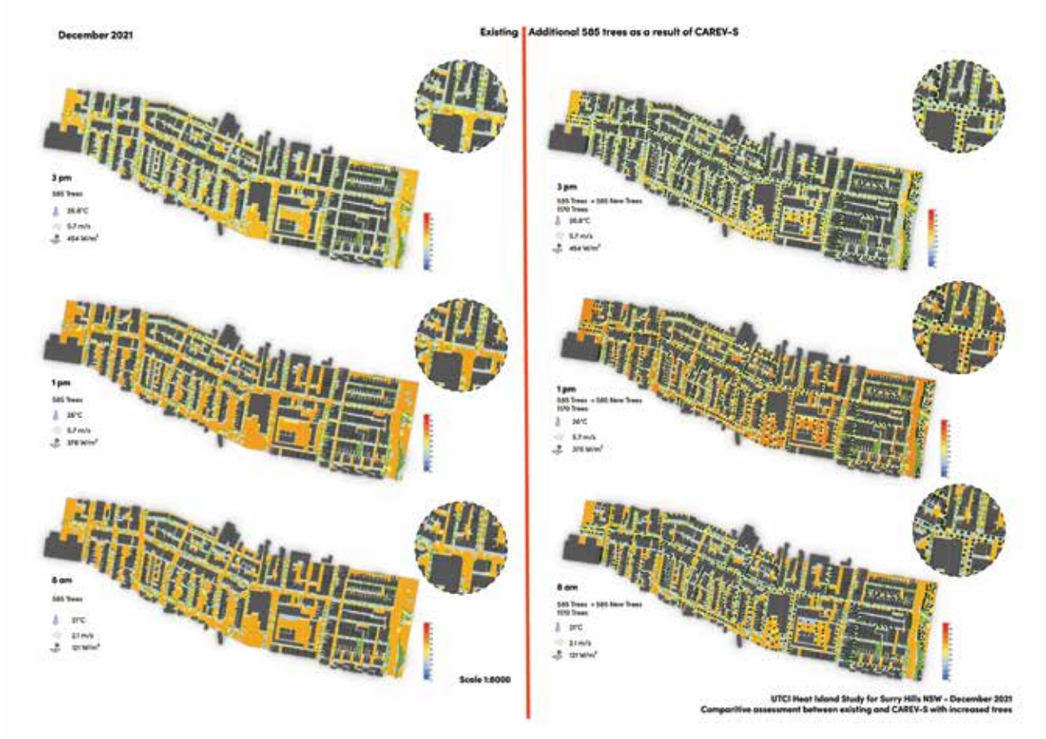


Figure 123: The spatial investigation for CAREV included a UHI study in Surry Hills.

The research also noted the potential impacts of CAREV-S. Increased traffic movement is expected, but the road space used by the vehicles would be redistributed, and city SI logistics could mitigate the impact. Potential additional consumption could be expected as reduced pricing for smaller vehicles reflects lower production costs. Consumption is difficult to manage as there are capitalist incentives that would have to be managed through taxing or user-limiting policies. Potential additional extraction for vehicle manufacturing in the face of population increases, urbanisation and the need for more people could be managed by employing circular economy principles. All impacts must be assessed carefully utilising environmental principles to assess, monitor and improve outcomes at all stages.

The UHI study for Surry Hills investigates the combined environmental effects of CAREV on the city. If designed and with appropriate environmental input the city could experience lower UHI temperature effects through CAREV.

The research aimed to disseminate its findings through academic publications, conference presentations, symposium discussions and an online research interface. While academic audiences may be interested in the methodology and interdisciplinary aspects, practitioners could gain insights into how academic research informs practice and vice versa. However, communication with the motor vehicle industry posed challenges, indicating the need for more inclusive approaches to technology development and the SI city. Additionally, the AV industry should adopt a more socially inclusive approach, prioritising community needs over individual vehicle owners' demands.

Further research opportunities exist in exploring legal, economic, and social aspects of synthetically intelligent vehicles, especially in developing economies.

Future research in the AV field should adopt a systemic approach, considering all AV modalities, including flying vehicles, goods and freight distribution, and personal mobility vehicles, accepting this is a dynamic field of innovation and incentive. Intermodal and multimodal AV systems are being explored in various applications, including agriculture and military contexts, in Australia and elsewhere. Mapping the intermodal network using GPS, digital or SI systems presents significant opportunities for further research.

The research on CAREV technology emphasises reshaping societal perceptions regarding future city design to achieve an ecologically conscious civic system. It advocates for a clear vision to achieve environmental, social, and economic impacts, rather than allowing for opaque, evolving vehicle development with established practices such as planned obsolescence. Transparency in the design and development process is crucial, and advocating for appropriate changes is necessary at various levels, from grassroots community initiatives to local, national and international efforts.

As the city remains a site of contested space, new AV modalities will continue to impact public realms and urban liveability. Research funding and insights will be essential for managing the challenges that arise from the community learning to live with the new SI technologies such as CAREV, in the public realm. Ultimately, CAREV has the potential, if designed systemically, to transform road-based transportation into a more socially, culturally, and environmentally sustainable system, benefiting communities and enhancing urban liveability.

The CAREV visions presented in the research prioritise environmental considerations and are intentionally subtle, aligning with my practice approach. Subtlety in design is a powerful yet demanding approach as it is unexpected.

Unlike the often exaggerated and polarised portrayals in the visual history of AV, the CAREV images in the report respond to existing urban development patterns in an environmentally and culturally conscious and spatially focused manner. The utilisation of the Capra–Luisi-Schneider systems framework in this research underscores the potential for positive regenerative environmental benefits. It offers an alternative perspective on how to approach challenges and enact change, ultimately aiming to shift paradigms and achieve desired outcomes.

The conclusion drawn is that if CAREVs are designed environmentally and systemically, they could become integrated technologies within synthetically intelligent cities, thereby enhancing urban liveability, refer to Figure 121. By incorporating culturally appropriate, cognitively aligned computational semiotics, CAREVs could offer multiple benefits. Viewing CAREVs as part of a larger environmentally semiotic system could lead to systemic benefits, enhancing our understanding and appreciation of the CAREV transport ecology as an environmentally conscious systemthat emerges from this research vision.

The research includes multiple novel research components they can be summarised as:

- The application of the Capra-Luisi ecological framework to CAREV and the SI City
- The transdisciplinary and systemic symposium method, a feature of combining my practice methods and the Royal College of Art's renowned academic methods
- A comprehensive challenge to the SAE automation classification, highlighting the ecological and limitless potential of a future technology
- An ecological approach to semiotics and cognitive responses between human and synthetic intelligences arrived at through an appreciation of cognitive sciences, and experimental semiotic design
- A systemic approach to a spatial study in CAREV and the SI city focussed on environmental justice.

Refer to Figure 124

Figure 124: Mixed CAREV-S view at the corner of Cleveland and Crown Streets, Surry Hills, birds eye view at night (orange cyan colour).

The spatial investigation for CAREV and CAREV-S in Crown Street inlcuded a mixed MaaS, CAREV and CAREV-S (narrow vehicle) mixed traffic scenario with increased active transport provisions. The CAREV in this vision are spatial envelopes with semiotic systems attached. The CAREV are not intended to be representative of vehicle design. CAREV semiotics as a conceptual outcome, Video 2 shows the animated version and the choreographed nature of a variety of CAREV semiotic systems as a design exploration. Refer also to Appendix F.10.

Overall, this research advocates for a vision of a holistic and intergenerationally responsible approach to the design, operation, and conceptualisation of CAREVs, emphasising their potential to impact urban environments positively and people's lives, contributing to safe and environmentally safe road-based transport ecology, refer to Figure 124. Measured against the current system, such an outcome would be magical.

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Chapter 6.0 Bibliography

The bibliography is arranged by themes in the thesis as follows:

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Technology: AV/CAV/CAREV

Environmental

Semiotics

Economics

Method and Practice

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Films

General

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Age of Tanks, dir. Florian Dedio, Anna Kwak, Barbara Necek & Tatiana Ushenko (IMDb Netflix 2017–2018 TV Series)

Written by Florian Dedio, Anna Kwak, Barbara Necek & Tatiana Ushenko. Narrated by Rachael Williams. Produced by Elodie Polo Ackermann, Gunnar Dedio, Jan Heinrich Müller, Astrid Ozanne, Igor Prokopenko, Birgit Rasch, Olga Zatulkina. Series Music by Henrik Albrecht, Moritz Denis, Laurent Eyquem, Eike Hosenfeld, Gerhard Daum, Jean-Claude Mejstelman, Achim Gieseler, Michael Hartmann, Jens Fischer. Series Film Editing by Dirk Seliger, Vincent Daudeij, Ursula Pürrer

Aladdin, dir. by Ron Clements, John Musker (Walt Disney, 1992)

Based on *Aladdin and the Magic Lamp* from *One Thousand and One Nights* tr. *Les mille et une nuits* by Antoine Galland. Produced by Ron Clements John Musker. Screenplay by Ron Clements, John Musker, Ted Elliott, Terry Rossio. Story by Burny Mattinson, Roger Allers, Daan Jippes, Kevin Harkey, Sue Nicholas, Francis Glebas, Darrell Rooney, Larry Leker, James Fuji, Kirk Hanson, Kevin Lima, Rebecca Rees, David S. Smith, Chris Sanders, Brian Pimental, Patrick A. Ventura

Film starring Scott Weinger, Robin Williams, Linda Larkin, Jonathan Freeman, Frank Welke, Gilbert Gottfried, Douglas Seale. Music by Alan Menken. Edited Mark A. Hester, H. Lee Peterson. Production: Walt Disney Distributed by Buena Vista Pictures.

Aladdin the musical, music by Alan Menken, lyrics by Howard Ashman, Tim Rice, Chad Beguelin (Walt Disney Animation Studios, 2011)

Based on *Aladdin and the Magic Lamp* from *One Thousand and One Nights* tr. *Les mille et une nuits* by Antoine Galland. Book by Chad Beguelin. Premiere 2011, 5th Avenue Theatre, Seattle. Productions in 2011 Seattle, 2013 Toronto, 2014 Broadway, 2015 Tokyo, 2015 Hamburg, 2016 West End, 2016 Australia, 2017 North American Tour. Tony Award for Best Featured Actor in a Musical. Drama Desk Award for Outstanding Featured Actor in a Musical.

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An Inconvenient Truth, dir. David Guggenheim (Paramount Classics, 2006)

Directed by Davis Guggenheim. Written by Al Gore. Starring Al Gore. Produced by Laurie David, Lawrence Bender, Scott Z. Burns. Music by Michael Brook. Cinematography Bob Richman, Davis Guggenheim. Edited by Jay Cassidy. Dan Swietlik. Production Company Lawrence Bender Productions. Distributed by Paramount Classics.

Avatar, dir. by James Cameron (20th Century Fox, 2009)

Written by James Cameron. Produced by James Cameron, Jon Landau. Starring Sam Worthington, Zoe Saldana, Stephen Lang, Michelle Rodriguez, Sigourney Weaver. Music by James Horner. Cinematography Mauro Fiore. Edited by Stephen Rivkin, John Refoua, James Cameron. Production Company Lightstorm Entertainment, Dune Entertainment, Ingenious Film Partners. Distributed by 20th Century Fox. Country: United States. Budget $237 million. Box office $2.788 billion.

Batman and Robin, dir. by Leslie H. Martinson (20th Century Fox, 1966)

Based on Characters by Bob Kane and Bill Finger (uncredited). Produced by William Dozier. Written by Lorenzo Semple, Jr. Starring. Adam West, Burt Ward, Lee Meriwether, Cesar Romero, Burgess Meredith, Frank Gorshin. Music by Nelson Riddle. Cinematography Howard Schwartz. Edited by Harry Gerstad. Production Companies William Dozier Productions and Greenlawn Productions. Distributed by 20th Century Fox.

Blade Runner, dir. Ridley Scott (Warner Brothers, 1982)

Based on Philip K. Dick. 1968. Do Androids Dream of Electric Sheep? (USA: Doubleday). Produced by Michael Deeley. Screenplay by Hampton Fancher, David Peoples. Starring Harrison Ford, Rutger Hauer, Sean Young, Edward James Olmos. Music by Vangelis. Cinematography Jordan Cronenweth. Edited by Terry Rawlings, Marsha Nakashim. Production company The Ladd Company, Shaw Brothers, Blade Runner Partnership Distributed by Warner Bros.

Chitty Chitty Bang Bang, dir. by Ken Hughes (United Artists Pictures Inc., 1968)

Based on Chitty Chitty Bang Bang by Ian Fleming. Produced by Albert R. Broccoli. Screenplay by Roald Dahl and Ken Hughes. Starring Dick Van Dyke, Sally Ann Howes, Lionel Jeffries, Gert Fröbe, Anna Quayle, Benny Hill. Music by Irwin Kostal (score), Richard M. Sherman (songs), Robert B. Sherman (songs). Cinematography Christopher Challis. Production company Warfield Productions. Distributed by United Artists Pictures Inc.

Crash dir. Paul Haggis (Lionsgate Films 2004/5)

Produced by Don Cheadle Paul Haggis, Mark R. Harris, Bobby Moresco, Cathy Schulman, Bob Yari. Screenplay by Paul Haggis Bobby Moresco. Story by Paul Haggis Starring Sandra Bullock, Don Cheadle, Matt Dillon, Jennifer Esposito, Brendan Fraser, Terrence Howard, Chris Bridges, Thandie Newton, Ryan Phillippe, Larenz Tate. Music by Mark Isham. Cinematography J. Michael Muro. Edited by Hughes Winborne. Production company Bob Yari Productions, DEJ Productions, Blackfriars Bridge, Harris Company, Apollo, ProScreen Productions, Bull's Eye Entertainment. Distributed by Lionsgate Films 2004/ 2005

Dirty Money, Hand NOx, dir. Alex Gibney (Netflix, 2018)

Executive producers, Adam Del Deo, Yon Motskin, Lisa Nishimura, Stacey Offman, Jason Spingarn-Koff, Alex Gibney. Production company Jigsaw Productions. Distributor Netflix

Dirty Money is an American documentary television series which documents corporate corruption. The executive producers include Oscar-winning documentary filmmaker Alex Gibney. Hard NOx is the session that deals with The Volkswagen emissions scandal.

Enders Game, dir. By Gavin Hood (Summit Entertainment 2013)

Based on Ender's Game and Ender's Shadow by Orson Scott Card. Produced by Gigi Pritzker, Linda McDonough, Alex Kurtzman, Roberto Orci, Robert Chartoff, Lynn Hendee, Orson Scott Card, Ed Ulbrich. Screenplay by Gavin Hood. Starring Harrison Ford, Asa Butterfield, Hailee Steinfeld, Viola Davis, Abigail Breslin, Ben Kingsley Music by Steve Jablonsk. Cinematography Donald McAlpine, Edited by Zach Staenberg, Lee Smith. Production company OddLot Entertainment, Chartoff Productions, Taleswapper, K/O Paper Products, Digital Domain, Sierra/Affinity. Distributed by Summit Entertainment. Budget $110–115 million. Box office $125.5 million.

Flip the Frog, dir. by Ub Iwerks, (Celebrity Prod. & (after 1928 Disney) 1931)

Produced by Pat Powers (1869-1948). Distributed Celebrity Productions and Disney productions after 1928. Screenplay Ub Iwerks. Drawn. Ub Iwerks. Starring Flip the Frog.

I, Robot, dir. by Alex Proyas (20th Century Fox, 2004)

Based on the premise suggested by *I, Robot* by Isaac Asimov. Produced by Laurence Mark, John Davis, Topher Dow, Wyck Godfrey. Screenplay by Jeff Vintar and Akiva Goldsman. Story by Jeff Vintar. Starring Will Smith, Bridget Moynahan, Bruce Greenwood. Music by Marco Beltrami. Cinematography, Simon Duggan. Edited by Richard Learoyd. Production company Davis Entertainment, Laurence Mark Productions Overbrook Films, Mediastream IV. Distributed by 20th Century Fox.

Knight Rider, dir. Glen A, Larson (Knight Rider orig. 1982)

Created by Glen A. Larson included a television series *Knight Rider* 1982-1986, *Team Knight Rider* 1997-1998 and *Knight Rider* 2008-2009. The franchise included three television films, computer and video games, novels and a Knight Rider Convention named *KnightCon.* The original Knight Rider is an adventure series of Michael Knight, a crime fighter who uses an artificially intelligent automobile called KITT. The series debuted on NBC in the USA in 1982. The Knight Rider actor was David Hasselhoff, and KITT's voice was variously William Daniels, Steve Forrest, Val Kilmer, Carmen Argenziano and Hudson Leick.

Metropolis, dir. Fritz Lang (Parufamet 1927)

Based on Metropolis a 1925 novel by Thea von Harbou. Directed by Fritz Lang. Produced by Erich Pommer. Screenplay by Thea von Harbou and Fritz Lang (uncredited). Starring Alfred Abel, Brigitte Helm, Gustav Fröhlich, Rudolf Klein-Rogge. Music by Gottfried Huppertz. Cinematography Karl Freund, Günther Rittau. Production company UFA. Distributed by Parufamet. Silent film German intertitle. Budget 5.3 million Reichsmarks (estimated). Box office 75,000 Reichsmarks (estimated).

Matrix, dir. The Wachowskis (Warner Bros, Village Roadshow Pictures, Groucho II Film Partnership, Silver Pictures, 1999)

Written by The Wachowskis, produced by Joel Silver. Starring Keanu Reeves, Laurence Fishburne, Carrie-Anne Moss, Hugo Weaving, Joe Pantoliano. Music by Don Davis. Cinematography Bill Pope. Edited by Zach Staenberg. Distributed by Warner Bros. (United States) Roadshow Entertainment (Australia). Budget $63 million. Box office $463.5 million. Matrix won four Academy Awards, BAFTA Awards and Saturn Awards, and in 2012 was registered on the US National Film Registry for preservation.

Minority Report, dir. by Steven Spielberg (20th Century Fox, 2002)

Based on *The Minority Report* by Philip K. Dick. Produced by Gerald R. Molen, Bonnie Curtis, Walter F. Parkes, Jan de Bont. Screenplay by Scott Frank Jon Cohen. Starring Tom Cruise, Colin Farrell, Samantha Morton, Max von Sydow. Music by John Williams. Cinematography Janusz Kamiński. Edited by Michael Kahn. Production company 20th Century Fox, DreamWorks Pictures, Amblin Entertainment, Blue Tulip Productions. Distributed by 20th Century Fox (North America), DreamWorks Pictures (International).

The Fifth Element, dir. by Luc Besson (Columbia Pictures, 1997)

Story by Luc Besson. Produced by Patrice Ledoux. Screenplay by Luc Besson, Robert Mark Kamen. Starring Bruce Willis, Gary Oldman, Chris Tucker, Ian Holm, Milla Jovovich. Music by Éric Serra. Cinematography Thierry Arbogast. Edited by Sylvie Landra. Production company Gaumont. Distributed by Gaumont Buena Vista International (France). Columbia Pictures (United States).

The Love Bug, dir. by Robert Stevenson (Buena Vista, 1968)

Story by Gordon Buford. Produced by Bill Walsh. Screenplay by Bill Walsh, Don DaGradi. Starring Dean Jones, Michele Lee, David Tomlinson, Buddy Hackett. Music by George Bruns. Cinematography. Edward Colman Edited by Cotton Warburton. Production company Walt Disney Productions. Distributed by Buena Vista Distribution.

Total Recall, dir. by Paul Verhoeven (TriStar Pictures, 1990)

Based on *We Can Remember It for You Wholesale* by Philip K. Dick. Produced by Buzz Feitshans, Ronald Shusett. Screenplay by Ronald Shusett, Dan O'Bannon Gary Goldman. Story by Ronald Shusett Dan O'Bannon Jon Povill. Starring Arnold Schwarzenegger, Rachel Ticotin, Sharon Stone, Michael Ironside, Ronny Cox. Music by Jerry Goldsmith. Cinematography Jost Vacano. Edited by Frank J. Urioste Carlos Puente. Production Company Carolco Pictures. Distributed by TriStar Pictures.

Transformers, dir. by Michael Bay, Travis: 2018 (DreamWorks Pictures and Paramount Pictures 2007/9/11/14/17/18)

Transformers is a series/franchise of American science fiction action films based on the toys and comics by Hasbro. The first series of Marvel Comics written by Bob Budiansky, with Marvel UK writer Simon Furman (later issues) ran from 1984 to 1991; Generation 2 of 12 issues started in 1993 and ended in 2005. The third series produced by IDW Publishing Michael Bay started in 2006 and is current. Transformers (2007), Revenge of the Fallen (2009), Dark of the Moon (2011), Age of Extinction (2014) and The Last Knight (2017) were directed by Michael Bay. Bumblebee (2018) was directed by Travis Knight. The Transformers film series has received negative to mixed reception. It is the 13th-highest-grossing film series to-date, with a total of US$4.3 billion; two films in the series have individually grossed over US$1 billion.

Upgrade dir. by Leigh Whannell (OTL Releasing BH Tilt 2018)

Directed by Leigh Whannell. Produced by Jason Blum, Kylie Du Fresne, Brian Kavanaugh-Jones. Written by Leigh Whannell. Starring Logan Marshall-Green, Betty Gabriel, Harrison Gilbertson. Music by Jed Palmer. Cinematography Stefan Duscio. Edited by Andy Canny. Production company Blumhouse Productions Goalpost Pictures Automatik Entertainment Nervous Tick Film Victoria. Distributed by OTL Releasing BH Tilt.