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Points of Exchange

Spatial Strategies for the Transition Towards Sustainable Urban Mobilities

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Industrial PhD Thesis by
Robert Joseph Martin

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0 Preface

0.1 Acknowledgements

This PhD thesis is the culmination of a three-year Industrial PhD research project with JAJA Architects and the research group Planning for Urban Sustainability (PLUS) at the Department of Planning, Aalborg University (AAU). As an architect stumbling his way through the complexities of academia, I have relied on the support of a great many people without whom this project would have never been completed. The following is my small attempt to acknowledge their huge contributions.

First and foremost, I would like to thank JAJA Architects for giving me the opportunity to do this research and their generosity in funding this project. The last three years has been an incredible experience, and one that will forever shape my future career. In particular, I would like to thank my principal company supervisor and JAJA founding partner, Jakob Steen Christensen. His vision and always-questioning nature conceived the initial idea for this PhD, and he has consistently challenged my position on it, and ultimately pushed the research in novel directions. I am also hugely grateful to JAJA's two other founding partners, Jan Tanaka and Kathrin Susanna Gimmel, for their trust and encouragement throughout this very foreign journey of academic enquiry.

Of equal importance is the contribution of my main academic supervisor, Malene Freudendal-Pedersen. Thank you for introducing me to the world of academia while reassuring me to stay true to my epistemological foundations and training as an architect. Your knowledge, support, and straight-talking have brought me to this position today. I would also like to thank my third-party supervisor, Boris Brorman Jensen, for his eagerness to engage with the project and for providing vital guidance at key moments throughout the process. I would like to pay special gratitude to the Head of the Department of Planning at AAU, Morten Elle, for his assistance in navigating the challenges of university administration as an Industrial PhD candidate. I must also mention Katrine Lotz, the Head of the Institute of Architecture, Urbanism, and Landscape at the Royal Danish Academy who helped JAJA navigate the

0.2 Abstract (English)

The future of sustainable urban mobilities is a topic that is of increasing interest to researchers, politicians, planners, and the public around the world. Dominant discussions focus on what these future urban mobilities will constitute and whether they will achieve targets to successfully de-carbonise and to minimise the effects of climate change. Historically, transportation in our societies has mainly been approached from a positivist worldview that has attempted to understand the future through predictive models based on historical trends and relational extrapolation. However, the ambiguity created by the emergence of new transport innovations, such as self-driving cars, micromobility, battery-electric vehicles, and digital services, has created a high level of uncertainty about the future. These innovations are constantly changing in their adoption timelines, and doubts persist about whether they will replace or be adopted by existing transport regimes. Consequently, this confusion creates difficulty for planners and policymakers, as the tools that modern societies rely on to plan, such as forecasting and simulation, are dependent on a degree of certainty to qualify their projections. As the degree of uncertainty increases, the extent and accuracy of these tools to anticipate and plan for the future decreases. Therefore, in view of this ambiguity about the future of urban transport, planners require new methods of enquiry and knowledge production.

This Industrial PhD thesis takes this challenge as a starting point to discuss how I, as an architect, may contribute to the sustainable urban mobilities agenda. First, the thesis rejects the dominance of positivistic transport-planning approaches within the urban mobility discourse. Second, it explores how I could deploy architectural modes of enquiry and tools of visualisation to develop novel methods for the development of sustainable mobilities for the future. The main research question is thus *How can an architectural approach to spatial knowledge and methods of visualisation help reconceptualise visions for sustainable mobilities futures?*

To answer this question, I have employed a 'research-through-design' methodological framework that provides

an established epistemology to incorporate architectural spatial knowledge and methods into mobilities research. This methodology is elaborated through a programmatic design research approach that provides a structured framework for knowledge generation and theory building through the development of design experiments that utilise mixed, transdisciplinary methods. The results of these design experiments are presented as four distinct yet interconnected academic articles that form the main body of this Industrial PhD thesis. Although the thesis is presented as a collection of articles, it is intended that the articles form a coherent storyline within the context of the design research.

As an Industrial PhD, this research contributes to both theory and practice. The thesis was motivated by a desire to integrate architectural methods with sustainable urban mobilities and has therefore contributed significantly to the development of theories that reconceptualise space as a critical component enabling transitions to sustainable urban transportation systems. Moreover, as a transdisciplinary project, the work contributes to the development of applied mobilities research by bridging architecture, practice, and social science to create new planning processes through empirical evidence. Primarily, through the application of a research-through-design methodology, this project contributes to practice by formalising techniques for mobilities design within architectural practice.

0.3 Resumé (Dansk)

Bæredygtig mobilitet i fremtidens by er et emne af stigende interesse for forskere, politikere, planlæggere og offentligheden, nationalt såvel som internationalt. Diskussionerne fokuserer primært på hvilken type af mobilitet vi skal have i byen for at opnå en mindre CO_2 udledning og minimere effekterne fra klimaforandringerne. Historisk set er transport i det moderne samfund hovedsageligt blevet planlagt fra et positivistisk udgangspunkt, med det formål at forudse transportbehovet i fremtiden via forudsigelige modeller baseret på historiske tendenser og relationel ekstrapolering. Fremkomsten af innovationer på tranportområdet, såsom selvkørende biler, mikromobilitet, elektriske køretøjer og digitale tjenester har skabt et højt niveau af usikkerhed i forhold til skiftende tidshorisonter for implementering. Samtidig eksisterer der stadig tvivl om hvorvidt disse nye teknologier skal erstatte eller integreres i eksisterende transportløsninger. Det giver udfordringer for planlæggere og beslutningstagere, da værktøjer såsom prognoser og simulering af fremtider, er afhængige af en vis grad af forudsigelighed for at kvalificere fremskrivningerne. Når graden af usikkerhed øges, bliver disse værktøjers omfang og nøjagtighed til at foregribe og planlægge for fremtiden, utilstrækkelige. I lyset af dette er der brug for nye værktøjer og metoder til at kortlægge og skabe viden om fremtidens mobilitet i byer.

Denne ErhvervsPhD-afhandling tager udgangspunkt i denne udfordring og diskuterer hvordan en arkitektfaglighed kan bidrage til en bæredygtige dagsorden for mobilitet i byen. Afhandlingen stiller spørgsmålstegn ved dominansen af positivistiske transportplanlægningsmetoder og udforsker hvordan arkitektoniske undersøgelsesmetoder og visualiseringsværktøjer kan bruges til at udvikle fremtidens mobilitet. Afhandlingens forskningsspørgsmål er: Hvordan kan en arkitektfagligheds rumlige viden og visualiseringsmetoder hjælpe med til at rekonceptualisere visioner for bæredygtige mobilitets fremtider?

For at besvare dette spørgsmål har jeg anvendt den metodologisk ramme 'research-through-design', som er en etableret

epistemologi der kan inkorporere arkitektonisk rumlig viden og metoder i mobilitetsforskningen. Denne metode er uddybet gennem en programmatisk designforskningsmetode, der giver en struktureret ramme for vidensgenerering og teoribygning gennem udvikling af designeksperimenter, der anvender tværfaglige metoder. Resultaterne af disse designeksperimenter præsenteres gennem fire akademiske artikler i en sammenhængende historie inden for rammerne af designforskningen.

Som industriel ph.d. bidrager denne forskning både til teori og praksis. Afhandlingen er motiveret af et ønske om at anvende arkitektoniske metoder til at forstå bæredygtig mobilitet i byen og bidrager til udviklingen af teorier, der gentænker rummet som en kritisk komponent i overgangen til bæredygtige transportsystemer i byen. Desuden bidrager arbejdet til en tværfaglig tilgang hvor praktisk mobilitetsforskning bygger bro til arkitektur, praksis og samfundsvidenskab og skaber nye planlægningsprocesser med et empirisk udgangspunkt.

Chapter 1: Introduction

Figure 1.1:
Point of exchange.
Robert Martin, 2021

1.1　Points of Exchange

The world is filled with speculation on the future of urban mobilities. Technologies that were once considered science fiction have (supposedly) arrived. Driverless cars, personal flying vehicles, and on-demand ride-hailing at the press of a button, controlled and managed by vast digital infrastructure networks, promise effortless and frictionless mobility while also offering solutions to the world's most challenging problems. However, the discussion surrounding these emerging technologies appears to largely remain isolated to the complex environments of the cities in which they are supposedly to be applied. Unlike the ever-expanding dominance of the automobile in the twentieth century, these new technologies will not be implemented and applied universally across the globe. Instead, they will need to be adapted to the existing social and spatial constellations of the built environments in which they are intended to be utilised. Traditionally, governmental land-use and transport-planning authorities have been responsible for the implementation of new transportation systems. However, these institutions face significant challenges. These include confusion surrounding the technological readiness of new mobility technologies, growing concern about the accuracy of modern transport-planning tools, and lack of knowledge of how cities should transition towards new technologies and best utilise them to meet sustainability targets.

This Industrial PhD thesis has emerged as a response to this situation. First, it rejects the dominance of positivistic transport planning approaches within future sustainable mobility discourse. Second, it considers how an architect may reconceptualise sustainable mobility futures through their unique spatial knowledge of scale, form, proportion, experience, atmosphere, context, and materiality (Kürtüncü et al., 2008).

This Industrial PhD project was inspired and conceived by the Danish architecture studio, JAJA architects, who for many years had felt frustrated by their lack of agency to drive the transition towards sustainable urban development. This frustration was rooted in the recognition of the extent to which

road authorities and traffic engineering form the framework of public spaces and urban developments but do not necessarily prioritise their spatial quality. One need only picture traffic arteries splintering urban centres, the expanse of carparks surrounding individual buildings, or the dormant cars lining neighbourhood streets to understand the frustration felt by these architects. However, JAJA saw an opportunity to join the discussion on the future of urban mobility with a position that prioritises spatial and sustainable outcomes. This is based on the belief in an imminent paradigm shift in the way people move around cities that may disrupt traditional approaches and actor constellations within mobility planning and reshape society's understanding of streets as places of dwelling. As a starting point, this Industrial PhD thesis seeks to address the divide between architects, with their interest in spatial, material, and formal qualities, and traffic engineers, who focus particularly on safety, capacity, and flow.

The title of this Industrial PhD thesis, *Points of Exchange*, refers to three emergent themes developed in the thesis. The first is the recognition that there will be no single point at which society exchanges our current unsustainable system of transportation in favour of a new sustainable one. Rather, this process will proceed in incremental steps through multiple developments. Transitions literature posits that these exchanges are slow-moving and non-linear and that they co-evolve through the involvement of a vast array of actors and social groups. Therefore, 'points of exchange' in this sense refers to the multiple time horizons this thesis considers. The second interpretation emphasises that the transition to sustainable urban mobilities will vary significantly according to each cities' urban form and local context. Unlike transport systems built around private automobile use, emerging transportation technologies will be highly context-dependent, reliant on things such as the level of digital infrastructure integration, levels of population density, coverage of public transportation networks, and topography. Furthermore, in this future where a plurality of transport modes exist, places of interchange (or change between modes) – train stations, mobility hubs, carparks or urban streetscapes – become increasingly important in the transition to sustainable mobilities. In this interpretation, 'points of exchange' refers to the many sites in which this thesis investigates future mobilities. The final theme that the title refers to is the various moments throughout this Industrial PhD in which a re-framing of its research agenda has pivoted its focus and ideas. This research project has followed a designer-based methodology to scholarly research that has favoured a transdisciplinary approach over strict schools of

thought by engaging with a variety of theoretical positions and practitioners' experiences. The result is a thesis that has evolved over time, as emerges in the progression of this text.

1.2   Motivation and Aim

This Industrial PhD research project is concerned with creating knowledge of emerging transportation technologies and how they may enable sustainable mobility systems in the development of future cities. With my background as an architect, my primary focus has been to understand the spatial dimensions of sociotechnical transitions to sustainable urban mobilities. This focus on space has derived from my own perception that transportation planning lacks a spatial awareness when planning mobility infrastructures. One need only consider the streets of most cities to see how society treats these public spaces as the domain of automobiles rather than people. Furthermore, there is a growing body of literature suggesting that reliance on positivistic transport planning tools means that planners are ill-equipped for the necessary planning of future mobility projects (e.g. Flyvbjerg et al., 2006). I believe that by including a spatial perspective that prioritises public space and streets as places of living and dwelling instead of only movement, novel methodologies for the planning of future sustainable urban mobilities may arise.

The primary area investigated in this Industrial PhD thesis is the mainland area of the Greater Copenhagen Region. This area presents an interesting case to explore emerging transportation trends, as the modal share in the city differs from that of many other western capitals. While other cities have a majority modal share of private car use, the Greater Copenhagen Region has an almost even split between car and bicycle use. This means that within the region, infrastructures for both sustainable and unsustainable modes of transport exist. However, uncertainty created by the emergence of new transport technologies, their varying timelines of introduction, and whether they will replace or be adopted by existing system actors has created complexity for planners. Municipal and regional planning authorities have traditionally relied on tools such as forecasting to develop frameworks for the future. However, as the degree of uncertainty increases, the extent and accuracy of these tools to anticipate change decreases. The challenge of uncertainty for planners in the Capital Region is no different from that of others: they lack appropriate tools

to plan with emerging transport technologies. While there is an ambition to reduce carbon emissions through cleaner fuels for motor vehicles, intelligent traffic systems, and expanded bicycle infrastructure, these initiatives are only being implemented incrementally and predominantly act to reinforce existing transport systems. There is a fundamental lack of knowledge at the municipal and regional levels of planning in Greater Copenhagen of the possibilities of emerging mobility technologies, and my research seeks to address this gap.

The project's ambition has therefore been to develop a novel approach to the design and planning of future urban mobilities that can be utilised by planning authorities in Copenhagen to create alternative narratives and futures of sustainable mobility systems. My ambition is that this work also contributes to global discourses on sustainable urban development by engaging with the UN's 17 Sustainable Development Goals (SDGs), which have been adopted by the national Danish government, the Copenhagen Municipality, and Aalborg University. As an architect, I am acutely aware of how the built environment, planning, and transport interact with every SDG. The process of global urbanisation is a major consumer of energy and contributor to natural-resource depletion. It displaces communities, creates spatial segregation, exacerbates inequalities, and reinforces unhealthy life practices that lead to non-communicable disease. While unable to address each of the SDGs within the scope of this project, the thesis addresses the following SDGs: 3 – Good Health and Well-being; 7 – Affordable and Clean Energy; 8 – Decent Work and Economic Growth; 9 – Industry, Innovation, and Infrastructure; 11 – Sustainable Cities and Communities; 12 – Responsible Consumption and Production; and 13 – Climate Action. By developing expert knowledge on the future of sustainable urban mobilities early, this project may create further opportunities to mitigate the impact of these challenges on the planet.

1.3 Linking Spatial Thinking with Sustainability Transitions in Transport

To determine how emerging transport technologies may drive the transition towards sustainable urban mobility systems, it is important to first understand what was unsustainable about current mobility practices. Fundamentally, sustainability means that the current generation can meet its needs today without compromising the ability of future generations to meet theirs (World Commission on Environment and Development, 1987, p. 8). Today, there are many ideas about sustainability that arose from environmental conservationism. However, the *Our Common Future* report shows that, even from its earliest conception, sustainability should include social, economic, and environmental considerations (ibid.). Public discourse on sustainability is often tied to discussion of climate change caused by global warming. While the cause of global warming is unverified, it is considered 'extremely likely' to be the result of an increase in greenhouse gas (GHG) concentrations in the atmosphere due to anthropogenic drivers (IPCC, 2018).

1.1 Carbon neutrality does not mean zero emissions, but that CO_2 emissions are reduced to a minimum and any remaining CO_2 emissions are compensated with carbon offset.

In Europe, urban transportation accounts for 25% of GHG emissions (Moradi & Vagnoni, 2018), of which road passenger transport accounts for 58% (European Environment Agency, 2013). The European Union (EU) has committed to the Paris Agreement to reduce GHG emissions by at least 40% by 2030 compared to 1990 and to be carbon neutral[1.1] by 2050 (European Commission, 2018). Despite significant efforts, the transport sector in the EU has been unable to achieve its decarbonising efforts and if current transport trends continue, the sector is expected to contribute 50% of all CO2 emissions in the EU by 2050 (European Environment Agency, 2018). To achieve GHG emissions targets, the EU needs to radically transition its current urban mobility systems to new, low-carbon systems (Dennis & Urry, 2009; F. W. Geels, 2012).

The automobile, powered by an internal combustion engine, is the dominant mode of urban transportation in Europe and represents 84.1% of passenger transport demand (European Environment Agency, 2019). There are a number of works that document how the car became such an integral part of the modern way of life (Davison, 2010; Dennis & Urry, 2009; Kulash, 1996; Norton, 2010). However, it has now become apparent that the original connotations of the car – providing a sense of freedom, luxury, and independence – have faded, leaving a dependence on the car for participation in economic and social society (Goodwin, 1995). This phenomenon has been labelled the 'motor age' (Lyons, 2015), as there has been a correlation between economic growth and passenger transport growth. Moreover, the automobile has become so engrained in society, that it is difficult to envision any system that is fundamentally different (ibid.). A transition to a sustainable urban mobility system is therefore complicated, as it can only be realised through radical structural changes that also stimulate economic development while reducing carbon emissions.

The socio-technical approach to sustainability transitions provides an interdisciplinary framework to understand and respond to the complex socio-technical systems of transport, superseding the positivist epistemological frameworks of neoclassical economists and engineers (F. W. Geels, 2012). It conceptualises transport systems as a constellation of elements that includes technology, policy, markets, consumer practices, infrastructure, spatial structures, and cultural meaning (2012, p. 471), which has influenced how mobility transitions may be imagined and described in future scenarios (Sheller & Urry, 2016). The Multi-Level Perspective (MLP) is a framework within socio-technical transition theory that describes transitions as 'non-linear processes that result from the interplay of multiple developments at three analytical levels' (F. W. Geels, 2012, p. 472), which apply to various constellations of increasingly hierarchical stability. The three analytical levels are:

- Socio-technical landscapes, which form the context that influences both niche and regime dynamics. They are, in a literal sense, something that can be moved through as well as including urban layouts, political ideologies, societal values, and macroeconomics

- Socio-technical regimes, which are existing technologies, regulations, and user patterns that form established practices and associated rules

- Niches, which are radical innovations that deviate from existing regimes and are either incorporated into an existing regime or replace it

The motor age, described by Lyons (2015), can be reconceptualised as the automobility regime within the MLP (F. Geels et al., 2008; F. W. Geels et al., 2012) as they both present cars as a dominant socio-technical system that is reinforced and reproduced by various actor groups. There is a temporal dynamic between the different analytical levels, as the MLP analyses and describes multiple processes that may affect transitions rather than simple causality. Transitions can arise through the dynamic relationship between these levels: a niche innovation creates internal momentum or changes at the landscape level place pressure on regimes and form windows of opportunity for niche innovation (F. W. Geels, 2012, p. 473). Emerging transport technologies can be re-conceptualised as niche innovations within the MLP framework. There are a number of emerging niche innovations that may aid the transition to sustainable mobility systems. They hold potential for transition change not only because they offer alternative transport choices, but also because they can unlock material preconditions in the built environment (Dennis & Urry, 2009).

To engage spatial thinking within transition theory, I utilise an understanding of space as a social construct. This perspective has its origins in the theories of Lefebvre, from the 1970s, which argued for a contextual spatial understanding that studied space in relation to economic, political, and social processes (Cresswell, 2013). According to Lefebvre, 'every society – and hence every mode of production with its sub-variants (...) – produces a space, its own space' (Lefebvre, 1991, p. 31). To better describe space, and its role in society, Lefebvre identified a triad of interconnected spatial concepts: physical space, mental space, and social space (1991, p. 33). Physical space, or perceived space, refers to physical form, or spaces that are measurable and mappable. Mental space, or conceived space, arises from thinking and ideas and is represented by drawings produced by architects and planners. Finally, social space, or lived space, is dominated by both physical and mental space but also has the capacity for change through imagination. The production of space, according to Lefebvre, is more than a physical act; it is the interplay between these spatial concepts that are (re)produced through social processes and practices (1991, p. 38).

The 'spatial practice' of a society, which Lefebvre deems is revealed through the deciphering of its space (1991, p. 31), was surely an inspiring concept to the development of the new

mobilities paradigm (Sheller & Urry, 2006). Spatial practice embodies the daily routines of society within the urban reality of routes and networks that constitute places for work, private life, and leisure. This is reflected in Sheller and Urry's mobility cultures that are described as incorporating technologies, practices, infrastructures, networks, and assemblages (ibid). Furthermore, through the implications that Lefebvre demonstrates, it can be argued that (social) space is a (social) product (Lefebvre, 1991, p. 26). In addition, this implies that mobility culture produces its own spaces through different modes of production, providing theoretical arguments that mobility has had (physical) spatial implications in the built environment and so will future mobilities. The interplay between Lefebvre's spatial triad and spatial practice provides a new theoretical lens to understand the power that architects have in the production of space. Throughout this thesis, a Lefebvrean understanding of space is explored that investigates not only the effect of physical space, but also the effect of how it is conceived and represented.

A spatial perspective on sustainability transitions in transportation is investigated through a framework that is based upon the 'research-through-design' methodology. This methodology provides an established epistemology to include architectural spatial knowledge and methods in mobilities research. This methodology is elaborated through a programmatic design research approach which provides a structured framework for knowledge generation and theory building through the development of design experiments that utilise mixed, transdisciplinary methods. To meet the requirements of the Industrial PhD programme, different forms of knowledge are produced through the qualitative analysis of these design experiments, which have been published as four academic journal articles and are collected in the thesis. Furthermore, an exemplar design project is presented to finalise this research project to contextualise the process and respond to the outside world.

RESEARCH
THROUGH DESIGN

SUSTAINABILITY
TRANSITIONS

SPATIAL THINKING

MOBILITIES

EXEMPLAR
DESIGN PROJECT
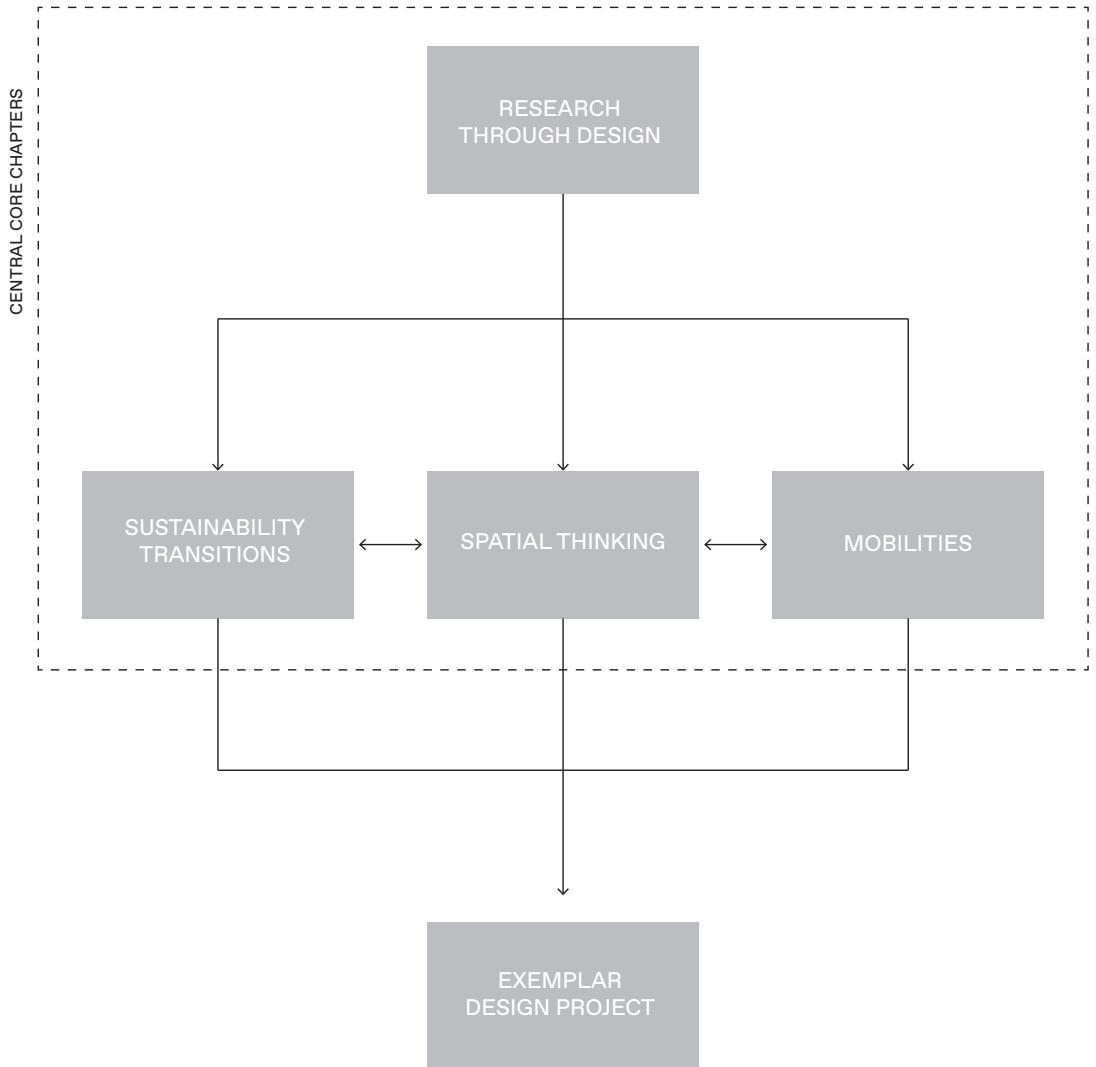
Figure 1.2:
Theoretical framework diagram.
Robert Martin, 2021

1.4   Research Questions

The above motivations and theoretical basis led to the following main research question:

> *How can an architectural approach to spatial knowledge and methods of visualisation help reconceptualise visions for sustainable mobilities futures?*

This main research is supported by the following supplementary research questions:

- *What is the role of emerging transportation technologies in driving a transition to sustainable urban mobility systems?*

- *How can different spatial characteristics of the urban environment drive the transition to sustainable mobility systems?*

- *How do visualisations of future mobility systems affect stakeholder input and planning processes?*

1.5   Overview of the Industrial PhD Thesis

Although this PhD thesis is presented as a collection of published articles, it is intended that the articles form a coherent storyline within the context of the designerly research that I conducted in the past three years. Through a theoretical lens that reconceptualises the spatial dimensions of socio-technical systems, the project attempts to connect future mobility technologies with spatial strategies to develop new competencies within sustainable mobilities design. This project has been driven by a research programme outlining the development of a future sustainable urban mobilities system for Copenhagen, Denmark. Chapter 2, entitled 'A Designerly Approach to Methodology' provides a comprehensive overview of this designerly approach to research enquiry by elaborating on the work of Donald Schön (1983), Michael

Gibbons (1994), and Christopher Frayling (1993) before arriving at the project's outline for the design experiments in the programmatic design research.

In Chapter 3, 'Research Programme: Copenhagen as a Case', a research programme is presented that frames and contextualises this project's scope of work. In more established fields of academic research, this may be seen as the architect's way of establishing a state of the art. Throughout the chapter, I establish an understanding of the spatial and sociotechnical conditions in Copenhagen and their implications for the planning of sustainable urban mobilities. The chapter outlines these conditions in comparison to global transport innovations while providing a basis to understand the connection between the four published articles.

Article 1 (Chapter 4), 'Transformations of European Public Spaces with Autonomous Vehicle' introduces design experiments that highlight possible trajectories for the redesign of public spaces and streetscapes to illustrate connected and automated driving futures in a Copenhagen context. Connected and automated driving is one of several emerging mobility trends that will fundamentally impact the use and design of public spaces in the coming decades. To ensure that public spaces remain a common spatial infrastructure, urban planners need to rethink whose interests they place at the centre of future streetscapes and public spaces and which transport modes are given priority. This article investigates how design experiments can provide a vital tool in support of coordinated planning, decision-making, and the development of future sustainable urban mobility systems.

In Article 2 (Chapter 5), 'AV Futures or Futures with AVs', the visualisations of future mobility systems produced in Article 1 are analysed against examples from an established car manufacturer using a framework incorporating automobility (Urry, 2005), transitions (F. W. Geels, 2012), and imaginaries[1.2] (Jasanoff, 2015). This article argues for a more complex approach to such visualisations, in which they are understood as vessels for sociotechnical imaginaries that direct and de-limit what is possible in the future. This article is a methodological exploration of how policymakers, planners, and the general public can begin to interpret visualisations of future mobility systems. The article concludes with a discussion of the potential implications of these visualisations for future transportation systems.

While Article 1 questioned the spatial demands of emerging technologies, Article 3 (Chapter 6), 'Reconceptualising Space

1.2 The term 'imaginaries' is used throughout this thesis as "collectively imagined forms of values, institutions, and symbols through which people imagine social life and order." This term is elaborated in Chapter 5.

in Sustainability Transitions', asks the opposite: what spatial features do cities have and which technologies fit best? A theoretical basis that links theories on transitions (F. W. Geels, 2012) with spatial thinking is applied to three case studies of European cities' efforts to limit automobile-based transport within 'car-free' discourses. This article presents a case for the role of the built environment in influencing the transition to sustainable urban transportation systems. It also offers a roadmap of spatial criteria for planners and policymakers who wish to limit car use.

The final article (Chapter 7), 'Ontological Expansion Through the Visualisation of Space', presents an exploration of how architects can contribute to the planning of sustainable urban mobilities through their own design methods and outlook. This article presents the insights from two visioning workshops, in which findings from the first three articles were used as a basis for the co-development of a vision for a car-free Copenhagen. Central to these workshops was that this vision was expressed through images and drawings. These glimpses of the future became artefacts for the workshop participants to elaborate on new and existing policies for future sustainable urban mobilities.

The final three chapters are presented as a closure to this Industrial PhD thesis. In Chapter 8, 'Copenhagen Car-free(dom)', the primary empirical output of this PhD project is showcased. Throughout the PhD project, a future scenario for a sustainable urban mobilities system in Copenhagen, Denmark, is designed and developed. In this chapter, the work is presented in its final iteration as a series of drawings, illustrations, diagrams, and visualisations. Its presentation may seem foreign in the context of a PhD thesis. However, as an architect, with an architectural studio as an industrial partner, I believe that it is within the tradition of our profession and supports our attempt to engage with the outside world. Chapter 9, 'Conclusions', in contrast, finalises this thesis within an academic tradition by reflecting on how this work has addressed the overall and subsequent research questions and its contribution to theory and practice. In the 'Afterword' (Chapter 10), I leave with a final remark on the impact of this thesis.

01. INTRODUCTION
In the midst of the current crisis in urban mobility, how can an architect's spatial knowledge and methods of visualisation help reconceptualise visions for sustainable mobilities futures?

02. A DESIGNERLY APPROACH TO METHODOLOGY

03. RESEARCH PROGRAM: COPENHAGEN AS A CASE

CENTRAL CORE CHAPTERS

04. TRANSFORMATION OF EUORPEAN PUBLIC SPACES WITH AVS
Through a series of design investigations on autonomous vehicles, this chapter investigates how can design experiments aid coordinated planning efforts for planners and policymakers in the development of future sustainable urban mobility systems?

05. AV FUTURES OR FUTURES WITH AVS
Through an analysis of visual material produced in the previous chapter, this study explores the power of images of the future to guide the planning of sustainable urban mobilities.

06. RECONCEPTUALISING SPACE IN SUSTAINABILITY TRANSITIONS
Through a reconceptualisation of physical space in sustainability transitions, this article uses empirical case studies of 'car-free' cities to showcase spatial strategies for sustainable urban mobility systems.

07. ONTOLOGICAL EXPANSION THROUGH VISUALISATIONS OF SPACE
This chapter unfolds the potential for architectural design methods to bring together stakeholder collaboration in transport planning through empirical data based on two visioning workshops.

08. COPENHAGEN CAR-FREE(DOM)

09. CONCLUSIONS

10. AFTERWORD

Figure 1.3:
PhD Chapter structure diagram.
Robert Martin, 2021

1.6 References

Cresswell, T. (2013). Geographic Thought: A Critical Introduction. Wiley-Blackwell.

Davison, G. (2010). Car Wars: How the Car Won Our Hearts and Conquered Our Cities. Labour History. https://doi.org/10.2307/27516254

Dennis, K., & Urry, J. (2009). After the Car (1. ed.). Polity Press.

European Commission. (2018). A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_en.pdf

European Environment Agency. (2013). A closer look at urban transport. TERM 2013: transport indicators tracking progress towards environmental targets in Europe (Issue 11). https://doi.org/10.2800/94848

European Environment Agency. (2018). Progress of EU transport sector towards its environment and climate objectives. https://www.eea.europa.eu/publications/progress-of-eu-transport-sector-1

European Environment Agency. (2019). Passenger transport modal split. https://www.eea.europa.eu/data-and-maps/daviz/passenger-transport-modal-split-9#tab-googlechartid_chart_51_filters=%7B%22row-Filters%22%3A%7B%7D%3B%22column-Filters%22%3A%7B%22pre_config_transport%22%3A%5B%22Bus%22%3B%22Car%22%3B%22Rail%22%5D%3B%22pre_confi

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2006). Inaccuracy in traffic forecasts. Transport Reviews, 26(1), 1–24. https://doi.org/10.1080/01441640500124779

Frayling, C. (1993). Research in Art and Design. Royal College of Art Research Papers, 1(1), 1–5.

Geels, F., Hekkert, M. P., & Jacobsson, S. (2008). The dynamics of sustainable innovation journeys. Technology Analysis & Strategic Management, 20(5), 521–536. https://doi.org/10.1080/09537320802292982

Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. Journal of Transport Geography, 24, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021

Geels, F. W., Kemp, R., Dudley, G., & Lyons, G. (2012). Automobility in transition? : a socio-technical analysis of sustainable transport (F. W. Geels, R. Kemp, G. Dudley, & G. Lyons (eds.)). Routledge.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. In College & Research Libraries. SAGE Publications. https://doi.org/10.5860/crl_56_06_558

Goodwin, P. (1995). Car Dependence. Transport Policy. https://doi.org/10.1016/0967-070X(95)96744-6

IPCC. (2018). Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change,. https://doi.org/10.1038/291285a0

Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power (p. 341). University of Chicago.

Kulash, W. (1996). The third motor age. Places, 10(2), 42–49.

Kürtüncü, B., Köknar, S. A., & Dursun, P. (2008). Decoding Spatial Knowledge and Spatial Experience. Design Train Congress, 2.

Lefebvre, H. (1991). The Production of Space (D. Nicholson-Smith (ed.)). Blackwell.

Lyons, G. (2015). Transport's digital age transition. Journal of Transport and Land Use, 8(2), 1–19. http://www.jstor.org/stable/26202710

Moradi, A., & Vagnoni, E. (2018). A multi-level perspective analysis of urban mobility system dynamics: What are the future transition pathways? Technological Forecasting and Social Change, 126(December 2016), 231–243. https://doi.org/10.1016/j.techfore.2017.09.002

Norton, P. D. (2010). Fighting Traffic: The Dawn of the Motor Age in the American City. The Journal of American History. https://doi.org/10.2307/27694848

Schön, D. A. (1983). The Reflective Practitioner. Basic Books Inc. https://doi.org/10.4324/9780203963371

Sheller, M., & Urry, J. (2006). The new mobilities paradigm. Environment and Planning A, 38(2), 207–226. https://doi.org/10.1068/a37268

Sheller, M., & Urry, J. (2016). Mobilizing the new mobilities paradigm. Applied Mobilities, 1(1), 10–25. https://doi.org/10.1080/23800127.2016.1151216

Urry, J. (2005). The "System" of Automobility. In Automobilities (pp. 25–40). SAGE Publications.

World Commission on Environment and Development. (1987). Our Common Future. https://doi.org/10.1080/07488008808408783

Chapter 2:

A Designerly Approach to Methodology

2.1 Introduction

This chapter describes the methodology used to frame the 'Points of Exchange' PhD project. Initially, I discuss the gap between scholarly research and architectural design practice. Donald Schön's work on 'reflection in action' is used as a framework to make tacit knowledge explicit through the interaction between a designer's ways of knowing and reflective analysis. A distinction is then made between the various forms of knowledge required in the unique position of an Industrial PhD researcher who must navigate the space between different forms of knowledge. Through an exploration of Christopher Frayling's categorisation of practice-based research and the subsequent work of Scandinavian design scholars, a definition of a research-through-design methodology is formed. Subsequently, a programmatic design research approach is utilised to provide a structured framework for knowledge generation and theory building through the dialectic relationship between a research programme and design experiments. The chapter concludes with a description of the research methods used in the PhD project.

2.2 Epistemological Foundation

At the beginning of my journey as a PhD student within the Industrial PhD Programme, I had no clear foundation; I had no exposure to research methods during my experience as a bachelor or graduate student in architecture. Architecture occupies a murky space in the university sector, as it is not considered entirely an artistic, technological, or scientific practice, but lies somewhere in between. As an architecture student, I learnt that to produce architecture, I must literally and metaphorically project a vision into the world. To arrive at that vision, I was taught not to copy, but to borrow, splice, collage, and reference across disciplines with almost complete freedom. This mode of working is grafted onto an engagement with theory, data, and public discourses and with professional life. The challenge of navigating this transdisciplinary landscape can become problematic within an academic environment, which requires rigorous scholarly requirements to be awarded a PhD. This illuminates the anxiety I felt within the academic community about the legitimacy of the knowledge I produce as an architect.

When discussing the production of knowledge, my experience is that there exists an underlying feeling of insecurity in the field of architecture when talking about knowledge production: a gap remains between the practices of architectural design and engagement in academia. Depending on worldview, the validity of scientific knowledge depends on explicit results that are easily replicated by peers. Architecture, however, produces a great deal of implicit knowledge that is internalised and embodied rather than understood and remembered intellectually (Pallasmaa, 2017). While this knowledge is vital to the practice of design, it is difficult to disseminate and validate because of its tacit nature. With this observation in mind, I now discuss the work of academics who have investigated and classified new epistemologies that incorporate design practice over the last 40 years.

In his book, *The Reflective Practitioner* (1983), the philosopher and urban planner, Donald Schön reinforces practitioners' tacit knowledge through what he labels 'knowing-in-action'.

In a later text, Schön describes knowing-in-action using the example 'if you are riding a bicycle, and you begin to fall to the left' (1990, p. 25). He states that people who know how to ride a bicycle do the right thing *in situ* and adjust their balance, but they would not be able to correctly articulate that response if asked to describe it in a classroom, outside of a bicycle-riding situation. According to Schön, this type of tacit knowledge is represented in that 'practitioners usually know more than they can say' (1983, p. 8). How does one extract this knowledge in a format that can be disseminated within a PhD thesis? Schön suggests that it can occur through a process called 'reflection-in-action'. Reflection-in-action is the epistemological evolution of knowing-in-action. By becoming aware of what they are doing, designers can uncover their tacit knowledge, making the implicit explicit. This internal dialogue creates knowledge through the analysis of the protocol. For instance, instead of problem *solving*, the designer aims for problem *framing*: each design decision becomes a local experiment that contributes to the re-framing of the problem. Designers, therefore, frame and re-frame the problem throughout a design process. Schön emphasises the importance of this process, in which designers 'name the things to which we will attend and frame the context in which we will attend to them' (1983, p. 40). A reflective practitioner, he claims, can become 'a researcher' through architectural practice, as the process is at once exploratory, problem-framing, and hypothesis-testing.

The architectural theorist Ranulph Glanville builds on the idea of Schön's reflective practitioner by making a distinction between researchers, who search for *knowledge of* existing phenomena, and designers, who seek *knowledge for* changing a phenomenon (Glanville, 2016). He makes the case that although there has been academic research in architecture for some time, such as historical research or research into building materials, this alone cannot aid architects in the medium of design practice. Glanville deplores the fact that 'science' has become a word used to mean knowledge within academic circles. In the domain of architectural research, a broader understanding of knowledge is needed to help architects and designers perform their work. According to Nigel Cross (2006), this form of knowledge is unique to how designers think and work. He refers to this phenomenon as designerly ways of knowing. Some may refer to this form of knowing as intuition, which is shared among practitioners and researchers. However, I believe that due to varying epistemological foundations, there are different levels of acceptance between architects, who freely utilise it, and researchers who must review and verify it.

From this perspective, design research can be viewed as generative and critical as well as a means of creating knowledge. In areas that are new and yet to be explored, such as the future of mobility, qualitative approaches have the potential to answer and explain, rather than test hypotheses and make cause-and-effect predictions. These are key features of positivist paradigms in the dominant transport planning schools of thought. I have already outlined this PhD's opposition to this dominant positivist and empiricist position in Chapter 1. Having presented a fundamental argument in support of design research, I now analyse in more detail the kinds of knowledge that can be derived from the combination of research and design in the context of this industrial PhD.

2.2.1   Forms of Knowledge

To be awarded a PhD, one must contribute substantially to 'knowledge' in a scientific field. As an Industrial PhD researcher, there are two main differences between my programme and a traditional PhD. The first, is that I am employed by a host company (JAJA architects) and am therefore contractually obliged to deliver 'knowledge' that must 'have direct or indirect short- or long-term commercial significance and effect' (Innovation Fund Denmark, 2021, p. 2). Second, I do not have any teaching obligations and must instead disseminate 'knowledge' within the host company, the wider business community, and to non-academic audiences (Innovation Fund Denmark, 2021, p. 12). This double life of the Industrial PhD researcher has made balancing the knowledge objectives of academia and business one of the main challenges of this PhD thesis. Only through a dialectical process of knowledge production (Nielsen et al., 2017) have I been able to bridge the different communities of practice.

In his 1994 book *The New Production of Knowledge*, Michael Gibbons and his co-authors developed a new taxonomy for describing types of knowledge, referring to them as 'Mode 1 scientific discovery' and 'Mode 2 knowledge production' (1994). Mode 1 refers to 'the complex of ideas, methods, values and norms that has grown up to control the diffusion of the Newtonian model of science to more and more fields of enquiry and ensure its compliance with what is considered sound scientific practice' (Gibbons et al., 1994, p. 2). Mode 2, in contrast, is 'knowledge production conducted in the context of application and marked by its transdisciplinary, heterogeneity, organisational hierarchy and transience; social accountability and reflexivity' (Gibbons et al., 1994, p. 2).

In simpler terms, Mode 1 refers to a conventional model of university knowledge production applied in positivist paradigms, while Mode 2 is knowledge generated within the context of its application and disseminated socially. In 2003, Gibbons, Nowotny, and Scott (2003) revisited the discussion in response to a vast amount of criticism of the simplicity of the distinction:

> *Of course, like all theses that gain a certain popularity (and notoriety), this thesis was radically simplified, and collapsed into a single phrase – 'Mode 2'. The old paradigm of scientific discovery ('Mode 1') – characterised by the hegemony of theoretical or, at any rate, experimental science; by an internally-driven taxonomy of disciplines; and by the autonomy of scientists and their host institutions, the universities – was being superseded by a new paradigm of knowledge production ('Mode 2'), which was socially distributed, application-oriented, trans-disciplinary, and subject to multiple accountabilities. (2003, p. 179)*

This is an ongoing discussion within the production of knowledge. I do not intend to pursue it further here but present it as a reflection of how an Industrial PhD researcher often occupies the space between these two modes, bouncing between practitioner-orientated knowledge and scientific literature. Even if the department the PhD student works in has a strong tradition of mode 2 knowledge, academic publishing (which is a requirement to be awarded the PhD) is perceived as less relevant by the host company. They are more interested in applied insights they can use in their everyday practice.

One of the more significant aspects of the methodology for this PhD involves the use of the research-through-design method, through which it is possible to produce both Mode 1 and Mode 2 knowledge. It has allowed me to conduct design work that is seen as valuable to the host company, within a reflexive framework that permits time for analysis, scholarship, and knowledge production from the design output. To satisfy the dissemination criteria, knowledge produced in this Industrial PhD project has been distributed through this thesis, peer-reviewed academic journals, book chapters, private and public lectures, interviews, workshops, and media contributions. In the following section, I outline the methodological considerations for this PhD thesis.

2.3 Research x Design

The following section navigates the variety of research forms within creative practice, eventually arriving at this PhD project's initiation within a research-though-design framework. The development of academic research methodologies incorporating design practices has been occurring over the last two decades, most frequently within the context of architecture and design. Research design is an established aspect of scientific enquiry, which directs the procedures of study through the intersection of philosophy, scope, and methods (Creswell, 2014). However, design research encompasses both the study of design and the process of generating knowledge through it (Roggema, 2016). The design research paradigm originates in an influential paper written by Christopher Frayling, 'Research in Art and Design' (1993). He first introduced the term as a way to integrate research into creative practice and show how it differs from traditional scientific methods of enquiry. In the paper, Frayling proposes three ways of categorising research within the fields of art and design: research *into* art and design, research *through* art and design, and research *for* art and design (1993).

For Frayling, research *into* art and design is the most straightforward and easy category. This research is conducted on a subject, such as history, aesthetics, or theory, to understand what has been done. Here, the researcher observes the subject being investigated from an outside position. Frayling believes that this is the most straightforward category because the empirical evidence already exists before the research is conducted in countless archives. Research *through* art and design is less straightforward as a category but still tangible, as it involves conducting experiments to produce new empirical evidence. The production of empirical data in the design process is used to contextualise the results. The final category, research *for* art and design is considered the most difficult to conduct. In this area of study, the aim is to conduct research 'where the end product is an artefact – where the thinking is, so to speak, *embodied in the artefact*, where the goal is not primarily communicable knowledge in the sense of verbal communication, but in the sense of visual or iconic or imagistic communication' (1993, p. 5). The process of research *for* art and design could also be seen as traditional artistic practice, in which the artefact is the intended outcome of the research.

The differences between these categories may seem minute, but I believe that it is important to clarify that even from its earliest conceptions, the combination of research and design has been utilised in different formats. To the outsider, the substitution of the words *into*, *through*, and *for* may appear inconsequential. However, as shown by Frayling, their interchange can have epistemological consequences and major implications for the application of art and design to research. I make this point to emphasise my specific approach to the combination of these two fields.

One of the major components of my doctoral research has been the use of a research-through-design methodology. This methodology takes Frayling's category of 'research *through* art and design' as a basis but has been further developed by design scholars over the past twenty years. Research-through-design entails designing artefacts iteratively over time to investigate different possibilities of the future (Zimmerman et al., 2010). An artefact need not be physical, but can be a product, system, space, or medium. However, this methodology calls for constant realignment of the creation of artefacts in response to complex design challenges, based on trial and error (Toeters et al., 2012). Importantly, research-through-design allows for 'designerly ways of knowing' to emerge during the course of the project, which is essential for generating the required knowledge in various forms. Within the context of the 'Points of Exchange' PhD project, artefacts emerge as drawings, maps, illustrations, and diagrams as part of the development of a scenario for a sustainable urban mobilities system for Copenhagen, Denmark.

2.3.1 Programs and Experiments

An emerging group of Scandinavian researchers has placed design experiments at the core of research-through-design (Bang & Eriksen, 2014; Binder & Brandt, 2017; Brandt et al., 2011). This has been further elaborated as a programmatic design research approach, in which design experiments are performed in the context of a framework: a research programme (Redström, 2017). The group acknowledges that within the design research community, design experiments, such as prototypes, mock-ups, scenarios, and models, play a central role in the generation of knowledge in practice-based research. Furthermore, to this group of researchers, design experiments are not considered tests in a scientific sense, to

confirm a hypothesis, but as the developing of the research to challenge the research programme (Brandt et al., 2011).

The programmatic design research approach provides a framework to structure empirical research as design experiments in relation to the research objective. According to Redström (2017), the approach is structured around two core elements:

- A programme that establishes a knowledge regime to frame and contextualise the research project.

- A number of design experiments that challenge and re-frame the programme.

In this approach, the programme and design experiments are connected: they have a dialectic relationship, where knowledge is generated from their interconnection (Brandt et al., 2011). Thus, the programme serves as a framework and a foundation within which a design researcher can investigate a particular research topic through design experiments. As the design experiments are conducted, they act as an opportunity to re-frame the programme.

A design research programme outline establishes the basic conditions and limitations for the scope of the research. In more established fields of academic research, the programme may be seen as the architect's way of establishing a state of the art. The programme should set the scene for the research project because 'a program that allows anything to happen will not work' (Redström, 2017, p. 88). In many ways, they may be seen as a typical design brief in architectural education and practice with more space for open experimentation and drifting. Brandt and her colleagues view the development of the programme as establishing a situated 'provisional knowledge regime' (2011, p. 19). This makes the design experiments more than 'undirected explorations' while at the same time allowing for new insights and knowledge production from the experiments (2011, p. 22). In the context of this PhD project, the programme takes the form of a case study of the greater region of Copenhagen, Denmark, and a literature review of emerging transportation technologies. The programme is described in Chapter 3.

At the core of the programmatic design research are design experiments because they serve as a source of knowledge generation and theory building (Bang & Eriksen, 2014). This resonates with the research-through-design methodology, as the experiments produce artefacts which are used as

empirical evidence to contextualise the research insights. Brandt and Binder (2017) state that design experiments are a way to explore and challenge the programme. As a result of this, they can appear in many different forms. Therefore, it is important to clarify that design experiments should not be limited to traditional interpretations of design, such as drawing and model-making, but rather also include a designer-based and exploratory approach to existing methods across disciplines. This mode of enquiry can also be understood as pragmatic knowledge production in the tradition of the philosopher John Dewey and further elaborated by others (e.g. Kenneth Howe (1988)). Methodologically and philosophically, this looseness offers the design researcher a plurality of quantitative and qualitative methods, which is not limited to epistemological paradigms, to apply as design experiments within the notion of 'what works' (Howe, 1988)). This notion of epistemological looseness within design experiments supports the exploratory research process in the 'Points of Exchange' PhD project, which includes multiple methods within each design experiment. These methods are further described in sections 2.4.1–2.4.4.

As mentioned earlier, the main epistemological output occurs in the relationships between the research programme and design experiments. The combination of a research programme and design experiments can create knowledge that neither could achieve independently, according to Redström (2017). Other design researchers have concurred, arguing that design experiments and research programmes should be as one entity when discussing the production of knowledge (Brandt et al., 2011). This dialectic relationship corresponds to Schön's reflection-in-action, in which each subsequent experiment acts to drift the research programme or mature it or both or to finalise the research process (Bang & Eriksen, 2014). Therefore, it is the combination of the design experiments and research programme that addresses the core research question.

This dialectical process has been captured by Anne Bang (2010) in a diagram illustrating the relationship between the design experiment and the research programme (Figure 2.1). This diagram illustrates how research questions and design experiments ultimately become interconnected as research responds to the outside world (Markussen et al., 2012). Bang's diagram is divided into five different elements: Challenge, Programme (T), Design Experiments (X), Research Questions (Q), and Exemplar, which is the finalised output of the research. In her own words,

'the dotted beginning of the programme line symbolises that the programme itself in the beginning is initial and only vaguely constructed. As the research progresses it is challenged and strengthened due to the dialectics between the programme and the design experiments. This is symbolised in the way the dotted line is transformed into a thick and massive line, which finally point[s] to exemplars as an outcome of a research project like this' (2012, p. 9).*
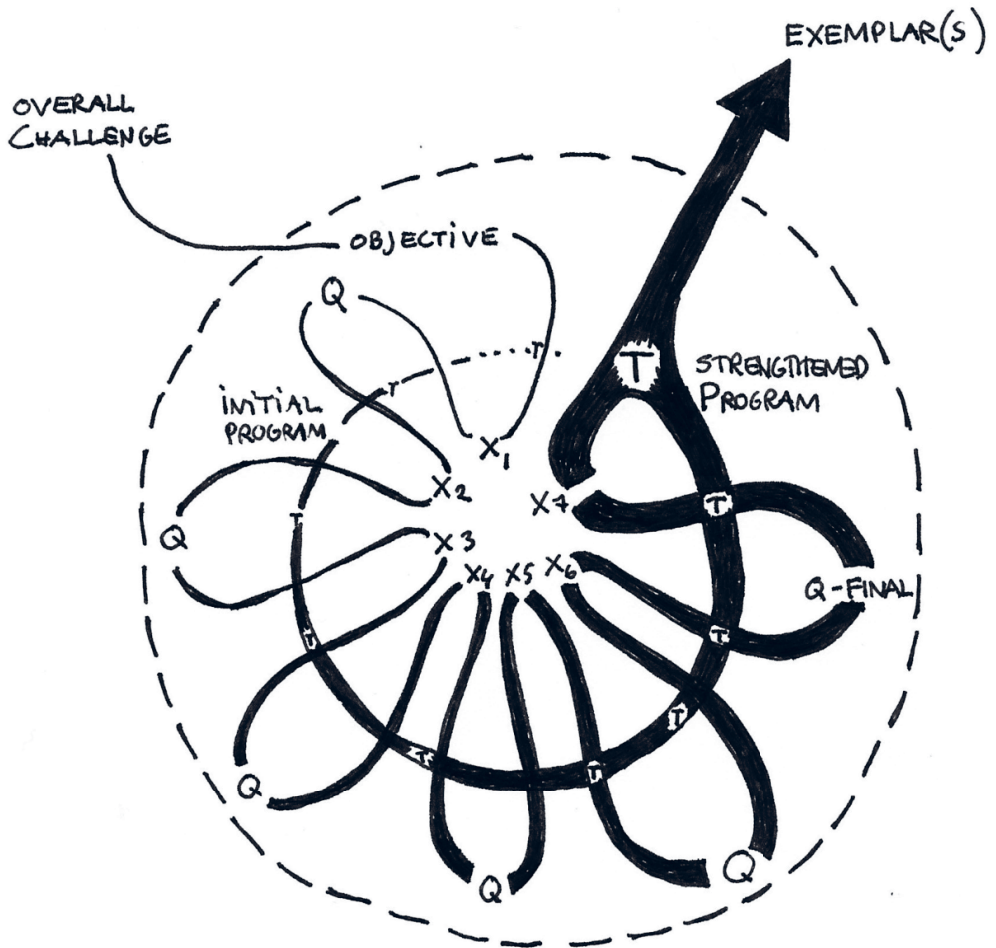
Figure 2.1:
Visualisation of a programmatic approach to design research.
Anne Bang, 2010.

2.4 Programmatic design experiments in Points of Exchange

For my research project, I am utilising a programmatic design research approach to frame the empirical research as design experiments relevant to a larger research problem. Therefore, I have adapted Bang's (2010) diagram to create an overview of my PhD research through a programmatic approach (Figure 2.2). I, too, have five elements: Challenge (C), Research Programme (T), Design Experiments (X), Articles (A), and an Exemplar (E). This framework should help describe and explain the rationale for submitting an article-based PhD thesis.

The The introductory chapter explained the wider context and overall challenge (C) of this PhD project. The programme (P), outlined in chapter 3, responds to the overall challenge (C) by investigating the topic of sustainable urban mobilities in the city of Copenhagen, Denmark. As suggested earlier, some may interpret elements of the programme as state of the art. The design experiments (X) and articles (A) emerged and developed throughout the process of the PhD research. The overall research question and sub-questions are explored through the interaction between the programme, experiments, and wider context. The experiments emerged freely during the research period. Finally, the outcome of the PhD, the design proposal, emerges as an exemplar (E), which acts as the finalisation of the research project.

This framework also makes it possible to distinguish between the production of Mode 1 and Mode 2 knowledge. As an Industrial PhD researcher, it has been critical to clearly define knowledge that can be translated for commercial use and academic knowledge to meet the requirements of the Industrial PhD programme: comprehensible vs comprehensive. This has been achieved through the separation of design experiments and academic articles, where the former create the most value to JAJA and the latter place the empirical

evidence within the theoretical context to contribute to the scientific community. In the following subsections, I describe my selection of methods in each design experiment.

CHALLENGE

EXEMPLAR

T = Programme
X_1 = Design Experiment 1
X_2 = Design Experiment 2
X_3 = Design Experiment 3
X_4 = Design Experiment 4
A_1 = Journal Article 1
A_2 = Journal Article 2
A_3 = Journal Article 3
A_4 = Journal Article 4
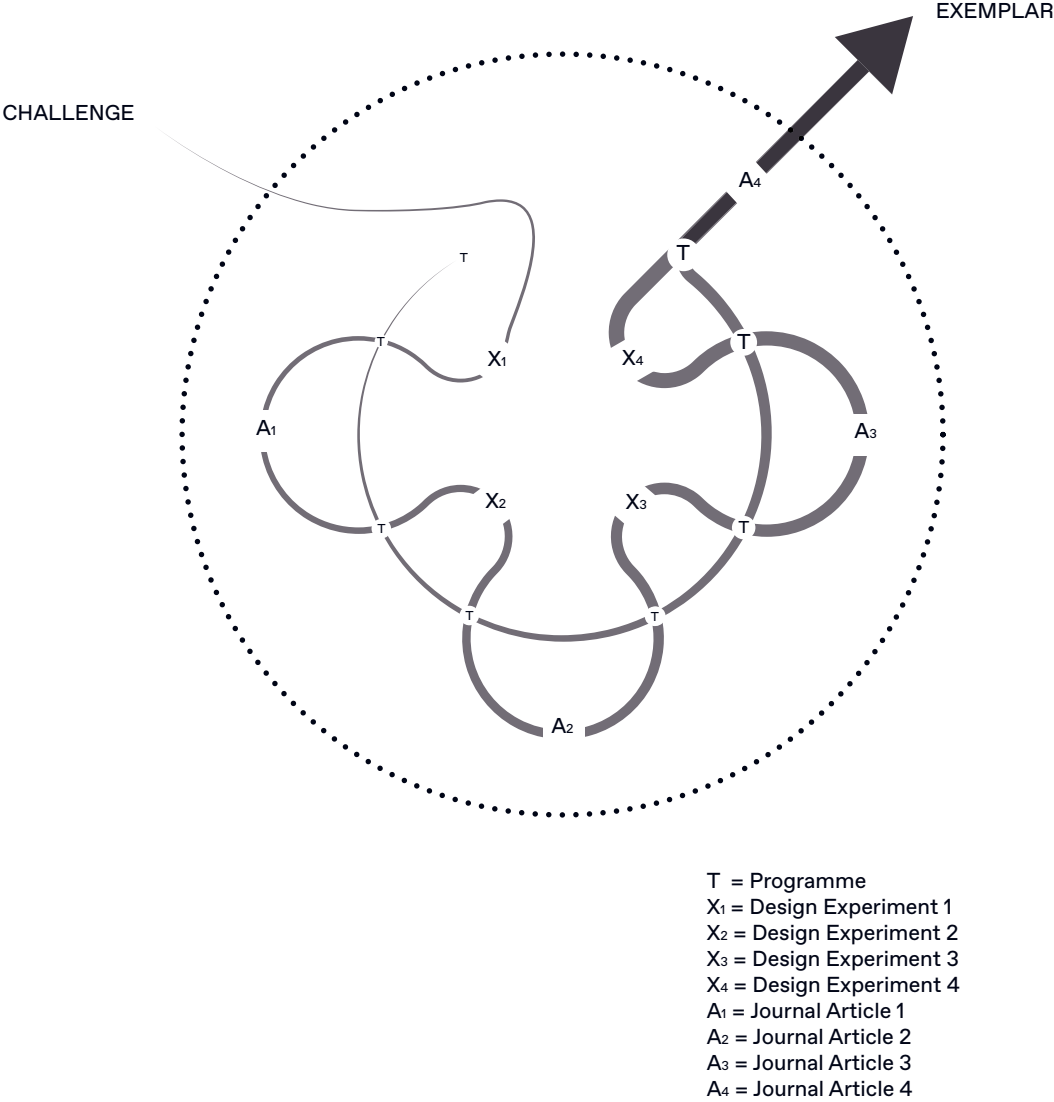
Figure 2.2:
The journey through the PhD has involved the exchange between design experiments and journal articles, which come together to emerge as an exemplar project.
Robert Martin, 2021

2.4.1 Design Experiment 1 (X$_1$)

Design experiment #1 had been initiated prior to starting the PhD while I was still employed by JAJA as an architect but continued into the beginning of the PhD. It is included in this PhD thesis as the experience of conducting the experiment and the insights obtained were crucial in the initial formulation of the research program. While this may seem counter-intuitive to conduct an experiment before the program, Redström (2017) states that design experiments may precede the formulation of the program in order to articulate the overall challenge and objectives for the PhD project. The empirical from this experiment was also used as an outset for developing the scenarios described in Article #1 (Martin et al., 2021).

The experiment attempted to investigate the question *What is the spatial impact of emerging transportation technologies?* It focused on using traditional architectural media and methods to explore the spatial impact of switching to a shared, autonomous vehicle fleet in different urban settings in Copenhagen, Denmark. Through an abductive process (Alvesson & Sköldberg, 2018), the practice of moving between the reading of data and theory, 'designerly ways of knowing', and sketching produced specific representations on screens and paper. By creating these representations, I could see what was practical and what was impractical before then revisiting the design. It is a process that alternates between theory and design, whereby both are successively reinterpreted in the light of the other (ibid). The final output of this experiment was a series of visualisations, maps, diagrams, and drawings illustrating the future scenario.

Before engaging the architectural tools of design, a general literature review (Onwuegbuzie & Frels, 2016) was performed on both academic and grey literature to further refine the objective of the general question. This was a wide and broad review of different literature to better understand the field that I was entering. By studying the results of this review, I discovered the wide field of different transportation technologies, the readiness of their underlying technology, and the many criticisms directed towards them. Furthermore, the analysis highlighted scepticism towards emerging transportation technologies' projected timelines of adoption and integration into existing transportation systems. These last two points were critical, as they introduced me to the scholarly work on the new mobilities paradigm (Sheller, 2014; Sheller & Urry, 2006) and transitions literature (Geels, 2005;

Kemp, 1994). The introduction to this literature re-framed the research to look outside the narrow topics of spatial impact and transport to understand these phenomena through the lenses of sociotechnical systems and the movement of people, objects, and information. The research programme (Chapter 3) summarises this analysis, which is also present throughout the four published articles.

Figure 2.3+2.4:
A visualised street transformation in Copenhagen.
Robert Martin/JAJA, 2018

2.4.2   Design Experiment 2 (X_2)

There was a wide range of responses from different stakeholders (such as the project partners, public transport authorities, industry professionals, and the public) to the visual output of the first design experiment. The second design experiment was therefore conducted to provide an enhanced understanding of the power of images of future mobility systems in planning sustainable mobilities. While some social scientists may approach this through structured interviews about the visual output to produce empirical material as text, as an architect (within a traditional that communicates through images), I chose visual empirical material. This idea is further elaborated within the analytical framework explained in Chapter 5 (Martin, 2021), which describes how images can be viewed as vessels for sociotechnical imaginaries (Jasanoff, 2015) that direct and de-limit what an individual thinks is possible. To find an appropriate method to deconstruct images, I reviewed literature on media studies. Within the literature, I found that visual discourse analysis (Albers, 2013) is an established method to deconstruct meaning in visual material and has already been applied in architectural case studies (Raaphorst et al., 2017).

After committing to this method of enquiry, I decided to set up a comparative analysis between the visualisations produced in the first design experiment and visualisations of autonomous vehicles produced by the German automotive manufacturer, The Daimler Group. Daimler were selected because I was already aware that they were producing visualisations of future mobility systems from attending the launch workshop of the Cooperative, Connected, and Automated Mobility: EU and Australian Innovations (CCAMEU) Network, in which a representative from Daimler presented the company's 'Vision for Autonomous Mobility Services'. To collect visual material from Daimler, I used the search term 'autonomous vehicles' on their Global Media website. The search request returned 445 images results, but only three images were selected because they depicted an autonomous vehicle within a future urban environment. The rest were discarded because they depicted event pictures, renderings of concept designs, safety features, and infographics.

After gathering the material, I analysed each image according to the visual discourse analysis (VDA) method. Both sets of images were analysed systematically using two different frames of reference: social modalities, which use semiology to understand the images' social and political ideologies; and

compositional, which references the formal structures of the image and composition elements (Rose, 2010). A coding scheme was established during this process which resulted in the identification of different versions and ambitions for the future. Chapter 5 (Martin, 2021) describes this coding process and presents the results in more detail. The qualitative coding of the images resulted in an important insight for the development of the research programme. I observed that although images from both sets of visual material presented the same transportation technologies (such as autonomous vehicles, bicycles, and public transport), the composition of the built environment varied greatly. To me, this indicated that there are multiple ambitions for the future of transportation, in which the built environment is as important for sustainable urban mobility systems as the emerging transportation technologies themselves. To investigate this hypothesis, a third design experiment was conceived.

Figure 2.5:
An example of the coding system
applied during visual discourse analysis.
Robert Martin, 2019

2.4.3   Design Experiment 3 (X$_3$)

The third design experiment utilised a multiple case-study method to understand the role of physical space in sustainability transitions. As emerging niche technologies do not yet exist at a scale to enable understanding of how spatial features shape their use, it was important to derive which spatial characteristics exist now that are contributing to sustainable urban mobilities. Reflection on the first two design experiments showed that unsustainable urban mobility systems were supported by urban environments that were designed around car use. Therefore, I decided to investigate cities that were currently in the process of reducing car travel through 'car-free' discourses. To limit the number of cases, the search criteria focused on European cities, as they were deemed most appropriate for deriving insights to be applied to Copenhagen. The cities were selected from the Urban Access Regulations in Europe database (Sadler Consultants, 2020). Five cities were initially chosen from the database because of their diverse geographical locations, climates, cultures, topography, size of car-free areas, and the available documentation in academic and grey literature. The cities were Oslo, Norway; Ghent, Belgium; Milan, Italy; and Barcelona and Madrid, Spain.

The application of the case-study method involved gathering academic and grey literature, municipal plans and policy reports, and news articles to determine how each city was utilising different strategies to reduce car use. Once the data was collected and analysed, the strategies were distilled into a catalogue of mobility strategies to limit car use. Each strategy was abstracted into a pictogram, as shown below (Figure 2.6) These pictograms are further discussed in Chapter 3 (Section 3.4.4). This catalogue was intended as a form of industrial dissemination that JAJA could easily integrate into their design practice.

2.1 OpenStreetMap is an open-source map depository where a community of mappers contribute and maintain data about roads, trails, cafes, railway stations and more.

Once the catalogue was finished, each city's strategy was spatially mapped using geographic information system (GIS) data available through OpenStreetMap[2.1]. As this data was open source, this process should have been supported by fieldwork visits to each city to document how the car-free strategies had been executed, but this plan was cancelled due to COVID-19 safety and travel restrictions. Instead, I had to rely on the accuracy of the open-source data. The spatial information was retrieved using QGIS, a freely available desktop GIS application that supports the viewing and analysis of geospatial data, and the QGIS OpenStreetMap plugin. Each

city was queried through the software using search terms such as 'buildings', 'land use', 'landscape features', 'transport', 'traffic', 'roads', and 'railways' to build a comprehensive spatial map of the elements required to illustrate the car-free strategies.

As a tool for comparing, showcasing, and analysing this spatial data, a series of maps was produced. Mapping is an established medium through which architects communicate knowledge (Simpson et al., 2018), so it was relevant to present the work in this way to engage JAJA and communicate to the academic community. To create each map, the spatial data was exported as a series of PDFs from QGIS before being re-compiled in Adobe's Illustrator software. Once in Illustrator, the maps were developed using consistent colour schemes, adjusted line weights, and legends to make them easily readable. The cities of Oslo, Ghent, and Barcelona were eventually used for the empirical data in Chapter 6, which includes a selection of maps in section 6.4.1-6.4.3.

Figure 2.6:
Four examples of the car-free strategy pictograms.
Robert Martin, 2020

SUPERBLOCKS

TRAFFIC ISLANDS

PEDESTRIANISATION

RULE-BASED ENTRY
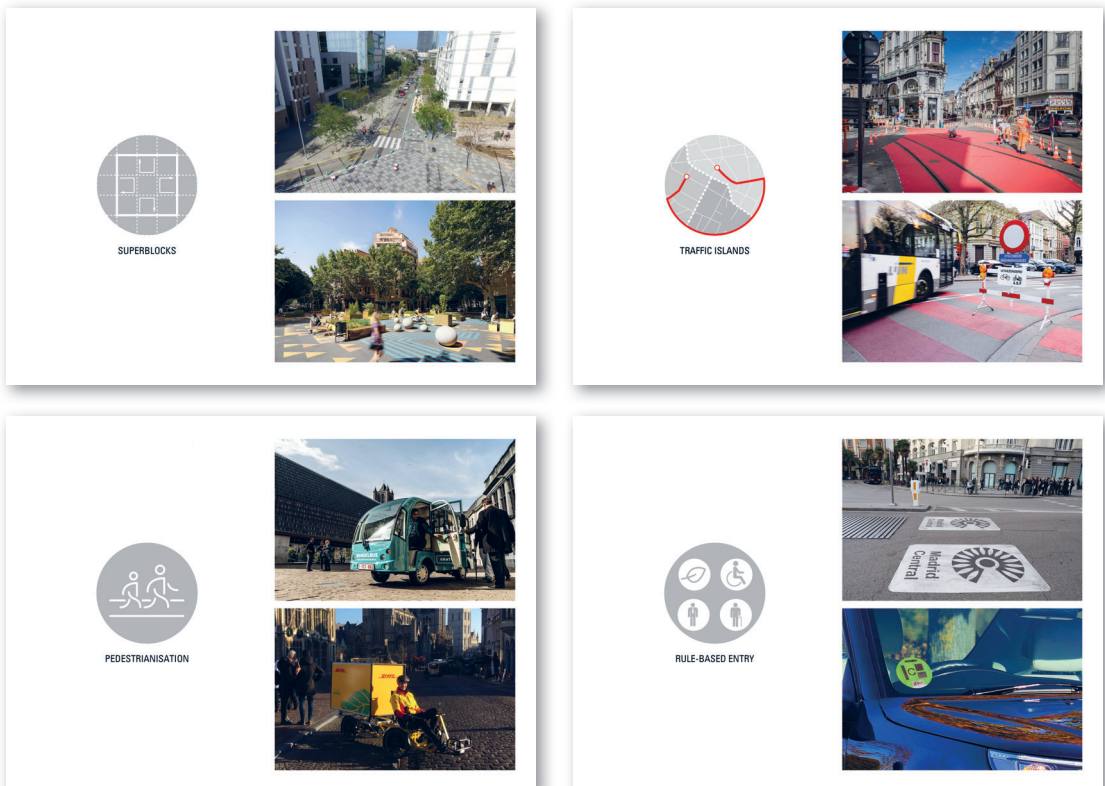
2.4.4   Design Experiment 4 (X$_4$)

The final design experiment is a study that aims to synthesise the analytical research from the first three experiments with architectural design methods to create a scenario for a sustainable urban mobility system in Copenhagen, Denmark. The primary methodological component of this design experiment was two visioning workshops. These workshops are a development of the Future Workshop methodology (Andersen & Jæger, 2001; Jungk & Mullert, 1987) but deviate from this method by co-designing the proposed future with participants using architectural design tools and methods.

Thirty participants from different fields related to transport and urban development in Copenhagen were identified and invited to participate in the two workshops. The participants were identified through desktop research and less traditional means, such as networking at industry events and through LinkedIn. A large proportion of my time as a PhD student was spent trying to engage with transport industry professionals across the public and private sectors as much as possible to develop contacts and relationships for participation in these two workshops. The participants at each workshop were chosen to have a broad range of representative disciplines. Participant backgrounds included politicians, municipal workers, city developers, urban planners, researchers, public and private mobility operators, and representatives from various advocacy groups. Unfortunately, due to COVID-19 restrictions, only twelve participants were able to attend.

Prior to the start of the first workshop was a three-month design sprint to prepare the necessary inspirational material. A defining feature of the workshops was the application of architectural methods to visualise the spatial implications of urban transportation decisions. The visual material included photographs, maps, infographics, diagrams, collages, eye-height visualisations, and drawings, such as plans, sections, and axonometric projections (Figures 2.7 & 2.8). The empirical basis for this design sprint was the analytical research from the first three experiments. The visual materials were collated into stimulus kits that were used to inspire the ideation process and prompt discussion between workshop participants.

Within each workshop, participants were divided into three separate tables to obtain the widest possible spread of disciplinary backgrounds. There was a conscious decision to mix professional backgrounds so that worldview differences could be uncovered in smaller table discussions before being

considered in full workshop discussions. Each workshop was divided into three sessions. Each session included a ten-minute presentation by me to introduce the topic, a 15-minute group exercise, and a 25-minute common discussion. Broad questions were posed to the workshop participants during each group exercise to prompt the participants' ideation. Chapter 7 elaborates more on the details of this method in Section 7.3.

Figure 2.7:
Group discussion using stimulus kit during workshop 1.
Robert Martin, 2020

Figure 2.8:
Group discussion using stimulus kit during workshop 2.
Robert Martin, 2020

2.4.5 Introducing the Four Articles

Four academic articles form the main body of this PhD thesis. Whereas the previous section described the methods applied in each of the design experiments, this section describes how the four articles connect and contribute to the shaping of this thesis. In the following figure, I visualise how the four articles link different bodies of literature to study sustainable urban mobilities and then outline how each article builds on the previous article to form the thesis.

The four articles connect as the findings from one article re-frame the research programme and contribute to the motivation behind the next design experiment. This is subsequently used as empirical evidence for the next article (Figure 2.9).

Article 1 (A1) took the findings and insights from Experiment 1 as a basis to investigate how this design experiment may support the coordinated planning efforts of planners and policymakers in the development of future sustainable urban mobility systems. Article 2 (A2) builds on these insights by analysing the images produced to understand the power of images of the future in guiding the planning of sustainable urban mobilities. The findings showed that the way in which space was constructed in each image was far more powerful than the depiction of emerging transport technologies. Ultimately, these findings shifted the programme's focus away from emerging technologies, such as autonomous vehicles, to understanding how space informs sustainable transport.

To enhance the relevance of A2's insights, Article 3 (A3) became a manifesto for the PhD thesis. By considering empirical spatial strategies from different European cities, the article argued for a re-consideration of the value of space when discussing sustainable urban mobilities as a way for architects to engage with discussions on transportation transitions. To put this manifesto into practice, Article 4 (A4) was a reflection on the process of visioning in the two workshops in Experiment 3. Ultimately, this article made the case for the architect's involvement in the planning of future urban mobility systems. It explained theoretically the potential for architectural design methods to create stakeholder collaboration and new methods for transport planning through a process of ontological expansion.
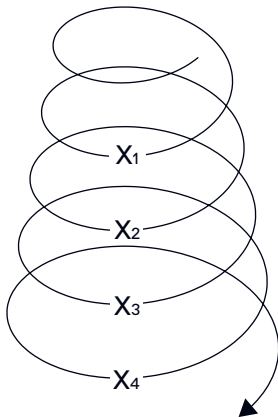

Figure 2.9:
Article progression diagram. Each article expands on and builds on the previous.
Robert Martin, 2021

2.4.6   The Exemplar

The exemplar (E) emerged as the natural completion of the programmatic design research approach. Rob Roggema describes this aspect as the post-design phase of research-through-design, in which the processes of research and design are de-coupled (2016, p. 14). This is where the research exits the confines of the PhD to meet the outside world. This empirical outcome was a proposal for a future sustainable urban transportation system in Copenhagen, Denmark. These drawings, illustrations, and diagrams embodied all the knowledge and insights from the past three years to become a form of comprehensible knowledge. To JAJA, this proposal is seen as the success of the PhD. They often label these drawings as 'The PhD', disregarding the fact that they are only a small part of the knowledge that this three-year process has contributed to the scientific community. However, I find this appropriate, as it serves as a testament that I have met the specific requirements of the Industrial PhD programme to produce knowledge that is relevant to the industry. The exemplar is described and presented in Chapter 8.

2.5 Chapter Summary

In summary, the methodological framework for the 'Points of Exchange' PhD project is centred on the research-through-design methodology, which provides an established epistemology for designer-based modes of research enquiry. A programmatic design research approach provides a structured framework for knowledge-generation and theory-building through the dialectic relationship between a research programme and design experiments. Different forms of knowledge were produced to meet the requirements of the Industrial PhD programme through the qualitative analysis of the design experiments, which were published in four academic journal articles. These design experiments utilised different mixed-methods approaches, which were described in detail. Finally, an exemplar design project emerged to finalise the research project to contextualise the process and respond to the outside world as a form of comprehensible dissemination. The following chapter presents the final iteration of the research programme.

2.6 References

Albers, P. (2013). Visual discourse analysis. New Methods of Literacy Research, February, 85–97. https://doi.org/10.4324/9780203104682

Alvesson, M., & Sköldberg, K. (2018). Reflexive methodology : new vistas for qualitative research / (M. Alvesson & K. Sköldberg (Eds.); Third, revised an...) [Book]. Sage.

Andersen, I.-E., & Jæger, B. (2001). Scenario workshops and urban planning in Denmark. PLA Notes 50, February, 53–56.

Bang, A. L. (2010). Emotional Value of Applied Textiles: Dialogue-oriented and participatory approaches to textile design. (Issue December).

Bang, A. L., & Eriksen, M. A. (2014). Experiments all the Way in Programmatic Design Research. Artifact Journal, III(2), 1–14. https://doi.org/10.1386/art

Binder, T., & Brandt, E. (2017). Design (research) practice. In L. Vaughan (Ed.), Practice-based Design Research (pp. 101–110). Bloomsbury.

Brandt, E., Redström, J., Eriksen, M. A., & Binder, T. (2011). Beginnings. In XLAB (pp. 1–55). The Danish Design School.

Creswell, J. W. (2014). Research Design: Qualitative, Quantitaive, and Mixed Methods Approachs. SAGE.

Cross, N. (2006). Designerly Ways of Knowing (1. Aufl.) [Book]. Springer Verlag London Limited. https://doi.org/10.1007/1-84628-301-9

Frayling, C. (1993). Research in Art and Design. Royal College of Art Research Papers, 1(1), 1–5.

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930). Technology Analysis and Strategic Management, 17(4), 445–476. https://doi.org/10.1080/09537320500357319

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (1994). The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies. In College & Research Libraries. SAGE Publications. https://doi.org/10.5860/crl_56_06_558

Glanville, R. (2016). Design prepositions. In G. Joost, K. Bredies, M. Christensen, F. Conradi, & A. Unteidig (Eds.), Design as Research: Positions, Arguments, Perspectives (pp. 153–165). Birkhäuser. https://doi.org/https://doi.org/10.1515/9783035607383

Howe, K. R. (1988). Against the Quantitative-Qualitative Incompatibility Thesis or Dogmas Die Hard [Article]. Educational Researcher, 17(8), 10–16. https://doi.org/10.3102/0013189X017008010

Innovation Fund Denmark. (2021). Guidelines for Industrial PhD.

Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power (p. 341). University of Chicago.

Jungk, R., & Mullert, N. (1987). Future workshops : how to create desirable futures. Institute for Social Inventions.

Kemp, R. (1994). Technology and the transition to environmental sustainability. The problem of technological regime shifts. Futures, 26(10), 1023–1046. https://doi.org/10.1016/0016-3287(94)90071-X

Markussen, T., Bang, A. L., Knutz, E., & Pedersen, P. (2012). Dynamic Research Sketching: A new explanatory tool for understanding theory construction in design research. Proceedings of Design Research Society Conference 2012 (DRS'12), July, 1126–1143. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Dynamic+Research+Sketching+–+A+new+explanatory+tool+for+understanding+theory+construction+in+design+research#0

Martin, R. (2021). AV futures or futures with AVs? Bridging sociotechnical imaginaries and a multi-level perspective of autonomous vehicle visualisations in praxis. Humanities and Social Sciences Communications, 8(1), 1–15. https://doi.org/10.1057/s41599-021-00739-4

Martin, R., Bruck, E. M., & Soteropoulos, A. (2021). Transformations of European Public Spaces with AVs. In M. Mitteregge, E. Bruck, A. Stoerpoulos, A. Stickler, M. Berger, J. S. Dangschat, R. Sceuvens, & I. Banerjee (Eds.), AVENUE21 Volume 2: Policy and Planning Considerations for Automated Mobility (pp. 159–178). Springer Vieweg.

Nielsen, R. K., Buono, A. F., & Poulfelt, F. (2017). At the Knowledge Interface: Developing Co-Created Research Competency. Academy of Management Proceedings, 2017(1), 11156. https://doi.org/10.5465/ambpp.2017.11156abstract

Nowotny, H., Scott, P., & Gibbons, M. (2003). "Mode 2" Revisited: The New Production of Knowledge. Minerva, 41(3), 179–194.

Onwuegbuzie, A. J., & Frels, R. (2016). 7 steps to a comprehensive literature review : a multimodal & cultural approach (A. J. Onwuegbuzie & R. Frels (Eds.)) [Book]. SAGE.

Pallasmaa, J. (2017). Embodied and Existential Wisdom in Architecture [Article]. Body & Society, 23(1), 96–111. https://doi.org/10.1177/1357034X16681443

Raaphorst, K., Duchhart, I., van der Knaap, W., Roeleveld, G., & van den Brink, A. (2017). The semiotics of landscape design communication: towards a critical visual research approach in landscape architecture. Landscape Research, 42(1), 120–133. https://doi.org/10.1080/01426397.2016.1257706

Redström, J. (2017). Making Design Theory. The MIT Press.

Roggema, R. (2016). Research by Design: Proposition for a Methodological Approach. Urban Science, 1(1), 2. https://doi.org/10.3390/urbansci1010002

Rose, G. (2010). Visual Methodologies. An Introduction to the Interpretation of Visual Materials (2nd ed.). SAGE Publications. https://doi.org/10.5212/Rlagg.v.3.i2.178180

Sadler Consultants. (2020). Urban Access Regulations in Europe. https://urbanaccessregulations.eu/userhome/map

Schön, D. A. (1983). The Reflective Practitioner. Basic Books Inc. https://doi.org/10.4324/9780203963371

Schön, D. A. (1990). Educating the reflective practitioner : toward a new design for teaching and learning in the professions. [Book]. Jossey bass wiley.

Sheller, M. (2014). The new mobilities paradigm for a live sociology. Current Sociology, 62(6), 789–811. https://doi.org/10.1177/0011392114533211

Sheller, M., & Urry, J. (2006). The new mobilities paradigm. Environment and Planning A, 38(2), 207–226. https://doi.org/10.1068/a37268

Simpson, D., Gimmel, K., Lonka, A., Jay, M., & Grootens, J. (Eds.). (2018). Atlas of the Copenhagens. Ruby Press.

Toeters, M., ten Bhömer, M., Bottenberg, E., Tomico, O., & Brinks, G. (2012). Research through Design: A Way to Drive Innovative Solutions in the Field of Smart Textiles. Advances in Science and Technology, 80, 112–117. https://doi.org/10.4028/www.scientific.net/ast.80.112

Zimmerman, J., Stolterman, E., & Forlizzi, J. (2010). An analysis and critique of research through design: Towards a formalization of a research approach. DIS 2010 - Proceedings of the 8th ACM Conference on Designing Interactive Systems, January 2014, 310–319. https://doi.org/10.1145/1858171.1858228

Chapter 3:

Research Programme: Copenhagen as a Case Study

3.1 Introduction

The following text presents a research programme that frames and contextualises the scope of research conducted within the 'Points of Exchange' PhD project. In the previous chapter, I described an approach for programmatic design research that was based on the research-though-design methodology. This methodology provides a structured framework for knowledge generation through the relationship between the research programme and design experiments. The design experiments were conducted, within the context of this research programme, as 'designerly' explorations that challenged, tested, and shifted the programme. In this instance, the programme consisted of a case study of the greater region of Copenhagen, Denmark. The aim of this chapter is to develop a greater understanding of the spatial and sociotechnical conditions in Copenhagen and their implications for the planning of sustainable urban mobilities. In this Industrial PhD project, a special focus is placed on the role of the representation of space in sustainability transitions, which directs the programme to focus on certain systems. Over the course of this chapter, an overview of the plurality of mobility practices that exist within the city and its ambitions are explained. By outlining these in comparison to global transport innovations, this chapter provides a basis to understand the connections between the four published articles.

3.2 Copenhagen

Copenhagen is the capital and largest city of Denmark. The metropolis of Copenhagen lies along the east coast of Denmark within the Øresund, a region in the Baltic Sea (Figure 3.1). With a total area of 526km2, the Greater Copenhagen region, in which the city sits, consists of 16 municipalities (Figure 3.2). Residents of Copenhagen are referred to as 'Copenhageners'.

Copenhagen city consists of four municipalities: Copenhagen, Frederiksberg, Tårnby, and Dragør. Together the city has a population of 799,033 (Statistics Denmark, 2021a). The Greater Copenhagen region has a population of 1,330,022 (Statistics Denmark, 2021a). The population of the region is forecast to grow by 9% to 1,487,156 by 2045 (Statistics Denmark, 2020b). The population of Copenhagen was 17% foreign-born in 2021, representing many different nationalities and making Copenhagen one of Denmark's most multicultural cities (Statistics Denmark, 2021b).

Although it is considered one of the most expensive cities in the world (The Economist Intelligence Unit, 2019), the Monocle Quality of Life Survey 2019 ranks Copenhagen fourth in the world in terms of quality of living, making it one of the most liveable cities. According to the survey, Copenhagen performs well because of its strong design industries, first-rate educational facilities, cycling culture, and culinary scene. The city fell places in the survey because of inflation in the real estate market and lack of affordable housing (Monocle, 2019).

Copenhagen has an advanced market economy with strengths in transport, communications, trade, and finance. Its gross regional product was €126.9 billion in 2019, the largest in Denmark and 26th in the EU (Eurostat, 2021). The region has a particular focus on encouraging the development of several key sectors, including IT, bio-technology, pharmaceuticals, clean technology, and smart city solutions (European Commission, 2020). An analysis of cities by Deutsche Bank found that people living in Copenhagen earned the ninth highest monthly salaries in the world (2019).

Copenhagen is classified as having an oceanic climate with unstable weather conditions throughout the year because of low-pressure systems from the Atlantic Ocean. The rainfall varies moderately throughout the year, although there can be slightly higher precipitation from July to September. Due to the city's latitude, the amount of daylight varies considerably throughout the year. At its summer peak, the sun rises at 04:37 and sets at 21:57, while at the winter low it rises at 08:38 and sets at 15:50: a difference of 10 hours and 8 minutes (Almanak, 2021).

Figure 3.1:
Copenhagen's position in Europe.
Robert Martin, 2021

1 Copenhagen
2 Frederiksberg
3 Dragør
4 Tårnby
5 Albertslund
6 Ballerup
7 Brøndby
8 Gentofte
9 Gladsaxe
10 Glostrup
11 Herlev
12 Hvidovre
13 Høje-Taastrup
14 Ishøj
15 Lynby-Taarbæk
16 Rødovre

Figure 3.2:
The Greater Copenhagen Region
combines 16 different municipalities.
Robert Martin, 2021

3.2.1 A Testcase for Sustainable Future Urban Mobilities

The following design experiments imagine a future Copenhagen, transformed through the introduction of sustainable urban mobility systems. The city is an exemplary context to investigate the future of sustainable urban mobilities for several reasons. First, the city is already a model of green mobility. Within the Municipality of Copenhagen, 29% of all journeys that either begin or end within its boundary occur by bicycle, 70% of households are car-free, and it has one of the most accessible public transport systems in Europe (City of Copenhagen, 2017; Scheurer, 2013). According to the public transport authority, Movia, roughly 89% of residents within the municipality of Copenhagen, and 64% of suburban residents have good access (2016) (Figure 3.7).

Although the city's relatively sustainable transportation system is impressive, it did not appear overnight. A rich planning tradition has existed in Copenhagen since the 1947 Finger Plan, under which urban development systematically proceeded along a series of 'fingers' built beside commuter rail lines, stretching from the 'palm' of dense urban fabric within the city's urban core. (Figure 3.6). With the subsequent construction of an underground metro system and establishment of a dense bicycle path network the Municipality of Copenhagen has become one of the world's lowest per capita car emission areas. (City of Copenhagen, 2016).

Unfortunately, there are no fixed public transport lines that connect the fingers to each other. Instead, three ring roads extend from the edge of the Copenhagen Municipality. Motorways also run parallel to each of the commuter rail lines, including the Helsingørmotorvejen in the north, which was Denmark's first motorway. Future transport infrastructure projects, such as the new Capital Region Lightrail and extensions to the metro network, are planned to fill the gaps in these extensive transportation networks (Figure 3.8). Furthermore, the Copenhagen Municipality is experimenting with car-free (in reality car-light) urban developments (Københavns Kommune, 2019). However, as these only represent a small fraction of the total area within the municipality and do little to ameliorate traffic between the city centre and the surrounding municipalities.

Second, despite its high levels of cycling and sustainable transport and its ambition to be the first carbon-neutral

MODAL SHARE: ALL TRIPS WITH START AND/OR
STOP IN COPENHAGEN MUNICIPALITY

☐ Walk

☐ Public transport

☐ Bicycle

☐ Car
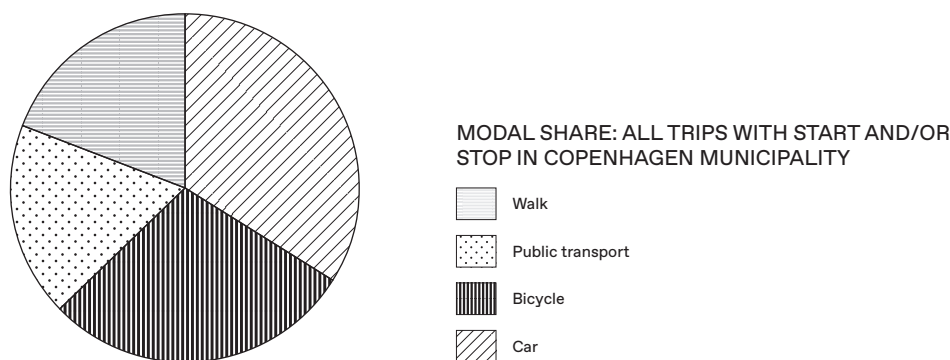
Figure 3.3:
Modal share of trips in Copenhagen
Municipality. Source: Copenhagen
Muncipality, *City of Cyclists*, 2017

capital in the world by 2025 (The City of Copenhagen Technical and Environmental Administration, 2012), car use in Copenhagen is rising. Studies from the municipality show that from the turn of the millennium to 2014, Copenhagen gained 30% more cars (Københavns Kommune, 2016). This statistic cannot be explained by a general increase in population, as the population only increased over the same period by 12.4%. Furthermore, the increase in cars is unevenly distributed over the city (Figure 3.4). This uneven distribution of car use could be related to the attraction of some districts for certain socio-economic groups. For example, Amager Vest, which has shown the largest increase of cars in Copenhagen, is a new urban development that was built specifically to house families with children.

After decades of policies aimed at attracting tax-revenue-generating families back to the city, Copenhagen is being challenged by demographic and cultural changes that are leading to new mobility options, residential and job location preferences, and recreational activity types. Whereas in 1990, only 16% of Copenhagen households were married couples with children, by 2020 this share had increased to 25% (Statistics Denmark, 2020a). At the same time, the average disposable family income grew 275% (Statistics Denmark, 2020c). There are now 30% more families in Copenhagen with considerably more disposable income ready to spend on luxuries, such as car ownership. Rather than dreaming of a free-standing home in the suburbs, the current generation of families increasingly prefers a more urban lifestyle in higher-density, mixed-use built environments. They also desire the ability to access their car easily to escape the city to their summer house or for recreational activities. This has significantly increased the demand for car-parking and street space in new urban developments around the city. Now, when

Cars ▨   Population ▨

80%
70%
60%
50%
40%
30%
20%
10%
0%

INDRE BY · ØSTERBRO · NØRREBRO · VESTERBRO/KONGENS ENGHAVE · VALBY · VANLØSE · BRONSHØJ-HUSUM · BISPEBJERG · AMAGER ØST · AMAGER VEST · CPH TOTAL

Cars ——   Population ——·   Disposable income (DKK 1.000.000.000) ——

140%
135%
130%
125%
120%
115%
110%
105%
100%
95%
90%

100
95
90
85
80
75
70
65
60
55
50

2000 · 2001 · 2001 · 2003 · 2004 · 2005 · 2006 · 2007 · 2008 · 2009 · 2010 · 2011 · 2012 · 2013 · 2014
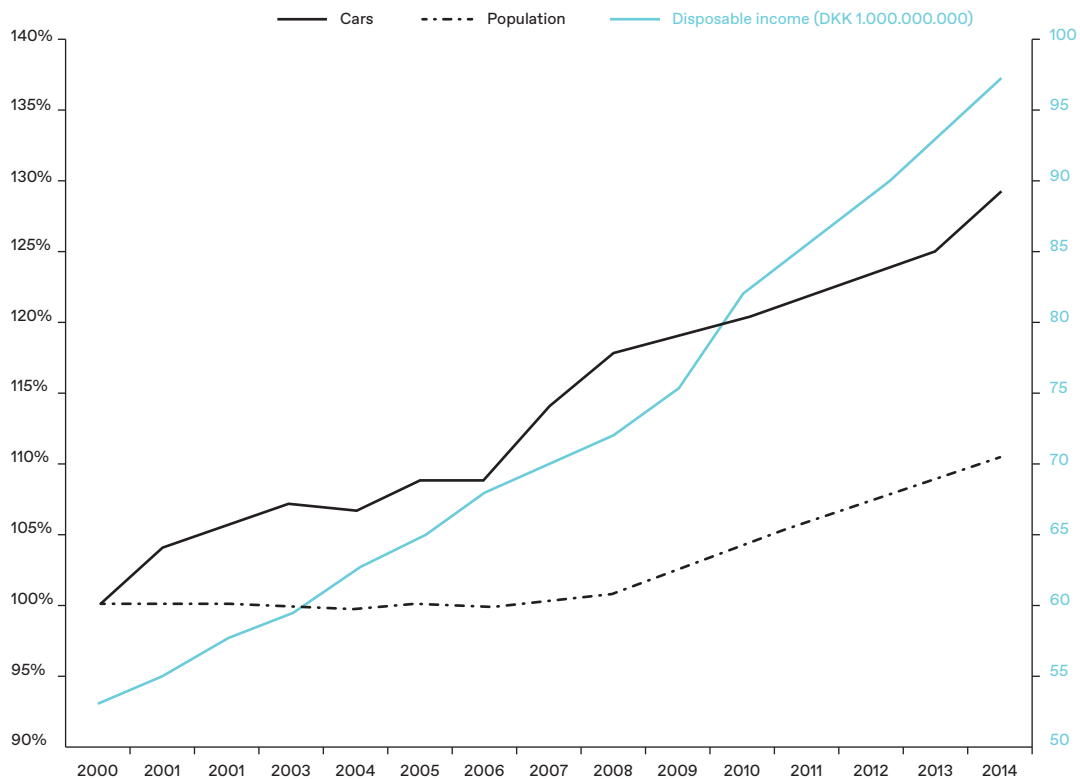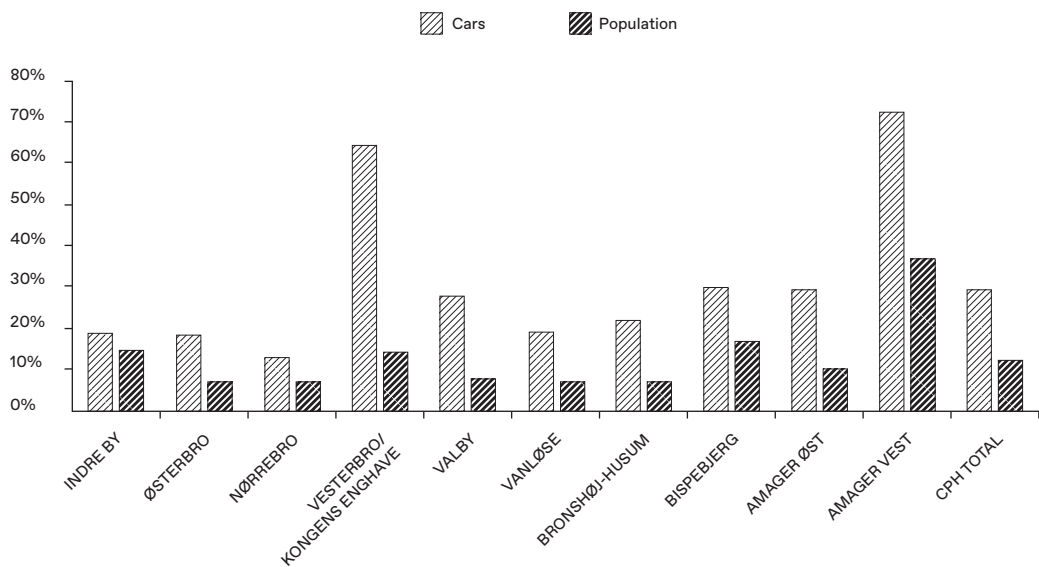
its sustainable transport system is most at risk due to the desire for cars in the growing population, is the moment that Copenhagen needs to know how to curb this trend.

Finally, Copenhagen is a city that others look to from around the world. Only thirty years ago, the City of Copenhagen was bankrupt, was experiencing a net loss in migration, was losing industry, and had a substantial annual budget deficit. Today, the city has been transformed into one of the wealthiest in the world, consistently ranked top in terms of quality of living and urban development. This rapid transformation has not gone unnoticed, and leaders from around the world flock to the city to try to understand and replicate the Copenhagen model. In 2019, mayors from 96 of the world's top cities congregated in Copenhagen for the C40 conference to discuss strategies for bold climate action, taking the city's approach to liveable sustainability as inspiration. With the spotlight on Copenhagen as a leader in sustainable mobility, it is now more important than ever for the city to continue to provide a model for other cities to follow.

Figure 3.4:
Variation of increase in the number of cars and population growth within the districts of Copenhagen Municipality. Source: Copenhagen Muncipality, Danmarks Statistik 2016.

Figure 3.5:
Comparison in growth of disposable income, population, and number of cars.Source: Copenhagen Muncipality, Danmarks Statistik 2016.

Figure 3.6:
Map. Copenhagen transportation network.
Robert Martin, 2021.
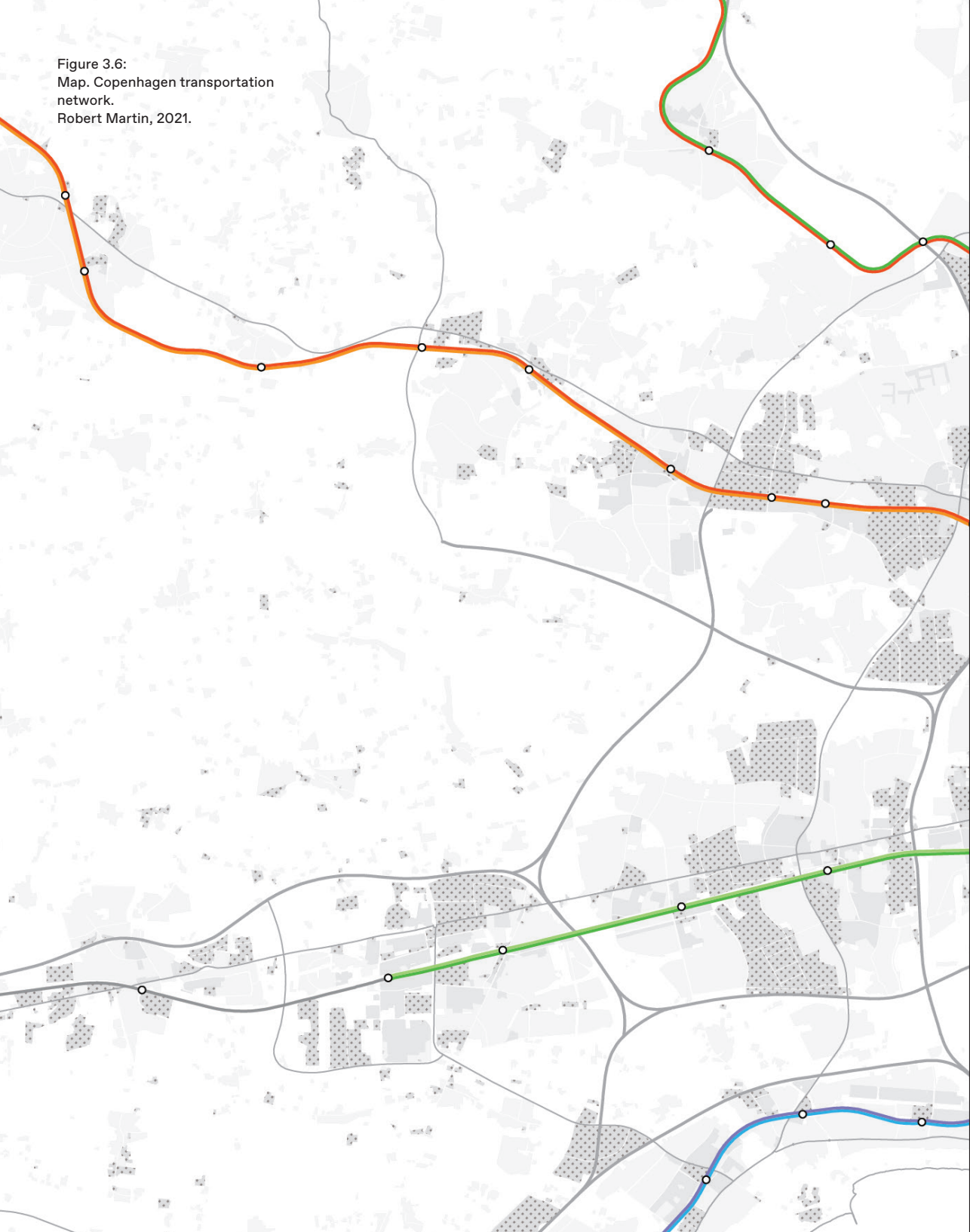
COPENHAGEN, DENMARK/
TRANSPORTATION NETWORK

0   1   2   3   4   5km
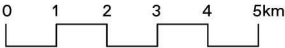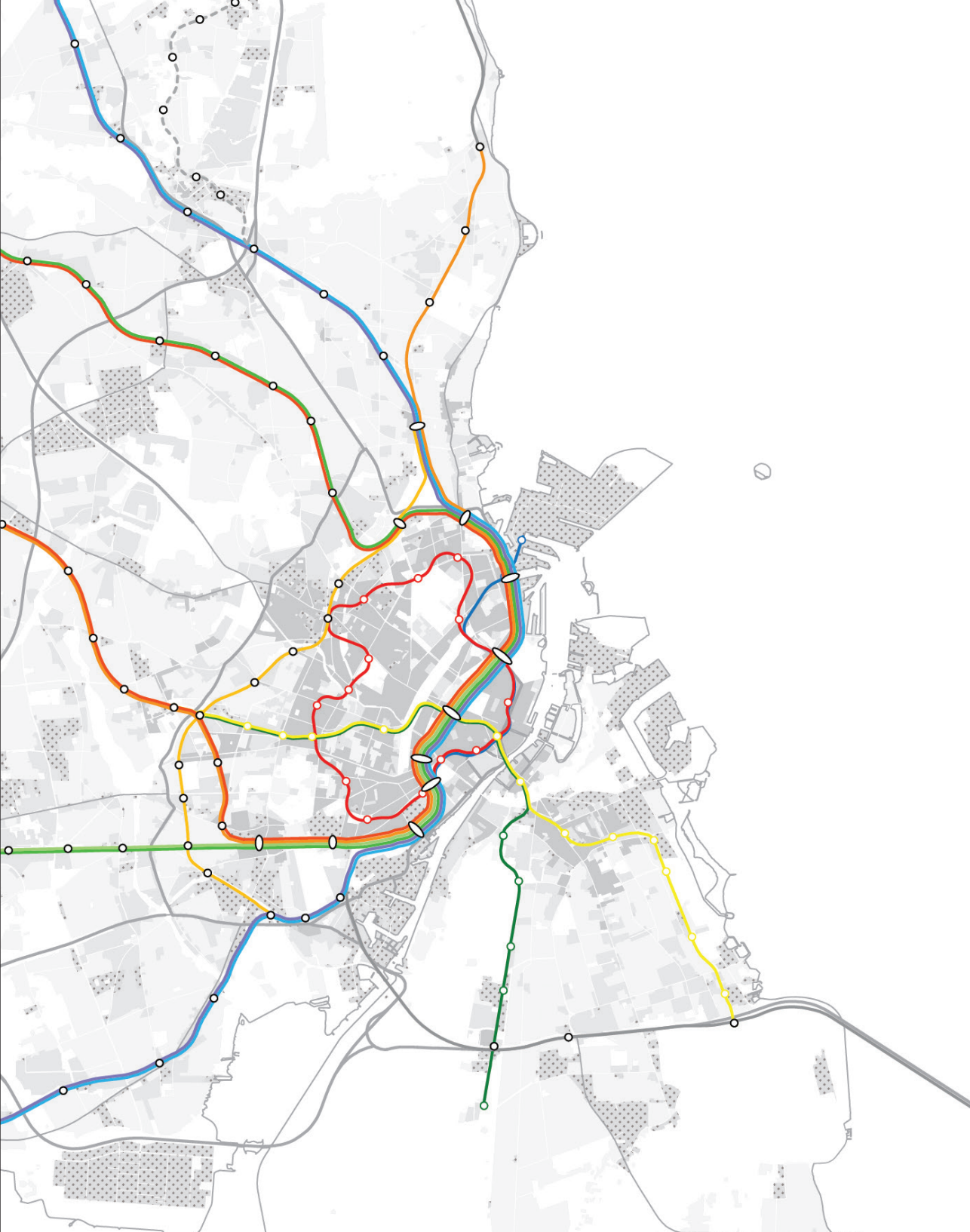
▰ High density	━━ S-tog C Line	━━ S-tog H Line	┅┅ Local train line
▰ Medium density	━━ S-tog A Line	━━ S-tog F Line	━━ Metro M1+2
▰ Low density	━━ S-tog E Line	━━ S-tog Bx Line	━━ Metro M3
⣿ Commercial & Industry	━━ S-tog B Line	━━ Regional train line	━━ Major road

71

Figure 3.7:
Map. Copenhagen public
transportation access.
Robert Martin, 2021.
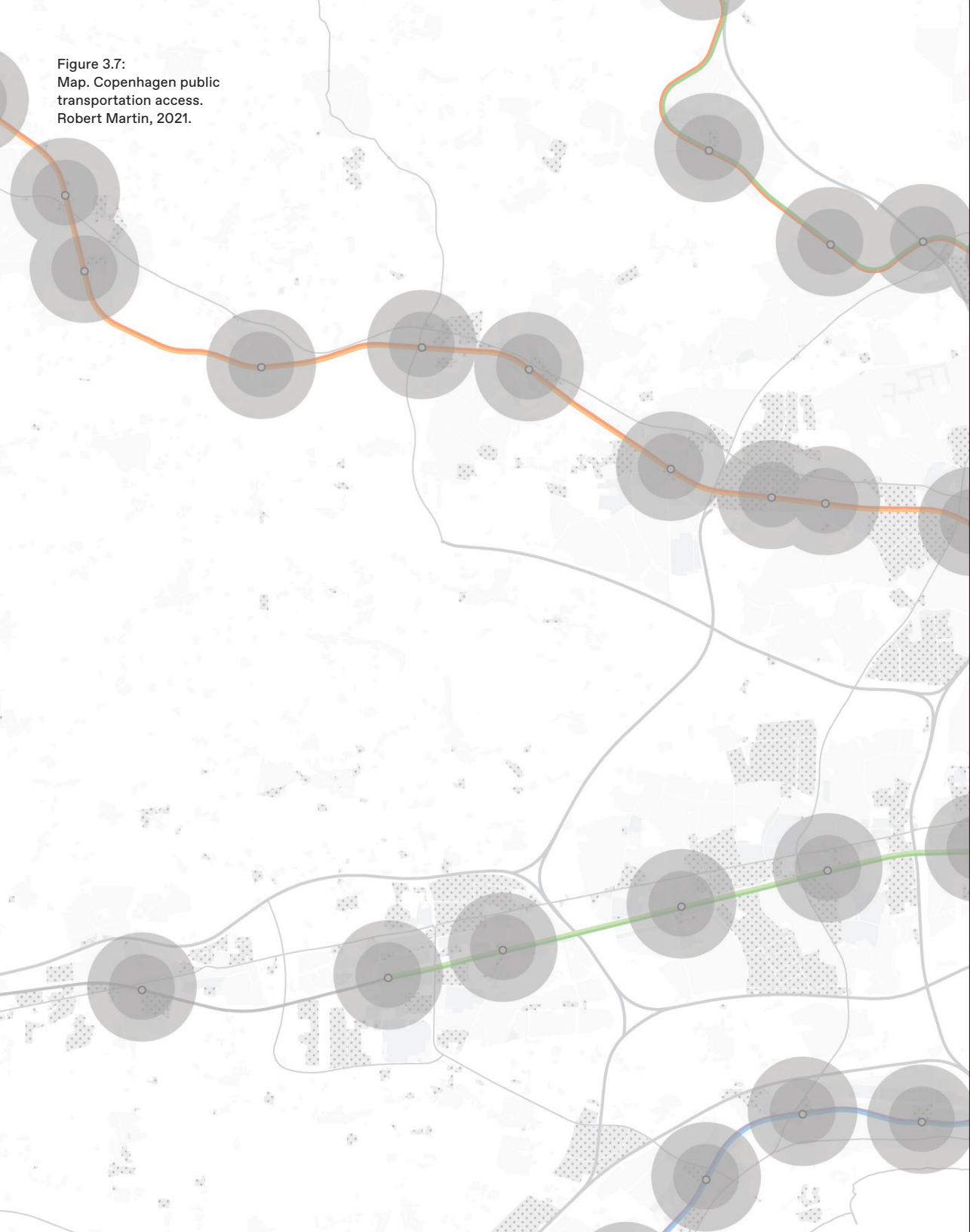
COPENHAGEN, DENMARK/
PUBLIC TRANSPORT ACCESS

0 1 2 3 4 5km
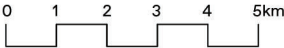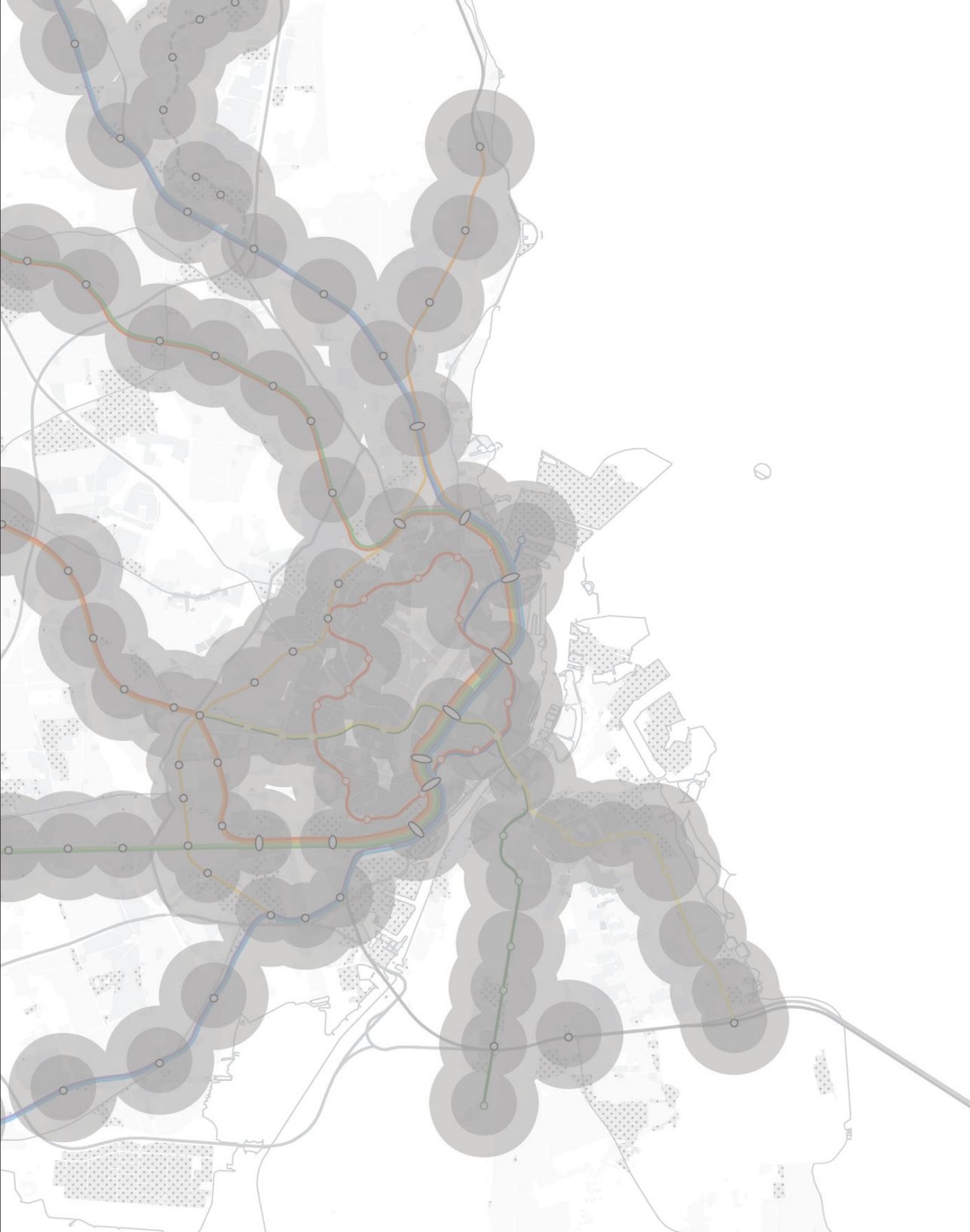
600m offset
1000m offset

Figure 3.8:
Map. Copenhagen future development projects.
Robert Martin, 2021.
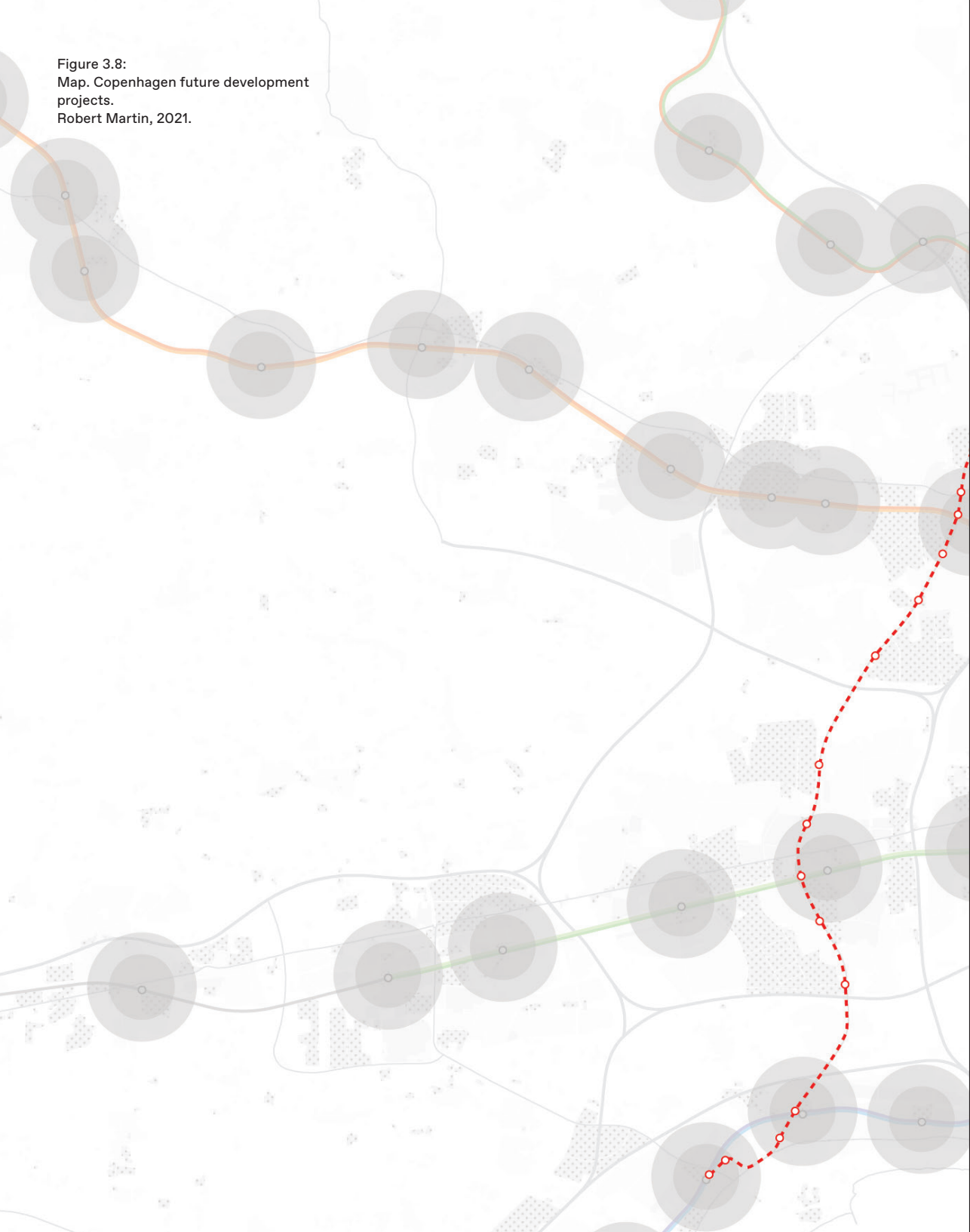
COPENHAGEN, DENMARK/
FUTURE DEVELOPMENT PROJECTS

0 1 2 3 4 5km
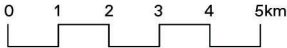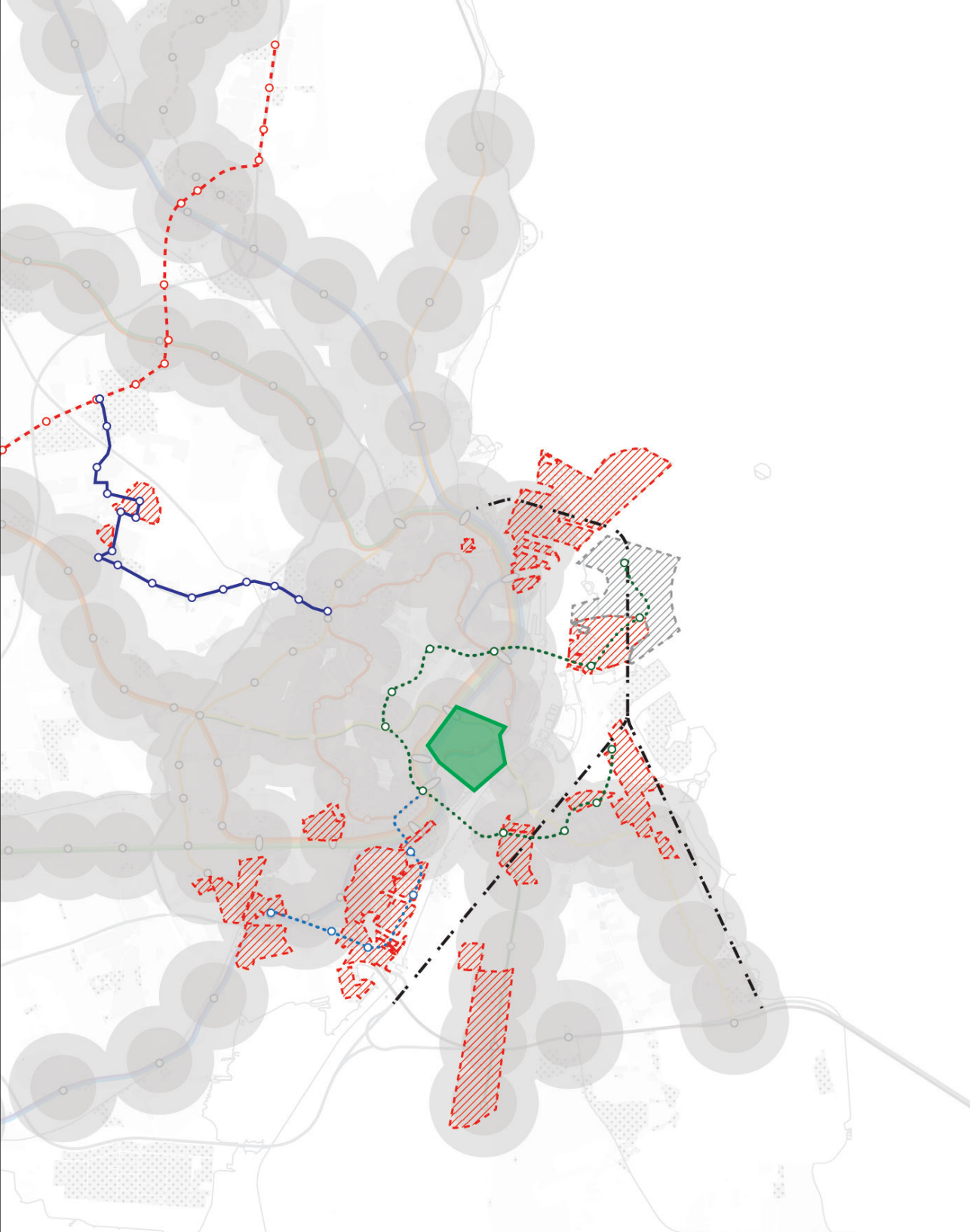
▨▨ Lynetteholmen	╍╍ Capital Region Lightrail
▨▨ New car-light districts	▬▬ Nørrebro Lightrail
▨▨ Car-free medieval city	⋯⋯ Metro M4 Line extension
·–·–· Eastern Ring Tunnel	⋯⋯ Metro M5 Line

3.3 The True Cost of Transport

The impending threat of climate change has brought into focus the impact of transport on the environment. Globally, transport contributes to 16.2% of all GHG emissions (Ritche & Roser, 2021). This is primarily a result of the burning of fossil fuels in internal combustion engines and does not include the emissions from the manufacture of vehicles. Within the transport sector, road transport contributes 11.9% of global GHG emissions (ibid). Sixty percent of this arises from passenger travel, which includes cars, motorcycles, and buses (The International Energy Agency, 2019). While flight shaming has become a social movement recently in an effort to reduce the environmental impact of transport, air travel pales in comparison to the impact on the planet of current systems of road passenger and freight movement. Theoretically, this means that if humankind could electrify our entire road transport sector through a fully decarbonised electricity mix, we could eliminate 11.9% of GHG emissions. However, commentators have rightly highlighted that the timeframe to transition the global population of internal combustion engine vehicles to electric would far exceed the necessary measures to keep global warming under the target of increasing 2.0°C (Bruce, 2021).

3.3.1 The Case against Car Use

There is no denying the economic and social benefits that derived from driving. However, when society considers the cost of driving, we need to consider more than just the price of petrol, insurance, and maintenance. There are several direct and indirect social and environmental costs that are rarely considered when a person jumps into a car to get from A to B. In a European context, car travel represents 80% of passenger transport demand (European Environmental Agency, 2016). It also represents 25% of GHG emissions (Moradi & Vagnoni, 2018), which is expected to grow to 50% by 2050 if trends continue (European Environment Agency, 2018).

Emissions from cars are also one of the most substantial environmental health risks (EEA, 2018). Road traffic emissions

are one of the largest sources of air pollution (Johansson et al., 2017): 40% of nitrogen oxides and 40% of particulate matter$_{2.5}$ (PM$_{2.5}$) derives from road transport (European Environment Agency, 2017). Cities are particularly at risk of air pollution because of the mixture of urban activities, proximity to roads, and the difficulty of dispersing air pollutants away from highly urbanised areas. While many associate unhealthy cities with images of smoke billowing from flue-gas stacks, it is emission sectors with low emission heights, such as road traffic, which have greater health impacts in urban areas (European Environmental Agency, 2019). The problem is so bad that these emissions are responsible for almost 400,000 premature deaths per year in the EU (ibid.).

Automobile use also has second-order implications for health. There is a correlation between developed countries that have high levels of car use and populations with sedentary lifestyles and low levels of activity. Globally, 71% of deaths from non-communicable diseases are associated with modifiable risk behaviours that could be prevented and treated by regular physical activity (World Health Organization, 2020). For example, mortality is 30% lower in cycle commuters compared to those who use automobile transport (Sallis et al., 2016). Furthermore, urban environments designed around car use inhibit physical activity. Walkability requires a density of shops, services, and public transport options with ready access to public parks and open spaces. Design of the urban environment to limit car use can contribute to 90 min/week of physical activity (60% of the WHO 150 min/week guideline).

There are endless other socio-economic costs that are associated with private car use, such as time lost in congestion[3.1] and the financial burden for those living in lower income areas (Chatterton et al., 2018). However, the final cost that I would like to highlight is the physical space that an automobile consumes. The amount of space automobile systems use is often underestimated. A car needs 90 times more space than a bus or tram to travel to and from work or home (Nieuwenhuijsen & Khreis, 2016). This is because the average car only has 1.4 passengers, and all the associated infrastructure needs. For instance, a typical parking space is 2.4–3.0m wide and 5.0–6.0m deep, totalling 13–19m2. If parking off the street, it would require 28–33m2, including access and landscaping. All this space adds up: the current amount of space dedicated to road infrastructure is 1,900,000m2 in the municipality of Copenhagen (Københavns Kommune, 2017), which is badly underutilised. Only 9% of Copenhagen residents use cars within the city, while 66% of Copenhagen street space is

3.1 It is estimated that Copenhagen drivers waste 9.3 million hours sitting in traffic congestion each year (Region Hovedstaden, 2017).

dedicated to cars (City of Copenhagen, 2018). Figure 3.9 shows the amount of space compared to the municipal boundary.
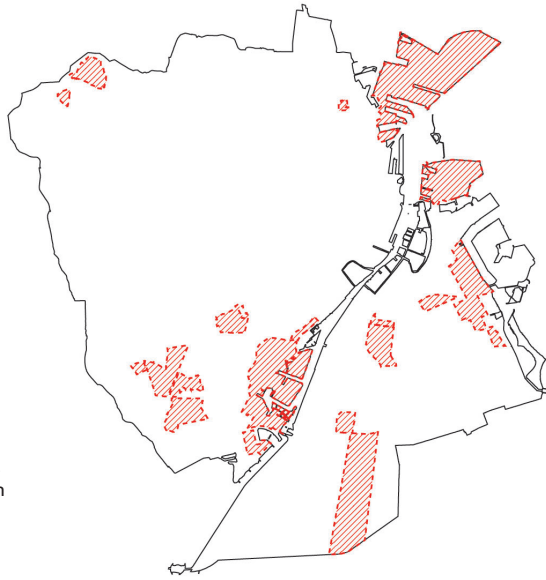
Figure 3.9:
Comparison between the area of street space in Copenhagen (grey), new urban developments (red), and Copenhagen Municipal boundary.
Robert Martin, 2021

3.4 The emergence of new transport technologies

Many rumours surround the future of mobility. Technologies that were once thought to be the domain of science fiction has now seemingly arrived. Despite this, much of the discussion surrounding these emerging technologies remains detached from the complex urban environments in which they are supposed to be immediately integrated. The following section will unpack several of these emerging technologies, including their relevance to the transition towards sustainable urban mobility systems.
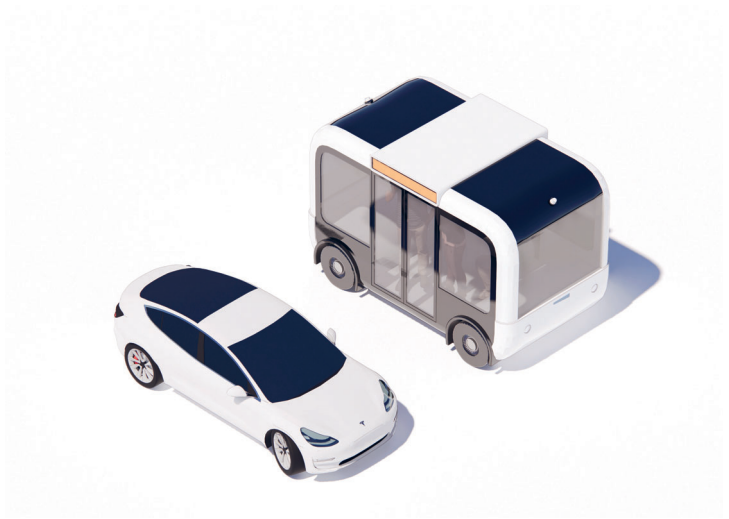
3.4.1 Autonomous vehicles

Despite the fact that autonomous vehicles (AV) have been making headlines throughout the last decade, the idea dates back more than 75 years (Kornhauser, 2013). Technology has been the main barrier to implementation, but with recent advancements in wireless communication, sensor technology, and exponential increases in computing power, the technical means to operate autonomous vehicles is drawing ever closer (Lamon et al., 2006).

Nomenclature surrounding AV technology is mixed. Common terms, including 'driverless car', 'self-driving vehicle', 'autonomous vehicle (AV)', and 'connected and autonomous vehicle' are more prevalent in public forums. However, the term 'automated vehicles' seems to be more commonly used by engineers within technical discussions and conferences. Some terms appear to promote some discourses and disempower other discourses For instance, 'driver-less' takes a stab at humans as the main cause of traffic accidents, vindicating the vehicles. 'Automated', however, provides a more accurate description of the vehicle as operating according to a series of computer logics and commands rather than having personal agency. The author, Malcolm Gladwell, has commented that the term 'autonomous' vehicle is inaccurate when describing these vehicles, as they are bound by the rules and restrictions established by authorities and developers. Gladwell states that 'the autonomous vehicle is the one we already have', implying that the freedoms afforded by automobiles throughout the twentieth century are at risk through the introduction of automation (Horwitz, 2019).

The vehicle's ability to exchange information with other vehicles and infrastructure is known as its connectivity. This ability to connect can be achieved through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication This capacity can be realised through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. When combined, these are referred to as vehicle-to-everything (V2X).

The Society for Automotive Engineers (SAE) levels of driving automation (Figure 3.11) is a taxonomy offered by the SAE with which to compare vehicle automation systems (SAE International, 2018a). It is the most widely used method for understanding the limitations of AV technology. The taxonomy consists of a six-rung ladder, which ranges from Level Zero (no automation) to Level Five (full, unconditional automation). It was introduced to enable engineers to describe, compare, and categorise the technical differences between systems. Each level focuses on the role played by the human in performing safety critical operations. Levels 0–2 clearly state that the human is driving at all times and that the driving automation features merely support the human driver. Level 3 is the first step in which the human is considered a passenger and not a driver, although the human must be ready to take over driving responsibilities if the vehicle requests it.

Figure 3.11:
Taxonomy of automated driving systems. Source: Society for Automotive Engineers, 2018
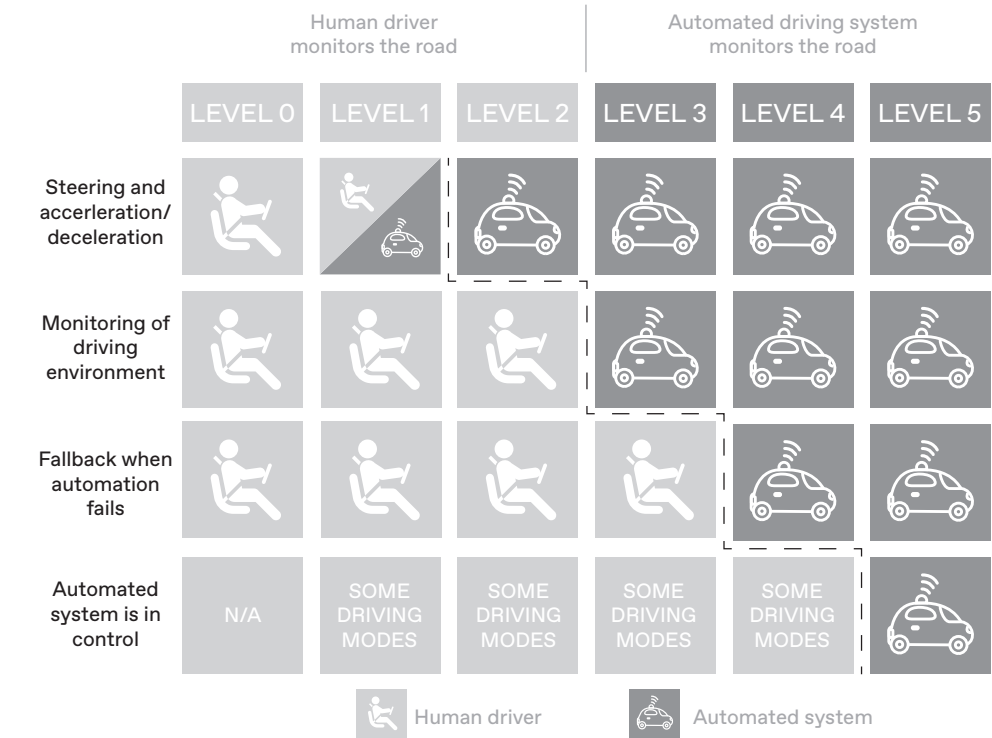
Levels 4 and 5 are vehicles that are considered to have full self-driving capability. The difference between these two levels is the environment in which the vehicle is expected to operate. While Level 4 vehicles have limitations on the environment and will only operate if certain conditions are met inside Operational Design Domains(ODD), a Level 5 system is expected to perform 'anywhere that a typically skilled human driver can reasonably operate a conventional vehicle' (SAE International, 2018a, p. 33).

Some authors believe the SAE levels are misleading and place too much emphasis on technological development instead of societal benefit and circumstances (Stayton & Stilgoe, 2020). However, I believe that the levels offer an unintended gift to society that is often overlooked. In 2018, the CEO of Waymo, John Krafcik, admitted that Level 5 autonomous vehicles were impossible:

> *"I'm not sure that we're ever... going to achieve a Level 5 level of automation... I think it's sort of silly that we think about it. And it's important I think for all of us to be really clear on the language around self-driving because it does end up confusing people... autonomy I think is always going to have some constraint on it."*[3.2]

By framing self-driving technology as having an unattainable end state of full autonomy, the SAE framework has forced AV developers to consider the technology outside of the system of automobility. In a way consistent with one of the hallmarks of modernity, the system of automobility worked within total designs that ignored contextual factors. On the one hand, a human-controlled automobile has no problems operating within the grid-like structures of suburbia; the outskirts of rural environments; the complex, medieval street-layouts of cities in Europe; or hyper-bustling metropolises of Asia. AVs' operability, on the other hand, is limited by the spatial complexities of their deployment (Soteropoulos et al., 2020). When John Krafcik announced that humankind would never have the same level of operability with AVs as with cars, society made its first step towards understanding AVs beyond the lens of cars.

By accepting these limitations, and only operating at Level 4 within ODDs, AV companies are having to think about where they are deploying AVs and why. Understanding that the technology may never reach a level sufficient to safely navigate complex urban environments, full of pedestrians and cyclists, is a positive outcome. Rather than forcing the technology into these places, spaces that are not suited to AVs can be left

free, and transportation systems can develop as a plurality of modes that operate at different scales and efficiencies.

Figure 3.12:
Mobility as a Service diagram. The smart phone unlocks a new way to access mobility.
Robert Martin, 2021

3.4.2   Mobility as a Service

Mobility as a Service (MaaS) describes the trend of moving away from personally owned modes of transportation to those provided by shared services. The term refers to not only modes of transportation but also the heterogeneous physical and digital infrastructures that are connected to assist users in reaching their destinations efficiently(Expósito-Izquierdo et al., 2017, p. 432). Through a range of on-demand mobility alternatives, MaaS aims to offer a similar level of service as privately owned vehicles that can be selected based on journey type (ibid.)(Figure 3.10). In this way, users can avoid commitments to pre-specified transportation modes. Instead, the transportation mode can be best suited to the journey type in terms of economy, time, and environmental impact.

Users access MaaS systems through a smartphone application or the web. A user may then order transport between two locations or for an amount of time using an integrated payment system and receive travel choices based on transport schedules, modes, rapidity, cost, and comfort (Kamargianni et al., 2016). Transport solutions can consist of public transportation, cars, bicycles, or scooters, among others, depending on what fits the customer and their journey. MaaS has the potential to increase the modal share of more sustainable modes of transport as users' individual journeys become less reliant on a car to fulfil all transport needs. A study in

the city of Helsinki, Finland, found that MaaS users were far more likely to take public transportation in combination with a shared bicycle or taxi than typical Helsinki residents (Hartikainen et al., 2019). Ultimately, users receive the benefits of private car ownership without the problems of parking, maintenance, insurance, and so on.

Even though the concept of MaaS is relatively simple, there are competing ideas of how it should be implemented. The original concept focused on providing a single platform combining all transport services in an integrated solution[3.3]. This platform would host a number of different mobility providers offering different mobility services. The platform operates as a dispatcher, matching users with the mobility provider or combing several providers to meet the journey criteria. The dispatcher may then control the number of mobility providers operating in each area, decide where services should be located, have greater access to transport data, and provide a uniform payment platform. This form of MaaS is called a horizontally integrated framework.

3.3 See for instance, the Finnish MaaS company, Whim.

1/

2/

3/
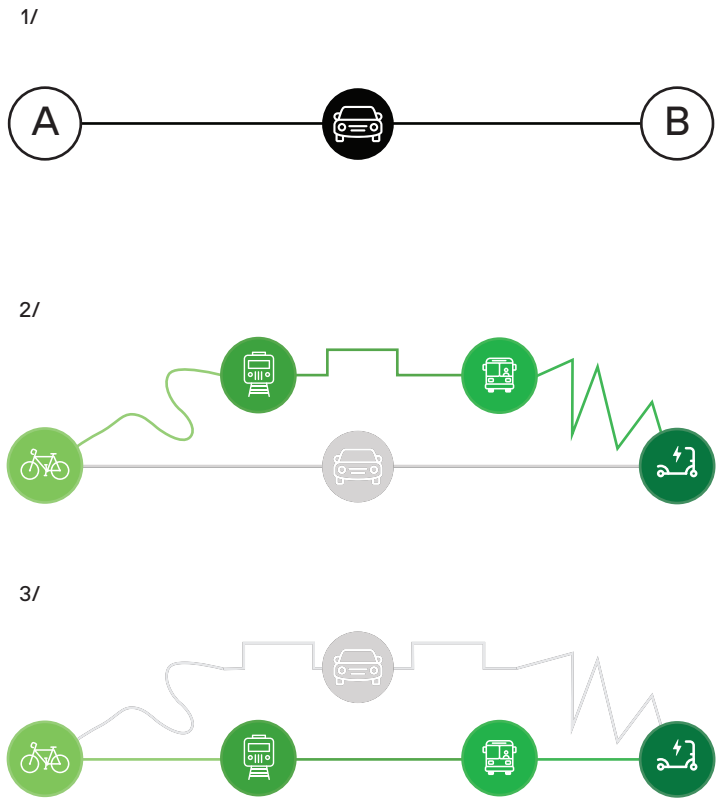
Figure 3.13:
Multimodal system diagram.
1/ Current monomodal transport
2/ Multimodal system to reach same destination as car.
3/ Multimodal system that preferences sustainable modes over cars.
Robert Martin, 2021

However, several mobility providers have realised the opportunity to provide multiple services within their own platform. For example, Uber, the American ride-hailing company, acquired the bicycle-share and e-scooter company, Jump, and expanded their public transport ticketing offerings in an effort to increase their share of the mobility market. By integrating a number of services vertically, companies can offer a more comprehensive service to their customers and ensure that more transactions are kept within their platform (and bottom line). However, there are criticisms of this form of MaaS. Some suggest that it will lead to only a few companies dominating, which would prevent competition from smaller companies entering the market, limit mobility options, and reduce the economic benefits of MaaS (Larco, 2018).

The emergence of MaaS was stimulated by the rise of mobility operators seeking to disrupt the taxi and automotive industries (Steckler et al., 2020). This industry evolved from the traditional hiring of cars from fleet operators to include peer-to-peer-based car rental, which connects landlords to tenants with application-based solutions, and on-demand ride-sourcing that connects drivers directly to passengers (Østli et al., 2017). In the following subsections, I describe the three most common forms of this mobility offering, in which cars are no longer seen as a product but as a service.

3.4.2.1   Ride-hailing

The term ride-hailing refers to booking and paying for a ride with a transportation network company (TNC), such as Uber, Lyft, or DiDi. Users access rides through a smartphone application that matches journey demand to available drivers. Transportation network companies do not hire drivers; instead, they connect users to drivers through their platform, which has led to scandals regarding proper licensing and insurance (Marin et al., 2020). The global market for ride-hailing is estimated to be 250 million users, with a total market value of $113 billion (Mordor Intelligence, 2021).

The introduction of ride-hailing companies into cities has caused significant debate about the way in which this service should be regulated. While some studies suggest that ride-hailing reduces car ownership, there is more evidence suggesting that it attracts users away from public transportation and onto already congestion transport corridors. Studies have shown that up to 61% of ride-hailing journeys would not otherwise have been made or would have been made by

walking, bicycle, or transit (Clewlow & Mishra, 2017). This correlates with research showing that TNCs are increasing vehicle kilometres travelled (VKT) in cars (Erhardt et al., 2019; Steckler et al., 2020). However, increased adoption of journeys by a TNC is reducing parking demand in urban cores (ibid.). In turn, this is placing greater demand on curb-space for pick-up and drop-off of food, goods, and people (Crist & Martinez, 2018).

3.4.2.2   Car-pooling

Car-pooling is an old concept. The original idea involved decreasing the number of vehicles on the road by individuals sharing a vehicle with others on a similar commute. An early policy to promote this concept was introducing car-pooling lanes which provided express times when journeys were shared. This was generally known as casual carpooling, in which no money was exchanged for the journey (SAE International, 2018b).

Transportation network companies have adopted the concept of car-pooling in response to concerns that they produce more congestion in cities. In 2014, Uber and Lyft announced car-pooling services that utilised their large user base and algorithms to match passengers along similar routes to share rides and save money. Uber's UberPool and Lyft's Line are in-application features that encourage users to share rides. In exchange for a cheaper fare, users share their ride with others with similar destinations. This is known as real-time carpooling (SAE International, 2018b). While car-pooling can help in reducing traffic and emissions, the benefits only appear if there is a sufficiently high density of individuals (Alonso-González et al., 2020). Estimates indicate that between 20–50% of all ride-hailing journeys must be pooled to see tangible environmental improvements (Fagnant & Kockelman, 2018).

3.4.2.3   Car-sharing

Car-sharing is an evolution of traditional car-rental services that is tailored towards the residents of an area rather than tourists or business travellers. Although versions of the concept have existed since the 1950s (Ferrero et al., 2018), car-sharing came to prominence with the emergence of Zipcar, a US company, in the 1990s. In Zipcar's service, individuals joined a member-based programme in which access

to the shared cars is gained as needed. High level of vehicles are available in dense urban areas which may be borrowed on a per hour basis. The service differs from traditional car rental in many ways, such as the following:

- Vehicles are more flexible in their rental periods that can be by the minute, hour, or day.

- Reservation, pick up and drop off are all self-service.

- Fuel costs and insurance are included in the rate.

Since the success of Zipcar, there have been several new business models for car-sharing platforms. The three most prominent are as follows:

- Station-based. Users collect and return the vehicles in the same place (Nourinejad & Roorda, 2015). Often, the car-sharing company has arranged a permanent parking space with the municipality for the vehicle to use. In Copenhagen, the main station-based operator is LetsGo.

- Free-floating. A shared-vehicle can be collected or returned anywhere within the service zone (Firnkorn & Müller, 2011). In Copenhagen, there are two competing free-floating operators, ShareNow and Green Mobiliet.

- Peer-to-peer. This model operates similarly to station-based and free-floating. However, rather than renting from a fleet owner, users rent directly from a private vehicle owner (Østli et al., 2017). The main peer-to-peer operator in Copenhagen is GoMore, which also allows car owners to offer car-pooling on shared journeys and a leasing service for users who wish to own a car yet offer it to other users.

While the verdict is still pending on ride-hailing and car-pooling, the benefits of car-sharing are well documented, and it is a viable alternative to private car ownership (Urban Creators, 2021). Studies have shown in pilots across cities that a single shared car can replace up to 16 privately owned vehicles, thereby reducing parking demand in dense urban cores (Schreier et al., 2018). Moreover, it has been found that car-sharing users make fewer journeys by car and more journeys using active and sustainable modes, thereby reducing their transport-related energy use and GHG emissions (Chen & Kockelman, 2016). However, the integration of car-sharing systems requires support from policymakers and planners,

as their need for dedicated parking places can create conflicts over the right to public space (Kent & Dowling, 2016). Furthermore, the shift from private to shared ownership of cars requires a cultural change in society's expectations and relationship to automobiles (Kent, 2014; Sheller, 2004).

Figure 3.14:
Diagram showcasing the different categories of micrmobility: deck, handlebars, seat, and cover.
Robert Martin, 2021

3.4.3 Micromobility

Micromobility has emerged as an obvious solution to the challenge of moving around densifying cities. While the implicit definition may appear obvious, the term describes far more than bicycles and skateboards. The man credited with the name, Horace Dediu, describes the inspiration of the term as not necessarily coming from 'micro' meaning 'small', but from his belief that micromobility will do for transportation what microprocessing did for computing[3.4]. From Dediu's point of view (Dediu, 2019), the standard definition of micromobility is a personal mobility device (PMD) that is under 500kg. Secondary traits include electrification (micromobility wishes to distinguish itself from the bicycle), and utility (these mobility devices are not toys but are used to commute to and from work and school). Within this broad definition lies a number of different transportation options that may be used for different journey types. These PMDs may be privately owned or shared through a mobility provider. Micromobility devices are categorised based on the inclusion of the following characteristics: deck, handlebars, seat, and cover (Figure 3.14).

The growth of micromobility has been exponential over the past two years. Demand for e-bicycles exceeds demand for

3.4 This is only one definition as it has been rapidly adopted by popular media and scholarly literature. There is no clear singular definition of the term.

electric cars by a factor of 10:1 in Europe and 20:1 in China (Bruce, 2019). Shared e-scooters were only launched in 2018 but were used for over 38.5 million rides globally by the end of that year (National Association of City Transportation Officials, 2019). While these figures are incredible, they are not at all surprising. It costs less (in terms of fuel, space, and money) to transport a 100kg passenger using a 20kg vehicle with an efficient electric motor than it does to complete the same task using a 2,000kg car with an energy-inefficient internal combustion engine. Moreover, 50% of all vehicle journeys in the Copenhagen region are under 10km, journeys that are far more suited to small, more active, and less polluting modes (Christiansen & Baescu, 2020). Micromobility also has the potential to service longer journeys when included within a multi-modal system as a first or last mile connection. Studies suggest that shared bicycles and e-scooters increase accessibility when located near public transportation nodes (Milakis et al., 2020).

Larger style micromobility devices, such as electric cargo bicycles, offer alternatives to car ownership in urban areas (City Changer Cargo Bike, 2019). Although traditional cargo bicycles have been in use for over a century, the additional of a pedal-assist motor has made the vehicle far more useful for both personal and commercial uses, as it is capable of carrying up to 350kg in cargo. Use cases include food delivery, logistics, and the everyday needs of families, such as carrying children, groceries, dogs, and so on. While electric cargo bicycles are a common sight on the streets of Danish and Dutch cities, their use is being adopted globally as a green alternative for last-mile deliveries. Studies have found that the adoption of electric cargo bicycles for e-commerce delivery can reduce operational costs by 25% while decreasing GHG emissions by 73%, with limited effect on the logistic company's network efficiency (Browne et al., 2011; Melo & Baptista, 2017).

However, as concluded in a number of academic studies, there is not yet a conclusive argument that micromobility is a sustainable mobility solution (Milakis et al., 2020). This does not mean these new technologies do not hold potential to be sustainable, but that there are a number of implications that must be considered in terms of accessibility, physical activity, pollution, and safety. For instance, a lifecycle assessment of the carbon footprint of shared e-scooters versus cars found that a journey using a shared scooter produces half as much GHG emissions as the same journey by car (Hollingsworth et al., 2019). While this is good, a vehicle that weighs 1/100 of a car should produce far less than half the GHG. Furthermore,

e-scooters were found to produce more GHG per mile than buses. These disappointing results come from inefficient systems for spatial relocation and recharging and the short lifespans of the vehicles (ibid.). However, many shared scooter operators are focused on solving these problems, increasing operational lifespans by over two years and introducing new recharging pilots that use swappable batteries to reduce journeys by heavy delivery vans.

There is also documented evidence that micromobility replaces journeys that would have otherwise been taken by more sustainable modes while reducing physical activity (Hyvönen et al., 2016). A study in New Zealand found that 57% of e-scooter journeys replaced journeys that would have been undertaken by active mobility: foot, bicycle, or skateboard (Fitt & Curl, 2019). Moreover, e-bicycle users perceive that their physical activity increases once switching to an e-bicycle, but the physical benefits of e-bicycles remain unclear (Jones et al., 2016). Active mobility is seen as a key element in people's social wellbeing (Singleton, 2019), and therefore efforts must be made in local policy to prevent the replacement of active-mode journeys by micromobility.

While shared micromobility modes have been found to improve accessibility, this is dependent on the number of vehicles provided in each area (Stuart et al., 2018). The availability of shared micromobility has been found to be driven by demand and not equally distributed across pilot cities, often excluding lower-income areas if access is dependent on having a credit card and smartphone (Mooney et al., 2019). Furthermore, shared, dockless modes have been found to litter city streets, creating obstacles for pedestrians and those with disabilities and decreasing their mobility accessibility. This leads to questions regarding whom micromobility is improving accessibility for and the role of public authorities to direct micromobility adoption in the right direction.

3.4.4   The Rise of Car-free(dom)

The incoming trend of car-free living is not an emerging technology but an innovation in transport and urban planning policy intended to drive the transition towards sustainable urban mobility systems. Despite its name, the term 'car-free' does not mean life with no cars but an imagined life in which limited or no car use is required for participation in everyday life (Topp & Pharoah, 1994). Therefore, I try to work with the idea of car-freedom, which I believe signals a liberation from

perceived dependencies on private car ownership. However, I also recognise that many perceive car ownership as an integral part of everyday life (Freudendal-Pedersen, 2020). There are a number of socio-economic groups who may be disadvantaged by limiting car use. Therefore, there are several strategies and policies within the discourse of 'car-free' to balance this sensitive issue. In the following paragraphs, I summarise several of these approaches, which have been further considered in Chapter 6, Section 3.1.

The first attempts at car-free strategies found within European cities focused on the pedestrianisation of shopping streets to increase the attractiveness and economic prosperity of shopping districts (Topp & Pharoah, 1994). Successful examples include the shopping street, Støget in Copenhagen, Denmark; zona a traffic limitato in Bologna, Italy; and autowrije Binnenstad in Amsterdam, the Netherlands. Traffic was limited to only what was considered necessary, while still allowing access for residents to their apartments, the delivery of goods to stores, and access for tradespeople and building construction.

More contemporary car-free initiatives have expanded their scope beyond shopping districts to include business districts, residential areas, and new mixed-use developments, and they utilise various digital and physical infrastructures (Ricci et al., 2017). In Europe, rather than use the term 'car-free', policies to limit motorised vehicles fall under the category of Urban Access Regulations (UAR). While some may feel there has been limited action to reduce GHG emissions from transport, there are actually over 350 cities in the EU that have implemented some form of UAR (Sadler Consultants, 2020). According to the EU, there are primarily three forms of UAR schemes:

- Urban Toll-roads (or toll-rings), in which drivers are charged a fee to enter certain areas of the city at certain times. Successful examples are London and Stockholm. After London introduced a toll-ring in 2003, congestion decreased by 10–25%. With more commuters shifting from car to public transport, the city also saw bus delay times decline and ridership increase (United States Department of Transportation, 2011). During Stockholm's pilot of a toll-ring from 2006–2007, the city was able to remove 100,000 cars from its urban core (City of Stockholm Traffic Administration, 2009). After a referendum, which saw the residents of Stockholm vote in favour of keeping the toll but the residents in neighbouring municipalities vote against it, the toll-ring was implemented permanently.

- Low Emission Zones (LEZs) are areas where polluting vehicles are regulated or banned. These zones were originally intended to remove heavily polluting vehicles, such as trucks and vans, from cities but are now being extended to other vehicles. For example, the Danish term for a LEZ is a miljøzone (environmental zone), and these are found in four main cities. These zones are controlled by automatic camera-checking of number plates to exclude heavy, diesel-powered vehicles. In Copenhagen, the impact of the LEZ has meant a decrease of 60% in the emission of harmful particles from traffic (Jensen et al., 2011).

- Key Access Regulation Schemes (Key-ARS) are where vehicle access to urban areas is regulated by other means than by payment or emissions. Generally, access to areas is determined by specific criteria, such as vehicle type, time of day, or residential status. However, there is no set definition of this form of UAR, and cities across Europe have utilised various strategies within this group. The following icons (Figure 3.15) describe some of these strategies, which were analysed in Design Experiment 3 and explained in Chapter 6.

PARK N RIDE

RULE-BASED ENTRY
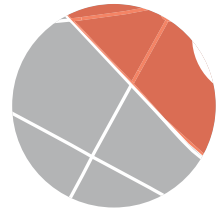
30KM ZONES

FIXED ROUTE ACCESS
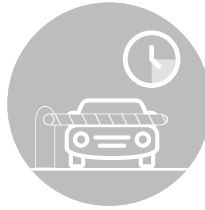
TIMED ENTRY

TRAFFIC ISLANDS
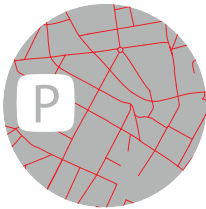
OFF-STREET PARKING

PRE-BOOKED PARKING

RING ROADS

PEDESTRIANISATION

DYNAMIC CURB SPACE
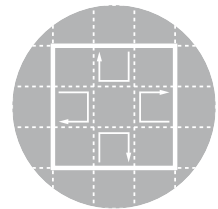
SUPERBLOCKS

CARGO BICYCLES

PARKLETS

MULTI-MODAL

3.5 Chapter summary

In summary, this chapter has described the research programme element of the programmatic design research approach within the research-through-design methodology. This research programme should be seen as a frame to direct the design experiments conducted in this PhD project. During the previous three years, this research programme has also evolved and shifted in scope due to the findings and insights from each design experiment. The research programme has taken the form of a case study of the greater region of Copenhagen, Denmark, which has outlined the current spatial and sociotechnical conditions for transport in the city. By exploring these in comparison to global trends in transport innovation, an overview of the plurality of mobility practices that may form sustainable urban mobilities has been clarified.

The following four chapters present the submitted journal articles that respond to this research programme. These articles form the main body of work of this PhD thesis and may be read in chronological order or as individual explorations.

Figure 3.15:
Icons showcasing the wide range of car-free strategies that cities throughout Europe are using to limit car use.
Robert Martin, 2021

3.6 References

Almanak. (2021). Sun up/down. http://www.suninfo.dk/#

Alonso-González, M. J., Cats, O., van Oort, N., Hoogendoorn-Lanser, S., & Hoogendoorn, S. (2020). What are the determinants of the willingness to share rides in pooled on-demand services? In Transportation (Issue 0123456789). Springer US. https://doi.org/10.1007/s11116-020-10110-2

Browne, M., Allen, J., & Leonardi, J. (2011). Evaluating the use of an urban consolidation centre and electric vehicles in central London. IATSS Research, 35(1), 1–6. https://doi.org/10.1016/j.iatssr.2011.06.002

Bruce, O. (2019). If you care about climate change you should care about micromobility. Micromobility.Io. https://micromobility.io/blog/2019/10/22/if-you-care-about-climate-change-you-should-care-about-micromobility

Bruce, O. (2021). How Micromobility Can Save The World. Micromobility.Io. https://micromobility.io/podcast/112-how-micromobility-can-save-the-world

Chatterton, T., Anable, J., Cairns, S., & Wilson, R. E. (2018). Financial Implications of Car Ownership and Use: a distributional analysis based on observed spatial variance considering income and domestic energy costs. Transport Policy, 65(January 2017), 30–39. https://doi.org/10.1016/j.tranpol.2016.12.007

Chen, T. D., & Kockelman, K. M. (2016). Carsharing's life-cycle impacts on energy use and greenhouse gas emissions. Transportation Research Part D, 47, 276–284. https://doi.org/10.1016/j.trd.2016.05.012

Christiansen, H., & Baescu, O. (2020). TU årsrapport for Region Hovedstaden 2019.

City Changer Cargo Bike. (2019). A Mayor's Guide to Cargo Bikes.

City of Copenhagen. (2016). Copenhagen CPH 2025 - Climate Plan.

City of Copenhagen. (2017). Copenhagen: City of Cyclists.

Clewlow, R. R., & Mishra, G. S. (2017). Disruptive Transportation: The Adoption, Utilization, and Impacts of Ride-Hailing in the United States. In Genome. https://doi.org/10.1139/gen-44-3-401

Crist, P., & Martinez, L. (2018). The Shared-Use City: Managing the Curb.

Dediu, H. (2019). The Micromobility Definition. Micormobility Industries. https://micromobility.io/blog/2019/2/23/the-micromobility-definition

Deutsche Bank. (2019). Mapping the World's Prices 2019.

EEA. (2018). Europe's urban air quality — re-assessing implementation challenges in cities. In EEA Report No 24/2018 (Issue 24). https://doi.org/10.2800/214599

Erhardt, G. D., Roy, S., Cooper, D., Sana, B., Chen, M., & Castiglione, J. (2019). Do transportation network companies decrease or increase congestion? Science Advances, 5(5). https://doi.org/10.1126/sciadv.aau2670

European Commission. (2020). Capital Region of Denmark. https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/capital-region-denmark#:~:text=Complete Regional Profile-,Economy,rest of the Danish regions.

European Environment Agency. (2017). Air Pollution Sources. https://doi.org/10.1201/noe0849398438.ch6

European Environment Agency. (2018). Progress of EU transport sector towards its environment and climate objectives. https://www.eea.europa.eu/publications/progress-of-eu-transport-sector-1

European Environmental Agency. (2016). Passenger transport modal split. https://www.eea.europa.eu/data-and-maps/daviz/passenger-transport-modal-split-8#tab-googlechartid_chart_51_filters=%7B%22row-Filters%22%3A%7B%7D%3B%22column-Filters%22%3A%7B%22pre_config_transport%22%3A%5B%22Bus%22%3B%22Car%22%3B%22Rail%22%5D%3B%22pre_confi

European Environmental Agency. (2019). Air quality in Europe - 2019 report. https://doi.org/10.2800/822355

Eurostat. (2021). Regional gross domestic product by NUTS 2 regions - million EUR. Regional gross domestic product by NUTS 2 regions - million EUR

Expósito-Izquierdo, C., Expósito-Márquez, A., & Brito-Santana, J. (2017). Mobility as a Service. In Smart Cities: Foundations, Principles, and Applications (pp. 409–435). https://doi.org/10.1002/9781119226444.ch15

Fagnant, D. J., & Kockelman, K. M. (2018). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. Transportation, 45(1), 143–158. https://doi.org/10.1007/s11116-016-9729-z

Ferrero, F., Perboli, G., Rosano, M., & Vesco, A. (2018). Car-sharing services : An annotated review. 37(November 2016), 501–518. https://doi.org/10.1016/j.scs.2017.09.020

Firnkorn, J., & Müller, M. (2011). What will be the environmental effects of new free-floating car-sharing systems ? The case of car2go in Ulm. Ecological Economics, 70(8), 1519–1528. https://doi.org/10.1016/j.ecolecon.2011.03.014

Fitt, H., & Curl, A. (2019). E-scooter use in New Zealand: Insights around some frequently asked questions. June, 21. https://doi.org/10.13140/RG.2.2.13510.93761

Freudendal-Pedersen, M. (2020). Sustainable urban futures from transportation and planning to networked urban mobilities. Transportation Research Part D: Transport and Environment, 82(March), 102310. https://doi.org/10.1016/j.trd.2020.102310

Hartikainen, A., Pitkänen, J.-P., Riihelä, A., Räsänen, J., Sacs, I., Sirkiä, A., & Uteng, A. (2019). WHIMPACT: Insights from the world's first Mobility-as-a-Service (MaaS) system.

Hollingsworth, J., Copeland, B., & Johnson, J. X. (2019). Are e-scooters polluters? the environmental impacts of shared dockless electric scooters. Environmental Research Letters, 14(8). https://doi.org/10.1088/1748-9326/ab2da8

Horwitz, A. (2019). Autonomy. Haven Entertainment.

Hyvönen, K., Repo, P., & Lammi, M. (2016). Light Electric Vehicles: Substitution and Future Uses. Transportation Research Procedia, 19(June), 258–268. https://doi.org/10.1016/j.trpro.2016.12.085

Johansson, C., Lövenheim, B., Schantz, P., Wahlgren, L., Almström, P., Markstedt, A., Strömgren, M., Forsberg, B., & Sommar, J. N. (2017). Impacts on air pollution and health by changing commuting from car to bicycle. Science of the Total Environment, 584–585, 55–63. https://doi.org/10.1016/j.scitotenv.2017.01.145

Jones, T., Harms, L., & Heinen, E. (2016). Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. Journal of Transport Geography, 53, 41–49. https://doi.org/10.1016/j.jtrangeo.2016.04.006

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia. https://doi.org/10.1016/j.trpro.2016.05.277

Kent, J. L. (2014). Driving to save time or saving time to drive ? The enduring appeal of the private car. Transportation Research Part A, 65, 103–115. https://doi.org/10.1016/j.tra.2014.04.009

Kent, J. L., & Dowling, R. (2016). "Over 1000 Cars and No Garage": How Urban Planning Supports Car(Park) Sharing. Urban Policy and Research, 34(3), 256–268. https://doi.org/10.1080/08111146.2015.1077806

Københavns Kommune. (2016). Kort om København - Analyser og Tal: København får flere personbiler. 2. https://www.kk.dk/sites/default/files/København får flere personbiler A.pdf

Københavns Kommune. (2017). Parkering 2017: Parkeringsredegørelse. 1–24. https://www.kk.dk/sites/default/files/edoc/b57fcc12-373f-4adf-9d8f-fd73ee0969f-c/54aad0d9-27a6-47c7-a45e-1ec2736fa463/Attachments/17729710-23065597-1.PDF

Københavns Kommune. (2019). Københavns Kommuneplan 2019: Verdensby med ansvar. Kommuneplansstrategi 2018 for Københavns Kommune.

Kornhauser, A. L. (2013). Smart Driving Cars: History and Evolution of Automated Vehicles. Florida Automated Vehicles Summit.

Lamon, P., Kolski, S., & Siegwart, R. (2006). The SmartTer-a vehicle for fully autonomous navigation and mapping in outdoor environments. 9th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, January.

Larco, N. (2018). Ensuring the Benefits of Vertically Integrated MaaS. Urbanism Next (University of Oregon). https://www.urbanismnext.org/news/ensuring-the-benefits-of-vertically-integrated-maas

Marin, J., Petrović, S., Mudrić, M., & Lisičar, H. (Eds.). (2020). Uber—Brave Competition: Legal Analysis of the Nature of Uber Services. Springer Nature Switzerland. https://link-springer-com.zorac.aub.aau.dk/book/10.1007%2F978-3-030-31535-1

Melo, S., & Baptista, P. (2017). Evaluating the impacts of using cargo cycles on urban logistics: integrating traffic, environmental and operational boundaries. European Transport Research Review, 9(2). https://doi.org/10.1007/s12544-017-0246-8

Milakis, D., Gebhardt, L., Ehebrecht, D., & Lenz, B. (2020). Is micro-mobility sustainable? An overwiev of implications for accessibility, air pollution, safety, physical activity and subjective wellbeing. Handbook of Sustainable Transport, c, 12.

Monocle. (2019). Quality of Life Survey: top 25 cities, 2019. https://monocle.com/film/affairs/quality-of-life-survey-top-25-cities-2019/

Mooney, S. J., Hosford, K., Howe, B., Yan, A., Winters, M., Bassok, A., & Hirsch, J. A. (2019). Freedom from the station: Spatial equity in access to dockless bike share. Journal of Transport Geography, 74(August 2018), 91–96. https://doi.org/10.1016/j.jtrangeo.2018.11.009

Moradi, A., & Vagnoni, E. (2018). A multi-level perspective analysis of urban mobility system dynamics: What are the future transition pathways? Technological Forecasting and Social Change, 126(December 2016), 231–243. https://doi.org/10.1016/j.techfore.2017.09.002

Mordor Intelligence. (2021). Ride-Hailing Market Growth, Trends, COVID-19 Impact, and Forecasts (2021-2026). Mordor Intelligence. https://www.mordorintelligence.com/industry-reports/ride-hailing-market

Movia. (2016). Trafikplan 2016.

National Association of City Transportation Officials. (2019). Shared Micromobility in 2018. Nacto, 1–16.

Nieuwenhuijsen, M. J., & Khreis, H. (2016). Car free cities: Pathway to healthy urban living. Environment International, 94, 251–262.

Nourinejad, M., & Roorda, M. J. (2015). Carsharing operations policies : a comparison between one-way and two-way systems. Transportation, 497–518. https://doi.org/10.1007/s11116-015-9604-3

Østli, V., Ørving, T., & Aarhaug, J. (2017). Betydningen av ny teknologi for oppfyllelse av nullvekstmålet. En litteraturstudie.

Region Hovedstaden. (2017). Faktaark om trængselsudfordringen. 2012, 2012. https://www.regionh.dk/til-fagfolk/trafik/Analyser-og-rapporter-om-trafik/transport-for-greater-copenhagen/Documents/Faktaark1_Trængselsudfordringen.pdf

Ricci, A., Gaggi, S., Enei, R., Tomassini, M., Fioretto, M., Gargani, F., Stefano, A. Di, & Gaspari, E. (2017). Final Report Study on Urban Vehicle Access Regulations. https://ec.europa.eu/transport/sites/transport/files/uvar_final_report_august_28.pdf

Ritche, H., & Roser, M. (2021). Emissions by Sector. Global Change Data Lab. https://ourworldindata.org/emissions-by-sector#energy-electricity-heat-and-transport-73-2

Sadler Consultants. (2020). Urban Access Regulations in Europe. https://urbanaccessregulations.eu/userhome/map

SAE International. (2018a). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

SAE International. (2018b). Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies.

Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., Salvo, D., Schipperijn, J., Smith, G., Cain, K. L., Davey, R., Kerr, J., Lai, P. C., Mitáš, J., Reis, R., Sarmiento, O. L., Schofield, G., Troelsen, J., Van Dyck, D., … Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: A cross-sectional study. The Lancet, 387(10034), 2207–2217. https://doi.org/10.1016/S0140-6736(15)01284-2

Scheurer, J. (2013). Measuring Copenhagen ' s public transport accessibility and network performance in a European context. Annual Transport Conference at Aalborg University, 1–20.

Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Keßler, S., & Möser, G. (2018). Analysis of the impacts of car-sharing in Bremen, Germany. 38. https://northsearegion.eu/media/5724/analysis-of-the-impact-of-car-sharing-in-bremen-2018_team-red_final-report_english_compressed.pdf

Sheller, M. (2004). Automotive Emotions: Feeling the Car. Theory, Culture & Society, 21(5), 221–242. https://doi.org/10.1177/0263276404046068

Singleton, P. A. (2019). Walking (and cycling) to well-being: Modal and other determinants of subjective well-being during the commute. Travel Behaviour and Society, 16(September 2017), 249–261. https://doi.org/10.1016/j.tbs.2018.02.005

Soteropoulos, A., Mitteregger, M., Berger, M., & Zwirchmayr, J. (2020). Automated drivability: Toward an assessment of the spatial deployment of level 4 automated vehicles. Transportation Research Part A: Policy and Practice, 136(February), 64–84. https://doi.org/10.1016/j.tra.2020.03.024

Statistics Denmark. (2020a). FAM55N: Households 1 January by region, type of household, household size and number of children in the household.

Statistics Denmark. (2020b). FRKM120: Population projections 2020 by region and time. https://www.statbank.dk/statbank5a/default.asp?w=1536

Statistics Denmark. (2020c). INDKF132: Disposable family income by family type, unit, region and time.

Statistics Denmark. (2021a). FOLK1A: Population at the first day of the quarter by region and time.

Statistics Denmark. (2021b). FOLK1C: Population at the first day of the quarter by time, region and ancestry. https://www.statbank.dk/statbank5a/Selectout/pivot.asp

Stayton, E., & Stilgoe, J. (2020). It's Time to Rethink Levels of Automation for Self-Driving Vehicles. SSRN Electronic Journal, 2019(2016), 391–397. https://doi.org/10.2139/ssrn.3579386

Steckler, B., Lewis, R., & Steckler, R. (2020). Emerging Technologies and Cities: Assessing the Impacts of New Mobility on Cities. https://ppms.trec.pdx.edu/media/project_files/NITC-RR-1249_Emerging_Technologies_and_Cities_hmC49k3.pdf%0Ahttps://scholarsbank.uoregon.edu/xmlui/handle/1794/25193

Stuart, S. C., Kaufman, S. M., & Buttenwieser, L. (2018). The State of Scooter Sharing in United States Cities. New York University Robert F. Wagner School for Public Service, August, 1–5. https://wagner.nyu.edu/files/faculty/publications/Rudin_ScooterShare_Aug2018_0.pdf

The City of Copenhagen Technical and Environmental Administration. (2012). CPH 2025 Climate Plan: A Green, Smart, and Carbon Neutral City. 64.

The Economist Intelligence Unit. (2019). Worldwide Cost of Living 2019 Which global cities have the highest cost of living? In The Economist Intelligence Unit Limited 2018. http://pages.eiu.com/rs/753-RIQ-438/images/WCOL_2018_Free_report.pdf?mkt_tok=eyJpIjoiWXpVd09UY3lObVF4T0RabSIsInQiOiJQUkRNc3R0SUFGcGhPNXlMY0J3OUJhZGlCZjMxTjNYS3Y5OHMwUWMxcXZacWRaR01Xd0oweGFmmd1BOODB0OVNqUlB2bENBUVQxWFc3WEp4QkIwSCsyZZmZJNG5SS1NscHhaMG8yZHc5Nk

The International Energy Agency. (2019). Transport sector CO2 emissions by mode in the Sustainable Development Scenario, 2000-2030. https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030

Topp, H., & Pharoah, T. (1994). Car-free city centres. Transportation, 21(3), 231–247. https://doi.org/10.1007/BF01099212

Urban Creators. (2021). Analyse af forskellige typer delebilisme og deres effekter i København.

Wall Street Journal. (2018). Are We There Yet? The Future of Driverless Cars. https://www.wsj.com/podcasts/wsj-the-future-of-everything/wsj-tech-dlive-are-we-there-yet-the-future-of- driverless-cars/a0c1b34e-fe21-4c19-8b98-8e74b0c0643f

World Health Organization. (2020). World Health Statistics 2020: Monitoring Health for the SDGs. https://doi.org/10.1155/2010/706872

Chapter 4:

Transformations of European Public Spaces with AVs

Co-authors: Bruck, E. M., & Soteropoulos, A

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4.0 Abstract

Connected and automated driving is one of several emerging mobility trends that will fundamentally impact the use and design of public spaces in the coming decades. Urban planners need to rethink whose interests they place at the center of future streetscapes and public spaces and which transport modes are given priority. To ensure that public spaces remain a common spatial infrastructure, design visions provide a vital tool in support of coordinated planning, decision-making, and development. In this light, this article introduces design experiments that highlight possible trajectories for the redesign of public spaces and illustrate new mobility futures in a European context. Set in three varying urban areas within Copenhagen, Denmark, the designs build upon the specificities of local neighbourhood structures and mobility requirements. Through plans and three-dimensional images, the possibilities of integrating AVs into a sustainable transportation system are showcased.

4.1 Introduction

Connected and automated driving is one of several emerging mobility trends that will fundamentally impact the use and design of public spaces in the coming decades. The uptake of transportation network companies (TNCs), such as Uber, has shown that a greater use of shared modes adds more vehicles to the road and shifts pick-up and drop-off locations onto the street, i.e., increasing activity at the curb (Larco 2018: 50; Erhardt et al. 2019). Similar effects were caused by recent waves of dockless micromobility options, such as free-floating bikes or e-scooters, which temporarily led to congested sidewalks and increased spatial demands in public space (Polis 2019). In effect, cities are challenged to rethink the exclusive rights given to cars within their mobility network. Ongoing mobility innovations and expected developments in automated mobility require a reallocation of public space and render existing categories of traffic division and regulatory frameworks outdated (Polis 2019: 12–13).

This article highlights possible trajectories for redesigning public spaces in a European context in order to illustrate urban futures in light of new mobility developments, such as automated mobility and a greater mix of traffic modes. To this end, this article views public space holistically, encompassing traffic infrastructure, public open spaces, as well as adjacent buildings. Considered as such, public spaces may comprise a variety of qualities, functions, and interests that differ, even diverge at times, depending on urban structure and street typology (Bendiks/Degros 2019, Marsden et al. 2020, Karndacharuk et al. 2014). With automated mobility on the horizon, urban planners need to rethink whose interests they place at the centre of their designs and what transport modes are given priority. While industry and policy representatives emphasise traffic advantages, such as safety and efficiency gains, spatial and social implications of automated use cases remain highly uncertain.

While a number of design studies have been made that envision how public spaces could be transformed with automated vehicles, the majority of them refer to North American cities

or no specific urban context at all (e.g., NACTO 2019; Schlossberg et al. 2018; Luo 2019; Sasaki 2018; Meyboom 2019). As a result, there is a lack of contextual design studies that highlight the specificity of urban form, mobility culture, and planning rationale. Just as "total designs" of the modern and postmodern era denied incremental growth of cities and pluralist decision-making (Venturi et al. 1977: 149), design visions for the ongoing mobility revolution need to take contextual factors into account in order to elucidate local implications—opportunities and risks—of new mobility technologies.

In contrast to most North American cities, many cities in Europe have high-density urban structures and compact historic cores. Many of those cities have urban transit networks that are well integrated into their urban fabric, providing the backbone of urban mobility. Beyond that, cities such as Amsterdam or Copenhagen are known for having high percentages of cyclists and pedestrians. While this applies to inner-city districts, it is less the case in urban extension areas developed since the 1950s and '60s or low-density suburban developments where public transport is often difficult to reach and basic services are less accessible by bicycle or foot (van Essen et al. 2009: 13; Alessandrini et al. 2015: 146; Gavanas 2019: 4). Finally, while North American cities are known for expansive off-street parking lots that enclose suburban shopping malls or carve voids into inner-city urban fabrics, European cities are faced with spatial constraints within their inner-city historical districts, where the existing intensity and diversity of uses put pressure on already limited public space (Marsden et al. 2020).

As the early euphoria around automated vehicles' (AVs') near-term market introduction wore off due to technological setbacks, it became more apparent that a longer-term period of mixed traffic conditions lies ahead in which automated vehicles share roads with conventional vehicles and rely significantly on connected services (Mitteregger et al. 2020; Backhaus et al. 2019). During this transition period, AVs will not be operating on the entire road network, but rather on designated streets or confined (geofenced) areas at limited speeds, i.e., special operational design domains that define the functional boundary of level-4 AVs (SAE International 2018). As of yet, few urban design studies have been made for European cities (e.g., Dijkstra & Ionescu 2019; ARUP 2018); they largely show visions of level-5 AVs that assume AVs would operate within the entire traffic network and do not consider mixed traffic scenarios. It is, however, critical that urban planners and designers take into account a possibly long-term transitional period where there will likely be a need

for strategies to manage the reallocation of curb space, a reclassification of street typologies and mode distribution, and the creation of transition zones where vehicles shift from automated to manual modes (Backhaus et al. 2019: 17).

To that end, design visions are a vital tool to support coordinated planning, decision-making, and development and ensure that public spaces remain a common spatial infrastructure contributing to quality of life in cities. This article introduces design experiments on possible public spaces with AVs, conducted by the Danish architectural firm JAJA Architects. Set in three varying urban areas within Copenhagen, Denmark, the designs build upon the specificities of local neighbourhood structures and mobility requirements. Through plans and three-dimensional images, possibilities of integrating AVs into a sustainable transportation system are explored. By doing so, varying urban futures unfold.

4.2 Copenhagen Design Experiments on the Sustainable Deployment of AVs

The following design experiments take place within the northern European capital city of Copenhagen, Denmark. The city is an exemplary context in which to investigate how AVs may impact urban form as part of a sustainable transportation system because Copenhagen is already a model of green mobility. Within the Municipality of Copenhagen, 29% of all trips that either begin or end within its boundary occur by bicycle, 70% of households are car-free, and it has one of the most accessible public transport systems in Europe (City of Copenhagen 2017a; Scheurer 2013). While the city's comparatively sustainable transportation system is enviable, it did not happen overnight. Copenhagen has benefited from a rich planning tradition starting with the Finger Plan from 1947, where urban development proceeded parallel to five "fingers" centred on commuter rail lines, which extend from a "palm" of dense urban fabric within the Copenhagen

municipal boundary (Figure 4.1). Subsequent investments in an underground metro system, as well as an extensive bicycle path network in the city centre, have led to the Municipality of Copenhagen having one of the lowest per capita car emissions in the world (City of Copenhagen 2016). However, despite this, its current transportation system is far from secure. Political tensions in Copenhagen over the space allocated for cycling, cars, and public transport create continual backlashes and conflicts over street space, and the introduction of new mobility modes means that modal distribution is in constant flux (Henderson / Gulsrud 2019). How the introduction of AVs into this debate will affect modal share will be a result of social acceptance, policy, and spatial intervention.
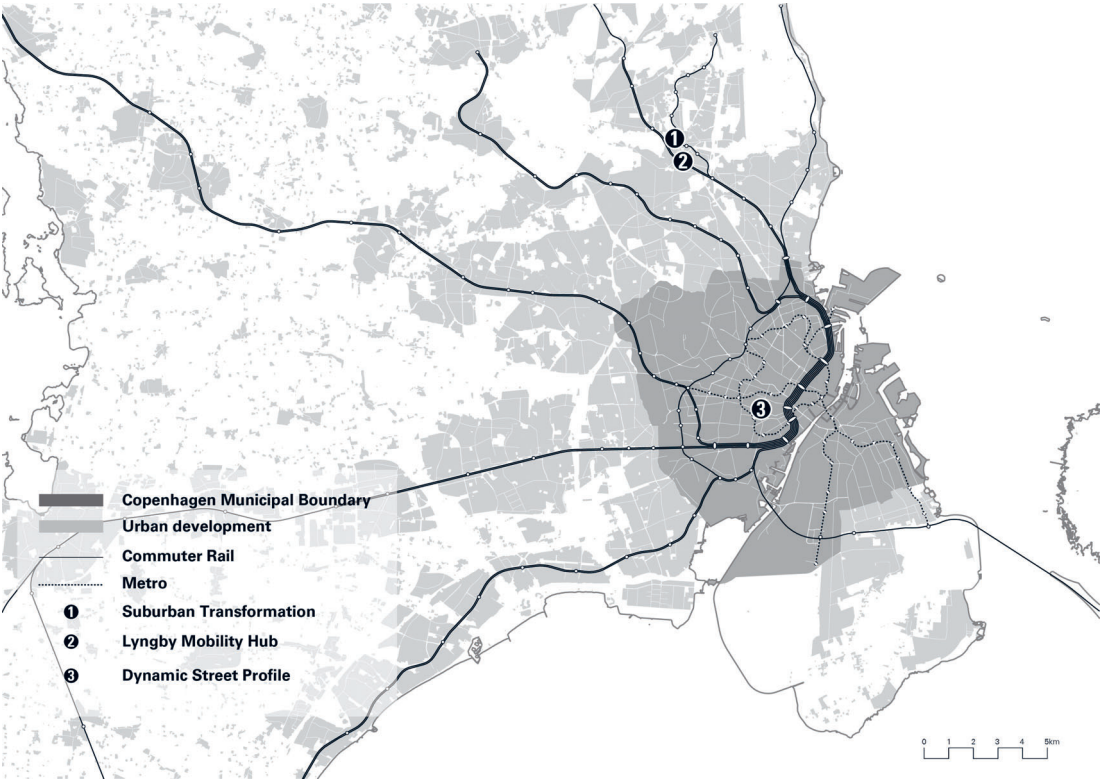
Figure 4.1:
Copenhagen metropolitan plan with project locations. Municipality of Copenhagen highlightedin grey with commuter rails (dashed) and metro (dotted).
Robert Martin/ JAJA Architects, 2018

As one moves along the fingers outside the municipal boundary, one finds a significantly different urban environment. Whereas only 7% of the residential building stock in the Copenhagen Municipality are single-family dwellings, this figure rises to 44% in the surrounding metropolitan region (Statistics Denmark 2019a). This dramatic change in spatial typology reflects a higher rate of car ownership (Statistics Denmark 2019a), sparser population density (Statistics Denmark 2020), and double the amount of space dedicated to road infrastructure per capita (Statistics Denmark 2016).

While the primary consideration of AV introduction in the inner-city will regard preserving and promoting active forms of transport, the real spatial transformative potential of AVs lies in the surrounding suburbs.

To understand how urban form may be affected throughout the Copenhagen metropolitan region by the introduction of AVs, the authors have chosen a future scenario that is radically different from how transport is today. In this scenario, privately owned automobile use has been virtually nonexistent in the dense inner city since the Copenhagen Municipality banned private car use. Instead, residents and commuters move through a combination of public transport, fixed-route AV shuttles that run along arterial roads, and micromobility devices that range in size from kick scooters to electric cargo bicycles. Residents living in less dense suburbs outside of the inner city still have the option to own a car. However, most have chosen to adopt a tailor-made Mobility-as-a-Service (MaaS) package that includes, among other offerings, an on-demand, free-floating AV shuttle that provides a last-mile connection to nearby public transport nodes. The technological development of AVs has reached a bottleneck and, therefore, they have only been deployed with Level 4 capabilities (SAE International 2018). This technical barrier means that AVs may only operate within geofenced areas where the density allows for the commercial viability of creating and maintaining the high-definition 3D maps required for AVs to function safely. Therefore, motorised/conventional cars remain necessary for edge-case situations where AVs cannot operate, and traffic may be a mix of AVs and traditional automobiles.

To visualise what effect this scenario may have on existing public spaces and streetscapes in Copenhagen, the authors offer three design studies in different urban contexts within the city. The first takes place in the suburb of Lyngby, approximately 10 km north of the city centre, and investigates how a shift to a shared AV system may offer spatial opportunities to dissolve spatially segregated boundaries and provide communal amenities in an otherwise highly privatised monofunctional area. The second design study explores how the existing commuter rail station in Lyngby could be adapted to integrate an AV shuttle system with adequate space for pick-up and drop-off that supports an efficient multi-modal transport system. The final design study investigates a modal space reallocation in an inner-city street where an increase in micromobility traffic places pressure on the spatial demands of a traffic artery used for a fixed-route AV shuttle.

4.2.1   Rethinking the Suburb

While inner Copenhagen enjoys low car use, this dramatically changes as one moves into the surrounding suburbs where population density falls as single-family dwellings replace apartment buildings. The site of this exploration, the northern suburb of Lyngby, is a typical example. Despite enjoying excellent commuter rail connections and a decent bus service, this suburb still has over double the inner city's car ownership rate at 549 cars per 1,000 residents (Statistics Denmark 2019b). Compared to the inner city, which hosts an array of public and semi-public amenities on its streets, the suburbanisation of Lyngby has created an urban condition wherein all functions occur within the boundary of the block, hidden behind high hedges or fences. This clear separation between public and private arenas has left the public realm somewhat vacant. Whereas in historical contexts, suburban streets would be full of playing children, now due to safety concerns the road lays empty, with only the occasional passing car, idling service van, or visitor's parked car (Figure 4.2 and 4.4). The division between private property and the public realm has become so stark that the only interface between the two is the driveway. A resident may, therefore, never actually physically touch the public domain, entering their vehicle within the boundary of their property before driving away to their destination.

Figure 4.2:
Existing residential street. High hedges and narrow sidewalks represent a public space that is designed only for automobile use.
Robert Martin/ JAJA Architects, 2018

JAJA's proposed adaptation to the street attempts to dissolve the suburban rationality of separation by spatially repurposing the abundant space given to automobiles in the road for new public amenities (Figure 4.3). The primary motivation behind this redistribution of space comes from both a radical decrease in traffic demand as residents shift from privately owned vehicles to shared AV shuttles and the technological ability of AVs to safely navigate intricate driving lines, always obey speed limits, and give way to pedestrians and children. Instead of providing a lane in each direction with enough room to overtake a parked car adjacent to the curb, the road width is limited to that of a conventional single-vehicle lane for both traditional and autonomous vehicles.

The road then undergoes a series of manipulations to ensure that there a right of access to all existing driveways remains so that residents still have the option to own a private car, and that there is space for vehicles travelling in opposite directions to give way or pass each other (Figure 4.5). The residual space provides opportunities to install fixed amenities that both foster community, such as vegetable gardens, outdoor dining areas, community houses, or sport facilities, and support the new multi-modal transport system, such as a covered waiting area for AV shuttle services and parking space for shared micromobility devices. The boundary of these new facilities is not limited to a demarcated area. Instead, through safely negotiated and temporal use, the facilities can spill out into the road area, better utilising the space for active functions that can stop when a vehicle passes.

Figure 4.3:
Proposed residential street. Life returns to the street as redundant road area is transformed into communal amenities. Fenced boundaries are dissolved as properties reconnect with the street's activities rather than blocking them out.
Robert Martin /JAJA Architects, 2018
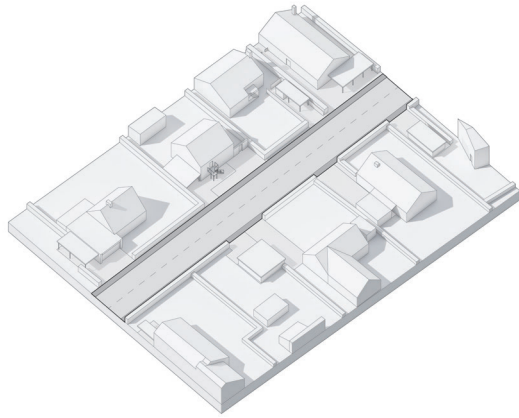
Figure 4.4:
Existing street axonometric. The majority of the streetscape is dedicated to car use.
Robert Martin/ JAJA Architects, 2018
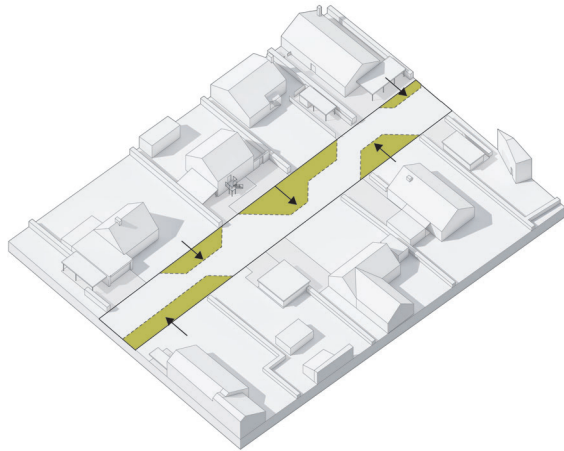
Figure 4.5:
Expansion of public space. By reducing the street profile to one way, but still providing spaces to overtake and connect to driveways, new pockets of space can be designate for communal amenities.
Robert Martin/ JAJA Architects, 2018
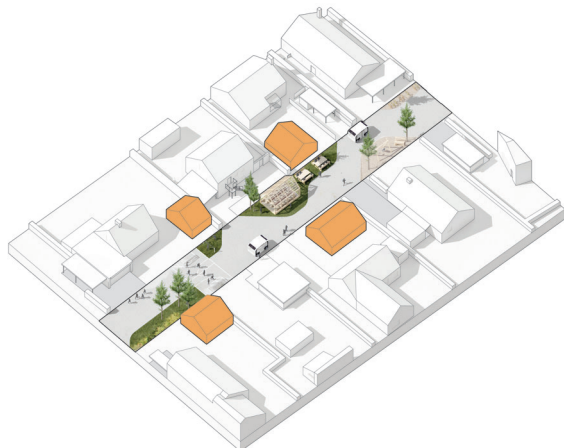
Figure 4.6:
Programming. New ancillary dwellings are placed adjacent to communal activity areas to dissolve the boundary between public and private along the street.
Robert Martin/ JAJA Architects, 2018

Through an increase in public amenities, an opportunity arises to renegotiate the threshold between public and private. With more functions becoming shared, the abundance of open space behind individual boundaries, especially adjacent to the street, are re-zoned to create new ancillary dwellings (Figure 4.6 and 4.7). These new dwellings vary in ownership models and typology, with many of the functions outsourced to the communal facilities to attract a diverse range of new residents not suited to the homogenous rows of single-family dwellings otherwise found in the area. The increase in population would drive demand for AV shuttles, reducing the operating costs of the system while increasing the efficiency and desirability of the system.

Figure 4.7:
Proposed site plan. Newly inserted buildings and functions operation at different scales disrupt the suburban grib and creates a gradient of zones with different levels of privacy.
Robert Martin/ JAJA Architects, 2018

4.2.2 From Train Station to Mobility Hub

Multi-modal transport routes are often proclaimed to be the sustainable alternative to car trips, where commuters shift between higher and lower-capacity modes to reach their destination. However, this system is reliant on the proximity to transport nodes and available connecting routes only found in higher-density urban fabrics. The challenge of transporting commuters to network nodes in lower-density suburbs is referred to as the first/last-mile gap. Shared AV shuttle systems, as used in the previous design example, are often discussed as one solution to this common problem. Conceptually, this system operates similarly to already established car-pooling services such as Uber, Lyft, and Via, where users' ride requests are bundled and assigned into trips with similar pick-up and drop-off points. However, the success of these services is highly dependent on population density, the concentration of users, and the similarity of users' departure and arrival points and times. By focusing the departure or arrival point around public transport nodes, the shared AV shuttle system's efficiency is improved by accumulating similar trips. Nevertheless, points of friction are likely to occur at the interchange between modes as existing transport infrastructure has not been designed to enable AVs. The following design explores how adaptations to the existing train station at Lyngby can spatially support this new technology as users

Figure 4.8:
Existing street view at Lyngby station. Commuters are separated from the station entrance by a series of roads that must be crossed in sections.
Robert Martin/ JAJA Architects, 2018

seamlessly transfer between AV shuttle and high-capacity train.

The existing Lyngby station is a train station on the Hillerød radial of the Finger Plan. It is centrally located within the suburb but is spatially segregated from the suburb's high street and mass of urban functions by a large bus terminal, two lanes of traffic, parking lots, and an elevated highway to the east. The station's entrance is located underneath the highway, where it is also connected to a shopping centre with 15 retail stores, including two supermarkets (Figure 4.8 and 4.10).

The primary design challenge for this proposal was to create adequate space for the pick-up and drop off areas for commuters arriving by AV shuttles. While many advocates for AVs suggest that excess parking space will be released from sharing these vehicles, studies have shown that the spatial requirements for pick-up and drop-off areas will be high as they should be designed to accommodate maximum inflow at peak times (Sinner et al. 2018). Therefore, the main decision made in the design is to consolidate the seven lanes of traffic that run in both directions adjacent to the station into one 150m long designated area for transfers (Figure 4.11). This area follows design principles found at airport kiss-and-ride locations where one lane is used for parking (coloured light orange), one is used to wait for a free space (coloured orange), and the final one is used to pass by when finished (coloured red). Due to a dramatic decrease in traffic demand from sharing and AV platooning, as well as increased safety

Figure 4.9:
Proposed street view at Lyngby station. A permeable station edge allows commuters to enter the stations from multiple points while an information-rich digital screen provides wayfinding connections to standing by AV shuttles. Robert Martin/ JAJA Architects, 2018
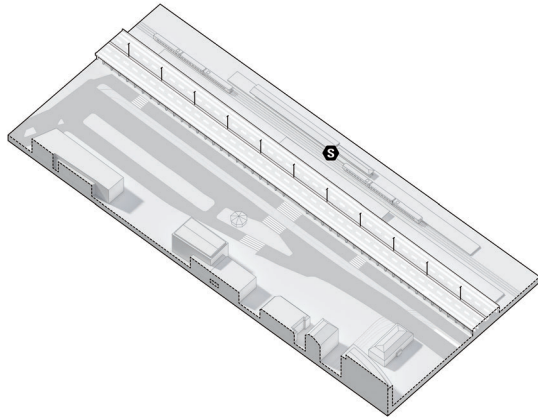
Figure 4.10:
The existing station axonometric highlights the many obstacles to enter the station.
Robert Martin/ JAJA Architects, 2018
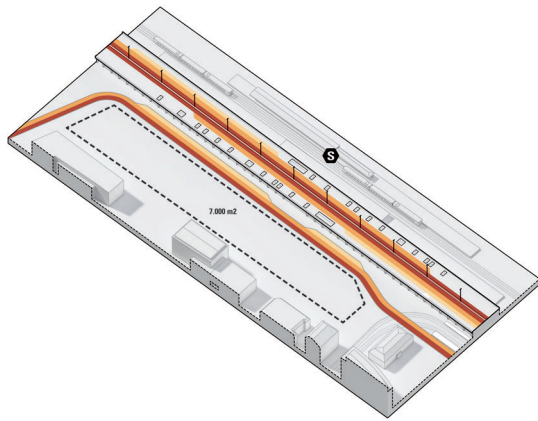
Figure 4.11:
Redistribution of infrastructure. Pick-up/drop-off areas are condensed into two areas: the first area lies adjacent to the station entrance while the second is located on the elevated highway.
Robert Martin/ JAJA Architects, 2018
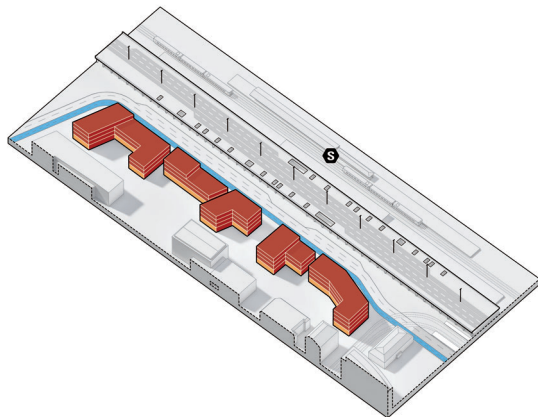
Figure 4.12:
Urban infill and densification. New mixed-use development is situated in the publicly owned former bus terminal. The new development not only adds spatial qualities and increases density, but the revenues from the development can be utilised by the municipality to fund public programs.
Robert Martin/ JAJA Architects, 2018

from connected vehicles, this principle is replicated on the elevated highway, which runs directly above the train station entrance. Cuts in the structure create vertical movement between the highway and the station, allowing more accessible routes to the station for residents who have to access it from the west.

The spatial benefit of this consolidation is the release of over 7,000 m² of publicly owned land directly adjacent to the train station. In this proposal, that space is utilised by constructing a mixed-use development of residential apartments, commercial space, public amenities, as well as parking facilities for micromobility devices adjacent to new separated bicycle paths (Figure 4.12). The proposed development takes its form by closing the urban block to the east, creating a series of public and semi-public courtyards of varying scales that respect the existing pathways between the station and the high street (Figure 4.13). The final move is to relocate the shopping centre from underneath the highway to the new mixed-use development. The now-vacant space is transformed into a permeable covered thoroughfare that gives access to the station platforms directly from the pick-up/drop-off area. There are also seated waiting areas and digital wayfinding screens that help commuters find their designated shuttle.

Figure 4.13:
Proposed site plan. A new mixed-use development completes the urban block, utilising the former bus terminal. AV shuttle pick-up and drop-off areas have been consolidated to be directly adjacent to the station and the reduced-capacity highway.
Robert Martin/ JAJA Architects, 2018
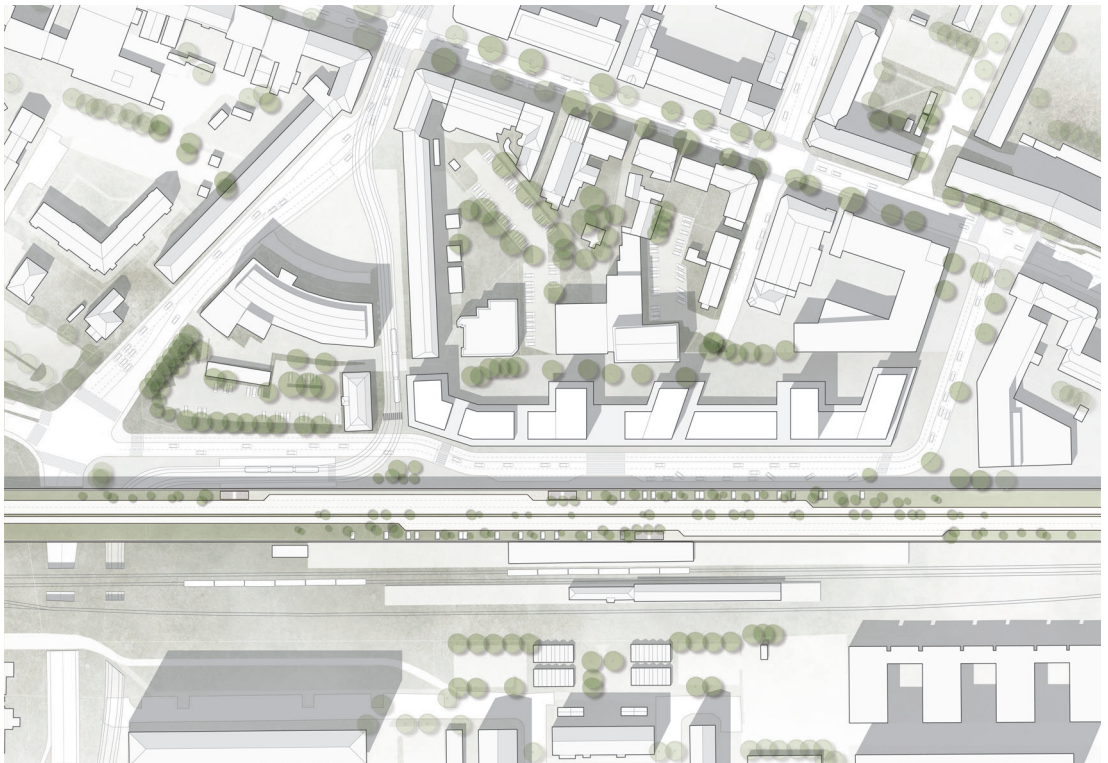
4.2.3   A New Dynamic Streetscape

Unlike the suburbs of Copenhagen, where road space is abundant due to car-centric planning principles since World War II, the inner city has to negotiate modal allowance within a narrow spatial context designed centuries before the invention of the car. Subsequent additions of transport modes have constrained pedestrian sidewalks and cycle paths to minimal widths. At the same time, two-way roads, car parking, and bus stops occupy the majority of space between buildings. Within inner Copenhagen, only 7% of citywide road space is taken up by cycle paths. In contrast, road space for cars amounts to 66% (City of Copenhagen 2017b), even though modal trips are split almost evenly between bicycles and cars. Overcrowding on cycle paths is already a severe problem in Copenhagen and a significant impediment for increasing the city's incredibly high levels of cycling (Danish Parliament 2016). Unfortunately, it is not merely an option to widen cycle paths on artery roads as the constrained context is filled by the spatial provision of on-street car parking. AVs promise to release this space through the logic of never having to park (Duarte and Ratti 2018). However, this logic ignores the new spatial demands of AVs. We expect that AVs will increase door-to-door mobility and will, therefore, require equal space to embark or alight from the vehicle.

Figure 4.14:
Existing street view at Lyngby station. Commuters are separated from the station entrance by a series of roads that must be crossed in sections.
Robert Martin/ JAJA Architects, 2018

The conflict between AVs and cycle paths has given rise to significant design considerations in JAJA's urban scenario below, where a projected substantial increase in modal share by micromobility devices has resulted from the banning of privately owned vehicles in the city centre. The street under investigation is Gammel Kongevej (Figure 4.14), which is one of the principal shopping streets in Copenhagen and dates back to the beginning of the 17th century. The street extends for 1.8 km from the western edge of the city centre and provides a direct connection to the western suburbs. The street is only 18 m wide from one building façade to the other, so it currently utilises a three-lane system to accommodate all the spatial demands from different modes. One lane each is dedicated to vehicle traffic in either direction; a third lane is located in an alternating manner on either side to allow for curbside parking and for buses to stop (Figure 4.16). While this system provides space for vehicle modes, it is an underutilisation of space (Figure 4.17), and the spatial implication of these fixed infrastructures means that cycle lanes along the street are below the legal minimum width at only 1.5 m (City of Copenhagen 2013). How then could pick-up/drop-off areas be integrated into this already crowded street while allowing an extension in the width of cycle lanes to meet increased travel demand by micromobility services?

This design proposal utilises advancements in the Internet of Things (IoT), where embedded sensors, lights, and transmitters allow vehicles to communicate with road infrastructure. Rather than having fixed street infrastructure that designates

Figure 4.15:
Proposed street view along Gammel Kongevej. A man safely departs his AV shuttle onto the dynamic street surface, knowing that the coming cyclist will pass outside the boundary of the designated area.
Robert Martin/ JAJA Architects, 2018

Figure 4.16:
Existing street design. Existing zone plan of the street highlighting the spatial preference toward automobiles over bicycles regardless of their equal modal share.
Robert Martin/ JAJA Architects, 2018

fixed traffic island   fixed traffic island

every 10 minutes

only when demand
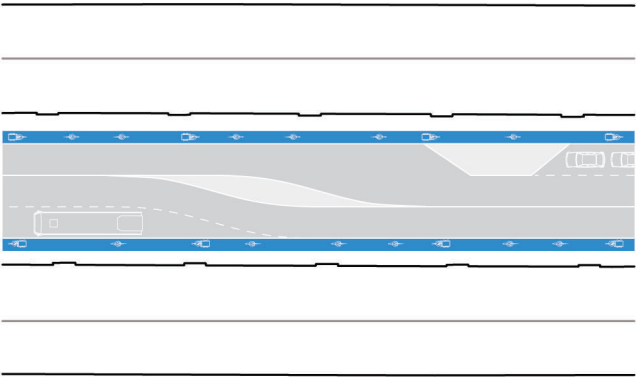
Figure 4.17:
Functional requirements. Analysis of function demand. Fixed spatial infrastructures underutilize the space.
Robert Martin/ JAJA Architects, 2018
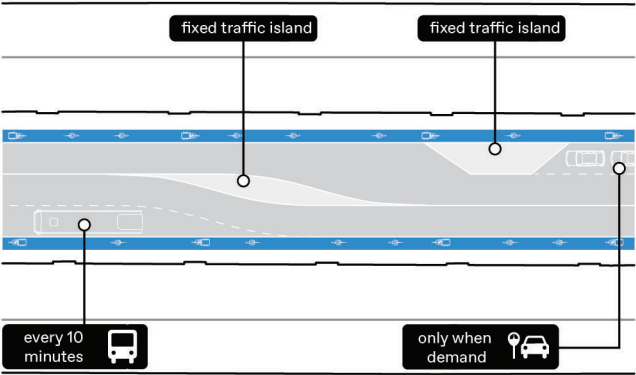
Figure 4.18:
Dynamic street design. Rather than have a fixed shuttle stop, dynamic hop-on/hop-off areas can pop up along the street as user, vehicle, and road surfaces are connected through the IoT.
Robert Martin/ JAJA Architects, 2018
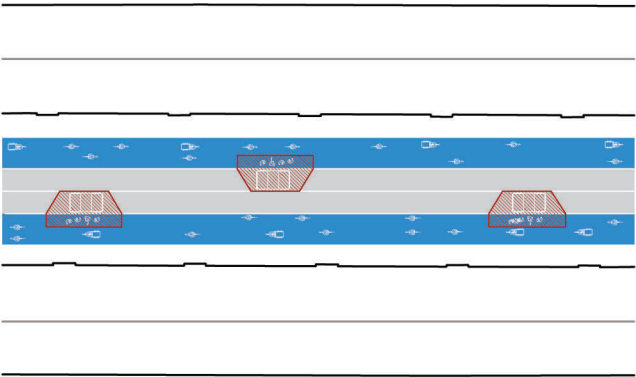
where certain functions should occur, the streetscape is enhanced with a grid of LEDs that can reallocate space in accordance with changing traffic volumes. Fixed on-street parking and bus stops are removed, allowing the third lane of the street to no longer be needed, and that space is redistributed to widen the cycle lanes to 3.5 m in both directions (Figure 4.19). AV shuttles do not have fixed stopping points but are free to stop anywhere along the road (Figure 4.18). When a user makes a request to be picked up or dropped off, GPS coordinates of the location are communicated between the mobile device, AV shuttle, and the road in preparation for the stop. As the AV shuttle approaches the destination, the road surface changes at the threshold between the road and cycle path to indicate a buffered area where passengers will alight and gives safe notice to incoming micromobility devices to avoid the buffered area. Modes using the cycle path will continue to have the right of way, although half of their expanded lane will now be demarcated as a buffered passenger zone. Enforcement of this buffered zone is enabled through sensors in the road that track infringements through in-vehicle unique identifiers (UID). These road sensors monitor the user's duration in the buffered zone, and the road surface only returns to normal once the user has left

Figure 4.19:
Proposed street plan. The removal of one lane of traffic has allowed the bicycle lane to be doubled in width. The new road surface is embedded with IoT-connected LEDs that can create temporary buffered zones to allow users to safely enter and exit AV shuttles that still allow bicycles to pass by.
Robert Martin/ JAJA Architects, 2018
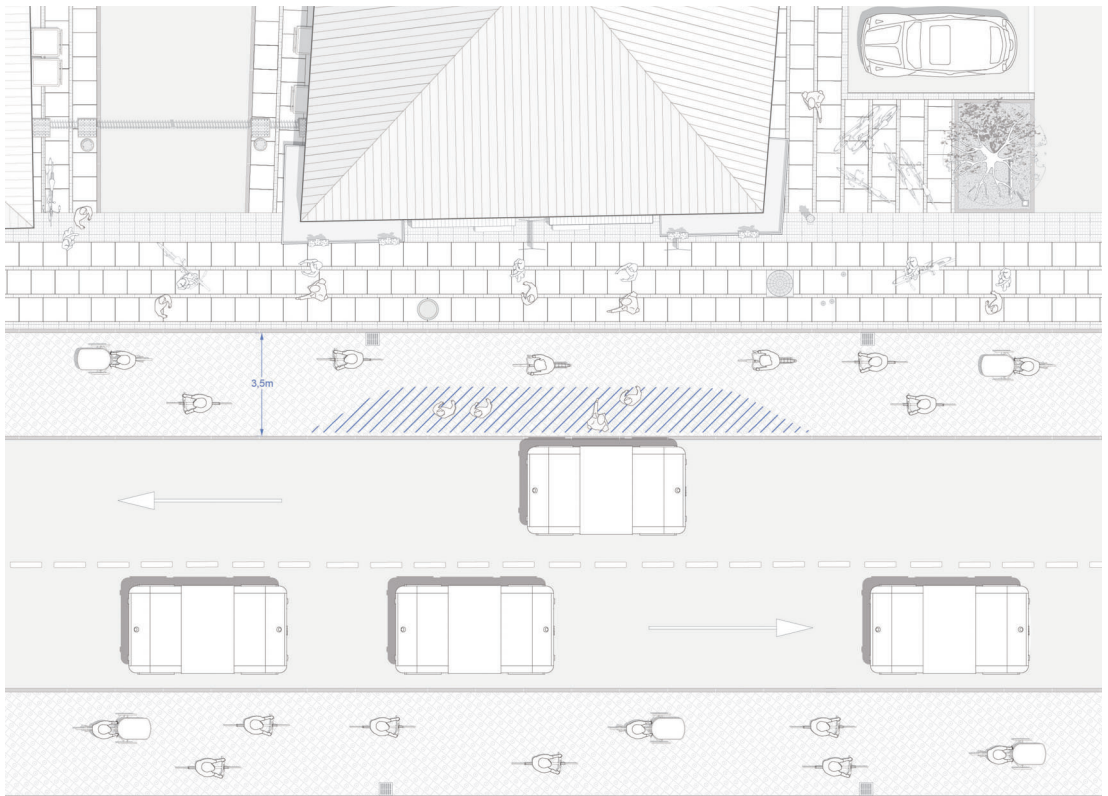
the area. It is important to note that in this design, priority is given to modes using the cycle path, so this form of traffic is not halted due to AV service. Modes using the cycle path will have the right of way, while AV shuttles will stand on the road rather than adjacent to the curb, knowing that other connected AV shuttles will anticipate the stop and wait or re-route if necessary.

4.3 Conclusion

This article presents design experiments on possible public spaces with AVs, i.e., how AVs may contribute to changes in urban form if integrated as part of a sustainable transportation system. The design experiments were set in three different areas within Copenhagen, Denmark, and focused on:

1) How a shift to a shared AV system could present an opportunity to dissolve spatially segregated boundaries and provide communal amenities in an otherwise highly privatised monofunctional area in the suburb of Lyngby

2) How an existing commuter rail station in Lyngby could be adapted to integrate an AV shuttle system with adequate pick-up and drop-off areas that support an efficient multi-modal transport system

3) How the reallocation of space toward active travel modes could take shape in an inner-city street of Copenhagen, where increasing micromobility traffic aggravates the pressure of spatial requirements on a traffic artery used for a fixed-route AV shuttle.

These design experiments highlight that changes in urban design and infrastructure development related to the introduction of automated mobility services may vary significantly according to urban form and street typology. The functional requirements of a street design vary within a city and are determined by factors such as adjacent land use types, position within the urban street network, diversity of travel modes and users, as well as designated speed limits.

Due to the expectation that automated vehicles could generate greater demand, the pressure on street designs to facilitate higher numbers of vehicles per hour could increase

(Larco/Tierney 2020). Thus, competing demands for street space might be aggravated in the future. The urban design challenge will rest even more than today in finding a suitable balance between catering to demands for more efficient movement and demands for attractive spaces. This is especially the case on inner-city streets where competing spatial demands are already high and heterogeneous. Dynamic solutions, e.g., demand-based hop-on/hop-off areas, as presented in the design experiment for an inner-city street in Copenhagen, could pose a design-based measure that complements mobility management policies.

However, determining factors for adequate design interventions are highly contextual, both in material and political terms, and therefore require well-attuned solutions. To this end, local design experiments are critical in envisaging how to reallocate potentially freed-up space—due to a reduction in on-street parking—and tap into urban development potentials. As cities need to reevaluate the prioritisation of modes and find solutions to safe mode interaction, design visions can elucidate the benefits of street design changes for the urban environment and surrounding land use. This also includes the question of how to spatially integrate modes and enhance a multi-modal transport system, as shown in the design experiment on the transformation of the Lyngby train station into a mobility hub. Visualising potential changes can serve as a critical tool that supports negotiation and collaboration between affected stakeholders or contrasting interests.

In addition, considering the long-term transition period leading toward automation, it is critical to reflect upon which changes could be implemented irrespective of vehicle automation and which changes need further investigation. Short-term issues that cities should address include strategies for curb management, prioritising pick-up and drop-off zones over on-street parking, increased cycling and micromobility lanes, as well as enhancing the integration between shared mobility and transit networks. While the influx of new mobility options is at a peak and the prospect of automated mobility does not appear to be fading, uncertainties regarding any trend's durability prevail. As a means of acting in uncertainty, cities are increasingly adopting pilot projects. Not merely to test AVs (see chapter 6), but also in order to test nighttime pick-up and drop-off zones (Washington, D.C.), clearing curbs from commercial loading during designated times of day (New York City), or geofencing streets with high levels of active mobility interaction so as to avoid conflict with ride-sourcing services (San Francisco) (Schaller 2019).

What is lacking are more comprehensive programs that would usher in the transition from public spaces characterised by parked cars and travel lanes to those that can be used flexibly and cater to shared modes. However, in order to develop guidelines on spatial requirements of new mobility options such as shared automated vehicles, further research and more comprehensive studies are necessary. Questions regarding the spatial demand for pick-up and drop-off activities or short-term parking need more thorough investigation through simulation and modelling. However, these should be developed in collaboration with design methodologies and visualisations that are better able to integrate the context of local development goals and neighbourhood characteristics.

4.4 References

Alessandrini, A., A. Campagna, P. Delle Sitte, F. Filippi, and L. Persia 2015. "Automated Vehicles and the Rethinking of Mobility and Cities," Transport Research Procedia 5, 145–160. https://doi.org/10.1016/j.trpro.2015.01.002.

ARUP 2018. FlexKerbs. Evolving Streets for a Driverless Future, report, London. https://www.arup.com/-/media/arup/files/publications/f/flexkerbs_roads-for-the-future_arup.pdf (Mar 23, 2020).

Backhaus, W., S. Rupprecht, and D. Franco 2019. Road vehicle automation in sustainable urban mobility planning, practitioner briefing, Cologne. https://www.eltis.org/sites/default/files/road_vehicle_automation_in_sustainable_urban_mobility_planning_0.pdf (Aug 19, 2020).

Bendiks, S. and A. Degros 2019. Traffic Space is Public Space: A Handbook for Transformation. Zurich: Park Books.

City of Copenhagen 2013. Focus on cycling: Copenhagen guidelines for the design of road projects, trans. Joan Høberg-Petersen, Copenhagen. https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1133 (Aug 4, 2020).

City of Copenhagen 2016. CPH 2025: Climate Plan. Roadmap 2017–2020, Copenhagen. https://urbandevelopmentcph.kk.dk/artikel/cph-2025-climate-plan (Aug 4, 2020).

City of Copenhagen 2017a. Copenhagen: City of Cyclists. The Bicycle Account 2016, Copenhagen. https://kk.sites.itera.dk/apps/kk_pub2/index.asp?mode=detalje&id=1698 (Aug 4, 2020).

City of Copenhagen 2017b. Cycle Track Priority Plan (2017–2025), Copenhagen. https://idekatalogforcykeltrafik.dk/wp-content/uploads/2019/05/cykelstiprioritering-splan-2017-2025pdf-_1620.pdf (Aug 4, 2020).

Dijkstra, R. and A. I. Ionescu 2019. "Streets and Robocars," in Robocar and Urban Space Evolution: City changes in the age of autonomous cars, edited by A. I. Ionescu, V. M. Sanz, R. Dijkstra. TU Delft, 31–39.

Erhardt, G. D., S. Roy, D. Cooper, B. Sana, M. Chen, and J. Castiglione 2019. "Do transportation network companies decrease or increase congestion?." Science Advances (5) 5, eaau2670. https://doi.org/10.1126/sciadv.aau2670.

Gavanas, N. 2019. "Autonomous Road Vehicles: Challenges for Urban Planning in European Cities," Urban Science (3) 61, 1–13. https://doi.org/10.3390/urbansci3020061.

Henderson, J., and N. M. Gulsrud 2019. Street Fights in Copenhagen: Bicycle and Car Politics in a Green Mobility City. London/New York: Routledge.

Karndacharuk, A., D. J. Wilson, and R. Dunn 2014. "A Review of the Evolution of Shared (Street) Space Concepts in Urban Environments," Transport Reviews 34 (2), 190–220. https://doi.org/10.1080/01441647.2014.893038.

Larco, N. 2019. "Urbanism Next: Autonomous Vehicles and the City," in Robocar and Urban Space Evolution: City changes in the age of autonomous cars, edited by A. I. Ionescu, V. M. Sanz, R. Dijkstra. TU Delft, 47–53.

Larco, N. and G. Tierney 2020. "Impacts on Urban Design," in Multilevel Impacts of Emerging Technologies on City Form and Development, edited by A. Howell, K. Lewis Chamberlain. Portland, OR: University of Oregon, 115–141.

Luo, Y. 2019. "From Transportation Infrastructure to Green Infrastructure—Adaptable Future Roads in Autonomous Urbanism," Landscape Architecture Frontiers (7) 2, 92–99. https://doi.org/10.15302/J-LAF-20190209.

Marsden, G., I. Docherty, and R. Dowling 2020. "Parking futures: Curbside management in the era of 'new mobility' services in British and Australian cities." Land Use Policy (91), 104012. https://doi.org/10.1016/j.landusepol.2019.05.031.

Meyboom, A. L. and L. Vass 2019. Driverless urban futures: A speculative atlas for autonomous vehicles. New York, NY/London: Routledge.

Mitteregger, M., E. M. Bruck, A. Soteropoulos, A. Stickler, M. Berger, J. S. Dangschat, R. Scheuvens, and I. Banerjee 2020. AVENUE21. Automatisierter und vernetzter Verkehr: Entwicklungen des urbanen Europa. Berlin: Springer Vieweg. https://doi.org/10.1007/978-3-662-61283-5.

NACTO 2019. Blueprint for Autonomous Urbanism: Second Edition, New York. https://nacto.org/publication/bau2/ (Aug 19, 2020).

POLIS 2019. "Macro Managing Micro Mobility: Taking the long view on short trips," discussion paper. https://www.polisnetwork.eu/document/macromanaging-micromobility/ (Aug 19, 2020).

SAE International 2018. "Surface vehicles recommended practice. J3016. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles." https://www.sae.org/standards/content/j3016_201806/ (Aug 19, 2020).

Sasaki 2018. Shifting Gears: An Urbanist's Take on Autonomous Vehicles. https://issuu.com/sasakiassociates/docs/shifting_gears_20180531_-_issue (Aug 19, 2020).

Schaller, B. 2019. Making the Most of the Curb: Managing passenger and parcel pick-up and drop-off on congested city streets, report, Brooklyn, NY. http://www.schallerconsult.com/rideservices/makingmostofcurb.pdf (Aug 19, 2020).

Scheurer, J. 2013. Measuring Copenhagen's public transport accessibility and network performance in a European context. Annual Transport Conference at Aalborg University, 1–20. Aalborg. https://www.researchgate.net/publication/286814648_Measuring_Copenhagen%27s_public_transport_accessibility_and_network_performance_in_a_European_context (Aug 4, 2020).

Schlossberg, M., W. Riggs, A. Millard-Ball, and E. Shay 2018. Rethinking the Street in an Era of Driverless Cars, Urbanism Next, University of Oregon. https://doi.org/10.13140/RG.2.2.29462.04162.

Sinner, M., P. Khaligh, and U. Weidmann 2018. "Consequences of Automated Transport Systems as Feeder Services to Rail. SBB Fund for Research into Management in the Field of Transport," IVT Schriftenreihe (184). https://doi.org/10.3929/ethz-b-000266025.

Statistics Denmark 2016. AREALDK1: Land by land cover, region and unit (DISCONTINUED). https://www.statbank.dk/statbank5a/default.asp?w=1920 (Aug 4, 2020).

Statistics Denmark 2019a. BIL800: Families disposal of vehicles by region and pattern of disposal. https://www.statbank.dk/statbank5a/default.asp?w=1440 (Aug 4, 2020).

Statistics Denmark 2020. FOLK1A: Population at the first day of the quarter by region, sex, age and marital status. https://www.statbank.dk/KM1 (Aug 4, 2020).

Van Essen, H., X. Rijkee, G. Verbraak, H. Quak, and I. Wilmink 2009. "¬EU Transport GHG: Routes to 2050? Modal split and decoupling options," Paper 5, draft. https://www.eutransportghg2050.eu/cms/assets/4823DraftPaper-5.pdf (Aug 19, 2020).

Venturi, R., D. S. Brown, and S. Izenour 1982. Learning from Las Vegas, 5th edition. Cambridge, MA: MIT Press.

Chapter 5:

AV Futures or Futures with AVs?

Bridging Socio-technical Imaginaries and a Multi-Level Perspective of Autonomous Vehicle Visualisations in Praxis

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5.0 Abstract

Current depictions of autonomous vehicle (AV) futures are produced primarily by automobile manufacturers that largely reflect and reinforce existing sociotechnical systems in a 'business as usual' model that frames this technology within a narrative of crisis and technological salvation. This article argues for a more complex analysis of AV futures in which images are understood as vessels for sociotechnical imaginaries that direct and delimit what we think is possible in the future. Through an analytical framework incorporating automobility, transitions, and imaginaries, I explore how depictions of AVs frame the technology as responding to various system pressures over time through a comparative analysis of two actors. The analysis suggests that regime actors deploy visual discursive material as a tool of regime stability or change to benefit their own agendas. The intention of the article is not to anticipate current trajectories but is a methodological exploration of how policymakers and planners can interpret AV visualisations. Therefore, the paper concludes with a discussion of the implications of these imaginaries for future transportation systems. It further suggests that policymakers and planners need to take a more active role in the development of AV futures by paying much more attention to the latent meanings behind AV visualisations and working collaboratively with those who produce them.

5.1 Introduction

Up to the present, academic discourses surrounding AVs have focused on safety, privacy, and accountability (Bonnefon et al., 2020), travel behaviour and land use (Soteropoulos, Berger and Ciari, 2019), as well as road capacity, fuel efficiency, and emission reduction (Milakis, Van Arem and Van Wee, 2017). However, these discussions take place within the silo of academia, leaving AV imaginaries to be produced primarily by incumbent regime actors, such as car manufacturers. These often take the form of visual depictions that frame AVs within the same paradigm as automobiles, leading them to become a simple substitution of existing transportation systems, rather than a radical transformation. Therefore, this paper is a methodological exploration to understand how these types of imaginaries can either aid or prevent transitions to new transportation systems.

New technologies such as AVs do not appear 'out of nowhere'—their development is entangled within complex sociotechnical systems (Fraedrich, Beiker and Lenz, 2015). This new technology will be implemented after being formed from the imaginaries of a variety of system actors. Alternative AV imaginaries also exist, utilising discrete innovation pathways to conceive of AVs not as part of existing transportation systems but as components within new sustainable constellations. Therefore, society should avoid deterministic assumptions as to whether or how AVs will shape future cities, and instead focus on the plurality of imaginaries that currently exist to unpack why and how we want this technology to be a part of our lives.

Although AVs are a transportation technology that has dominated news headlines throughout the past decade, the idea is almost 75 years old (Kornhauser, 2013). From an engineering perspective, the vision of AVs is an arrangement of technologies whose aim is to replace some or all of a driver's actions and responsibilities (Lamon, Kolski and Siegwart, 2006). Early visions of the technology required to achieve this task involved the integration of equally smart cars and highway systems (Wetmore, 2003). However, with the advent

of machine learning, AVs are now seen as independent arte-facts, able to navigate environments through a multitude of sensors, and computer processing power. AVs "see" the world through different data points that include GPS coordinates, radio waves, light detection, and sound to build up compre-hensive representations of the vehicle and its surroundings. Developers of AV technology claim that their detection sys-tems "can 'see' a vehicle's environment even better than human eyesight" (Burke, 2019). However, others have pointed out that there will always be an ontological gap between the world as it is, and the world as modelled by a computer vision system (Cheney-Lippold, 2019).

From a socio-technical perspective, visions of AVs typically lie outside of the artefact, critiquing existing forms of transport, addressing social needs, and solving many of the issues asso-ciated with traditional cars (Blyth et al., 2016). These visions of AVs have become a magic bullet for issues such as traffic deaths and injuries, pollution, congestion, and even climate change (Taiebat et al., 2018). So alluring has the promise of AVs become, that their role is not only imagined in relation to transport, but also in terms of national economic devel-opment, security and global leadership (Mladenović et al., 2020). However, these promises assume that AV technology is advanced and well-integrated and ignore the transition period until that point and ignore possible unintended con-sequences such as intensifying traffic volume, urban sprawl, and increasing inequality between the haves and have-nots (Cohen and Cavoli, 2019).

Nomenclature surrounding the technology is mixed. Common terms, including driverless car, self-driving vehicle, autono-mous vehicle, and connected and autonomous vehicle are more prevalent in public forums (Cavoli et al., 2017). The term "automated vehicles" appears more in technical documents, such as the SAE Levels of Driving Automation (SAE Inter-national, 2018), which is the benchmark for AV technology categorisation. Each term appears to serve some visions of autonomy and disempowers others. For example, many AV developers utilise the SAE taxonomy to describe their sys-tem's limitations legally, while at the same time advertising the vehicle as "fully self-driving" instead of "automated" to boost the public's and policy regulators' perception of its capabilities (Stilgoe, 2017).

The development of the SAE Levels represents a vision of autonomy in which driving tasks are delegated between human and machine by engineering standards. They range from zero assistance (Level 0) to full and unconditional automation (Level

5). The SAE Levels have contributed to a public narrative in which automation increases linearly, gradually removing human involvement and responsibility (Stayton and Stilgoe, 2020). However, Ganesh (2020) has found that rather than replacing human involvement, automation merely displaces it. Within autonomy, humans are designated micro-jobs to observe the machine and take responsibility. This can take the form of the passenger having to take control at a moment's notice or remote workers in developing countries teleoperating the machine from afar. This handover between machine and human creates murky legal responsibilities where the user is held accountable if there is an accident (Pattinson, Chen and Basu, 2020), and questions the very premise that this technology can ever truly be autonomous.

Within the SAE taxonomy, Levels 4 and 5 are the only vehicles to be considered to have full self-driving capability. The difference between these two levels is the environment in which the vehicle is expected to operate. While Level 4 has limitations on the environment and will only operate if certain conditions are met, a Level 5 system is expected to perform "under all conditions". Although Level 5 may be the future of AVs that the public mostly anticipates, it remains an unattainable end goal (Stayton and Stilgoe, 2020). The underlying technology of autonomy, machine learning, requires the tight identification of tasks and problem definitions in order for it to be 'solvable' (Stilgoe, 2018). All AV systems will need to operate within some form of constraint. By accepting this limitation, and only operating at Level 4 within Operational Design Domains (ODDs)[5.1], AV companies are having to rethink about where they are deploying AVs and why. However, there is a marked difference in the approach that different companies take. On the one hand, companies such as Waymo are acknowledging AVs' limitations in dealing with spatial complexity and choosing to deploy their autonomous service in contextually suitable Phoenix, Arizona, because the city's easily navigable grid-like structure and temperate climate. While on the other, companies such as Volvo and Tesla, problematise the outside world as something to be forged in a way that is best suited to autonomous driving (Sage, 2016; Stilgoe, 2017).

The idea for this paper came from a reflection on the results of a year-long research project that I completed while working as an architect for the Danish architecture studio JAJA Architects. The project investigated how AV integration may enable the transition towards sustainable transportation systems within the Copenhagen region. The output of the project was three scenarios depicting different AV futures, each illustrated through a series of diagrams, drawings, and

5.1 Operational Design Domains are "conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence f absence of certain traffic or roadway characteristics."(SAE International, 2018, p. 14)

visualisations of moments. The project was presented to a range of audiences, including academics, policymakers, and the general public, in various formats. Of the different mediums, the visualisations became the focal point of most discussions. Hajer and Versteeg (2019) describe this phenomenon as a discourse of experiencing the alternative, in which 'far from my bed'-type issues such as climate change can be addressed by presenting an alternative rather than through cognitive persuasion. In other words, the visualisations provided a way for the audience to discuss a vision of AVs that was embedded with concrete materialities with which they could connect to their everyday life.

Based on these experiences, the purpose of this paper is to discuss different AVs visualisations, considering their embeddedness within a sociotechnical system, to understand their consequences for the future of transport systems and mobility. By providing an understanding of AV visualisations based on imaginaries, aspects that enable or constrain transitions to sustainable transportation systems in the future can be identified. The paper begins by outlining my analytical framework, which synthesises concepts of a system of automobility, elaborated through a multi-level perspective (MLP) of transportation transitions, and sociotechnical imaginaries into an automobility–imaginaries–transitions triad. In this context, I explore how depictions of AV systems frame the technology within competing sociotechnical imaginaries that respond to various system pressures through a comparative analysis of AV futures from the German automobile company The Daimler Group and the Danish architecture studio JAJA Architects. Based on these considerations, I discuss these depictions and their implications for future sustainable transportation systems and then provide conclusions and an outlook regarding the need for and lines of future inquiry in the field.

5.2 Analytical Framework

5.2.1 The System of Automobility

To develop my analytical framework, I first establish my understanding of AVs as an emergent technological phenomenon within the system of automobility. The system

of automobility is a concept used to understand the roots of the twentieth-century car system and how the social, economic, and commuting practices afforded by the car established and exerted self-expanding domination across the globe (Urry, 2005). Established at the end of the nineteenth century, the system immediately offered great social and economic opportunities. The effectiveness of the system did not merely come from the replacement of existing modes such as horse-drawn carriages, bicycles, or public transport, but through new forms of movement (Adams, 1999; Vigar, 2013). Car journeys became a new type of mobility, where flexibility and speed vastly expanded physical proximity and thereby encouraging latent travel demand (Stradling, Meadows and Beatty, 2000).

However, these opportunities were limited by the infrastructure available for cars. Governments reacted by extending administrative powers and expanding car infrastructure, spatially and temporally splintering urban territories into districts of home, work, and leisure in the pursuit of further economic gain (Freudendal-Pedersen, Hannam and Kesselring, 2016). The ensuing mass production of the car made freedom and independence available to the many, and as more and more sought to take advantage, the car became cherished as a prized possession that embodied status and cultural significance (Sheller, 2004; Mom, 2014).

Throughout the twentieth century, the system of automobility took hold, and those ambitions of independence turned into dependence (Goodwin, 1995). Car use was no longer seen as a comfort but as a necessity for economic and social participation (Lyons, 2015). Society became forced to tolerate the consequences of mass car ownership and car use in the form of parked cars dominating the streets of urban centres, congestion and traffic jams, health-threatening pollution, and the financial burden of car maintenance (ibid.). Despite these negative consequences, the dominance of the system has been continually supported and reinforced by a perceived correlation between economic growth and car use (Mackinnon, Pririe and Gather, 2008). Global economies became tied to not only the movement of people but also the car's greater ecosystem of resource extraction, supply chains, manufacturing, sales, and infrastructure construction. To foster economic growth, policymakers ignored the negative externalities and physically and socially reconstructed cities in favour of the car (Norton, 2010). In spatial terms, the system of automobility became, quite literally, cemented into our cities' structures through a vast array of material infrastructures including street profiles, highways,

parking garages, petrol stations, and urban layouts (Zijlstra and Avelino, 2012).

To summarise, a central premise of my understanding of AVs is that the technology is an emerging phenomenon within a sociotechnical system in which our global economies, planning policies, cityscapes, and everyday livelihoods are entangled, all around a practice of privately-owned car use. Furthermore, the system of automobility has become so ingrained in our societies that it dominates our present and future understanding of the urban (Hajer and Versteeg, 2019). One must only look at any recent blockbuster film set in a future utopian or dystopian landscape to see the prevalence of the car, in some form or another, in our understanding of what is to come. Depictions of AV futures cannot escape this: Any discussion of AV imaginaries takes place within the framework of cars, set as either a reaction or compliment to them. Therefore, the system of automobility is used as one of the lenses for the interpretation of AV imaginaries because its legacy implies that a transition will require systems-level rethinking, rather than focus on the AV as an individual object.

5.2.2 A Multi-level Perspective of the System of Automobility

While the system of automobility may appear irreplaceable, discussions surrounding climate change, urbanisation, and road safety have highlighted the need for a transition to a new transportation system (Köhler et al., 2019). Geels (2012) introduced the MLP as a framework to understand transitions in complex sociotechnical systems that offers analytical insight into how AVs may enable such a transition. The MLP differs from other cause-and-effect–type processes by describing transitions not as a result of one single driver, but as the 'result of the interplay of multiple developments at three analytical levels' (Geels, 2012, p. 472). The three analytical levels, which refer to diverse constellations of increasingly hierarchical stability, are sociotechnical landscapes (the uppermost level and the context that frames both niche and regime dynamics), sociotechnical regimes (established practices and rules that enable and constrain various incumbent actors, that reproduce existing systems, and that are barriers to change), and niche innovations (radical innovations that deviate from existing regimes that may be either adopted

Figure 5.1:
An exemplary representation of the
system of automobility using the MLP.
Robert Martin, 2020

Landscape
• Urban Layouts
• Political Ideologies
• Societal Values
• Macroeconomics
• Urbanisation

Regimes
• Automotive lobby groups
• User preferences
• Governmental tax incomes
• Cultural significance of cars

Dynamic interaction
between layers

Niches
• Sharing economy
• Electric vehicle batteris
• MaaS
• Autonomous Vehicles
• ITS
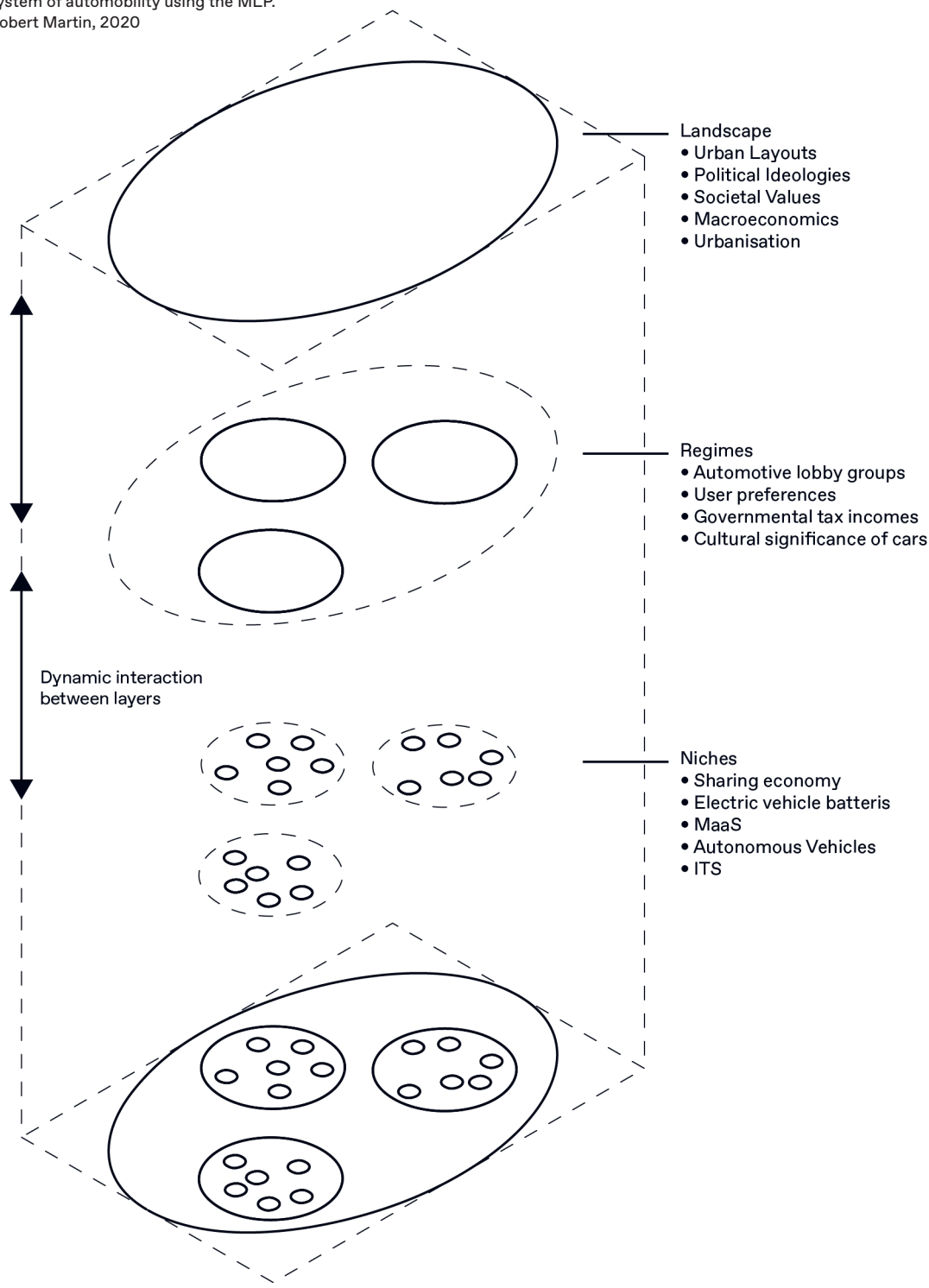
by the regime or replace it). Figure 5.1 shows an exemplary representation of the levels, visually showcasing analytical elements of the system of automobility without displaying the dynamic processes between them (see Moradi and Vagnoni, 2018, for a more comprehensive analysis of the system of automobility using the MLP).

An MLP on the system of automobility displays an entangled sociotechnical system arranged around a dominant auto-mobility regime (Geels, 2012). The regime is currently facing destabilising forces from landscape pressures such as climate change debates, urbanisation, road traffic deaths, and pollution, as well as emerging niche innovations such as AVs, micromobility devices, the sharing economy enabled through the diffusion of information and communications technology (ICT), and 'car-free' traffic planning. The regime is resisting these forces through instrumental, discursive, and institutional forms of power (Geels, 2014). These include governmental strategies to support automobile industries, exploitation of the cultural associations of the car with freedom, and induced demand for mobility. Some authors have also suggested that the automobility regime faces pressures from competing sub-altern regimes such as rail, bus, and cycling (Hodson, Geels and Mcmeekin, 2015; Turnheim et al., 2015).

The analytical framework of the MLP is a particularly helpful approach when focusing on how new technologies, such as AVs, enter sociotechnical systems through the 'niche' level. They do so through a long-term view on the co-evolution of technology and society involving multiple dimensions (industry lobby groups, consumer preferences, governmental policy, infrastructure and spatial arrangements, and cultural values) as well as considering the interactions among different groups of stakeholders. It demonstrates how new technologies, such as AVs, never enter sociotechnical systems alone, but rather are formed by the complex interactions among social groups, various actors, and landscape pressures. Importantly, the MLP covers, on the one hand, how the automobility regime may exploit AVs to stabilise its own position in the system through lock-in measures and resistance to change, and how other system actors deploy them to replace the regime, on the other hand.

5.2.3 Sociotechnical Imaginaries as Drivers of Transitions

Having grounded my analytical perspective in the understanding of AVs as an emerging niche innovation within an entangled sociotechnical system arranged around a dominant automobility regime, I turn to how sociotechnical imaginaries work as drivers of transitions. Transitions may occur through interactions between the different levels of the MLP. The nature of these interactions can be described as transition pathways (Geels and Schot, 2010). Transition pathways detail how niche innovations are developed over time by various social actors and how they contribute to replacing current regimes or stabilising incumbents. Generally, the dynamics that create transitions are that niche innovations build up internal momentum, changes at the landscape level generate pressure on the regime, and the destabilisation of the regime makes a window of opportunity for niche technologies to emerge (ibid.). However, the nature of the transition, and whether it moves towards a more sustainable system, depends on the timing and nature of the interaction among the different levels and the actors that drive the interaction.

Different entry points exist to understand this interrelation. Sociotechnical imaginaries (Jasanoff, 2015) offer one such explanation by illustrating 'the myriad of ways in which scientific and technological visions enter into the assemblages of materiality, meaning, and morality that constitute robust forms of social life' (Jasanoff, 2015, p. 4). Bridging the imaginary and the material, the concept of sociotechnical imaginaries is crucial in understanding how AVs are made and why. Sociotechnical imaginaries also allow us to understand technology in terms of storytelling, visualisation, and imagining, as these are the mediums in which new technologies are developed, stabilised, and propagated by different social groups and actors (McNeil et al., 2017). For example, Sadowski and Bendor (2018) have argued that large ICT companies utilise sociotechnical imaginaries to create a vision that presents the 'Smart City' within a narrative of crisis and technological salvation from the services that it offers. The authors have further claimed that these companies use this tool for 'directing and delimiting what we can imagine as possible' (2018, p. 5) to suit their corporate agenda and crowd out alternative visions for the future. Often, multiple imaginaries co-exist simultaneously, with actors competing for the dominant sociotechnical imaginary and, therefore, the basis on how the technology will eventually be used (Jasanoff, 2015).

Combining the above concepts into an automobility–imaginaries–transitions triad enables a deeper understanding of how depictions of AV futures are framed, developed, and deployed. By synthesising these concepts into a single analytical framework, I am better able to analyse the discursive meanings found in AV depictions by setting them alongside the broader context of automobility, landscape pressures, parallel niche innovations. Furthermore, this framework provides both a temporal and spatial overview of how these imaginaries change over time. Therefore, the AV depiction is not understood as a future, but as a figurative Band-Aid deployed to preserve existing regime constellations.

The next section explains the empirical evidence that I use within this framework to understand the consequences of AV imaginaries for the future of the transport system and mobility.

5.3 Methodology: A Visual Discourse Analysis of Two Competing Sociotechnical Imaginaries

This analysis is based on two data sets of visualisations from competing system actors regarding the role of AVs within a future transportation system. The first set of data is visual material from the German multinational automotive corporation Daimler. The material was collected from Daimler's Global Media website using the search term 'autonomous vehicle' within the date range 2015–2019 to see how the company's sociotechnical imaginary has evolved over time. Although the company had previously advertised vehicles with autonomous features to assist driving, this period marks when

Daimler advertised fully autonomous vehicles. The search request returned 445 images associated with Daimler's press releases. Three images were selected based on their depiction of AVs within a future urban environment. The rest were discarded because they represented event pictures, exterior and interior design, safety features, and charts.

The second set of data is visual material collected from a six-month research project conducted in 2017–2018 called Copenhagen 2050 (CPH2050), which looked into the spatial implications of AVs via scenario planning methods. The project was funded by the Danish Arts Foundation and was a collaboration between JAJA Architects and the engineering consultancy firm NIRAS. The visual material used for the data was produced at JAJA, where I was working as an architect at that time. The visualisations were based on inputs from transport planners, employees from local municipalities, representatives of public transport authorities, architects, landscape architects, and users. In total, nine visualisations were produced throughout the project. The data used in this article is a selection of three visualisations, which were chosen because AVs were depicted in part of the image.

After gathering the material, I analysed each image using visual discourse analysis (VDA; (Albers, 2013). Visual discourse analysis can unfold how images are used as a medium to construct and disseminate sociotechnical imaginaries. The method is based on semiotics (Hodge and Kress, 1988), discourse analysis (Gee, 2006), and the grammar of visual design (Kress and van Leeuwen, 2006) and is concerned with studying the structures and conventions within visual texts to identify how certain social norms are created in their production. Sociotechnical imaginaries 'reside in the reservoir of norms and discourses, metaphors and cultural meanings' (Jasanoff and Kim, 2009, p. 123), and VDA was therefore used to trace how individual images work within broader systems of meaning to uncover the underlying approach to AV development of each company. Within VDA, three modalities can contribute to a critical understanding of an image: (1) technological, which involves the various physical apparatuses used to create and view the image; (2) compositional, which references the formal structures of the image and compositional elements that denote visual content; and (3) social, which connotates social and political ideologies (Rose, 2010). As this study was not concerned with the apparatus employed to produce the image, the research only focused on the compositional and social modalities of the image through the use of semiology (Jewitt and Oyama, 2011) and compositional interpretation (Rose, 2010, p. 35).

Visualisation	First-order Sign (Denotation)	Second-order Sign (Connotation)
Mercedes-Benz F015 Luxury in Motion: Shared space in tomorrow's world. 2015 (Figure 2)	Vehicle	Luxury, futuristic, smart
	Darkened windows	Privacy, autonomy
	Missing rear-view mirrors	Autonomy
	Sensor/laser	Safety, trust
	Pedestrian	Safety, trust
	Digital sidewalk	Safety, trust
	Contemporary architecture	Futuristic, high-density, less space
	Trees/grass on buildings	Environmental awareness, less space
Futuremobility: Bosch and Daimler join forces to work on fully automated, driverless system. 2017 (Figure 3)	Robotaxis	Sustainability, accessibility, mobility, future
	Single-occupancy AV	Privacy, future, mobility
	AV shuttle	Sustainability, accessibility, mobility, future
	Parked AVs	Service, availability, future
	Metro	Sustainability, multimodality
	Cyclists	Sustainability, multimodality, micromobility
	Pedestrians	Sustainability, accessibility, liveability
	Delivery van	Logistics, integrated systems
	E-scooter	Sustainability, multimodality, micromobility
	Urban life	Liveability
	Pedestrian crossing	Safety
	Traffic lights	Safety
	Bicycle lanes	Safety, sustainability, micromobility
Bosch and Daimler: Metropolis in Califenoria to become a pilot city for automated driving. 2018 (Figure 4)	American flag	Nationalism
	Subway sign	Localism, sustainability, multimodality
	Doughnut sign	Cultural
	Larger vehicles	Success, luxury, privacy
	Taxis become private cars	Success, luxury, privacy
	Missing cyclists	Sustainability, accessibility, multimodality
	Palm trees	Localism, culture
	People of colour	Multiculturalism, localism
JAJA -CPH2050: Reconnecting the city. 2018(Figure 5)	Bicycle	Sustainability, multimodality
	Pedestrian crossing	Safety
	Pedestrian	Safety, trust
	AV shuttle	Sustainability, future, technology, safety
	Retail space	Commercial activity, liveability
	Yacht	Recreation, wealth, liveability
	Children	Safety, inclusion
	Contemporary architecture	Future, wealth, gentrification
	Traffic signs	Safety, law enforcement
JAJA - CPH2050: Suburban Transformation. 2018 (Figure 6)	AV shuttle	Sustainability, future, technology, safety
	Children	Safety, inclusion
	Residential architecture	Family, wealth, aspiration
	Solar panels	Sustainability, self-reliance
	Runners	Active lifestyle, diverse demongraphics
	Communal dining tables	Community
	Father with child	Family, lifestyle, socioeconomic status
	Greenhouse	Sustainability, community, self-reliance
	Play equipment	Community, family

Smart phone	Connected, technology, future
Bicycle	Sustainability, multimodality
Bicycle lane	Safety, multimodality
Pedestrian crossing	Safety
Pedestrian	Safety, trust
AV shuttle	Sustainability, future, technology
Traveller	Accessibility, efficiency
Commuter	Accessibility, efficiency, reliability
Train	Sustainability, multimodality
Trees	Environmental awareness, liveability
Real-time information screens	Connected, technology, efficiency, future

JAJA - CPH2050: Fram train station to mobility-hub. 2018 (Figure 7)

Table 5.1:
Results of semiotic analysis.
Robert Martin, 2020

By interpreting images through both a semiotic and compositional lens, I am able to explore how system actors attempt to engage with system pressures within their presentation of AVs as well as their perceived hierarchy of system elements that may reinforce or destabilise an existing regime. Through semiotic analysis, a coding scheme was established that identified the individual elements within each image as 'first-order signs', or what was being depicted in a denotative sense. A second coding scheme was produced by relating the 'second-order signifiers, or what values the signs express, to themes identified in the niche and landscape levels of the MLP. Alternatively, compositional interpretation ignores symbolic representation and mostly examines the composition of the physical world itself. Compositional analysis scrutinises images' content, colour, spatial organisation, and focalisers to understand the significance of the images.

Tables 5.1 and 5.2 display a limited selection of results from the semiotic and compositional analysis. Both methods produced far more results, but for clarity and efficiency, only results that were used further in the discussion are included. Together, these tables provide a temporal and spatial overview of the landscape of automobility, system pressures, and parallel niche innovations, as well as how actors construct their imaginaries through them.

Visualisation	Colour	Image Volume
Mercedes-Benz F015 Luxury in Motion: Shared space in tomorrow's world. 2015 (Figure 2)	• Stark difference in saturation levels between what is old and new. • High colour value for AV and futuristic buildings. • Low colour value for pedestrian, trees, and older buildings.	• Road space occupies the most volume of the image. • AV is the central figure (focaliser).
Futuremobility: Bosch and Daimler join forces to work on fully automated, driverless system. 2017 (Figure 3)	• Uniform colour saturation. Not trying to create a single focus, but displaying the messiness of urban life. • Bicycle lanes highlighted in red.	• The street is the focaliser, rather than a single object.
Bosch and Daimler: Metropolis in Califenoria to become a pilot city for automated driving. 2018 (Figure 4)	• Same as above except that bicycle lanes are coloured green.	• Same as above
JAJA -CPH2050: Reconnecting the city. 2018(Figure 5)	• Colour saturation from near to far. • High colour value for close objects, which decreases with distance from the viewer. • Warm colours used throughout. • Small amounts of green overtones throughout the middle of image.	• The image is split into three vertical parts to create a one-point perspective. • Pedestrian access is the focaliser of the image.
JAJA - CPH2050: Suburban Transformation. 2018 (Figure 6)	• Colour saturation is uniform. • High colour value for all objects. • Mix of warm and dark colours throughout image. • Abundance of green throughout image.	• The bulk of the image is in the foreground of children playing football. • Communal activities are staged in the mid-ground. • AV is placed in the background.
JAJA - CPH2050: From train station to mobility hub. 2018 (Figure 7)	• No saturation difference between old and new. Mostly dark tones of red, grey, and yellow. Suggests late afternoon. • High colour value for AV and futuristic buildings.	• The image is split into three horizontal parts. • The perspective is split with the train station sign as the centre point. • Transport is bundled on the left, pedestrians on the right.

Table 5.2:
Results of compositional analysis.
Robert Martin, 2020

Images Lines	Viewing Position	Light
• Pedestrian is connected to the AV through sensor beams. • Pedestrian is walking out of the image. • Perspective draws away from historic buildings towards futuristic architecture.	• Eye-height, placing the viewer within the scene. • Relation of intimacy between the viewer and the AV.	• Daylight is used to highlight the AV.
• The linearity of the image creates focus along the road.	• Viewer is placed above the scene. • No relation between the viewer and the scene. The viewer is seeing 'another place', a vision for the future.	• Daylight is cast over the entire image.
• Same as above.	• Same as above.	• Same as above.
• Two main lines concentrate along the pedestrian crossing. • Horizontal line of road crosses the image. • Building perspective leads to harbourfront.	• Eye-height, placing the viewer within the scene. • Separation of viewer from other objects indicates they are not part of the activity.	• Daylight creates a strong contrast in the image. The AV is cast in shadow, barely visible. Urban life is the focus in the image.
• One-point perspective along street line. • Objects create horizontal stripes of activity along the image.	• Eye-height, placing the viewer within the scene. • Separation of viewer from other objects indicates they are not part of the activity.	• Daylight illuminates the image evenly. It is not used to highlight any one part of the scene.
• Two main lines of the image. • Line to the left bundles transport: cycle lane, AV drop off, highway, and train line. • Line to the right connects pedestrians to the s-tog station.	• Eye-height, placing the viewer within the scene. • Relation of intimacy between the viewer and the woman holding the phone.	• Daylight is used to highlight pedestrians and train service. AVs are placed within relative shadow.

5.4 Competing Visions for Future Transport Systems

In analysing the visualisations produced by Daimler and JAJA, I identified that they are not only instances of marketing material or research outputs: They also present frameworks for the future that the companies want to create. Both companies offer a narrative about the salvation of cities through AVs that aligns itself with ongoing landscape discourses. Although there are strong similarities between the stories presented by the two companies, I found clear differences in the preferential treatment of certain systems over others, how signs relating to different sociotechnical elements are deployed, and the way in which each company's depictions present either regime stabilisation or replacement. These narratives, their relationship to landscape pressures, and their different utilisation of AVs are described below, as are their consequences for future transport systems and mobility.

5.4.1 AV Futures from the Incumbent, Daimler

5.4.1.1 Responding to Landscape Discourses

Publicly, the general stated motivation to pursue AVs is to improve road safety. This coincides with the landscape pressure and cultural reaction to the physical harm that the system of automobility imposes on societies around the world. Globally, road traffic accidents cause approximately 1.35 million deaths each year and are the leading cause of death among young people (World Health Organization, 2018). Similarly to 'jaywalking' campaigns of the 1930s, in which coalitions of automobility regime actors exercised their collective power to remove pedestrians from the streets in the name of road safety (Norton, 2007), incumbent regime

Figure 5.2:
Mercedes-Benz F 015 Luxury in Motion: A virtual zebra crossing indicating to pedestrians on the side of the road that it is safe to cross. Source: The Daimler Group, 2015.

actors are currently casting blame on the human driver as a means to accelerate AV development in an effort to vindicate the system of automobility itself.

While each image analysed includes signifiers connotating safety, Daimler's first presentation of an AV future (Figure 5.2) presents them in a way that prioritises vehicle use. Compositionally, the image applies a traditional way in which cars are advertised: The focaliser of the image is the vehicle, which is both the central figure in the image and highlighted through a stark contrast in colour between it and the rest of the scene. Furthermore, the AV sits both physically and metaphorically separated from the rest of its environment. Traditional safety elements that would connect a human driver to the outside world, such as rear-view mirrors and transparent windows, are noticeably absent in this vehicle. Instead, the notion of safety is implied through a system of computer vision, machine learning, and sensors that have instructed the vehicle to stop and that project an illuminated pedestrian crossing that allows the man dressed in business attire to cross the road safely. In this depiction, the passenger, if there is one, is cleared of all responsibility of safely manoeuvring, with complete control being outsourced to the AV system. By removing what incumbent regime actors see

as the weakest link in the system of automobility, the human element, this sociotechnical imaginary presents a future of continued automobile use devoid of road traffic accidents through the application of AV technology.

The landscape development of urbanisation also presents particular challenges to the automobility regime in Figure 5.2. Throughout the twentieth century, automobile-enabled suburbanisation was seen as a way to reduce urban problems (Geels, 2005), which became the signature characteristic of the system of automobility. The continued increase in car use required an ever-increasing suburban periphery, which reinforced itself by only being accessible by car. This trend is expected to be reversed in the twenty-first-century, with projections anticipating that 68% of the global population will live in dense urban centres by 2050 (United Nations Department of Economic and Social Affairs, 2019). Density is the nemesis of the car, and society is already experiencing the consequence of this tension through traffic congestion, high parking fees, and even road closures. Figure 2 presents a paradoxical solution to this problem. The image embeds the landscape development of urbanisation through the inclusion of futuristic high-rise architecture, implying that space is at such a premium that city residents are forced to live in smaller and smaller apartments and nature is confined to the facades of buildings. However, in this densified future, road space has actually increased. Physical road features such as pedestrian crossings, sidewalks, and road markings are removed, expanding the domain of AVs while also granting them complete control over when other modes can use the space. For example, the crossing pedestrian depicted in this future may only safely cross the road when the AV allows it, demonstrating that the sociotechnical imaginary presented here by Daimler is one ruled by AVs.

5.4.1.2 Emerging Niches Used to Mask Regime Stabilisation

The AV sociotechnical imaginaries presented by Daimler in this collected study are neither fixed nor static. Instead, they demonstrate a co-evolution in line with emerging niche innovations and landscape developments to absorb these destabilising forces into their own narrative of AVs. In the period between 2015 and 2017, corresponding to the time between the release of Daimler's first and second AV depiction, several transport technologies such as micromobility devices, Mobility as a Service, and urban multimodality have emerged and are seen by some as disrupting traditional

Figure 5.3:
Bosch and Daimler join forces to work
on fully automated, driverless system
Source: The Daimler Group, 2017.

transportation systems. These emerging technologies differ from the incumbent automobility regime, as they suggest a plurality of transport modes existing harmoniously, rather than the presence of a single dominant mode.

Demonstrating an alignment with this emerging discourse, Figure 3 presents a sharp departure from the traditional automobile advertisement shown in Figure 5.2. Rather than selling an object, Figure 5.3 presents a total system of mobility that is forged around Daimler's AV system. Compositionally, this depiction is viewed from a bird-eye position, showcasing the entire system within a dense urban environment of apartment dwellings, alfresco cafes, and cultural institutions with no set focal point. Instead, an array of elements are spread throughout the image that engage and contain many emerging niche innovations mixed in with traditional automobiles, implying the plurality of the system.

While the image showcases a wide range of vehicle types that include more sustainable modes such as bicycles, e-scooters, shuttle buses, and mass transit, which may indicate an environmentally sustainable transport system, it also showcases a clear hierarchy of modal preference in the way the image is constructed. For example, the bicycle lanes, which are highlighted in red, clearly preference AVs and automobiles in their design. Rather than continuing across intersections, bicycle lanes are discontinuous, always giving the right of way to AVs. Bicycle lanes are further de-prioritised in the way that they are subservient to other modes: The delivery van, with

no designated parking area is standing in the cycle lane; the AV shuttlebus is standing in one as passengers embark or disembark; and parking spaces are located adjacent to the sidewalk, rather the road, causing points of conflicts between passing cyclists and AVs. These examples showcase Daimler's ignorance of apathy towards other modes of transit.

Although signs of safety, multimodality, and sustainability appear in this depiction, a compositional analysis of the image demonstrates a preference for safety, convenience, availability, and efficiency for Daimler's AV users. Destabilising niche innovation elements are merely included in the image to mask an otherwise typical depiction of a streetscape within the system of automobility. If one were to remove these signifiers relating to emerging niche innovations, the core of this sociotechnical imaginary is a 'business as usual' approach, in which roads and parking spaces dominant the urban environment.

5.4.2.3 Translated Sociotechnical Imaginaries

The final AV depiction by Daimler (Figure 5.4) presents a translation of its sociotechnical imaginary across regional contexts. The depiction, which is arguably identical to that in Figure 5.3, simply swaps signs relating to a German context with those of a U.S. one. While the identities of both countries are intertwined with automobile production, their automobile practices and cultures have evolved along two divergent paths (Kaiserfeld, 2007). Rather than understand and depict a future that is representative of local conditions, Daimler simply superimposes a series of cultural signs relating to California on a generic futuristic landscape originally intended for a German audience. Palm trees, people of colour, a doughnut shop sign, and a U.S. flag are all simply added in an attempt to make its system palatable to a U.S. context. Furthermore, many of the changes dilute several of the environmental and health benefits in the original vision. Several cyclists are simply removed, shared robotaxis are relabelled as privately-owned vehicles, and the size of the cars is increased.

Kim (2018) has suggested that when sociotechnical imaginaries are simply transplanted from one context to another, gaps between the imaginary and practice can occur through the loss of the original meaning of the former. For example, the plurality of transport modes embedded in the narrative of both the original and transplanted sociotechnical imaginary presupposes a backbone of public transport infrastructure,

Figure 5.4:
Bosch and Daimler: Metropolis in
California to become a pilot for
automated driving.
Source: The Daimler Group, 2018.

which varies in each context. While European cities often have existing urban transit networks integrated into their urban fabric, this is rare in a U.S. context, as the country, despite outlier cities such as New York and Washington D.C., has historically had a complicated social, cultural, and political relationship to public transport (Conley, 2009). Daimler formally imitates a European streetscape as a benchmark of multimodality because this legitimises its own product as a measure of sustainability. This reflects the emphasis of the landscape pressures that automobile manufacturers are attempting to mitigate within their depictions of AVs. However, if this sociotechnical imaginary were to be established, the system would change in practice. To suggest that in this transplanted sociotechnical imaginary Daimler's AV system would accompany such large-scale public transit investments is well beyond its scope or desired outcome.

While some may perceive this as a car company only undermining discussions on sustainability to sell more cars, this would discard any thought regarding the coerciveness of the system of automobility. Daimler is not discussing multimodal systems because they only want to sell more cars; they're engaging with them because they see the zeitgeist shift and want to stay in business. As an incumbent regime actor, Daimler must remain fluid in order to react to landscape pressures. However, as the inconsistency in Daimler's presentation of the future indicates, the dominance of the system of automobility over their perception of the future means that they are unable to see one that doesn't involve the car.

5.4.2   Futures with AVs by JAJA Architects

5.4.2.1   Sociotechnical Imaginaries Shaped by Liveability Discourses

Unlike Daimler, whose visions primarily depict a future of regime stabilisation, the visualisations from JAJA's CPH2050 project reflect the expectations of a broad set of interests located outside the regime. These expectations represent discourses relating to the improvement of public transport, sustainability agendas, the improvement of citizens' welfare, and urban development. As a result, there is no single 'product' sold; rather, the product is a lifestyle contained within a particular form of urbanism. One can see overlapping similarities between this form of urbanism and wider landscape developments surrounding the metric of 'sustainable liveability', which has exploded over the past two decades through a series of city-ranking indices. Often, these indices tend to preference access to cultural amenities, cafes, bars, and restaurants, but they have also recently included less superficial metrics, such as housing affordability, well-functioning public transport, and access to clean water. While these rankings may seem innocent and objective, some criticise them for framing a particular expectation of what life and living in a city should be (Jacobs, 2014). Nonetheless, cities shape urban policy, strategy, and planning projects in pursuit of these rankings that draw in investment from around the world (McArthur and Robin, 2019).

Since the establishment of these indices, Copenhagen has consistently ranked as a top-tier global city, which has encouraged the city's politicians to continually chase this accolade so that it can market itself as the world's most 'liveable' city (Simpson et al., 2018). By engaging with liveability's discursive power, JAJA mobilises a counter-sociotechnical imaginary that rejects the system of automobility, reconnecting transport policy with everyday urban life. For example, instead of depicting a system of mobility, Figure 5.5 illustrates a mobility lifestyle associated with economic prosperity. Compositionally, the image guides the viewer through a one-point perspective of signs relating to liveability: commercial retail outlets, citizens swimming in the harbour, shaded places to sit, coffee stands, a yacht, and bicycles—all signs of a 'good

Figure 5.5:
CPH2050: Reconnecting the city.
Robert Martin/ JAJA Architects, 2018.

life'. The image literally casts a shadow on the single AV shown, utilising these denotations of wealth to propose the spatial, economic, and social benefits of deprioritising vehicles in urban contexts.

The idea of sustainability is communicated subtly in the image through the inclusion of trees, grass, a cyclist, and a clean harbour fit for swimming. Furthermore, a single AV is represented as a shared shuttle waiting for pedestrians to cross. This action is enabled by the only other symbol of technology present in the image, traffic lights. Safety, therefore, is not communicated through technological systems as in Daimler's depictions, but rather through fixed spatial infrastructure and children safely crossing the street. Herein lies a continuing theme throughout each of JAJA's visualisations: The transformation of space will drive the transition towards future transportation systems.

5.4.2.2 Transforming the Landscape of the Automobility Regime

As stated previously, suburbanisation is the physical manifestation of the system of automobility, which has locked car dependence into the landscape of transportation. Interestingly, none of Daimler's depictions of AVs engage with the environment, instead only presenting their use within dense

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inner-city contexts. Whether this is an oversight or a general acceptance that AVs will not change mobility practices in these areas cannot be deduced; however, as suburban areas have been so pivotal in staging our mobility practices, understanding actors' approaches in these areas is crucial to understanding their ambitions for future AV use.

JAJA's portrayal of a suburban environment (Figure 5.6) provides many insights into how it views the role of AVs. First, this depiction relies on the absence of transport to communicate its vision for the future of transportation. Landscape developments throughout the twentieth century saw streets become increasingly defined as transport arteries, rather than as spaces for social activity (Geels, 2005), which JAJA's visualisation counteracts. Apart from one lone AV in the far background, vehicles are not shown in this streetscape. Instead, the focal point of the image is road infrastructure that has been re-appropriated to provide temporary play space for neighbourhood children and a track for active people to jog on.

This denotes a response to two other ongoing landscape pressures to the current automobility regime: The suburban environment that is often associated with sedentary lifestyles enabled through car use is replaced with a more active and healthier environment, and the safety of streets for pedestrians to use. Although relying on the technological application of sensors on the AV to detect and safely stop for pedestrians, the typical straight suburban street has also been manipulated to slow incoming traffic.

Figure 5.6:
CPH2050: Reconnecting the city.
Robert Martin/ JAJA Architects, 2018.

Similar to all other examples in this analysis, this image also engages with the landscape pressure of climate change through the application of signs relating to sustainability. However, instead of only including sustainable modes of transport, this image utilises signs such as solar panels on the houses, a community greenhouse, and an abundance of trees to depict a sustainable lifestyle.

Finally, the vision also speaks to a group not often involved with the discourse on AVs—the family unit. While a quick google search of the term "autonomous vehicle"[5.2] returns images of business suit-clad elites and inner-city professionals giving PowerPoint presentations in the cabins of cars, this image presents a picture of idealised family life. Instead of generic cityscapes, the image showcases residential architecture, a man carrying his young daughter, and children playing in the street, which all create a vision of a community that extends beyond the boundary of the owned plot.

5.4.2.3 Promotion of Subaltern Regimes

The final image analysed does not portray a particular lifestyle, but rather a clear hierarchy of modes within JAJA's imaginary (Figure 5.7). This vision does not depict a new system, but a reconfiguration that promotes existing subaltern regimes such as trains, buses, and cycling, through

5.2 Term searched on 22nd September 2020 through www.google.com

Figure 5.7:
CPH2050: From train station to mobility hub.
Robert Martin/ JAJA Architects, 2018.

subservient AV shuttle services. Unlike previous depictions from both companies, public transit infrastructure forms the largest volume of this image. AVs are presented in the image, but are placed in the mid-ground, behind the cyclist and train station, indicating that they are a subservient feeder to the transport system, rather than the dominant mode. Road space, as a percentage of the total image, is small, with a pedestrian crossing appearing much more prominent than the small amount of space available to AVs. Public transport is further made prominent through the vanishing point of the image, which is directed towards the arriving train in the background, highlighted by a stream of pedestrians.

Finally, the image embeds numerous elements relating to emerging niche technologies: the woman navigating using a smartphone; real-time information screens indicating departure times and connections; and AVs, both on the ground and mirrored in the screen. However, these technologies do not dominate the image and are all overlaid over existing infrastructure. These signs are arranged carefully to indicate that physical infrastructure, not technological advancements, will be what leads this sociotechnical transition and indicate which transport modes are preferred.

5.4.3 Implications for Future Transportation Systems

This chapter has analysed two distinct approaches to conceiving AV futures. The goal has not been to compare Daimler to JAJA but to exemplify how actors from different system positions utilise depictions of AVs to frame the technology within competing sociotechnical imaginaries. Furthermore, the analysis shows that in the case of Daimler, these depictions are not fixed, but co-evolve along with other system pressures. However, while the content within the image changes, the sociotechnical imaginary of a car-based society fundamentally remains the same. For Daimler, engaging with landscape pressures and emerging niches merely becomes an exercise in maintaining its own position within the system.

The analysis also shows that these companies' imaginaries would lead to different transition pathways and regime constellations, and therefore, the shaping of AV technology and society in the future. Thus, at the core of disseminating these depictions is the understanding that visualisations such as these are not neutral, and that the development of AV

systems is not technologically determined, but the product of different actors' values. This is an important consideration, as Louise Reardon has already identified, is that discussions surrounding AVs have already been discursively depoliticised (Reardon, 2018). The entire idea of AVs is extremely politically optimistic with impatient politicians eagerly anticipating AVs as a package that can solve many of these most pressing challenges (ibid.).

This is most obvious in both companies' futures having a strong relationship to climate change and road safety discourses, although with large differences in approaches. As a legacy carmaker, Daimler present a future where CO_2 emissions and traffic safety accidents can simply be solved through the application of new technologies to the existing form of the car. The findings clearly demonstrate how Daimler frame AVs to stabilise their own position as a regime actor through a 'business as usual' approach that suppresses other uses of AV technology. Daimler is first and foremost a vehicle manufacturer, and unlike other AV developers with backgrounds in tech, such as Apple and Google, who may be motivated through an increased market share of the attention economy (de Berker, 2017), Daimler's business model relies on it selling and leasing vehicles. There are too many inconsistencies in Daimler's presentations of the future, such as increasing amounts of road space, poorly designed bicycle infrastructure, and formal imitations of European public transport systems, to interpret their future literally. The company are locked into the system of automobility and their responses to ongoing landscapes pressures are still framed around the car.

On the other JAJA's future is dominated by regime destabilisation. In an increasingly urbanised society, social, political, economic, technological, and digital systems are encroaching on each other's physical domains, and tensions are beginning to arise as space limitations force discussions on how that space should be allocated and used. JAJA's sociotechnical imaginary is based on the idea that shared AV use will lead to substantial urban renewal through the transformation of redundant road infrastructure (Duarte and Ratti, 2018). Instead of AVs becoming the dominant transportation mode, they will work as a supportive component in a broader system of multimodal transport. Through efficiency and appropriately sized vehicles, a total reduction in vehicle numbers could lead to previously used road space being transformed into new urban development, densification of suburban areas, and greater utilisation of public transport infrastructure. Just as Daimler try to protect their business model through their

framing of AVs, JAJA are expanding their business through their own.

The findings indicate the different approaches towards AVs from different system actors. It also demonstrates that if these visions become embedded in the dominant sociotechnical imaginary, they will play a major role in the shaping of assumptions of the role of AVs in the future. Moreover, the final constellation of regime actors and their ambitions will have implications for future sustainable transportation systems. However, the battle for the dominant sociotechnical imaginary should not be considered a negative process. Competition amongst actors from different system positions can increase the number of alternatives. By supporting pluralism, rather than focusing on minimising system deployment, AV developers and public authorities can open up new pathways for reconceptualising AV technology (Mladenović, 2019; Mladenović et al., 2020)

5.5 Conclusions

This paper aimed to analyse and discuss different imaginaries of AVs to understand their consequences for the future of transport systems and mobility. The paper particularly focused on how different system actors frame the role of AVs depending on their position within sociotechnical systems and their own business models. This was elaborated through a comparative analysis of AV futures visualisations from an incumbent regime actor, The Daimler Group, and an external system actor, JAJA Architects.

The concepts of a system of automobility, the MLP, and sociotechnical imaginaries shaped the theoretical background of the analytical framework. Combining them into a single framework enabled a deeper understanding of how depictions of AV futures are being framed, developed, and deployed, as well as their implications for future transition pathways and policy considerations. Although, there have been historical criticisms of transition theory for a lack of explicit attention for the politics of technology that underpin the development and implement of specific policies (Smith, Stirling and Berkhout, 2005; Meadowcroft, 2011), more contemporary applications of the framework have expanded the MLP to include power and politics (Geels, 2014; Köhler et al., 2019). Transitions are deep-rooted political processes,

in that different actors and groups will disagree about desirable outcomes and suitable ways in which to steer such a process. Furthermore, this process may lead to winners and losers: not only incumbent industries or new actors, but other user groups whose mobility access and opportunities may be reduced in alternative socio-technical configurations such as the elderly, cyclists, or lower socio-economic communities. Thus, this specific contribution to the politics of AVs debate has been to conceptualise, identify and translate visual discursive material as instruments of regime stability or disruption over time.

When applying the analytical framework to the studied images, the analysis revealed that subsequent battles between niches and regimes take place on multiple landscape dimensions (e.g. sustainability, safety, and infrastructure). Geels (2010) proposes that these struggles are not enacted by singular entities, but by numerous actors that "fight, negotiate, search, learn and build coalitions as they navigate transitions". This raises several different political-economy questions. Firstly, researchers and planners need to understand how collective actors may support different sociotechnical imaginaries. For example, an underlying challenge for advocates for shared AVs is the incumbent alliance between car manufacturers and governments. These alliances are built from mutual dependencies that see governmental revenue from car sales and fuel excises in exchange for favourable market conditions. Despite the impending challenge of climate change, without finding additional methods of raising revenue, governments may limit actions to transition towards more sustainable forms of AV use (Fishman, 2018), preferring to incorporate AV futures that replicate existing car system and revenue streams. JAJA's visualisations (Figure 5.4.) outline possible trajectories to counteract this mutual dependency. By engaging with liveability discourses, which centre around urban re-development, gentrification, and economic prosperity, JAJA offer a counterproposal to governments fixated on automobility tax revenues.

Additionally, planners and policymakers should move beyond trying to anticipate AV futures towards actively asking what they want to achieve with them (Marsden, 2018). While they focus on the implications of possible trajectories, companies such as Daimler and JAJA are creating sociotechnical imaginaries of futures they are trying to create. I acknowledge that planners face a raft of challenges in determining their role in the development of AVs (Reardon, 2018), but I believe they also bring a valuable spatial perspective that can focus the deployment of AVs to solve existing challenges (Harris,

2018). Furthermore, when considering the long-term transition towards AVs, it is critical to reflect on which challenges could be implemented irrespective of automation and which challenges need further investigation. Possible methodologies could involve collaborative design experiments between governments and companies that utilise the same visualisation techniques outlined within this paper but are integrated within the context of local development goals (Martin, Bruck and Soteropoulos, 2021).

In summary, the paper contributes to the literature by providing a critical examination of AV imaginaries in praxis. The findings also suggest that a more nuanced approach to reading AV visualisations requires moving beyond denotative readings to unpack the latent meanings alongside the broader context of automobility, landscape pressures, and parallel niche innovations. The work enriches the ability of academics and policymakers to understand the latent implications behind visual depictions of AVs over time through visual discourse analysis tools. However, the study is limited to data that was sourced between the years 2015-2018. In the following years, there have been a wide number of landscape shifts and new technologies. Therefore, an important subject for future research would include an analysis of AV futures since the beginning of the COVID-19 pandemic. An assumption could be that signifiers relating to sharing, and sustainability are replaced by ones communicating sterility, and private ownership. It would be important to identify this early, so that policymakers do not unravel important steps towards the development of sustainable transportation systems in an effort to contain the SARS-COV-2 virus. Finally, although the study mainly focused on the visual analysis of imaginaries, further research could focus on the effect of sociotechnical imaginaries in praxis (e.g., whether they affect policymakers' decision-making processes or if the image's author is aware of the system it is depicting). This could involve investigating the site where sociotechnical imaginaries are disseminated to show how power relations give a greater advantage to certain actors in the marketplace of AV visions of the future.

5.6 References

Adams, John. 1999. "The Social Implications of Hypermobility. Speculations about the Social Consequences of the OECD Scenarios for Environmentally Sustainable Transport and Business-as-Usual Trend Projections." Paris.

Albers, Peggy. 2013. "Visual Discourse Analysis." New Methods of Literacy Research, no. February: 85–97. https://doi.org/10.4324/9780203104682.

Berker, Archy de. 2017. "Driverless Cars and the Attention Economy." Medium. 2017. https://becominghuman.ai/driverless-cars-and-the-attention-economy-7efd6aa6a6a0.

Blyth, Pascale-l, Miloš N Mladenović, Bonnie A Nardi, Hamid R Ekbia, and Norman M Su. 2016. "Expanding the Design Horizon for Self-Driving Vehicles." IEEE Technology and Society Magazine, 2016.

Bonnefon, Jean-Francois, David Cerny, John Danaher, Nathalie Devillier, Veronica Johansson, Tatiana Kovacikova, Marieke Martens, et al. 2020. "Ethics of Connected and Automated Vehicles." Luxembourg. https://doi.org/10.2777/966923.

Burke, Katie. 2019. "Hw Does a Self-Driving Car See?" NVIDIA. 2019. https://blogs.nvidia.com/blog/2019/04/15/how-does-a-self-driving-car-see/#:~:text=Camera%2C radar and lidar sensors give autonomous vehicles super-human vision.&text=By combining a variety of,even better than human eyesight.

Cavoli, C, B Phillips, T Cohen, P Jones, and Transport Department for. 2017. "Social and Behavioural Questions Associated with Automated Vehicles: A Literature Review," no. January: 124p. https://www.gov.uk/government/publications/social-and-behavioural-questions-associated-with-automated-vehicles%0Ahttps://trid.trb.org/view/1457834.

Cheney-Lippold, John. 2019. "Accidents Happen." Social Research 86 (2): 513–36.

Cohen, Tom, and Clémence Cavoli. 2019. "Automated Vehicles: Exploring Possible Consequences of Government (Non)Intervention for Congestion and Accessibility." Transport Reviews 39 (1): 129–51. https://doi.org/10.1080/01441647.2018.1524401.

Conley, Jim. 2009. Car Troubles: Critical Studies of Automobility and Auto-Mobility. Edited by Arlene Tigar McLaren. London: Taylor & Francis.

Duarte, Fábio, and Carlo Ratti. 2018. "The Impact of Autonomous Vehicles on Cities: A Review." Journal of Urban Technology 0732. https://doi.org/10.1080/10630732.2018.1493883.

Fishman, Elliot. 2018. "Autonomous Vehicles: Opportunities, Challenges and the Need for Government Action." Planning Theory & Practice 19 (5): 764–67.

Fraedrich, Eva, Sven Beiker, and Barbara Lenz. 2015. "Transition Pathways to Fully Automated Driving and Its Implications for the Sociotechnical System of Automobility." European Journal of Futures Research 3 (1). https://doi.org/10.1007/s40309-015-0067-8.

Freudendal-Pedersen, Malene, Kevin Hannam, and Sven Kesselring. 2016. "Applied Mobilities, Transitions and Opportunities." Applied Mobilities 1 (1): 1–9. https://doi.org/10.1080/23800127.2016.1150562.

Ganesh, Maya Indira. 2020. "The Ironies of Autonomy." Humanities and Social Sciences Communications 7 (1): 1–10. https://doi.org/10.1057/s41599-020-00646-0.

Gee, James Paul. 2006. An Introduction to Discourse Analysis: Theory and Method. 2nd ed. London: Routledge. https://doi.org/10.1177/146144560600800308.

Geels, Frank. 2010. "Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective." Research Policy 39: 495–510. https://doi.org/10.1016/j.respol.2010.01.022.

Geels, Frank, and Johan Schot. 2010. "The Dynamics of Transitions: A Socio-Technical Perspective." In Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change, edited by John Grin, Jan Rotmans, and Johan Schot, 1st ed., 11–102. Routledge. https://doi.org/10.4324/9780203856598.

Geels, Frank W. 2005. "The Dynamics of Transitions in Socio-Technical Systems: A Multi-Level Analysis of the Transition Pathway from Horse-Drawn Carriages to Automobiles (1860-1930)." Technology Analysis and Strategic Management 17 (4): 445–76. https://doi.org/10.1080/09537320500357319.

———. 2012. "A Socio-Technical Analysis of Low-Carbon Transitions: Introducing the Multi-Level Perspective into Transport Studies." Journal of Transport Geography 24: 471–82. https://doi.org/10.1016/j.jtrangeo.2012.01.021.

———. 2014. "Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective." Theory, Culture & Society 31 (5): 21–40. https://doi.org/10.1177/0263276414531627.

Goodwin, Phil. 1995. "Car Dependence." Transport Policy, 1995. https://doi.org/10.1016/0967-070X(95)96744-6.

Hajer, Maarten, and Wytske Versteeg. 2019. "Imagining the Post-Fossil City: Why Is It so Difficult to Think of New Possible Worlds?" Territory, Politics, Governance 7 (2): 122–34. https://doi.org/10.1080/21622671.2018.1510339.

Harris, James. 2018. "Autonomous Vehicles - A Planner's Response." Planning Theory & Practice 19 (5).

Hodge, Roberte, and Gunther Kress. 1988. Social Semiotics. Cambridge: Polity Press.

Hodson, Mike, Frank Geels, and Andy Mcmeekin. 2015. "Land-Based Passenger Mobility System," no. 603942.

Jacobs, Sam. 2014. "Cities That Score Well Barely Qualify as Cities." Dezeen. 2014. https://www.dezeen.com/2014/09/04/sam-jacob-opinion-city-rankings-flawed-way-to-judge-best-cities-in-the-world/.

Jasanoff, Sheila. 2015. "Future Imperfect: Science, Technology, and the Imaginations of Modernity." In Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power, edited by Sheila Jasanoff and Sang-Hyun Kim, 341. Chicago: University of Chicago.

Jasanoff, Sheila, and Sang Hyun Kim. 2009. "Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea." Minerva 47 (2): 119–46. http://www.jstor.org/stable/41821489.

Jewitt, Carey, and Rumiko Oyama. 2011. "Visual Meaning: A Social Semiotic Approach." In Handbook of Visual Analysis, 135–56.

Kaiserfeld, Thomas. 2007. "Born to Run or Chained to the Car? American vs European Visions and Practices of Automobile Society." Stockholm: Royal Institute of Technology, Sweden. https://doi.org/10.1093/jdh/epm023.4.

Kim, Eun Sung. 2018. "Sociotechnical Imaginaries and the Globalization of Converging Technology Policy: Technological Developmentalism in South Korea." Science as Culture 27 (2): 175–97. https://doi.org/10.1080/09505431.2017.1354844.

Köhler, Jonathan, Frank W. Geels, Florian Kern, Jochen Markard, Elsie Onsongo, Anna Wieczorek, Floortje Alkemade, et al. 2019. "An Agenda for Sustainability Transitions Research: State of the Art and Future Directions." Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2019.01.004.

Kornhauser, Alain L. 2013. "Smart Driving Cars: History and Evolution of Automated Vehicles." Florida Automated Vehicles Summit.

Kress, Gunther, and Theo van Leeuwen. 2006. Reading Images: The Grammar of Visual Design. 2nd ed. London: Taylor & Francis Routledge.

Lamon, Pierre, Sascha Kolski, and Roland Siegwart. 2006. "The SmartTer-a Vehicle for Fully Autonomous Navigation and Mapping in Outdoor Environments." 9th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, no. January.

Lyons, Glenn. 2015. "Transport's Digital Age Transition." Journal of Transport and Land Use 8 (2): 1–19. http://www.jstor.org/stable/26202710.

Mackinnon, Danny, Gordon Pirie, and Matthis Gather. 2008. "Transport and Economic Development." In Transport Geographies: Mobilities, Flows and Spaces, edited by Richard D. Knowles, Jon Shaw, and Iain Docherty, 10–28. Oxford: Blackwell.

Marsden, Greg. 2018. "Planning for Autonomous Vechiles? Questions of Purpose, Place and Pace." Planning Theory & Practice 19 (5).

Martin, Robert, Emilia. M. Bruck, and Aggelos Soteropoulos. 2021. "Transformations of European Public Spaces with AVs (In Print)." In AVENUE21 Volume 2: Policy and Planning Considerations for Automated Mobility, edited by M Mitteregge, E Bruck, A Stoerpoulos, A Stickler, M Berger, J. S. Dangschat, R Sceuvens, and I Banerjee. Heidelberg: Springer Vieweg.

McArthur, Jenny, and Enora Robin. 2019. "Victims of Their Own (Definition of) Success: Urban Discourse and Expert Knowledge Production in the Liveable City." Urban Studies 56 (9): 1711–28. https://doi.org/10.1177/0042098018804759.

McNeil, Maureen Christena, Adrian Bruce MacKenzie, Richard James Christopher Tutton, Joan Haran, and Michael Arribas-Ayllon. 2017. "Conceptualizing Imaginaries of Science, Technology, and Society." In The Handbook of Science and Technology Studies, edited by Ulrike Felt, Rayvon Fouche, Clark A. Miler, and Laurel Smith-Doerr, 435–64. Cambridge, MA: MIT Press.

Meadowcroft, James. 2011. "Engaging with the Politics of Sustainability Transitions." Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2011.02.003.

Milakis, Dimitris, Bart Van Arem, and Bert Van Wee. 2017. "Policy and Society Related Implications of Automated Driving: A Review of Literature and Directions for Future Research." Journal of Intelligent Transportation Systems: Technology, Planning, and Operations 21 (4): 324–48. https://doi.org/10.1080/15472450.2017.1291351.

Mladenović, Miloš N. 2019. "How Should We Drive Self-Driving Vehicles? Anticipation and Collective Imagination in Planning Mobility Futures," 103–22. https://doi.org/10.1007/978-3-319-96526-0_6.

Mladenović, Miloš N., Dominic Stead, Dimitris Milakis, Kate Pangbourne, and Moshe Givoni. 2020. "Governance Cultures and Sociotechnical Imaginaries of Self- Driving Vehicle Technology : Comparative Analysis of Finland, UK and Germany." In Advances in Transport Planning and Policy, edited by Dimitris Milakis, Nikolas Thomopoulos, and Bert van Wee, 235–62. Academic Press. https://doi.org/10.1016/bs.atpp.2020.01.001.

Mom, Gijs. 2014. Atlantic Automobilism: Emergence and Persistence of the Car, 1895-1940. Berghahn Books.

Moradi, Afsaneh, and Emidia Vagnoni. 2018. "A Multi-Level Perspective Analysis of Urban Mobility System Dynamics: What Are the Future Transition Pathways?" Technological Forecasting and Social Change 126 (September 2017): 231–43. https://doi.org/10.1016/j.techfore.2017.09.002.

Norton, Peter D. 2007. "Street Rivals: Jaywalking and the Invention of the Motor Age Street." Technology and Culture 48 (2): 331–59. https://doi.org/10.1353/tech.2007.0085.

———. 2010. "Fighting Traffic: The Dawn of the Motor Age in the American City." The Journal of American History. https://doi.org/10.2307/27694848.

Pattinson, Jo Ann, Haibo Chen, and Subhajit Basu. 2020. "Legal Issues in Automated Vehicles: Critically Considering the Potential Role of Consent and Interactive Digital Interfaces." Humanities and Social Sciences Communications 7 (1): 1–10. https://doi.org/10.1057/s41599-020-00644-2.

Reardon, Louise. 2018. "Ensuring Good Governance: The Role of Planners in the Development of Autonomous Vehicles." Planning Theory & Practice 19 (5): 773–76.

Rose, Gillian. 2010. Visual Methodologies. An Introduction to the Interpretation of Visual Materials. 2nd ed. London: SAGE Publications. https://doi.org/10.5212/Rlagg.v.3.i2.178180.

Sadowski, Jathan, and Roy Bendor. 2018. "Selling Smartness: Corporate Narratives and the Smart City as a Sociotechnical Imaginary." Science, Technology, & Human Values. https://doi.org/10.1177/0162243918806061.

SAE International. 2018. "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles."

Sage, Alexandria. 2016. "Where's the Lane? Self-Driving Cars Confused by Shabby U.S. Roadways." Reuters. 2016. https://www.reuters.com/article/us-autos-autonomous-infrastructure-insig/wheres-the-lane-self-driving-cars-confused-by-shabby-u-s-roadways-idUSKCN0WX131.

Sheller, Mimi. 2004. "Automotive Emotions: Feeling the Car." Theory, Culture & Society 21 (5): 221–42. https://doi.org/10.1177/0263276404046068.

Simpson, Deane, Kathrin Gimmel, Anders Lonka, Marc Jay, and Joost Grootens, eds. 2018. Atlas of the Copenhagens. Berlin: Ruby Press.

Smith, Adrian, Andy Stirling, and Frans Berkhout. 2005. "The Governance of Sustainable Socio-Technical Transitions." Research Policy. https://doi.org/10.1016/j.respol.2005.07.005.

Soteropoulos, Aggelos, Martin Berger, and Francesco Ciari. 2019. "Impacts of Automated Vehicles on Travel Behaviour and Land Use: An International Review of Modelling Studies." Transport Reviews 39 (1): 29–49. https://doi.org/10.1080/01441647.2018.1523253.

Stayton, Erik, and Jack Stilgoe. 2020. "It's Time to Rethink Levels of Automation for Self-Driving Vehicles." SSRN Electronic Journal 2019 (2016): 391–97. https://doi.org/10.2139/ssrn.3579386.

Stilgoe, Jack. 2017. "SEEING LIKE A TESLA: HOW CAN WE ANTICIPATE SELF-DRIVING WORLDS?" Journal of Culture 3. https://doi.org/10.12893/gjcpi.2017.3.2.

———. 2018. "Machine Learning, Social Learning and the Governance of Self-Driving Cars." Social Studies of Science 48 (1): 25–56. https://doi.org/10.1177/0306312717741687.

Stradling, S. G., M. L. Meadows, and S. Beatty. 2000. "Helping Drivers out of Their Cars Integrating Transport Policy and Social Psychology for Sustainable Change." Transport Policy 7 (3): 207–15. https://doi.org/10.1016/S0967-070X(00)00026-3.

Taiebat, Morteza, Austin L. Brown, Hannah R. Safford, Shen Qu, and Ming Xu. 2018. "A Review on Energy, Environmental, and Sustainability Implications of Connected and Automated Vehicles." Environmental Science and Technology 52 (20): 11449–65. https://doi.org/10.1021/acs.est.8b00127.

Turnheim, Bruno, Frans Berkhout, Frank Geels, Andries Hof, Andy McMeekin, Björn Nykvist, and Detlef van Vuuren. 2015. "Evaluating Sustainability Transitions Pathways: Bridging Analytical Approaches to Address Governance Challenges." Global Environmental Change 35 (2015): 239–53. https://doi.org/10.1016/j.gloenvcha.2015.08.010.

United Nations Department of Economic and Social Affairs. 2019. "World Urbanization Prospects: The 2018 Revision." New York.

Urry, John. 2005. "The 'System' of Automobility." In Automobilities, 25–40. London: SAGE Publications.

Vigar, Geoff. 2013. The Politics of Mobility. The Politics of Mobility. https://doi.org/10.4324/9780203857557.

Wetmore, Jameson. 2003. "Driving the Dream - The History and Motivations Behind 60 Years of Automated Highway Systems in America." Automative History Review 4 (19).

World Health Organization. 2018. "Global Status Report on Road." World Health Organization, 20.

Zijlstra, Toon, and Flor Avelino. 2012. "A Socio-Spatial Perspective on the Car Regime." In Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport, edited by Frank W. Geels, René Kemp, Geoff Dudley, and Glenn Lyons, 373. New York: Routledge.

Chapter 6:

Reconceptualising Space in Sustainability Transitions:

Sociotechnical-spatial Landscapes and Three Cities Pursuing 'Car-free'.

6.0 Abstract

Despite the amount of interdisciplinary research into sustainability transitions, there has been limited engagement with the role of physical space in transitions. This article contributes to this gap in transitions scholarship through a reconceptualization of the spatial dimensions of sociotechnical landscapes as a critical component enabling transitions to sustainable urban transportation systems. A theoretical outset links the multi-level perspective on transitions with spatial thinking to develop the idea of a sociotechnical-spatial landscape. Stemming from this, the theoretical framework was applied to case studies of European cities' efforts to limit automobile-based transport within 'car-free' discourses. The analysis highlighted a number of spatial elements within the existing sociotechnical-spatial landscape that offered opportunities for the development of car-free niches. Overall, the paper expands on the role of the built environment in influencing sustainability transitions while also revealing the need for future research in the area.

6.1 Introduction

The effects of climate change have sparked a wave of interdisciplinary research into sustainable transitions in the transport sector. However, there has been a limited exploration of the role of the physical spatial dimensions of these transitions (Levin-Keitel et al., 2018; Munro, 2019; Nielsen & Farrelly, 2019). Although the literature about transitions has made a significant contribution to understanding the complex and multi-dimensional shifts considered necessary for sustainable systems, it often neglects where transitions occur and the physical spatial configurations of the networks within which they evolve (Coenen et al., 2012). While sustainable transitions are needed globally, each transition is nested in a specific spatial context with transport initiatives and ambitions that vary across regions through different pre-existing infrastructures (Kuokkanen & Yazar, 2018; Marx et al., 2014).

Attempts to address the need for greater sensitivity towards spatial perspectives have been included in the updated research agenda for the Sustainability Transitions Research Network (STRN) that includes a section on the 'geography of sustainability transitions' (GOST). The agenda presents the GOST as being 'primarily concerned with understanding how and why transitions are similar or different across locations' (Köhler et al., 2019, p. 14). While the GOST is framed within the subtitles of 'spaces, scales, and places', little is suggested regarding the physical attributes of space. Instead, space is presented as a context, appearing as either 'urban' or of a 'developing country'. Critics of GOST suggest that the agenda denotes a narrow representation of space and offers theories within human geography as an avenue of research development (Binz et al., 2020). However, when applied to a transitions context, human geography has not expanded space beyond spatial units such as 'nations', 'cities', 'regions', and 'clusters', or conditions like 'agglomeration and proximity' and 'centres and peripheries' (Coenen & Morgan, 2020). While these are relevant terms, they lack sufficient acknowledgement of the spatial characteristics that vary between spatial units within the same category. For instance, while Oslo, Ghent, and Barcelona all fall under the spatial unit of

'city', they vary greatly in terms of density, topography, urban layout, and material infrastructures, which I elaborate further on later in the article.

Cities have been identified as particularly important places of transitions, not only because of their impact on the environment (e.g., high energy consumption, high CO_2 emissions, or population growth) but also because of the number of initiatives to counteract unsustainable behaviour that originate within them (Fuenfschilling et al., 2019). Despite this, some scholars still doubt the role that cities play in sustainability transitions (Nielsen & Farrelly, 2019) and question if they merely provide the contextual conditions for transitions and do not exert any influence (Truffer et al., 2015). To better engage with the role of physical space in cities, I utilise the understanding of the city as an object of transition as proposed by Nielsen and Farrelly (2019). Rather than only positioning the city as a context where a transition occurs, this conceptualisation of the city as an object opens avenues to understand how the city is malleable to change while simultaneously exerting influence on niche and regime actors. This conceptualisation also probes questions about what kind of spatial criteria researchers find in urban environments that influences transitions, and how such criteria differ amongst cities.

Arguably, one of the most discussed examples of a sustainability transition concerns the decarbonisation of urban transportation systems. Inroads to this research agenda have emerged through 'car-free' discourses, which imagine life in cities with little and limited car-use (Topp & Pharoah, 1994). Although early understandings of the term 'car-free' were synonymous with being 'car-less', and therefore, mobility-constrained, being car-free is now promoted as an example of sustainable consumption, signalling liberation from car ownership dependence (Brown, 2017). The discourse of 'car-free' has become part of a larger movement promoting pedestrian zones, more public recreational space, and liveable cities (Ornetzeder et al., 2008). However, while such discourses paint an optimistic view of cities and car-free lifestyles, they fail to recognise that for many, owning and using a car is an integrated part of everyday life, and it is perceived as necessary for economic and social participation in society (Freudendal-Pedersen, 2020). For others, not owning a car is considered a burden, rather than a chosen freedom (Conley, 2009). Despite the negative social, economic, and environmental impact that cars have on society, they are still favoured by consumers and policymakers because of their perceived characteristics in terms of autonomy, flexibility,

and comfort. Therefore, those working towards sustainable transportation systems cannot simply discuss car-freeness merely as a transportation issue; it is also a socio-cultural and politico-economic challenge that requires a process of transformation and a fundamentally different system, structure, and practice. This transformation process is referred to as a sociotechnical transition (F. W. Geels, 2005).

This paper explores the role of physical space in sustainability transitions to uncover what kind of spatial features are found in urban environments that may influence transitions. First, the paper examines transition literature and links it to spatial thinking through a description of the system of automobility. It then highlights current efforts by cities to limit non-motorised transport within car-free discourses through case studies of cities within Europe. Finally, the paper identifies physical spatial aspects within the landscape layer of the multilevel perspective that provide a foundation for further conceptual and empirical work.

6.2 The Sociotechnical-spatial Landscape of Transitions

6.2.1 Sociotechnical Transitions

According to Geels (2012), sociotechnical transitions are large-scale, non-linear changes in societal systems from one system equilibrium state to another. In relation to the transport system, a sociotechnical transition is a co-evolutionary process represented by the transformation of transportation modes, travel patterns, energy use, and governance through the development of technology, policy, markets, consumer practices, infrastructure, and cultural meaning (ibid.) Sociotechnical approaches have drawn heavily on innovation, and science and technology studies. Grand societal challenges such as climate change, road traffic safety, and urbanisation have highlighted the need to transition towards new

low-carbon transportation systems. This shift has been more broadly labelled as 'sustainability transitions' (Loorbach et al., 2017). Within sustainability transitions, there are four dominant concepts:

1.   The multilevel perspective (MLP), an analytical framework that explains transitions as the 'result of the interplay of multiple developments at different analytical levels' (F. W. Geels, 2012, p. 472);

2.   Transition management, a descriptive lens to understand the impact of governance processes on transitions (Frantzeskaki et al., 2017);

3.   Technological innovation systems, which understand technological transitions as a systemic process that co-evolves with emerging markets, governance, and user preferences but ignores the incumbent context (Loorbach et al., 2017);

4.   Strategic niche management, which builds on the idea that technology innovations facilitate transitions developing in government-protected incubation spaces (Hoogma et al., 2002).

In focusing on how to integrate an understanding of space into transition studies, the analytical framework of the MLP is particularly useful. A MLP distinguishes itself from other cause-and-effect processes by describing transitions not pursuant to one single factor but as determined by the interaction between macro, meso, and micro levels. Three levels of analytical analysis are distinguished by expanding constellations of increasingly hierarchical stability (F. W. Geels, 2012). First, there are sociotechnical landscapes, which represent the highest level and are the basis for both niche and regime dynamics. Second, we have sociotechnical regimes, which pertain to practices and rules imposed by incumbent actors, which also enable and constrain system dynamics, reproduce existing systems, and impede their transition. Finally, niche innovations are deviations from existing regimes that can either be adopted by or replace the existing regime.

Using the lens of the sociotechnical landscape level offers a better understanding of the role of space. As stated previously, the sociotechnical landscape is the wider context which influences and frames niche and regime dynamics. According to critics of the MLP, the sociotechnical landscape is merely a residual analytical category for whatever does not fit into the niche or regime, such as demographic trends, political

ideologies, societal values, and macro-economic patterns (F. W. Geels, 2011). However, these criticisms emerge from studies that heavily focus on the metaphorical understanding of the sociotechnical landscape, including trends that destabilise existing regimes such as peak oil or climate change, rather than the literal understanding of sociotechnical landscape that stabilises existing regimes. Furthermore, these metaphorical understandings of the sociotechnical landscape ignore the power that regime actors have to change the sociotechnical landscape slowly over time (F. Geels & Schot, 2010, p. 26). Such as the way in which our urban environments have been shaped throughout the 20th century, so that they have become increasingly difficult to navigate without the ownership of a car.

The original definition of a sociotechnical landscape is 'a land-scape in the literal sense, something around us that we can travel through; and in a metaphorical sense, something that we are part of, that sustains us' (Rip & Kemp, 1998, p. 334), and this definition includes a spatial element. Furthermore, when Geels (2012) first introduced the MLP into transport studies, the landscape was defined as 'spatial structures (e.g., urban layouts), political ideologies, societal values, beliefs, concerns, the media landscape and macro-economic trends' (F. W. Geels, 2012, p. 473). Although it is not the explicit intention of the work, Geels' (2005) study on the transition of horse-drawn carriages to automobiles indirectly identifies space as creating niche opportunities for the development of electric trams. He states that the first market for electric trams, which pre-empted the automobile, was in Richmond, Virginia where horses had trou-ble drawing trams up the hilly topography (F. W. Geels, 2005, p. 457). This example offers evidence to support that the spatial context drove the transition from one technology to the next. The expansion of the electric-tram infrastructure supported the early introduction of suburbanisation, creating a spatial organisation that would later connect with automobile use. In other words, the topography drove electric tram use, and spa-tial elements of the sociotechnical landscape of electric trams were a contributing factor to the transition to automobiles. However, later definitions of sociotechnical landscapes, such as 'slow-changing developments (e.g., demographics, cultural repertoires, societal concerns, geo-politics, macro-economic trends) and external shocks (e.g., wars, financial crises, acci-dents, oil price shocks)' (F. Geels, 2019, p. 190) have dropped the spatial elements. Whether this was a conscious decision or not remains unclear. There is a dominant understanding that cities are designed around cars (Freudendal-Pedersen, 2020), and in this sense, urban layout, topography, and other spatial characteristics have become less relevant as our perception of the way cities look is so ingrained. Therefore, it may be a case

that of resignation that urban planning centres on infrastructure systems based on the logic of the automobile.

6.2.2 The Sociotechnical-spatial Landscape of Automobility

To clarify the intentions of this article, I must differentiate between current understandings of sociotechnical landscapes, which appear to have dropped the spatial element, and my own attempt to reconceptualise space, which I will refer to as a sociotechnical-spatial landscape. To illustrate my conceptualisation of a sociotechnical-spatial landscape, I further elaborate on the concept of autologic through the system of automobility, which is a term used to understand the roots of the twentieth-century automotive system and how social and economic benefits offered by the car established a global self-replicating practice (Urry, 2005). Although the system's benefits were immediate, they were limited to pre-existing street infrastructure available for the car to use. To facilitate even greater economic opportunity, governments created new public authorities to expand street infrastructure and to invent traffic systems, which splintered urban territories, both spatially and temporally, into districts of home, work, and leisure (Freudendal-Pedersen et al., 2016). As the mass production of the car extended social and economic benefits to many people, the car became a prized possession that embodied cultural significance and status (Mom, 2014; Sheller, 2004).

However, as the system of automobility became a dominant feature of the landscape throughout the twentieth century, the initial sense of independence transformed into dependence (Goodwin, 1995). Car use was no longer a luxury; rather, it was considered an integral part of everyday life (Lyons, 2015). Urban populations began to experience the negative externalities of excessive car-use in the form of parked cars dominating city streets, harmful pollution, congestion, and the financial cost of automotive maintenance, insurance, licensing, and increasing fuel prices (ibid.). Despite these challenges, the system of automobility has been reinforced and supported by governments because of a supposed relationship between car use and economic growth (Mackinnon et al., 2008). Economies worldwide became intertwined not just with the ability of their populations to commute by car, but also with the automotive industry's larger ecosystem of resource extraction, supply chains, manufacturing, dealerships, and large infrastructure construction. A major problem

with continued economic growth has been governments' disregard of the negative externalities and a physical and social redevelopment of cities in favour of the car (Norton, 2010). As a result, the automobile has become an integral part of cities' fabric through a variety of material infrastructures, including street profiles, parking garages, highways, petrol stations, traffic signals, and urban layouts that serve to accommodate cars through an autologic (Zijlstra & Avelino, 2012).

A 'traditional' sustainability transitions' perspective using the MLP would understand the replacement of the incumbent horse-carriage transportation system by the adoption of the automobile in terms of a de-alignment and re-alignment path (F. W. Geels & Schot, 2007). Geels (2005) outlines this transition through a multi-level analysis that highlights the many social, cultural, technological, and market-driven forces that contributed to replacing horse-carriages with cars. To briefly summarise his findings, landscape developments such as industrial growth, increased immigration, a burgeoning middle class, and the increased awareness of hygiene placed increasing pressure on the horse-based regime that was already facing problems due to technical and economic dimensions. These pressures created windows of opportunity for the breakthrough of niche technologies such as electric trams, bicycles, and automobiles. Ultimately, automobiles would form the dominant regime because of their speed, support from policymakers, and ability to fulfil a latent demand for social alternatives to urban living, amongst others.

Whilst Geels' analysis illustrates how the adoption of the automobile occurred through the alignment and interaction of dynamics at three levels, a spatial understanding of the landscape further reveals the dynamics of this transformation. To give an example, while horse-carriages were still the dominant regime in the US, public administrations undertook a significant change in road pavement since dirt and macadam pavements were unsuited to horse-carriages, because their wheels tore them apart. To support the incumbent regime, a wave of street improvements throughout the 1890s upgraded the street surfaces using concrete and asphalt. This process of a regime influencing the landscape to stabilise its position became one of the spatial conditions for the demise of the carriage. Without this new typology of streets, the adoption of automobiles may not have occurred. Another example is the development of suburbia, which was a response to a growing middle class wanting to escape the pollution of urban centres. The diffusion of the electric tram enabled the middle class to leave the city centre and live in the suburbs. The introduction of the automobile was linked to this spatial condition and

reinforced the process of change. The landscape development of suburbanisation, which is a spatial condition, allowed the automobile to overcome the tram. Cars then became the preferred mode of transportation to commute between home in the suburbs and work in the city. As the car diffused, it had wider spatial impacts. As explained through the concept of the system of automobility, the car has become ingrained in cities through multiple spatial infrastructures.

Although we may describe automobility as unreplaceable, a transition towards a new sustainable transportation system may now be possible as a result of discussions concerning climate change, urbanisation, and road safety (Köhler et al., 2019). However, in order to support this transition, discussions must also focus on efforts to limit car-use and 'go back' to mobility systems where the urban topography is once again essential. Possible starting points for this discussion have appeared through 'car-free' discourses emerging in many cities across Europe. The next section further elaborates on these car-free discussions and introduces three case studies to investigate the possible influence and dynamics that physical space has played within the transition.

6.3 Methodology: Case Studies of Car-free European Cities

6.3.1 Discourses on Car-free

Despite its name, the term 'car-free' does not necessarily mean the absence of cars. Since cars are an essential mobility mode for many people, such as the elderly, the disabled, and certain professionals, banning cars completely would disadvantage the many individuals who rely on them every day. To accommodate the needs of these people and the wider integration of car-use within society, several schemes and policies fall under the broader discussion of 'car-free'.

Early attempts at car-free strategies have focused on the medieval centres of European cities where motor traffic would be limited to only what is considered necessary (Topp & Pharoah, 1994). Often, these strategies have only focused on pedestrianizing small areas in shopping districts to increase their attractiveness and economic vitality (see Strøget in Copenhagen, zona a traffico limitato in Bologna, and autow-rije Binnenstad in Amsterdam). While measures have been implemented to severely limit the number of vehicles in these areas, streets have been designed to accommodate both pedestrians and cars so that residents may access their apartments, shops may receive deliveries, and tradespeople may bring the necessary tools for their work.

Contemporary car-free initiatives are more complex and utilise various physical and digital infrastructures to limit car-use. In contrast to the slowly moving response to climate action taken by national governments, European cities are using their own agency to progressively limit CO_2 emissions within their own administrative boundaries. Over 350 cities and towns throughout the EU have some form of urban access regulation (UAR) to limit vehicle use (Sadler Consultants, 2020). These schemes are utilised by cities to improve issues of air quality and congestion as well as how their residents and visitors experience the city. There are predominantly three forms of UAR schemes.

The first UAR is urban toll roads or toll rings, which involve charging drivers a fee to enter certain areas of cities during specific times. Successful examples of this scheme have been implemented in London and Stockholm. After London introduced a toll ring in 2003, congestion decreased by 10%–25% as more travellers chose public transport over cost concerns. With more commuters shifting from using a car to public transport, London also saw bus delay times decline as there was more road capacity for them to move freely (United States Department of Transportation, 2011). During Stockholm's pilot of a toll ring from 2006 to 2007, the city removed 100,000 cars from its urban core (City of Stockholm Traffic Administration, 2009). Through a referendum the residents of Stockholm voted in favour of keeping the toll, and the toll ring was implemented permanently; however, the residents in neighbouring municipalities voted against it.

The second UAR form is low emission zones (LEZs), which are areas where polluting vehicles are regulated or banned. These zones were originally intended to remove heavily polluting vehicles such as trucks and vans from cities, but the regulation is now being extended to other vehicles. The Danish term

for a LEZ is a miljøzone (environmental zone), and these areas are located in each of the four main cities. These zones are controlled by automatic cameras that check license plates, and they exclude heavy diesel-powered vehicles. In Copenhagen, the LEZ has contributed to a decrease of 60% of the emission of harmful particles attributed to traffic (Jensen et al., 2011). The success of the LEZ to reduce emissions has fostered a discussion within the political parties about whether they can extend the zone to passenger cars. The policy would first begin in 2025 with diesel cars registered before January 2012, and then going forward every year after that.

The final form of UAR is key access schemes. Rather than regulate by payment or emissions, this form permits access to areas based on specific criteria such as a time limit, vehicle type, or resident status. While UARs are intended to enforce the number of cars that should be in a city, cities may also employ other spatial strategies to limit cars. Parking, for instance, is another strategy to decrease car usage. If more parking becomes available in a city, it is an invitation for more car ownership as cars become easier to use. Parking removal, increased parking pricing, and no parking minimums in new housing areas are all proven car limitation policies (Shoup, 2005). Less parking availability entails that less cars are on the road, which means greater efficiency for public transportation systems, and more efficient public transportation systems mean people are more encouraged to use them (rather than cars).

In relation to the multiple examples of discourses of 'car-free', the next section explains the empirical data in this study. To better understand the role that physical space plays in transitions, this paper investigates the European cities of Oslo, Ghent, and Barcelona, which all currently utilise different strategies to reduce car-use.

6.3.2   Case Study Selection

A case study method was chosen to understand the role of physical space in transitions in different contexts. I selected a multiple case study approach as this offers increased external validity (Yin, 2003). The aim of this method is to be explanatory, exploratory, and descriptive, while using transition theory to create analytical and not statistical generalisations.

The case selection consisted of selecting three cities from Europe that are currently working with car-free strategies. The cities were chosen from the Urban Access Regulations

in Europe database, which provides an overview of all cities within the European Union that have urban traffic restrictions. Oslo, Ghent, and Barcelona were chosen from the hundreds of European cities because of their diverse geographical locations, climates, cultures, topography, and sizes of car-free areas as well as their status of being documented success stories through news media outlets.

The empirical research consisted of gathering academic papers, municipal plans and policy reports, and news articles on the three cities and their car-free strategies. Once the data was collected, each city's strategy was spatially mapped using geographic information system (GIS) data available through Open Streets Maps. This process was supposed to be supported by fieldwork visits to each city to document how these strategies have been implemented, but this plan was delayed and eventually cancelled because of the COVID-19 pandemic. Instead, this study relies on the accuracy of open-source data. The spatial information was accessed using QGIS, an open-source desktop GIS application that supports the viewing and analysis of geospatial data, and the QGIS OpenStreetMap plugin. Oslo, Ghent, and Barcelona were queried through the software using search terms such as 'buildings', 'land use', 'landscape features', 'transport', 'traffic', 'roads', and 'railways' to build a comprehensive spatial map of the elements required to illustrate the car-free strategies. A series of maps were then produced to compare the different cities and their strategies.

6.4 Three Cities Transitioning to Car-free

6.4.1 Oslo

In October 2015, the Norwegian capital, Oslo, announced it would ban all private cars from its central business district (CBD) within four years (Reuters, 2015). In its plans, the city

proposed establishing a car-free zone within the city's inner-ring road that would allow for 60 km of new bicycle lanes, a new public transport system, and pedestrianisation of its main shopping streets (The Municipality of Oslo, 2019). The plan was complemented by policy to introduce rush-hour congestion charging and a reduction of on-street parking spaces. Although politicians promoted the plan as a ban on cars, exceptions were made for those carrying people with a disability and vehicles transporting goods.

The narrative surrounding Oslo's plans for car reduction is based on reducing greenhouse gas (GHG) emissions. This strategy was part of a wider climate and energy strategy for Oslo to reduce GHG emissions by 50% by 2030 and to zero by 2050. In 2012, the transportation sector was responsible for 63% of GHG emissions with private cars being the main source (The Municipality of Oslo, 2015a). The city is the most populous in Norway with 689,242 municipal residents (Statistics Norway, 2020a), which is forecast to grow by up to 200,000 by 2050 (Statistics Norway, 2020b). For Oslo to meet its targets for GHG reduction, the city had to decouple private car-use from its forecasted population growth.

Oslo's car-free zone includes 1.9 km² inside the city's inner-most ring road, Ring 1, which diverts traffic around the city centre in combination with the Bjørvika Tunnel (Figure 6.1). The area contains Oslo's main commercial streets and shopping malls and approximately 90,000 jobs and 1,063 residents (Rydningen et al., 2017). As evident from these numbers, most visitors to the city centre every day are commuters. As the city's CBD, it is also well covered by public transport containing the city's main train station, a metro line, and six tram lines (Figure 6.3). With such a dense coverage of public transport, measures to transition away from private car-use have focused on increased cycling and walkability (The Municipality of Oslo, 2015b).

Parking policy has been one of the main tools to implement Oslo's car-free strategy. Within the car-free zone, there were 924 on-street parking places and 6,600 spaces in parking garages in 2015 (Rydningen et al., 2017). These parking garages had been developed on the periphery of the Ring 1. By 2018, 760 of the on-street parking places had been removed, and 2,400 places had been added in nearby parking houses along Ring 1 (The Municipality of Oslo, 2019) to discourage car traffic in the CBD (Figure 6.4). The released road space from the removal of street parking has primarily been used for bicycle lane development to make it easier and safer for cycling in the city centre as well as to accommodate parked

bicycles (Figure 6.0). Release road space has also been used to plant more trees, install benches, and create parklets to increase the attractiveness and vibrancy of the urban environment (The Municipality of Oslo, 2015b).

The pedestrianisation of three main shopping streets (i.e., Aker Brygge, Karl Johans gate, and Torggata) has forbidden private cars from driving through the city centre from east to west or north to south (Figure 6.2). Studies observed from 2016 to 2019 have found a considerable decrease in the number of passenger vehicles (Sweco, 2020). From 2016 to 2018 there was a reduction of 11%, and between 2018 and 2019 the decline was 19%. The greatest reduction has been from 2019 to 2020 in the western part of the city where a decrease of 36% of passenger vehicles was observed. The effect that this has had on GHG emissions has not yet been calculated.
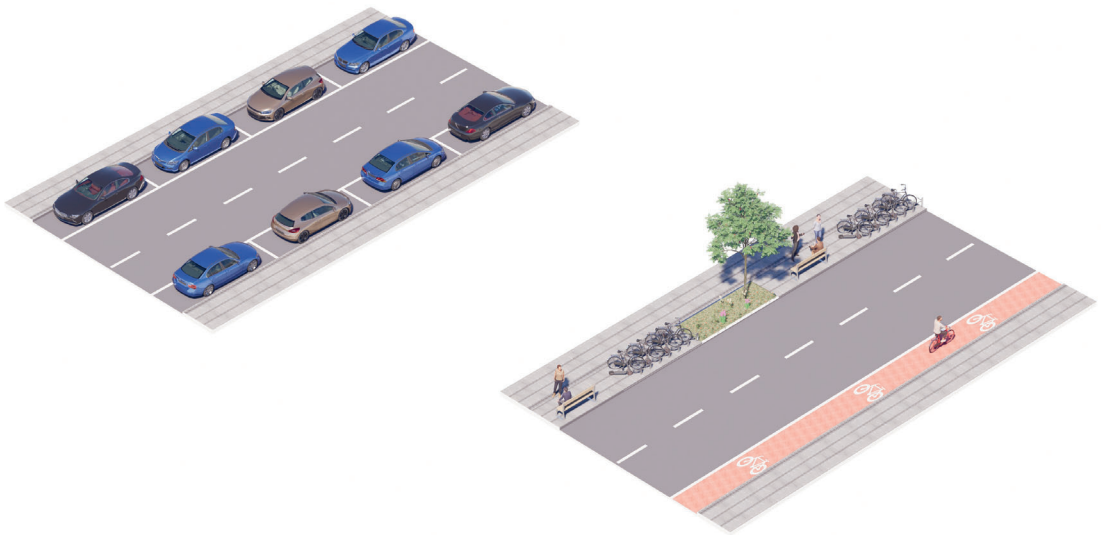
Figure 6.0:
Oslo street transformation (before and after) of on-street parking into public amenities.
Robert Martin, 2021.

In terms of the MLP, the main interaction has been that climate change awareness and a growing urban population at the landscape level have created pressure on the automobile regime which has opened up space for the development of the car-free niche. A sociotechnical-spatial reading of the landscape shows that Ring 1 and Bjørvika Tunnel, which were originally built to support the automobile regime, are now utilised to stop cars from entering the urban centre. This strategy was reinforced by utilising and expanding existent parking garages along Ring 1, as on-street parking was removed. This transfer of parking from on- to off-street corresponded with the development of bicycle lanes, which benefited from excess road width that was originally intended for parking

Figure 6.1:
Map. Oslo car-free area.
Robert Martin, 2021.

Ring 1

Bjørv

OSLO, NORWAY/
CAR-FREE AREA
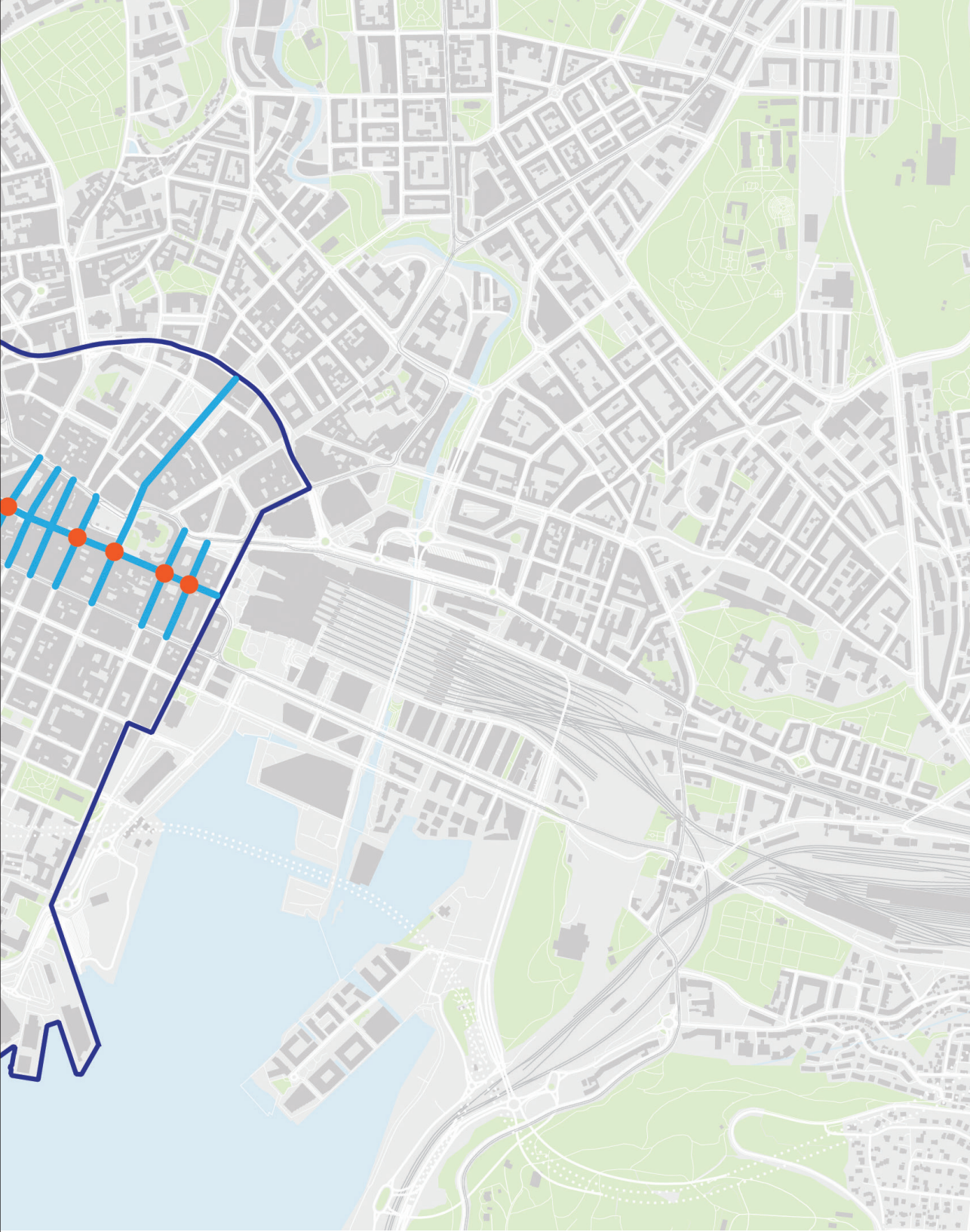
0   500m

Ring 1

ka T

Car-free area
Ring 1 road
Bjørvika tunnel

Figure 6.2:
Map. Car-free strategies.
Robert Martin, 2021.

OSLO, NORWAY/
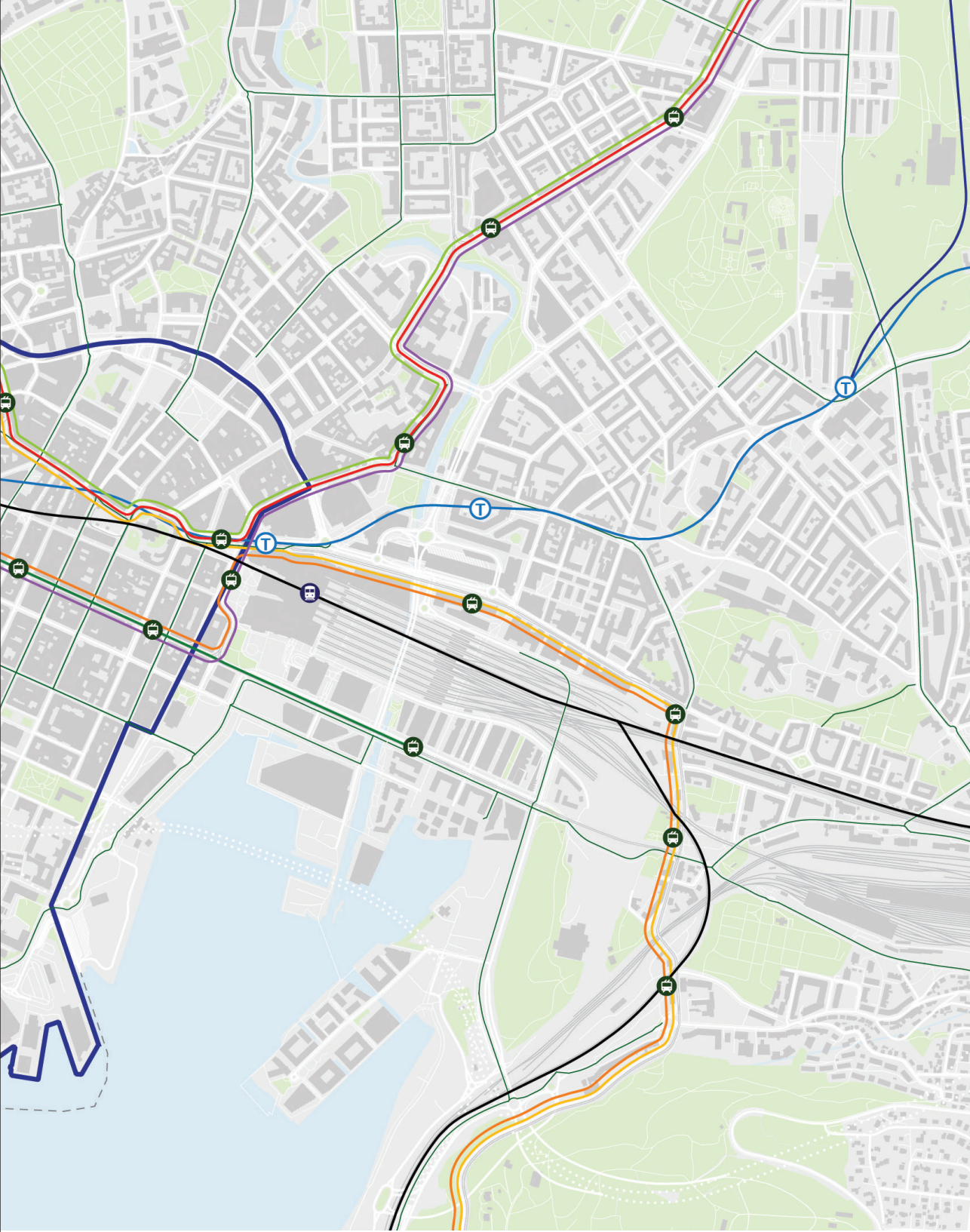CAR-FREE STRATEGIES

0   500m

Car-free area

Pedestrianised street

Road block

Figure 6.3:
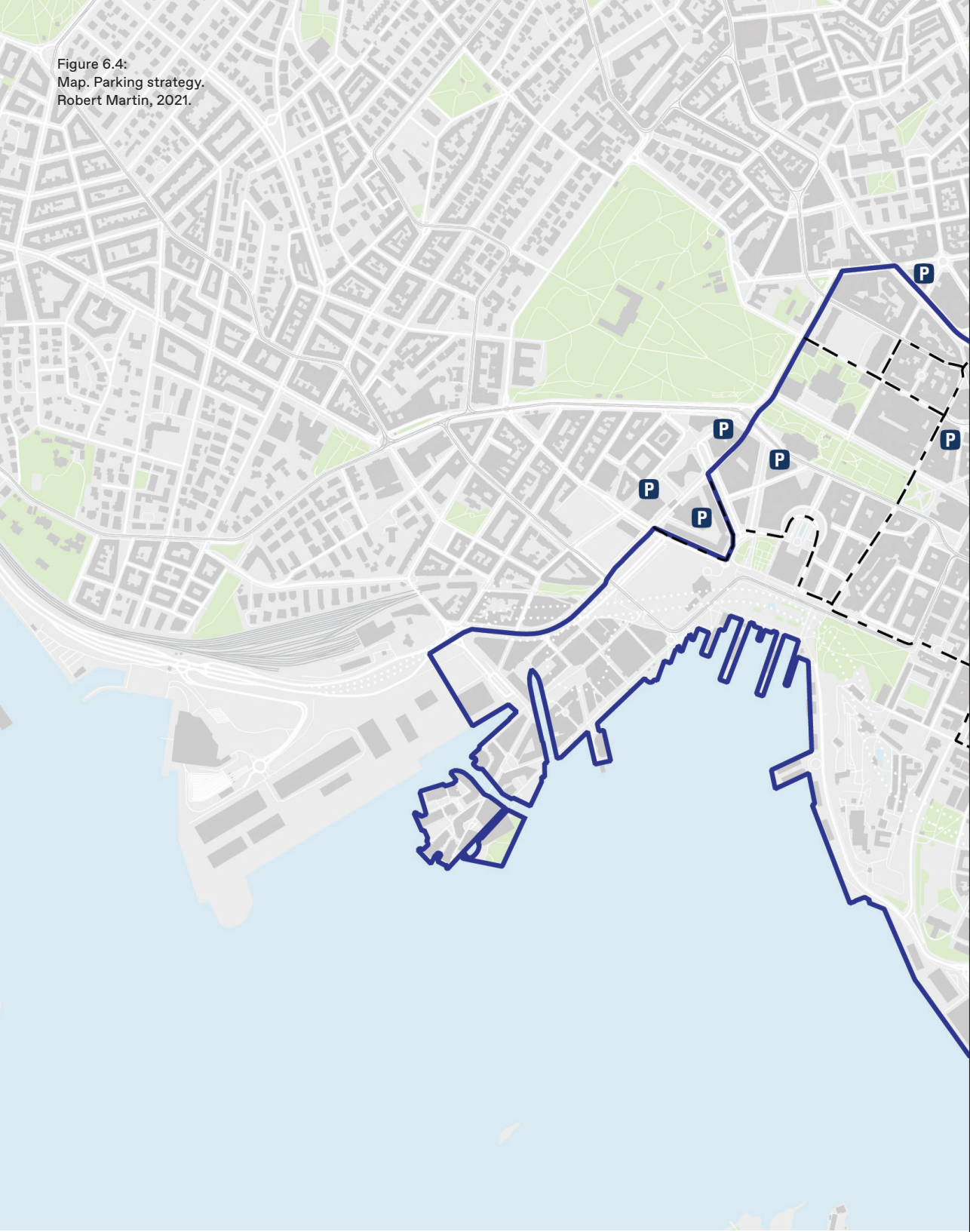Map. Oslo transportation network.
Robert Martin, 2021.

OSLO, NORWAY/
TRANSPORTATION NETWORK

0   500m

▬▬▬ Car-free area	▬▬▬ Metro line	
▬▬▬ Train line	🚈 Train station	
┄┄┄ Ferry route	Ⓣ Metro station	
▬▬▬ Tram lines	🚊 Tram stop	

Figure 6.4:
Map. Parking strategy.
Robert Martin, 2021.

OSLO, NORWAY/
PARKING STRATEGY

0   500m

Car-free area

Dedicated parking route

P Parking house

bays. Finally, the concentration of commercial outlets along two main streets gave the opportunity to pedestrianize them, which created roadblocks for cars going north-south and east.

6.4.2 Ghent

Ghent is a city in the Flemish region of Belgium. With a population of approximately 260,000, the city is the second-largest municipality in Belgium after Antwerp. The city dates back to the Middle Ages as a port city connected to the North Sea by the Ghent-Terneuzen Canal and comprises a medieval core of narrow streets, alleyways, canals and small bridges. The wider municipality includes the medieval centre and surrounding suburbs covering an area of 156 km² with an urban density of 1,700/km².

Ghent contains a number of transportation infrastructures. First, the city is surrounded by two ring roads. As well as connecting Ghent's suburbs with each other and with the surrounding towns, the R4 intersects with the inner ring road, the R40, which links the medieval city's downtown districts. The city's public transport network includes 56 bus and five tram lines as well as an intercity railway station, Gent Dampoort (Figure 6.8). Ghent also has one of Europe's largest cycling networks with over 400 km of cycle paths (URBACT, 2020), which utilise the flat topography of the area.

Ghent's plans for car reduction stem from a policy that was introduced in 1987 to reduce inner-city congestion. The plan involved preventing car traffic from driving through the historic city centre by diverting traffic through several inner-city streets. Although the plan achieved its objective of reducing car traffic in the historic centre, it was unpopular with the local residents, because it had not provided alternative measures for mobility such as increasing public transport services in the area (Korver et al., 2012). The plan was withdrawn after only six months.

Ten years after Ghent's failure to reduce car traffic, the city introduced a traffic plan that was nearly identical to the 1987 version. However, the revised plan was accompanied by several measures that helped facilitate alternative modes of mobility. These included increased public transport frequency and coverage, the construction of underground car parks with dedicated parking guidance streets, an expansion of the bicycle path network, and the pedestrianisation of 35 hectares of
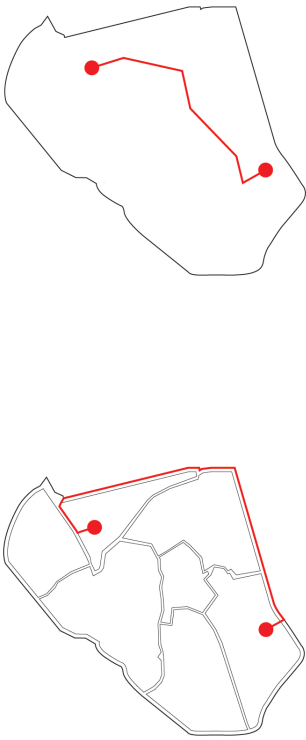
Figure 6.5:
Ghent circulation plan.
Robert Martin, 2021.

public streets in the city's historic core. Despite not being a comprehensive mobility plan for the whole municipality, the traffic plan coincided with a slight decrease in car traffic, an increase in the number of bicycle trips, and an increased level of liveability in the city (Gent Municipality, 2018).

Building on the initial success of the 1997 plan, Ghent introduced its new Mobility Plan 2030 in 2015 to combat a trend of increasing car ownership and pollution in the city (Gent Municipality, 2018). Fundamental to this policy was the creation of a LEZ of 12 km² (Figure 6.6) that would utilise a circulation plan to re-direct traffic around the city and provide increased accessibility for cyclists, buses, trams, and pedestrians (Amaral et al., 2018). To prevent motorists from driving through the historic centre of the city unnecessarily, the city was divided into six sectors (Figure 6.7). The basic concept of the plan was that cars would only be allowed to move from one sector to another by the inner-city ring road (R40), thereby discouraging drivers to use the city as a thoroughfare and for short trips within the city (Figure 6.5). Emergency services, waste collection vehicles, public transportation, and bicycles may still use all streets to travel between sectors. To enforce these new measures, the city changed the travel direction in 80 streets, extended the pedestrianised area by 150%, and made through-traffic by car impossible in 14 locations. Other measures in the Mobility Plan 2030 include the increase of parking restrictions and fees which limit access to parking houses to those who are not business owners or residents as well as the inclusion of park-and-ride infrastructure outside of the LEZ (Figure 6.9).

The success of Ghent's Mobility Plan 2030 has become an inspiration for other cities around the world, such as Birmingham, UK (Reid, 2020). From 2017 to 2018 there were significant impacts from the circulation plan with a 25% increase in bicycle users, 8% increase in public transport ridership, 12% decrease in car-use during rush hour and 58% less cars on residential streets (Cadence, 2018). Although the aim of the plan was to reach a cycling modal share of 25% by 2030, the city achieved this target by 2019 and is now re-evaluating further plans (Watteeuw, 2020).

In terms of a MLP, the main landscape pressure driving a transition away from the automobile regime was the growing cultural concern of inner-city pollution from excess car-use. A sociotechnical-spatial understanding of the landscape reveals that the congestion and pollution aligned with a dense urban fabric that was not suited to cars. This urban fabric developed from the city's medieval history when a horse regime

185

Figure 6.6:
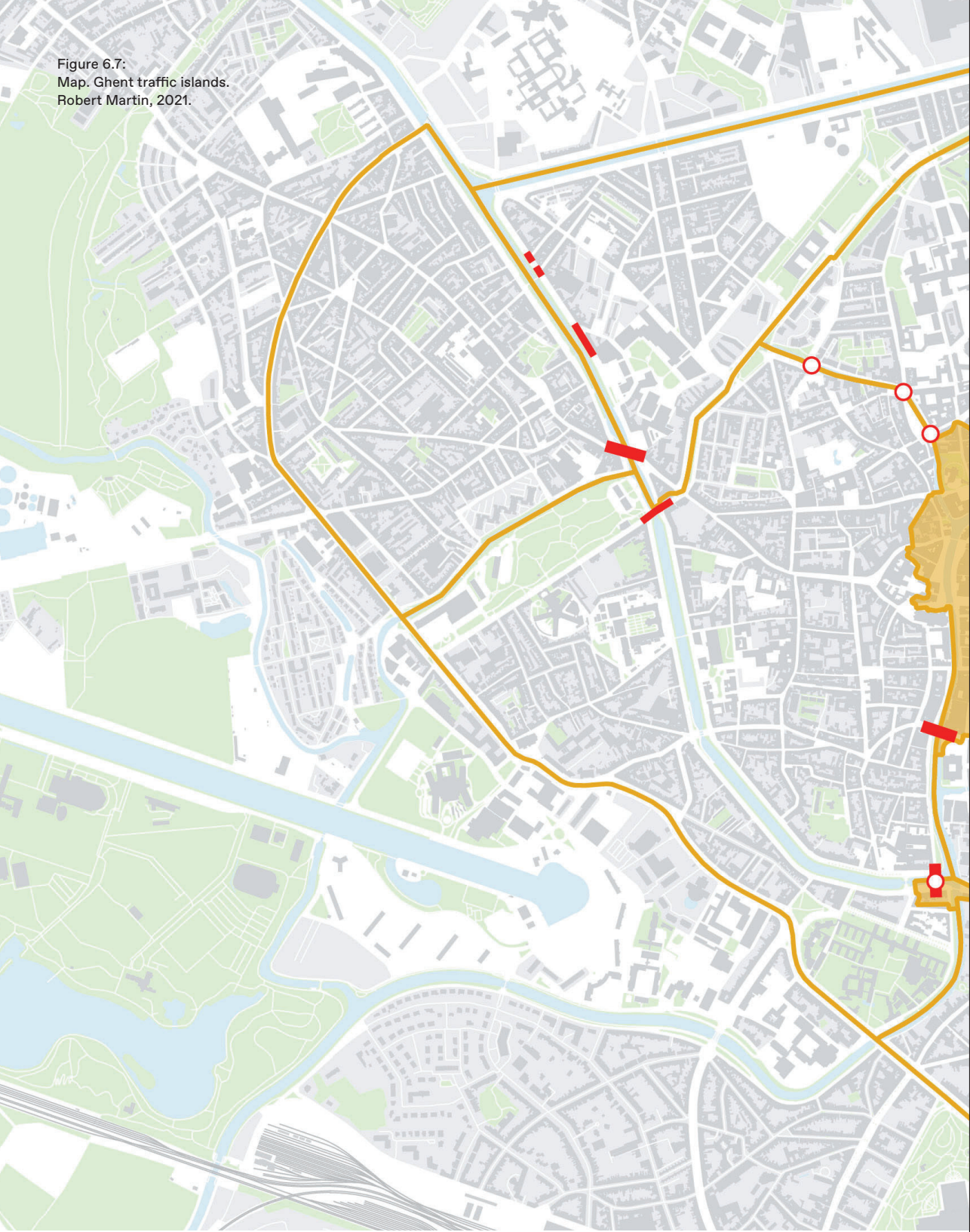Map. Ghent car-free area.
Robert Martin, 2021.

R40

R40
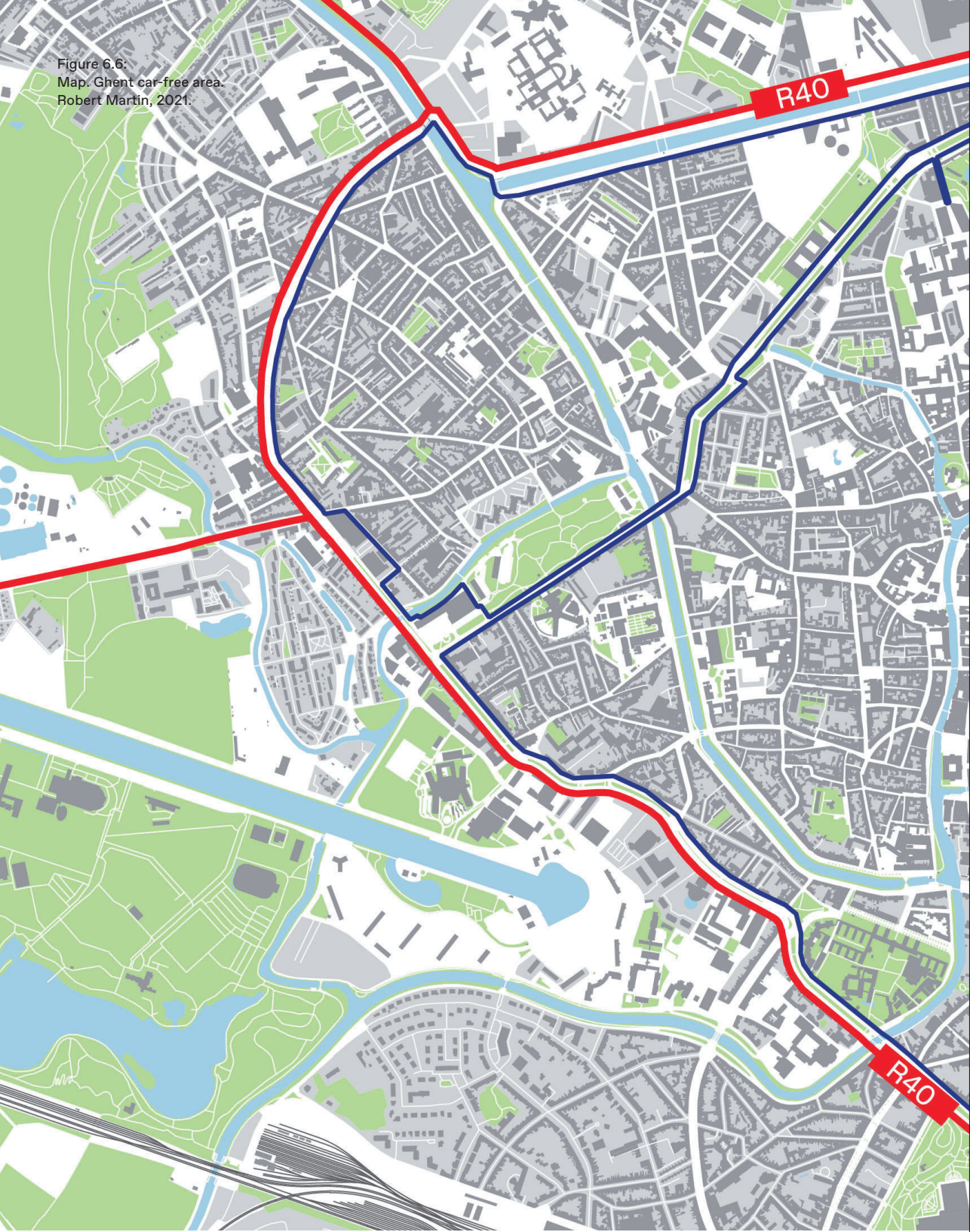
GHENT, BELGIUM/
CAR-FREE AREA

0   1km
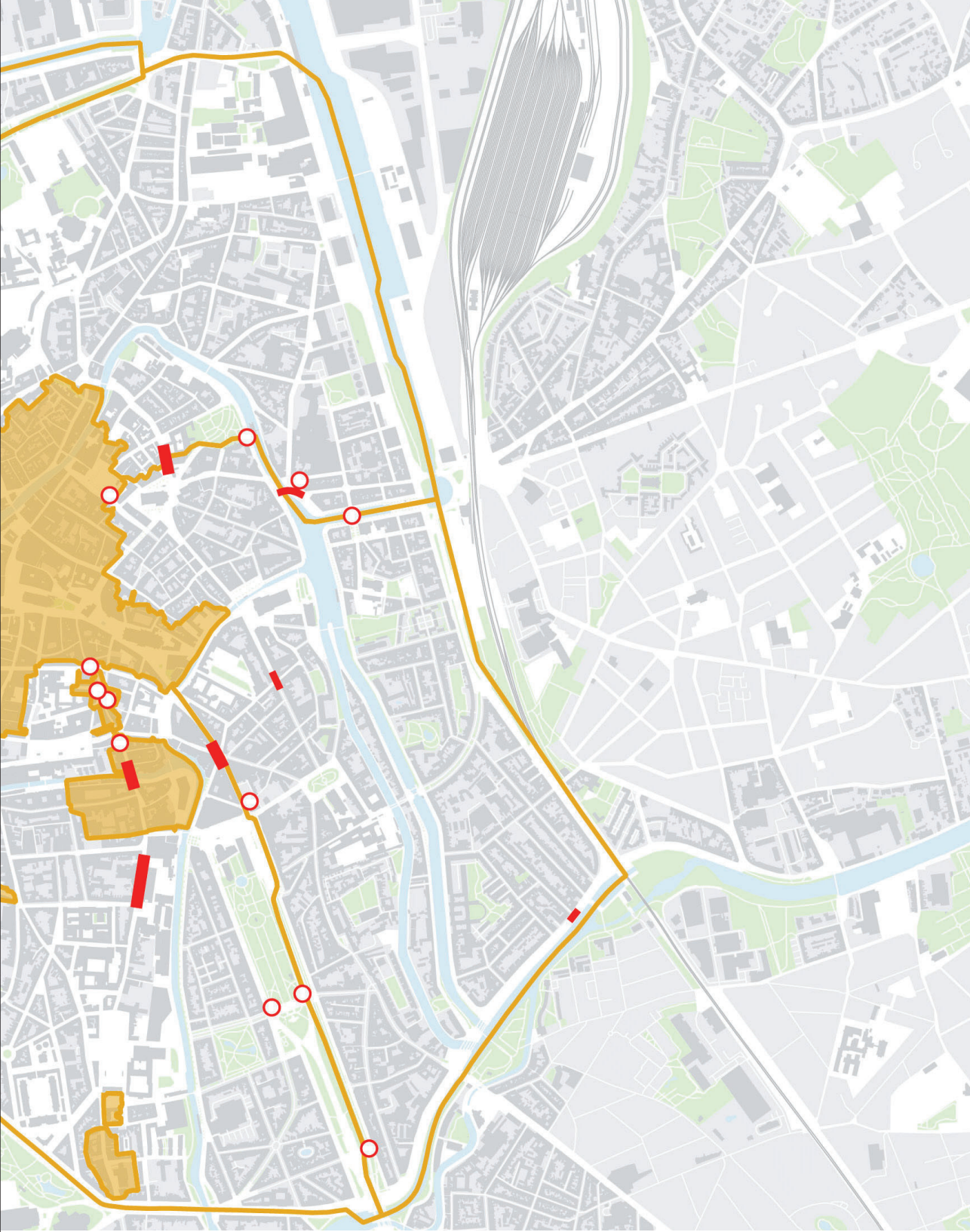
R40

Car-free area
R40 ring road

Figure 6.7:
Map. Ghent traffic islands.
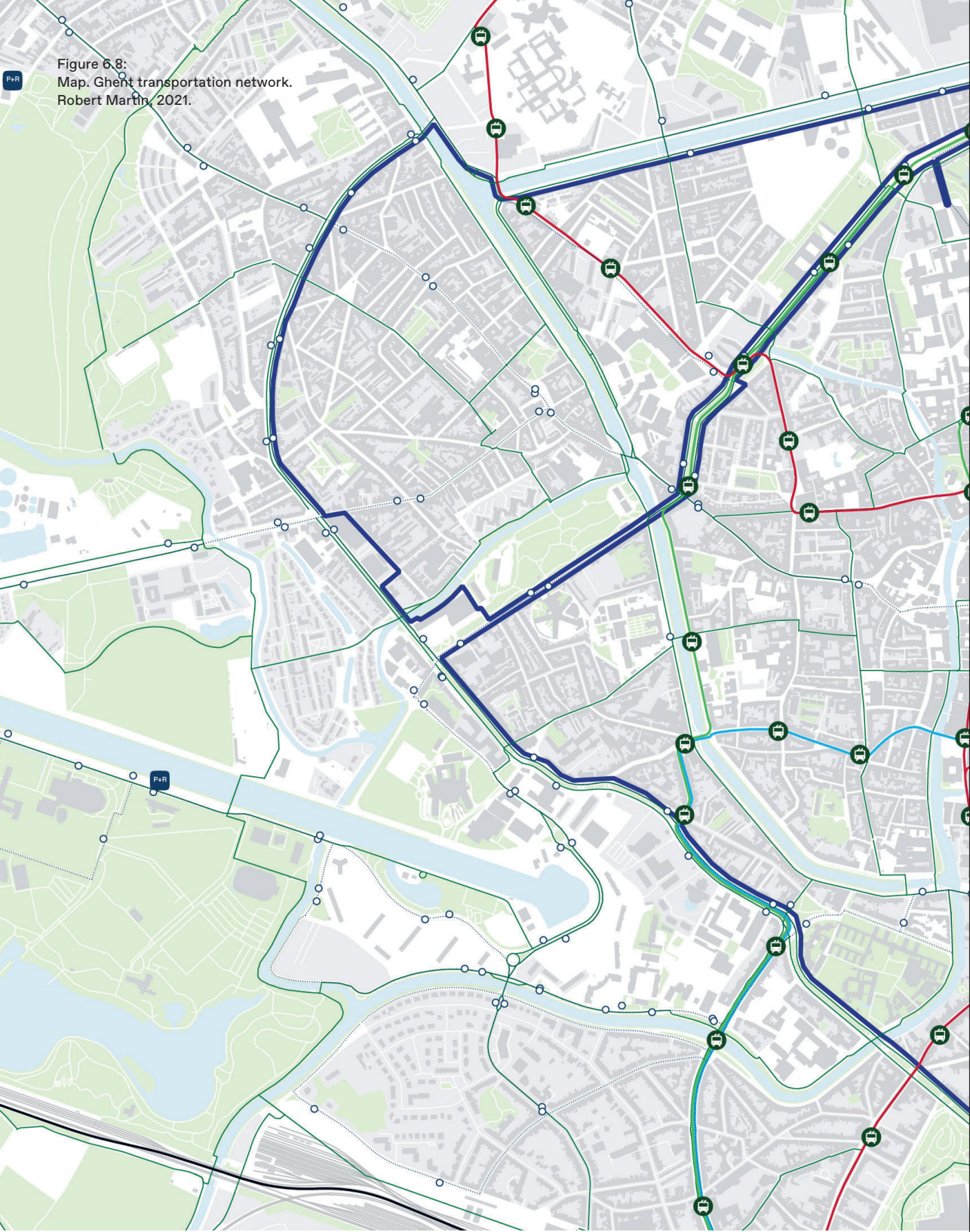Robert Martin, 2021.

GHENT, BELGIUM/
TRAFFIC ISLANDS

0   1km
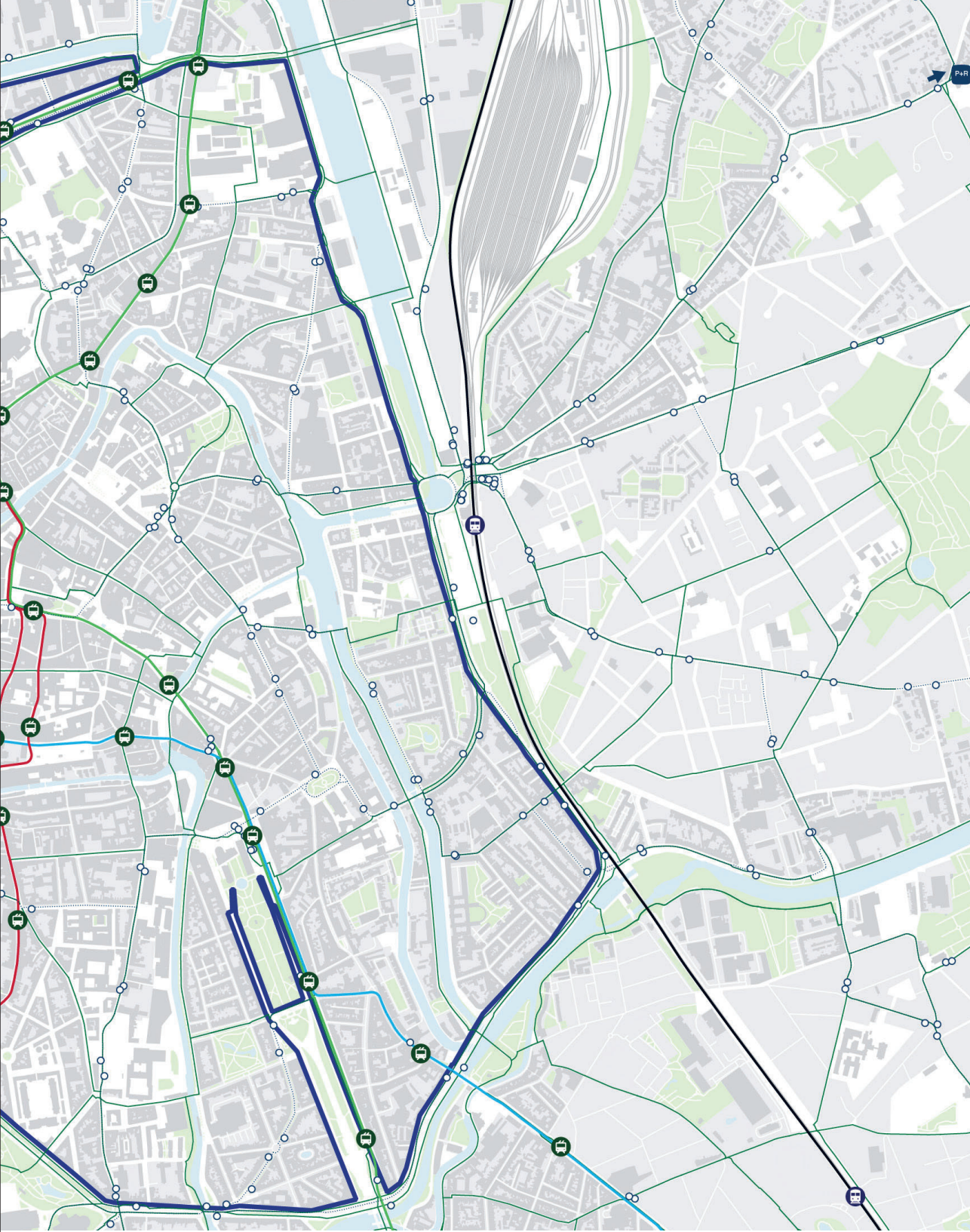
Traffic island

Pedestrianised area

Road block

Bollard

Figure 6.8:
Map. Ghent transportation network.
Robert Martin. 2021.

GHENT, BELGIUM/
TRANSPORTATION NETWORK

0   1km

	Car-free area		Train station		Park and ride
	Tram stop		Train line		
	Tram lines		Bus stop		
	Bicycle lane		Bus lines		

Figure 6.9:
Map. Ghent parking strategy.
Robert Martin, 2021.

GHENT, BELGIUM/
PARKING STRATEGY

0   1km
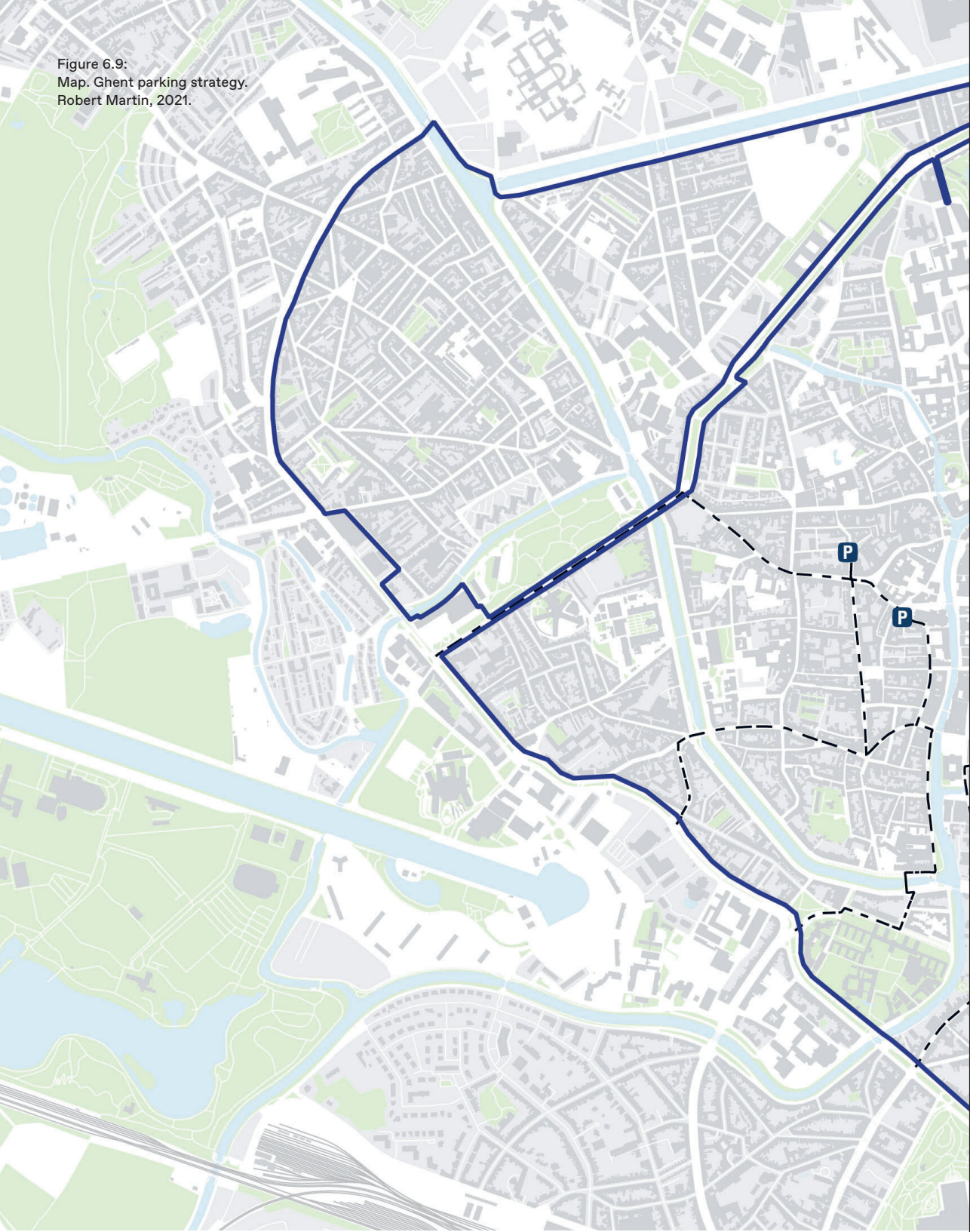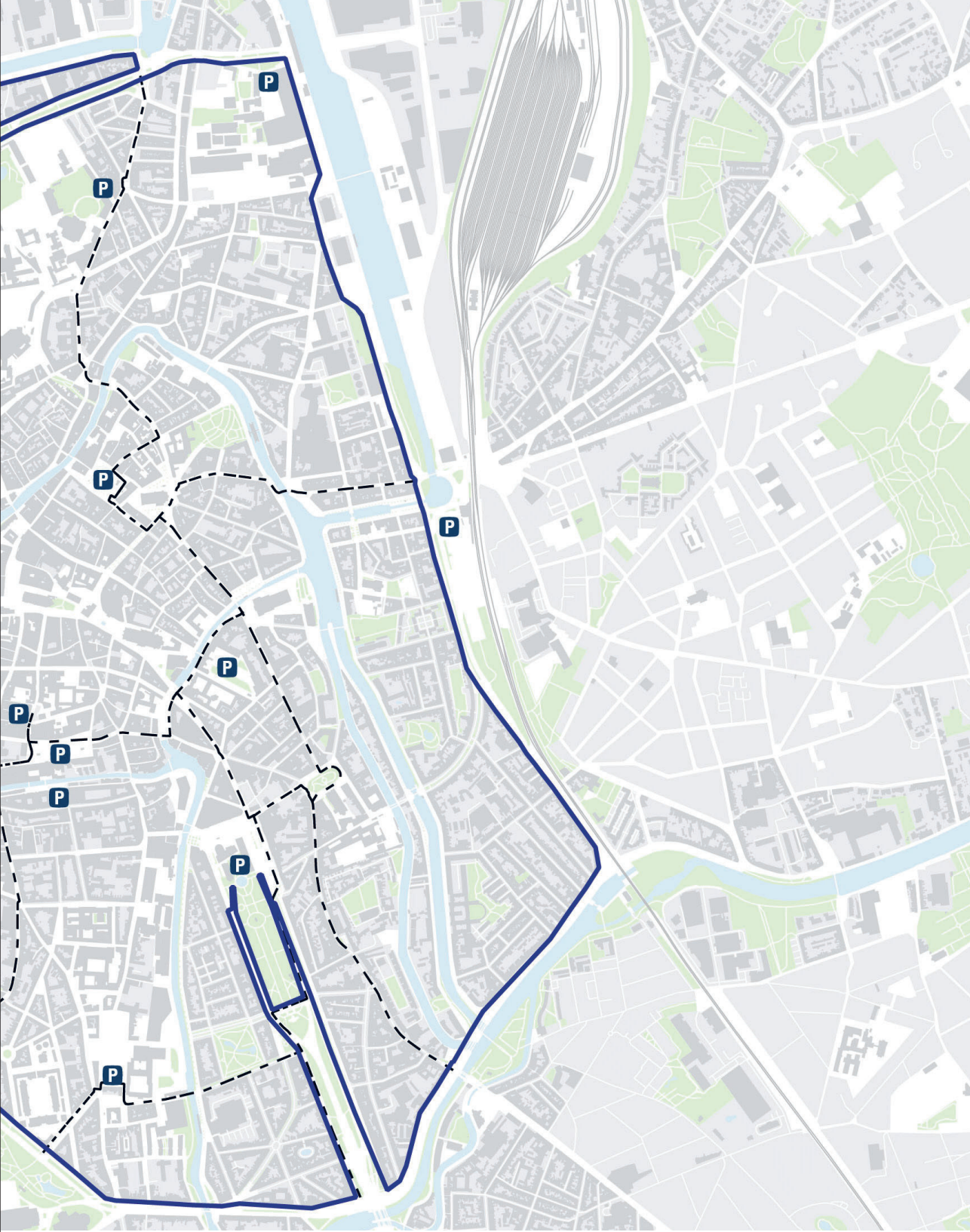
Car-free area

Dedicated parking route

P Parking house

was dominant, and close proximity was a spatial condition of the landscape. Although, this pressure opened the opportunity for a car-free niche in 1987, the niche was not supported spatially and could not succeed. Only after bicycle lanes and public transport coverage had been increased in 1997 were car-free discourses able to gain momentum and apply pressure on the car-regime from below—which ultimately led to the removal of cars from the historic centre.

The momentum from Ghent's 1997 plan increased with the introduction of the city's Mobility Plan 2030 in 2015. Like the one in Oslo, Ghent's LEZ was demarcated and spatially supported by a ring-road (R40) that had been originally built to stabilise the car-regime. Ghent's history as a port city also had spatial implications—the Ghent-Terneuzen Canal had splintered the city with waterways to give greater accessibility to boats. This spatial forming of the landscape was exploited by the Mobility Plan through the establishment of traffic islands. Rather than having to build physical barriers between the traffic islands, the waterways formed a natural border with only a few bollards needed on the bridges that crossed the canals. The historic sociotechnical-spatial landscape informed and facilitated the shift away from the automobile regime.

6.4.3   Barcelona

The final case study analysed in this paper is the Spanish city of Barcelona. Unlike Oslo and Ghent which have less than 1 million residents, Barcelona is the sixth largest city in the EU with an urban population of 1.6 million residents and with the wider metropolitan region being home to more than 5 million inhabitants. While Barcelona is celebrated as a global city of cultural and economic importance, the city suffers from the highest rates of air and noise pollution in Spain, which even surpass recommendations from the World Health Organization (Mueller et al., 2017).

The narrative surrounding Barcelona's plans for car reduction comes from both a reaction to climate change and a desire to restructure the city's fabric (Zografos et al., 2020). According to recent studies, the city is particularly vulnerable to climate change related threats, including sea-level rise, increasing temperatures including urban heat islands, the loss of biodiversity, and more frequent and intense drought periods (City of Barcelona, 2017). The heat island effect is so significant that temperatures in the city centre may be up to 8°C higher

than the surrounding less urbanised areas (Moreno-garcia, 1994). Black asphalt and car emissions bear the majority of responsibility for the heat islands in Barcelona (Rueda, 2016), with 60% of public land being devoted to automobiles (City of Barcelona, 2015), causing a lack of green space in the urban environment (WHO Regional Office for Europe, 2016). Barcelona's response to the climate crisis has been to establish a goal of reducing CO_2 emissions in 2030 by 40% compared to the 2005 levels as well as increasing urban green space by 1.6 km² (City of Barcelona, 2015).

A key aspect of Barcelona's climate policy has been the city's 2013–2018 Urban Mobility Plan in which the Superblock program has been a key element. The Superblock program is a spatial intervention that aims to transform multiple dimensions of the urban environment through increased greenery, sustainable mobility, and increased public space (Zografos et al., 2020). The strategy responds to two urban conditions in the city. The first appears in the Eixample neighbourhoods, an extension of the city first conceived in 1859 which covers most of the modern city in an orthogonal grid pattern (Figure 6.12). The grid of the Eixample was designed by architect and urban planner Ildefons Cerdà who envisioned the streets as a stream of trams for distributing people and goods. Within this grid, a Superblock is a traffic-regulated cell of approximately 400 m2, consisting of nine smaller blocks in a three-by-three block grid where approximately 5,000–6,000 residents live (Rueda, 2016). In the outer streets of the grid, bus and car traffic circulates, while the interior streets are mainly reserved for residents, pedestrians, and cyclists (Figures 6.10). Within these interior streets, the number of cars is reduced by inhibiting their movement between blocks. The space once occupied by cars is then given back to the residents in the form of new urban amenities (Figure 6.11). In other parts of city, such as the historic core or developments on hilly topography, the Superblock deviates to a less rigid design of pacified streets.

While only six superblocks have been built to date, Barcelona's ambition is to cover the entire city with a total of 503 superblocks over time, transforming 70% of the space currently used by cars into new bus lanes and bicycle paths as well as increasing the amount of pedestrian space by 270% (López et al., 2020). Forecasting from the city expects that the implementation of the superblocks would reduce car mode share by 19.2% with trips being shifted to public transport, cycling, and walking (City of Barcelona, 2014). As a result, CO_2 emissions would be reduced by 40% per capita, and NO_2 pollution would be reduced by 24% (López et al., 2020), which would

reduce premature deaths by approximately 667 cases each year and save EUR 1.7 billion in associated costs (Mueller et al., 2019).

In terms of an MLP, there were interactions between the landscape and automobile regime, particularly regarding the threat of climate change and the heat island effect felt by Barcelona's residents. For the city's politicians and residents, the transition away from the automobile regime has as much to do with increasing green space in the city as reducing CO2 emissions. For instance, the heat island effect, when understood through the lens of a sociotechnical-spatial landscape, is an example of the car-regime actor optimising the landscape for itself until it finally reached an inflexion point where it destabilises its own position in the system. The continual asphalting of roads for car-use in a dense urban environment has created the heat island effect along with the eventual backlash against cars and has opened a window of opportunity for other mobility niches to develop. Unlike Oslo and Ghent, which formed a LEZ by a ring-road, Barcelona created superblocks formed through the Eixample grid. Although initially designed to facilitate the horse-drawn tram regime, the landscape of wide streets and chamfered corners were particularly accommodating for the transition to the automobile and its parking requirements. However, the same grid that facilitated the transition to the automobile is now facilitating the transition away from it.

Figure 6.10:
Barcelona Superblock principle diagram.
Robert Martin, 2021.
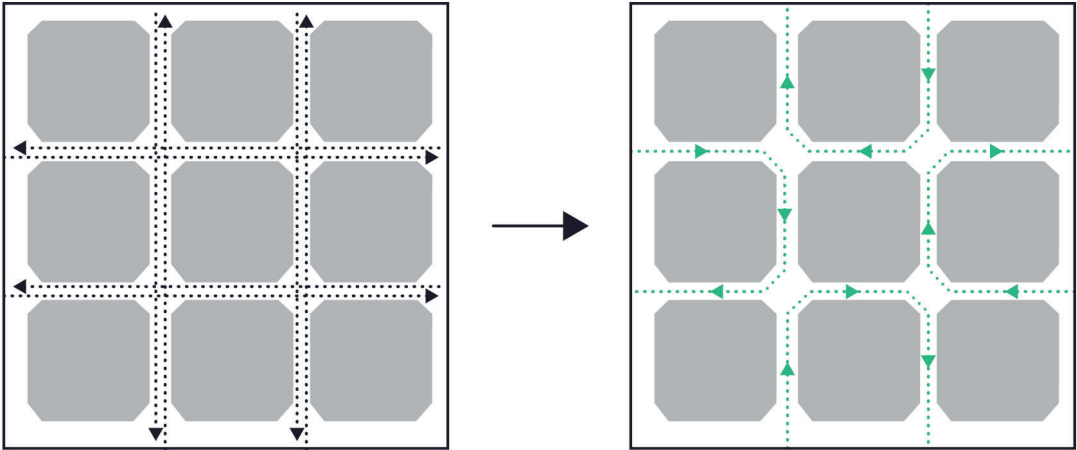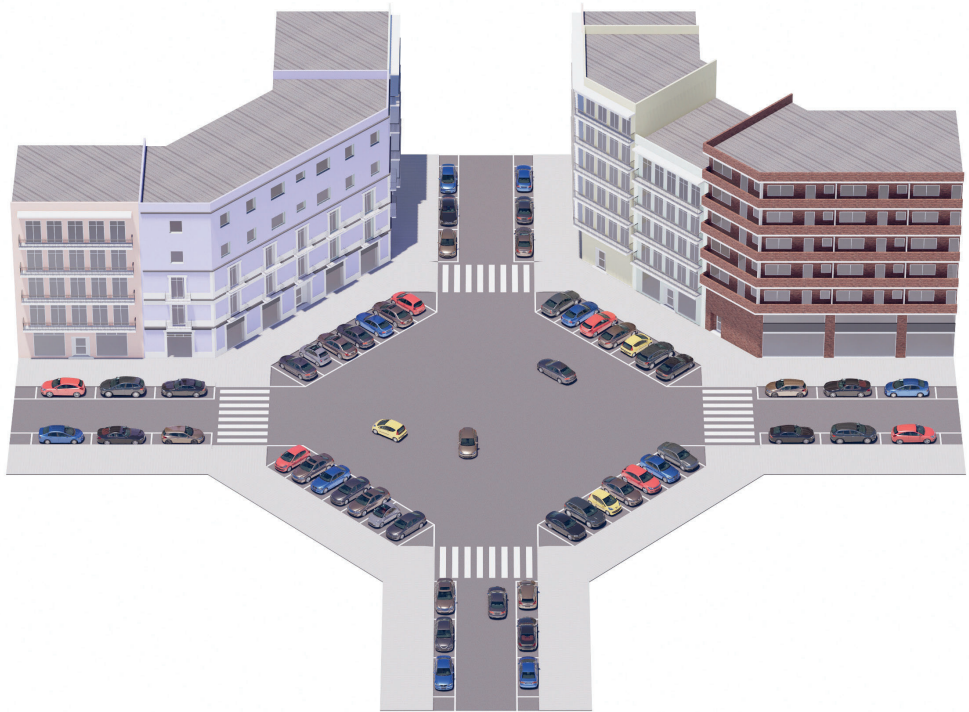
Figure 6.11:
Barcelona before and after superblock
axonometric.
Robert Martin, 2021.

Figure 6.12:
Map. Barcelona Superblocks
Robert Martin, 2021.
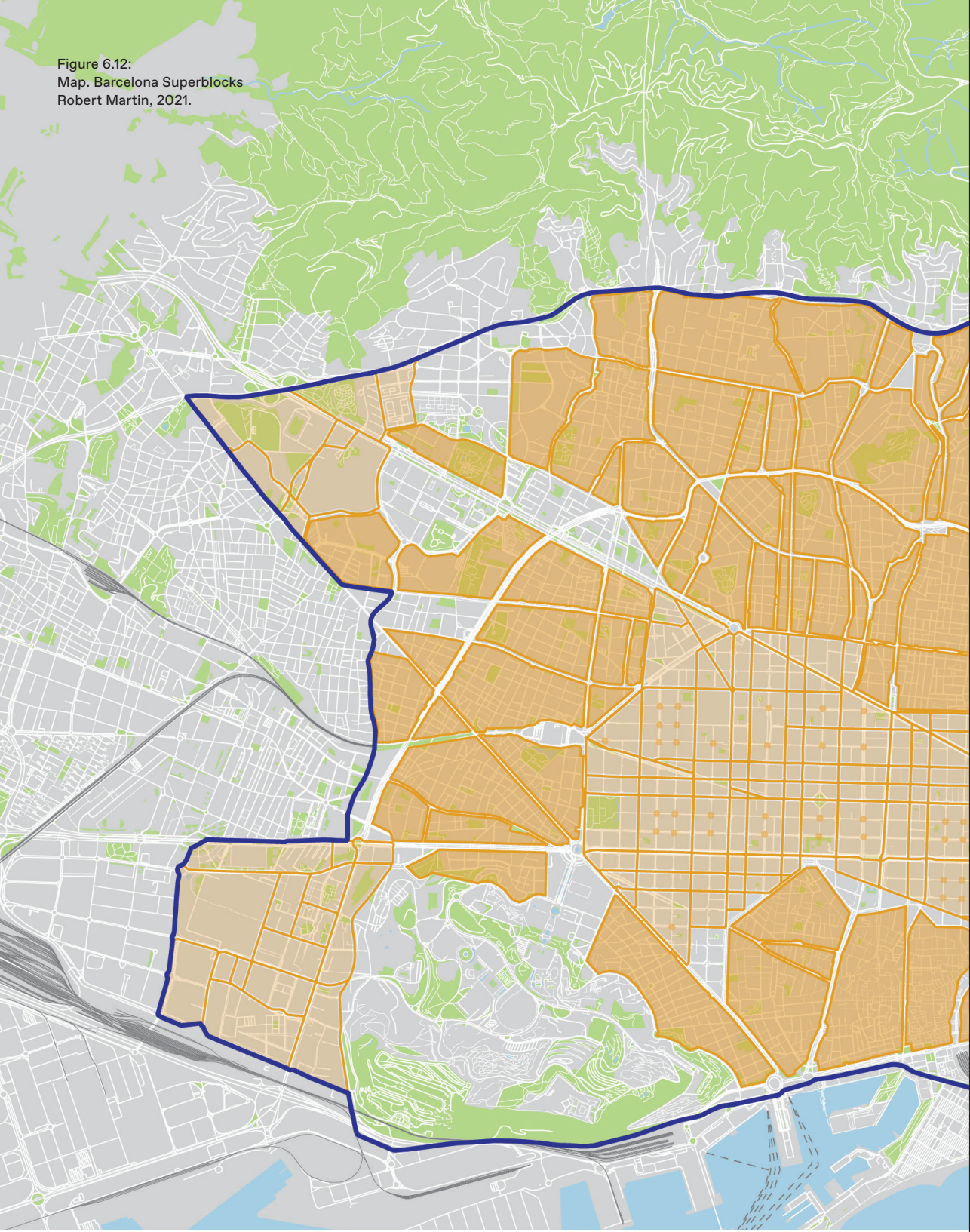
BARCELONA, SPAIN/
SUPERBLOCKS

0   2.5km
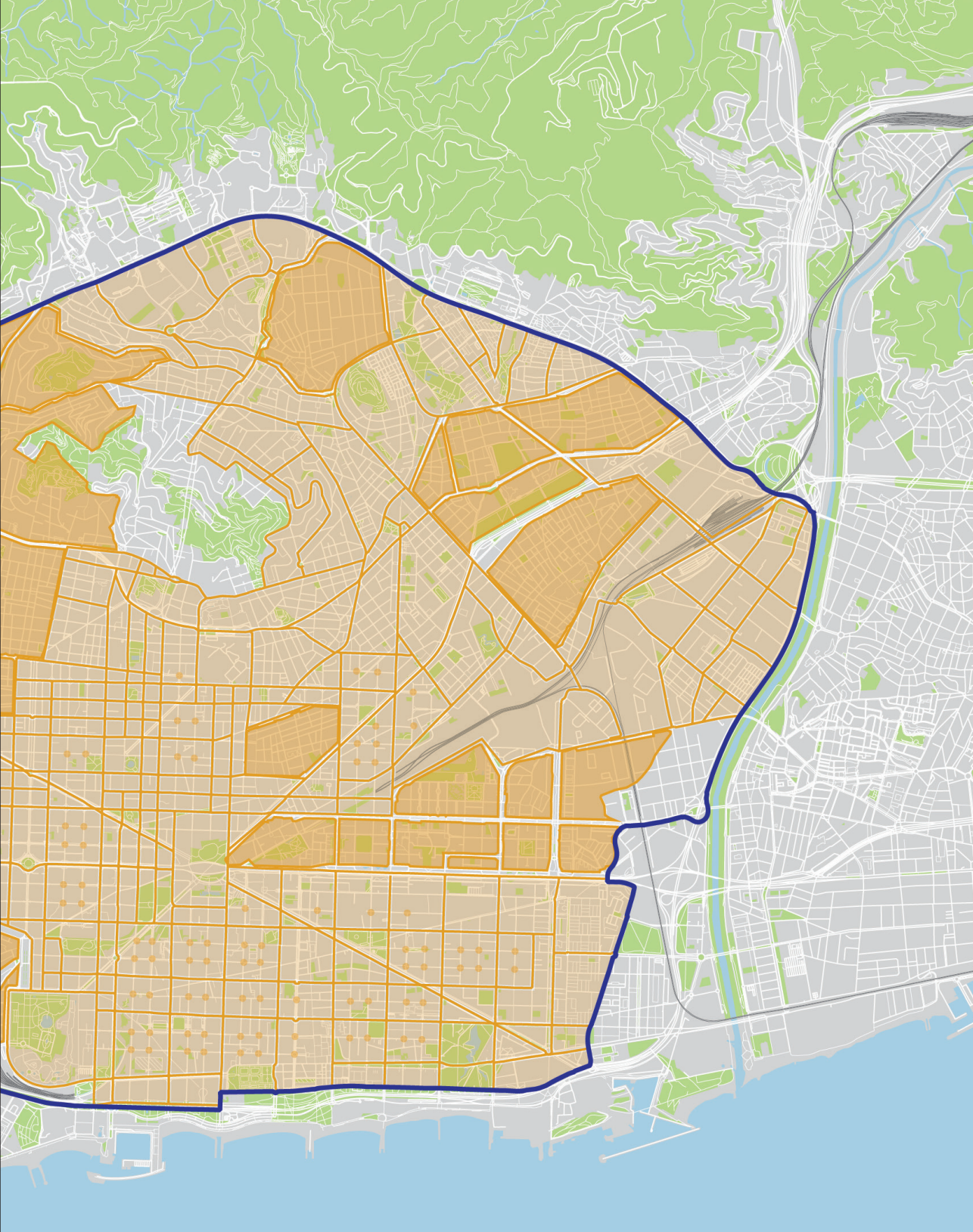
———	Municipal boundary
▬▬▬	Superblock
▬▬▬	30km/h zone
●	Intersecion

Figure 6.13:
Map. Barcelona transportation
network.
Robert Martin, 2021.
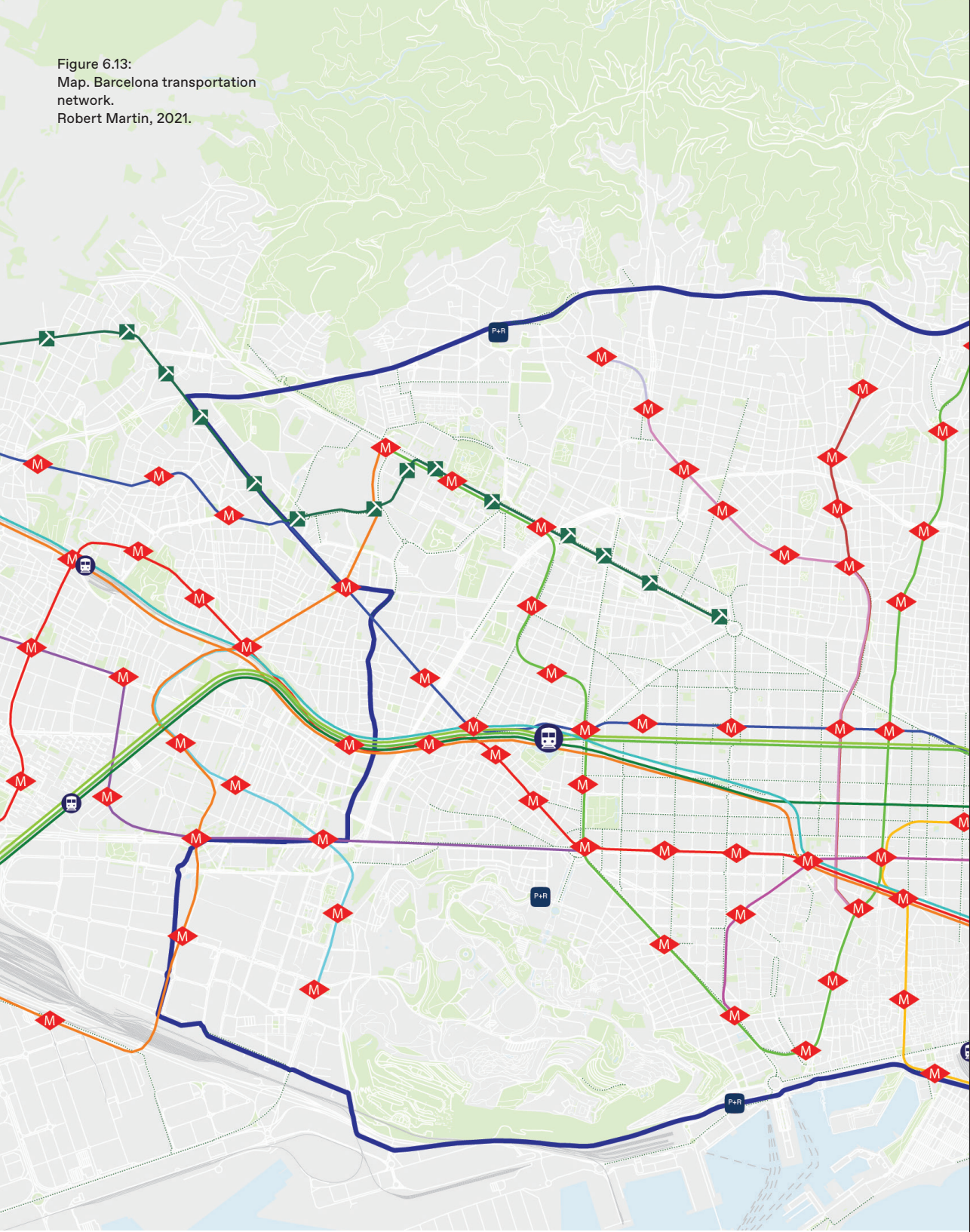
BARCELONA, SPAIN/
TRANSPORTATION NETWORK

0   2.5km

Legend

— Municipal boundary	⬆ Tram stop	◆M Metro stop
🚆 Train station	— Tram line	Metro line
Train lines	--- Ferry line	
⋯ Bicycle lane	P+R Park and ride	
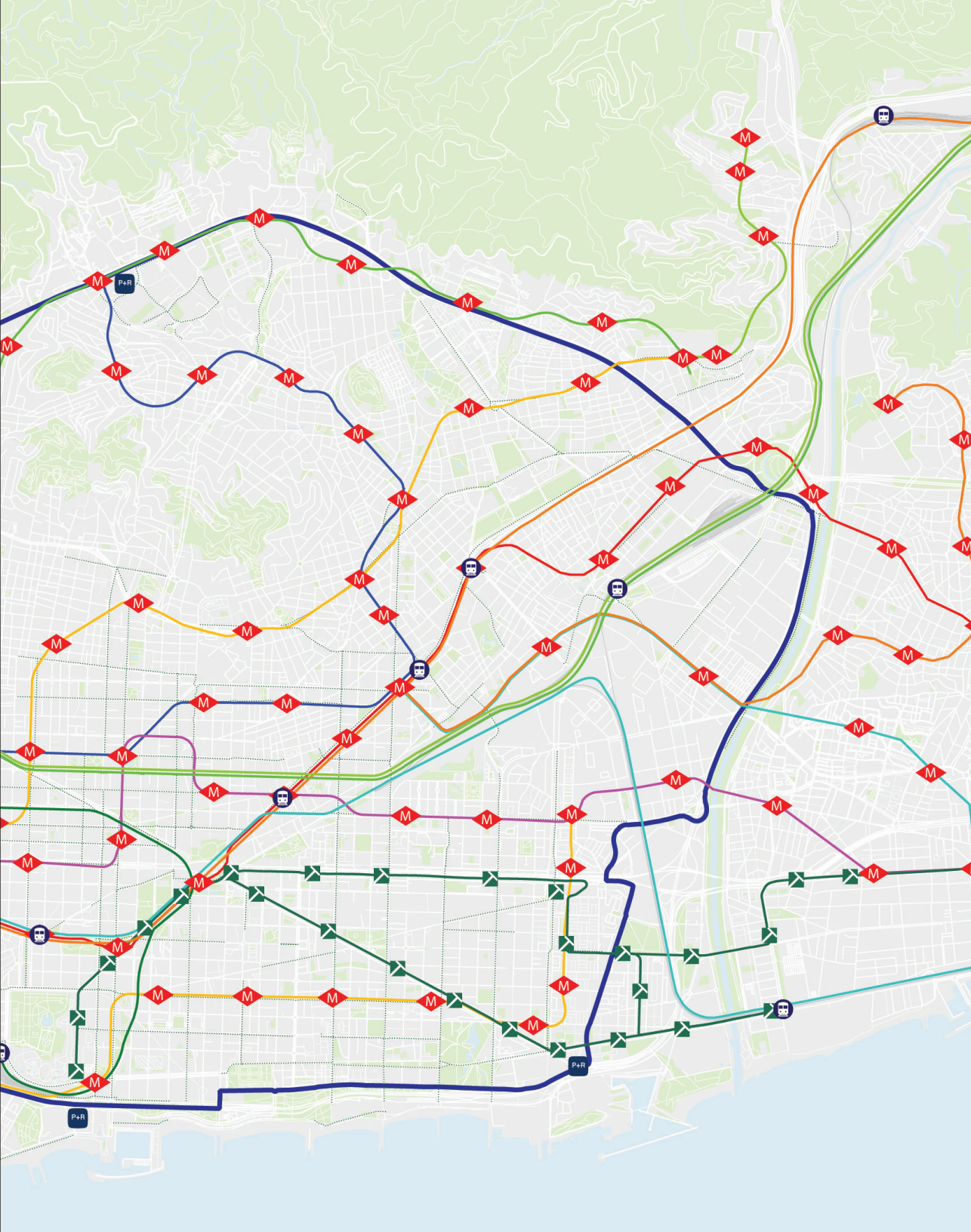
6.5 Discussion

When applying the analytical framework to the three case studies, the analysis revealed that a sociotechnical-spatial landscape contributed to the transition away from a car-dominant regime. In each of the three cities, a landscape that was created from previous regimes exerted pressure on the incumbent regime, opening opportunities for the development and support of car-free niches. For example, the narrow streets and tight urban fabric of Ghent lead to congestion and air-pollution when there became an abundance of cars. The analysis also revealed that the unique spatial strategy employed by each city was highly dependent on contextual factors found within their existing landscape. This relationship is important to note, because as an increasing number of cities plan to become car-free, they will look to each other for successful references and ideas. Without the necessary urban fabric or landscape features, cities may find it hard to replicate the strategies of their peers. Cities should, therefore, avoid cookie-cutter models in their pursuit to limit car-use. Instead, cities should pursue contextual approaches derived from the spatial conditions present within their administrative boundaries. Within the framework of the MLP, there are several spatial elements across the three case studies that can be conceptualised as elements of the landscape level that create opportunities for car-free niches.

In the case of Oslo, a landscape built around car-use ultimately contributed to the city's transition towards car-freeness. The combination of a ring road and tunnel built to service the car regime was fundamental to the city's ability to demarcate a zone that would be free of cars. Additionally, the presence of parking houses along the zone, which were built to allow greater car access (Shoup, 2005), in turn helped to facilitate the interchange between the car and other modes. Freeing the city centre from cars also freed road space that needed to be filled with alternative uses. Excess road width that was formally used for on-street parking was transformed into new infrastructure that supported the transition to more bicycle lanes, bicycle parking, and priority public transit routes. Without such shaping of the landscape to facilitate car-use through on-street parking, there would not have been the available width to accommodate new transport infrastructures within the street. Thus, spatial elements of the car regime created spaces for the development of car-free niches.

Similarly, the city of Ghent also utilised the landscape element of an existing ring road to demarcate a low emission zone. However, the city also benefited from a sociotechnical-spatial landscape that was developed through previous regimes throughout the city's history. Although relatively little is known about the planning processes involved in designing cities in the Middle Ages, their urban fabric is often a mixture of organic growth and irregular arrangements built around narrow streets and in proximity to the city's safety fortifications (Lilley, 2001). As a former medieval city, Ghent's historical core's dense urban environment was not suitable for car-use, which caused the negative externalities of congestion and air pollution and eventually lead the city's politicians to ban cars in the city's centre. Further ambitions to limit car access in the city were enabled and supported by the spatial legacy of Ghent's period as a port city. As a result, a series of canals run throughout the urban environment, limiting passage across them through only a few bridges. The city's planners took advantage of this spatial condition of a splintered urban form to create seven traffic islands within the R40 ring road whereby cars could not travel between the zones. Therefore, Ghent exemplifies how a sociotechnical-spatial landscape that has been formed by horse-, water-, and car-based transportation systems throughout the city's history has led to Ghent's car-free strategy.

Unlike the other case studies, Barcelona has followed a decentralised superblocks strategy to limit car-use rather than to implement a single car-free zone. One could argue that without a spatial landmark, such as a ring road, the city could not introduce such an area like that in Oslo and Ghent. Instead, the city has unlocked a hidden spatial potential in the Eixample city plan that was implemented in the mid-nineteenth century to aid horse-based transportation modes. By creating smaller, three-by-three block grids, miniature car-free zones have emerged over time in a literal interpretation of a niche as a protective space (Rip & Kemp, 1998). Within the protective space of a superblock, 'niche actors can nurture the path-breaking innovation so it becomes more robust through performance improvements and expansions in supportive sociotechnical networks' (Smith & Raven, 2012, p. 1025). This process has already been observed in the four superblocks that have been built independently from 2015 to 2018 that have involved different forms of civil opposition and support as well as various forms of citizenship engagement processes (López et al., 2020; Zografos et al., 2020). Furthermore, the transformation of each superblock has corresponded with the landscape pressure of heat island effects caused by excess road asphalt and offers a solution to more

than one societal problem. The spatial strategy of replacing roads with green infrastructure demonstrates an immediate effect that is recognised and felt by the local population, rather than the abstract success of meeting a CO_2 reduction target. As a result, spatial elements of the sociotechnical-spatial landscape, from the scale of a ring road to a single parking space, have been identified to contribute to the transition to car-free cities.

While the discussion so far has focused on the unique spatial conditions found within each city, the analysis also revealed many overlapping spatial qualities, which have been summarised in Table 6.1. This index deviates from the structure of the MLP, but it offers tangible inroads for planners and policymakers who are beginning to work with car-free strategies in their own cities. Although the index is not comprehensive and needs to be further developed into an applicable tool, it still offers certain benefits. By laying out the individual characteristics of cities that have had success limiting car traffic, the index offers a roadmap of spatial criteria to planners and policymakers who wish to limit car-use in their own cities. For example, high levels of population density and coverage of public transport and bicycle lane infrastructure are all present in the three case study cities. If a city wishing to reduce car-use does not meet any of those criteria, public authorities may wish to consider land-use zoning policies to increase density and the construction of bicycle lanes and public transport routes before pursing more intense car-free strategies. In this way, becoming 'car-free' can move beyond black and white understandings of car-use and towards a more nuanced understanding of a sociotechnical system in transition and the localised and spatial contexts in which they occur.

6.6 Conclusion

This paper argues for the role of physical space in sustainability transitions. It responds to knowledge gaps set out in Sustainability Transition Research Network's agenda (Köhler et al., 2019) regarding the geography of transitions, specifically by moving beyond spatial units towards spatial characteristics such as density, topography, urban layout, and material infrastructures. The paper particularly focuses on an understanding of the city as an object rather than a context of urban transportation and its ability to shape and be shaped by transition actors and forces. With this

Characteristic	Oslo	Ghent	Barcelona
Car-free area (sq.km)	12	1.3	60.94
Population	1,063	26,783	973,125
Urban density (persons/sq.km)	559	2,308	56,896
Number of buildings	934	24,333	56,596
Buildings within 100m of a bicycle lane	71.52%	75.58%	43.34%
Buildings within 600m of public transit node	100%	90%	99%
Ring road	Yes	Yes	No
Park and ride facilities	Yes	Yes	Yes
Roadblocks	Yes	Yes	No
Access requirements	Yes	Yes	Yes
On-street parking removal	Yes	Yes	Yes
Dedicated route to off-street parking	Yes	Yes	No
Urban structure	Grid	Medieval	Grid
30km Zones	No	No	Yes
Central station	Yes	Yes	Yes
Neighbourhood zones	No	Yes	Yes
Pedestrianised shopping streets	Yes	Yes	Yes

Table 6.1:
Spatial characteristics of the case-study cities.
Robert Martin, 2021

framework, a theoretical outset was established that links the multi-level perspective on transitions with spatial thinking to develop a greater understanding of the sociotechnical-spatial landscape.

To answer the research question of what kind of spatial features are found in urban environments that influence transitions, the theoretical framework was applied to multiple case studies of three European cities' efforts to limit automobile-based transport within 'car-free' discourses. The case studies demonstrate that a number of elements of the sociotechnical-spatial landscape that were formed from the current car-regime have offered opportunities for the development of 'car-free' niches. For Ghent and Barcelona, a sociotechnical-spatial landscape that included elements from previous dominant regimes such as horse-drawn carriages and water-based transportation also contributed to creating opportunities for car-free niches. Although each city had a unique spatial approach to their car-free strategy, several similarities were present; the summary of these attributes, presented in the discussion, may be useful to planners and policymakers working in the field.

In conclusion, the paper contributes to the sustainability transitions literature through a reconceptualization of the spatial dimensions of sociotechnical landscapes as critical components that enable transitions to sustainable urban transportation systems. Considering the levels of planetary urbanisation, this work is timely as it enriches the ability of

transitions scholars and policymakers to collaborate with urban professionals, such as architects, landscape architects, and urban designers, to support sustainability transitions through the analysis and shaping of the built environment. However, the study is limited to understanding how a sociotechnical-spatial landscape exerted pressure on a car-dominant regime, allowing opportunities for existing sub-regimes such as public transport, cycling, and car-free strategy niches to emerge. Further research should be directed to the study of emerging niche technologies such as e-scooters, connected and automated vehicles, and mobility as a service to understand their spatial demands and whether those spatial demands may be met within the existing landscape or adaptations to the built environment need to occur. This research may give a different understanding of the sociotechnical-spatial landscape and provide more insights into approaches towards the transition to sustainable transportation systems.

6.7 References

Amaral, R. R., Šemanjski, I., Gautama, S., & Aghezzaf, E. H. (2018). Urban mobility and city logistics – Trends and case study. Promet - Traffic - Traffico, 30(5), 613–622. https://doi.org/10.7307/ptt.v30i5.2825

Binz, C., Coenen, L., Murphy, J. T., & Truffer, B. (2020). Geographies of transition — From topical concerns to theoretical engagement : A comment on the transitions research agenda. Environmental Innovation and Societal Transitions, 34(November 2019), 1–3. https://doi.org/10.1016/j.eist.2019.11.002

Brown, A. E. (2017). Car-less or car-free? Socioeconomic and mobility differences among zero-car households. Transport Policy, 60(April), 152–159. https://doi.org/10.1016/j.tranpol.2017.09.016

Cadence. (2018). Ghent - Changing the Whole Circulation Overnight: a Strong Political Decision. Cadence. https://www.cadencemag.co.uk/ghent-changing-the-whole-circulation-plan-overnight-a-strong-political-decision/

City of Barcelona. (2014). Urban Mobility Plan Barcelona 2013-2018.

City of Barcelona. (2015). Barcelona Climate Commitment. http://ajuntament.barcelona.cat/premsa/wp-content/uploads/2015/11/Compromis_Bcn_Clima.pdf

City of Barcelona. (2017). How climate change affects us. https://www.barcelona.cat/barcelona-pel-clima/ca/com-ens-afecta-el-canvi-climatic/en-que-som-vulnerables

City of Stockholm Traffic Administration. (2009). Analysis of Traffic in Stockholm.

Coenen, L., Benneworth, P., & Truffer, B. (2012). Toward a spatial perspective on sustainability transitions. Research Policy, 41(6), 968–979. https://doi.org/10.1016/j.respol.2012.02.014

Coenen, L., & Morgan, K. (2020). Evolving geographies of innovation : existing paradigms , critiques and possible alternatives alternatives. Norwegian Journal of Geography, 74(1), 13–24. https://doi.org/10.1080/00291951.2019.1692065

Conley, J. (2009). Car troubles: Critical studies of automobility and auto-mobility (A. T. McLaren (ed.)). Taylor & Francis.

Frantzeskaki, N., Broto, V. C., Coenen, L., & Loorbach, D. (2017). Urban sustainability transitions. In Urban Sustainability Transitions. https://doi.org/10.4324/9781315228389

Freudendal-Pedersen, M. (2020). Sustainable urban futures from transportation and planning to networked urban mobilities. Transportation Research Part D: Transport and Environment, 82(March), 102310. https://doi.org/10.1016/j.trd.2020.102310

Freudendal-Pedersen, M., Hannam, K., & Kesselring, S. (2016). Applied mobilities, transitions and opportunities. Applied Mobilities, 1(1), 1–9. https://doi.org/10.1080/23800127.2016.1150562

Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Urban experimentation & sustainability transitions. European Planning Studies, 27(2), 219–228. https://doi.org/10.1080/09654313.2018.1532977

Geels, F. (2019). Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. Current Opinion in Environmental Sustainability, 39, 187–201. https://doi.org/10.1016/j.cosust.2019.06.009

Geels, F. W. (2005). The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860-1930). Technology Analysis and Strategic Management, 17(4), 445–476. https://doi.org/10.1080/09537320500357319

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. Environmental Innovation and Societal Transitions, 1(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. Journal of Transport Geography, 24, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. Research Policy, 36(3), 399–417. https://doi.org/10.1016/j.respol.2007.01.003

Gent Municipality. (2018). Ghent : A circulation plan as a step to the cycling heaven?

Goodwin, P. (1995). Car Dependence. Transport Policy. https://doi.org/10.1016/0967-070X(95)96744-6

Hoogma, R., Kemp, R., Schot, J., & Truffer, B. (2002). Experimenting for Sustainable Transport: The approach of Strategic Niche Management (D. Banister (ed.)). Routledge.

Jensen, S. S., Katzel, M. N., Klenø, J., & Becher, T. (2011). Hvad er Effekten af Miljøzoner for Luftkvaliteten?

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2019.01.004

Korver, W., Stemerding, M., Van Egmond, P., & Wefering, F. (2012). CIVITAS Guide for the urban transport professional. 132. http://www.civitas-initiative.eu/sites/default/files/Results and Publications/CIVITAS_Guide_For_The_Urban_Transport_Professional.pdf

Kuokkanen, A., & Yazar, M. (2018). Cities in sustainability transitions: Comparing Helsinki and Istanbul. Sustainability (Switzerland), 10(5), 1–18. https://doi.org/10.3390/su10051421

Levin-Keitel, M., Mölders, T., Othengrafen, F., & Ibendorf, J. (2018). Sustainability transitions and the spatial interface: Developing conceptual perspectives. Sustainability (Switzerland), 10(6), 1–15. https://doi.org/10.3390/su10061880

Lilley, K. D. (2001). Urban planning and the design of towns in the Middle Ages: The Earls of Devon and their "new towns." Planning Perspectives, 16(1), 1–24. https://doi.org/10.1080/02665430010000751

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources. https://doi.org/10.1146/annurev-environ-102014-021340

López, I., Ortega, J., & Pardo, M. (2020). Mobility infrastructures in cities and climate change: An analysis through the superblocks in Barcelona. Atmosphere, 11(4). https://doi.org/10.3390/ATMOS11040410

Lyons, G. (2015). Transport's digital age transition. Journal of Transport and Land Use, 8(2), 1–19. http://www.jstor.org/stable/26202710

Mackinnon, D., Pririe, G., & Gather, M. (2008). Transport and Economic Development. In R. D. Knowles, J. Shaw, & I. Docherty (Eds.), Transport Geographies: Mobilities, Flows and Spaces (pp. 10–28). Blackwell.

Marx, R., De Mello, A. M., Zilbovicius, M., & De Lara, F. F. (2014). Spatial contexts and firm strategies: Applying the multilevel perspective to sustainable urban mobility transitions in Brazil. Journal of Cleaner Production, 108, 1092–1104. https://doi.org/10.1016/j.jclepro.2015.09.001

Mom, G. (2014). Atlantic Automobilism: Emergence and Persistence of the Car, 1895-1940. Berghahn Books.

Moreno□garcia, C. (1994). Intensity and form of the urban heat island in barcelona. International Journal of Climatology. https://doi.org/10.1002/joc.3370140609

Mueller, N., Rojas-Rueda, D., Basagaña, X., Cirach, M., Hunter, T. C., Dadvand, P., Donaire-Gonzalez, D., Foraster, M., Gascon, M., Martinez, D., Tonne, C., Triguero-Mas, M., Valentín, A., & Nieuwenhuijsen, M. (2017). Urban and transport planning related exposures and mortality: A health impact assessment for cities. Environmental Health Perspectives, 125(1), 89–96. https://doi.org/10.1289/EHP220

Mueller, N., Rojas-Rueda, D., Khreis, H., Cirach, M., Andrés, D., Ballester, J., Bartoll, X., Daher, C., Deluca, A., Echave, C., Milà, C., Márquez, S., Palou, J., Pérez, K., Tonne, C., Stevenson, M., Rueda, S., & Nieuwenhuijsen, M. (2019). Changing the urban design of cities for health: The superblock model. Environment International, 134. https://doi.org/10.1016/j.envint.2019.105132

Munro, F. R. (2019). The geography of socio-technical transitions: Transition–periphery dynamics. Geographical Journal, 185(4), 447–458. https://doi.org/10.1111/geoj.12306

Nielsen, J., & Farrelly, M. A. (2019). Conceptualising the built environment to inform sustainable urban transitions. Environmental Innovation and Societal Transitions, 33(February), 231–248. https://doi.org/10.1016/j.eist.2019.07.001

Norton, P. D. (2010). Fighting Traffic: The Dawn of the Motor Age in the American City. The Journal of American History. https://doi.org/10.2307/27694848

Ornetzeder, M., Hertwich, E. G., Hubacek, K., Korytarova, K., & Haas, W. (2008). The environmental effect of car-free housing: A case in Vienna. Ecological Economics, 65(3), 516–530. https://doi.org/10.1016/j.ecolecon.2007.07.022

Reid, C. (2020). How a Belgian port city inspired Birmingham's car-free ambition. The Guardian. https://www.theguardian.com/environment/2020/jan/20/how-a-belgian-port-city-inspired-birminghams-car-free-ambitions

Reuters. (2015). Oslo aims to make city centre car-free within four years. Reuters. https://cn.reuters.com/article/norway-environment-oslo/oslo-aims-to-make-city-centre-car-free-within-four-years-idUSL8N12J1UX20151019

Rip, A., & Kemp. (1998). Technological Change. In S. Rayner & E. L. Malone (Eds.), Human choice and climate change. Vol. II, Resources and Technology (pp. 327–399). Battelle Press.

Rueda, S. (2016). La supermanzana, nueva célula urbana para la construcción de un nuevo modelo funcional y urbanístico de Barcelona. http://www.bcnecologia.net/sites/default/files/proyectos/la_supermanzana_nueva_celula_poblenou_salvador_rueda.pdf

Rydningen, U., Høynes, R. C., & Kolltveit, L. W. (2017). OSLO 2019: A car-free city centre. WIT Transactions on Ecology and the Environment, 226(1), 3–16. https://doi.org/10.2495/SDP170011

Sadler Consultants. (2020). Urban Access Regulations in Europe. https://urbanaccessregulations.eu/userhome/map

Sheller, M. (2004). Automotive Emotions: Feeling the Car. Theory, Culture & Society, 21(5), 221–242. https://doi.org/10.1177/0263276404046068

Shoup, D. (2005). The High Cost of Free Parking. Planners Press.

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. Research Policy, 41(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Statistics Norway. (2020a). Population and land area in urban settlements. https://www.ssb.no/en/befolkning/statistikker/beftett

Statistics Norway. (2020b). Regional population projections. https://www.ssb.no/en/befolkning/statistikker/regfram

Sweco. (2020). Program bilfritt byliv: Evaluering av trafikale effekter.

The Municipality of Oslo. (2015a). Det grønne skiftet: Klima- og energistrategi for Oslo. https://www.oslo.kommune.no/getfile.php/Innhold/Politikk og administrasjon/Etater og foretak/Klima- og energiprogrammet/Dokumenter og rapporter/Det grønne skiftet - Utkast til Klima- og energistrategi for Oslo.pdf

The Municipality of Oslo. (2015b). Smart, Trygg, Grønn. Kommuneplan 2015: Oslo mot 2030.

The Municipality of Oslo. (2019). Program Bilfritt byliv.

Topp, H., & Pharoah, T. (1994). Car-free city centres. Transportation, 21(3), 231–247. https://doi.org/10.1007/BF01099212

Truffer, B., Murphy, J. T., & Raven, R. (2015). The geography of sustainability transitions: Contours of an emerging theme. Transitions, 17, 63–72. https://doi.org/10.1016/j.eist.2015.07.004

United States Department of Transportation. (2011). Congestion Pricing: A Primer.

URBACT. (2020). Ghent. https://urbact.eu/ghent

Urry, J. (2005). The "System" of Automobility. In Automobilities (pp. 25–40). SAGE Publications.

Watteeuw, F. (2020). How to become a cycling city..

WHO Regional Office for Europe. (2016). Urban green spaces and health. 92.

Yin, R. K. (2003). Cast Study Research: Design and Methods (L. Bickman & D. J. Rog (eds.); Third). SAGE Publications. https://doi.org/10.1300/J145v03n03_07

Zijlstra, T., & Avelino, F. (2012). A Socio-Spatial Perspective on the Car Regime. In F. W. Geels, R. Kemp, G. Dudley, & G. Lyons (Eds.), Automobility in Transition? A Socio-Technial Analysis of Sustainable Transport (p. 373). Routledge.

Zografos, C., Klause, K. A., Connolly, J. J. T., & Anguelovski, I. (2020). The everyday politics of urban transformational adaptation: Struggles for authority and the Barcelona superblock project. Cities, 99(June 2018), 102613. https://doi.org/10.1016/j.cities.2020.102613

Chapter 7:

Ontological Expansion Through the Visualisation of Space

An Architect's Contribution to the Sustainable Urban Mobilities Agenda.

7.0 Abstract

A growing uncertainty about the future has driven transport planners and mobilities researchers to develop new methodologies and ontologies for planning sustainable urban mobilities. This article explores how architects can contribute to this agenda with their own visualisation methods and outlooks towards the future. The article presents data gathered during two visioning workshops for a car-free area in Copenhagen, Denmark where the visualisation of the spatial implication of transport choices was a key catalyst for the participants' discussion. The findings from the two workshops reveals that these visualisations helped the participants overcome different forms of resistance through a process of ontological expansion that inspired the participants to imagine possibilities beyond their existing worldviews. Overcoming this resistance within each workshop was integral to generating the different forms of knowledge necessary for the transition to sustainable transportation systems. The paper concludes with recommendations for future application of the methodology as well as an outlook for further research.

7.1   Introduction

The future of urban mobilities is a topic that is growing in interest for researchers, politicians, planners, and the public around the world. Dominant discussions focus on what these future urban mobilities will look like and whether they will achieve targets to successfully de-carbonise and minimise the effects of climate change. Historically, transportation in our societies has mainly been approached from a positivist and empiricist position that has attempted to understand the future through predictions models based on historical trends and relational extrapolation (Cresswell, 2011). However, the ambiguity posed by the emergence of new transport innovations such as self-driving cars, micromobility, and battery-electric vehicles; their constantly changing timelines of adoption, and doubts about whether they will replace or be adopted by existing transport regimes has created a high level of uncertainty about the future (Lyons & Davidson, 2016). Consequently, this ambiguity creates difficulty for planners and policymakers as the tools that modern societies rely on to plan, such as forecasting and simulation, are dependent on a degree of certainty to qualify their own projections. As the degree of uncertainty increases, the extent and accuracy of these tools to anticipate and plan for the future decreases (Flyvbjerg et al., 2006). Therefore, given such ambiguity about the future of urban transport, planners require new methods of inquiry and knowledge production.

In the face of this uncertainty, a growing body of disciplines are interested in developing new methodologies and ontologies for planning future mobilities. This article explores how architects can contribute to the mobilities agenda with their own methods and outlooks towards the future. Historically, architects have had a fascination for new transportation technologies which has been conceptualised in new forms of urban living (e.g., Le Corbusier's Ville Radieuse in 1930 and Frank Lloyd Wright's Broadacre City in 1932). However, this engagement with transportation subsided during the twentieth century as automobiles became the dominant transport mode through a 'system of automobility' (Urry, 2005) that lead many to take designing cities around cars

for granted. Nevertheless, the emergence of discourses surrounding autonomous vehicles has reignited architects' imaginations by defining new opportunities for architectural intervention in the urban realm (Duarte & Ratti, 2018; Martin et al., 2021). Furthermore, the boundary of possibility for architects' visions has expanded beyond the plot of private property and has begun to reimagine the transformation of automobile infrastructure into new forms of building such as collective housing, intermodal mobility hubs, climate resilient infrastructures, and typologies of urban living (Sevtsuk & Shieh, 2019).

These architectural visions of the future offer alternative methods for approaching the planning of urban mobilities. Rather than trying to predict the future, the approach is concerned with consciously shaping a vision that represents a better future. I suggest that this process moves transport planning away from 'predict and provide' ontologies, which have left cities with splintered territories and continual highway expansion with never-ending congestion, to 'decide and provide' explorations, which offer pathways to achieve the required spatial, social, and technical transformations of society to meet our climate goals. In this paper, I present how architectural visions have been used to introduce, inspire, and invert participant conversations within two visioning workshops that aimed to develop strategies and policies towards the transition to a car-free urban environment in Copenhagen, Denmark. Through my findings, I demonstrate how visualisations have been applied to overcome different forms of resistance, to illustrate emerging trends in urban mobilities futures, and to uncover a variety of futures that might not have been envisaged otherwise. The final section offers concluding remarks and a reflection for further research outlooks in the future.

7.2   Project Background

The scope of this paper covers four months of an Industrial PhD project funded by the Innovation Fund Denmark and JAJA Architects. The overall purpose of the PhD project is to articulate how to synthesise analytical research and architectural design methods to create a scenario for a car-free area of Copenhagen, Denmark. The city was chosen as a site of exploration for several reasons. First, Copenhagen is the home of JAJA Architects, therefore, the city's transportation

systems are considered as embodied mobilities by the project's stakeholders. Second, since Copenhagen is already a model for green mobility, it is an excellent case study context to study how a city can become car-free. Within the Municipality of Copenhagen, 29% of all trips that either begin or end within its boundary occur by bicycle, 70% of households are car-free, it has one of the most accessible public transport systems in Europe (City of Copenhagen, 2017; Scheurer, 2013), and the municipality aspires to be the first carbon-neutral capital in the world by 2025 (The City of Copenhagen Technical and Environmental Administration, 2012). Third, despite being a leader in green mobility, Copenhagen's transportation system is anything but secure due to economic, social, and political tensions (Henderson & Gulsrud, 2019). After decades of policies aimed at attracting tax revenue-generating families back to the city, Copenhagen risks becoming a more car-oriented city. Although Copenhagen has made significant investments into public transport, these have been paid for by new urban developments that enable families to own a car within the city boundary, which has increased the number of cars in the city by 30% since 2000 (Københavns Kommune, 2016). While Copenhagen has announced an unprecedented target of having 75% of all trips completed by either walking, bicycle, or public transport (Københavns Kommune, 2019), it has not seriously outlined how it will restrict car use. Strategies so far have focused on small-step initiatives relating to cycling infrastructure and electric vehicles, which are not radical enough to bring forward a vision of carbon neutrality (Freudendal-Pedersen et al., 2020). Calculations show that even if full phasing-in of smaller CO_2-emitting cars is accelerated, it cannot make transport in Copenhagen CO_2 neutral by 2025. Even if all new cars are electric vehicles, transport in Copenhagen will still emit approximately 300,000 tons of CO_2 in 2025 (Via Trafik Rådgivning A/S, 2020). In the background of this discussion, the transportation sector's share of Copenhagen's total CO_2 increased by 11% from 2010 to 2015 (City of Copenhagen, 2016), and congestion in and out of the city is estimated to grow by 150% by 2030 (Transport Construction and Housing Ministry, 2018).

Furthermore, despite its political ambition, the Copenhagen Municipality still lacks the planning tools to transition towards a decarbonised transportation system. The development of these tools may emerge from a creative practice that emphasises dynamic approaches that span across traditional organisational boundaries (Freudendal-Pedersen et al., 2020). The following section outlines how two visioning workshops were used to understand how architectural methods

can be utilised to develop new ways of thinking about and planning for sustainable urban mobilities.

7.3 Two Visioning Workshops for Future Mobilities in Copenhagen

The primary methodological component of the PhD project was two visioning workshops held at Aalborg University's Copenhagen campus. These workshops were developed based on the 'Future Workshop' methodology (Andersen & Jæger, 2001; Jungk & Mullert, 1987), but instead of asking the user groups to propose their own futures, I co-designed possible future developments with the participants through architectural design tools and visualisations. The aim of the workshops was to acquire knowledge and form a consensus between the different participants and derive planning pathways that can inform planning thinking for future mobilities. The two workshops were staged with a two-month break in between. Although they were held as two separate events, they were part of a reflexive methodology where the findings from the first workshop were used to develop the second. Central to both workshops was the co-development of a proposal for a car-free Copenhagen that was expressed through images and drawings. These images, or glimpses of the future, became a medium for the participants to elaborate on new and existing policies for future sustainable urban mobilities.

To facilitate a holistic and comprehensive process, 30 participants from different fields were identified and invited to participate in the two workshops. The participants were chosen based on their professional background and relationship to urban development and mobility in Copenhagen. The group of participants included politicians, municipal workers, city developers, urban planners, researchers, public and private mobility operators, and representatives from both automobile and cycling advocacy groups. Due to COVID restrictions, a total of 12 participants were able to attend.

Within each workshop, the participants were organised into three separate groups to obtain the widest possible spread of disciplinary backgrounds. It was assumed that mixing professionals from different backgrounds would uncover ontological differences through smaller, informal discussions before sharing these differences with the entire workshop during common discussions. These ontological differences were important to uncover as they provided pathways to avoiding business-as-usual planning approaches to transport.

Each workshop was divided into three sessions with the goal to build common ground between the participants (Freudendal-Pedersen & Kesselring, 2015). Each session lasted one hour and involved a short ten-minute presentation to introduce the session topic, a 15-minute small group exercise, and a 25-minute common discussion amongst all the workshop participants. Following these three sessions, 20 minutes was put aside for concluding remarks. The first workshop sessions centred on the following core questions: *What does car-free mean? What is everyday mobility without cars?* and *What does the car-free city look like?* The aim was for the participants to move closer to a collective idea of a car-free Copenhagen and a more material and concrete vision of it in each subsequent session. In the second workshop, the collective vision of a car-free Copenhagen was presented through the three sessions using a series of design proposals. In the second workshop, the discussions focused on the core questions of *What is missing from this vision?* and *How can we make this happen?*

The constant reminder of the urban implications of transport were central to the application of architectural methods in the visioning workshops. These reminders took the form of visual materials such as photographs, maps, graphs, diagrams, collages, visualisations, and architectural drawings such as plans, sections, and axonometric perspectives. These visual reminders were intended to embed the ideas that the participants were discussing within concrete materialities so that they could connect it to their everyday lives. The workshop participants were exposed to the visual materials through two different formats. The first was through the introduction presentation as the participants were shown up to 20 images to initiate the ideation process. The second format was during the small group exercises when images of a test site within Copenhagen were shown to the participants as part of a stimulus kit to inspire creativity amongst the group. Each session involved a new stimulus kit that was related to the session topic. For example, one kit included a map of Copenhagen, icons related to different strategies to

limit car-use, a smart phone with Google Maps to navigate available mobility options in unknown areas, and eye height images of streets where the road surface had been removed using photograph editing software (Figures 7.1 and 7.2). Participants in the workshop used these kits as prompts for the common discussion following the small group exercise. The discussion at the end of each session and review of the kit material was captured by notes, drawings, photographs, and voice recordings.

The findings from the first workshop were then analysed and used as prompts for a two-month design sprint that was then used as material for the second workshop. In this design sprint, I incorporated elements of the desktop research with the findings from the first workshop to inform a design process that was based on my experience as an architect and urban planner. The output of this sprint was a series of design proposals for a car-free zone that represented the collective vision of the participants. These proposals took the form of a series of images representing critical moments in the future. While the first workshop's aim was to build a collective vision amongst the participants, the second workshop was intended to test that vision. The workshop participants were presented the design proposals in the same manner as the first workshop. There were three goals in this process: to evaluate the feasibility of the design proposals from a wide range of disciplines, to determine whether the design proposals could prompt further design ideas, and to elaborate more potential pathways. Both workshops prompted a variety of inputs to the discussion of the transition towards a car-free Copenhagen. While the first workshop tended to focus on broad challenges and political processes, the collective design process of the second workshop created a space for elaborating on concrete ideas for car-free initiatives within the urban configuration of Copenhagen. The following sections present a summary of the key findings from the workshops from the perspectives of their relevance to Copenhagen and of the wider theoretical contributions to planning.

Figure 7.1:
Map of Copenhagen with car-free
strategy icons sued during workshop 1.
Robert Martin, 2020.

Figure 7.2:
Map of neighbourhood block with
street view images highlighting parking
space used during workshop 1.
Robert Martin, 2020.

7.4 Different Forms of Resistance Throughout the Visioning Workshops

Throughout the two workshops, I experienced various forms of resistance at different stages of participant interaction. These forms changed between the two workshops; participants during the first workshop were sceptical of whether creating a car-free city was possible while the participants in the second workshop challenged me to remove more cars. This section describes the different types of resistance that were encountered and highlights how they changed because of the visioning workshop methodology.

7.4.1 Workshop 1: You Cannot Be Too Radical!

Throughout the first workshop, I encountered different forms of resistance that questioned whether the notion of 'car-free' was realistic. An example of these was the expectation from all the participants that changes to limit car access in Copenhagen could not occur without strong political backing. Although all the participants recognised the need to address the rising car-use in Copenhagen, they did not believe that within their own professions they could accomplish the necessary impact. This response persisted after the participants were shown numerous examples of other European cities that had successfully implemented car-free strategies. This sentiment was captured towards the end of the workshop by one participant who noted that

> we do not have a political goal saying that we want to have fewer cars. Of course, we could achieve that reduction through regulation and restriction if there was political backing there to do it, but cars

are something the politicians do not dare to touch. It makes it very difficult and complicated for us.

The idea that cars are something that politicians 'do not dare to touch' is an example of a 'structural story' (Freudendal-Pedersen, 2009), which is a popular narrative that contradicts the actual situation. As mentioned earlier, 70% of Copenhagen's households do not own a car (City of Copenhagen, 2017). While this fact does not equate to political support for removing car access, the 30% of households that do own a car in the municipality certainly do not represent a majority. To suggest that removing cars would be political suicide is simply a form of resistance to change that is directed by global normativity.

Another example of resistance was the understanding that the transition to being car-free was not only a function of technological change but that it also required socio-cultural and structural change. Although not intended by the participants, this form of resistance became important for their discussions as it prompted discussions about alternative forms of living that challenged mainstream techno-optimist solutions. For example, one of the participants expressed the following concern after being asked about mobility choices in the car-free city:

> *We must remember that the new generation has grown up with the on-demand economy. Everything they do is on demand: they want it now, they want it in front of their door, they want to decide where they want to go, and they do not want to be dependent on other people. If I do not come up with a product that suits them, some American company will come in and do it.*

Others in the group responded by challenging whether society should take the on-demand economy for granted in the future. The workshop participants then considered the challenges of family life and how hard it is for them to coordinate within the complexity of everyday life. Stemming from this conversation, proposals of future transportation systems emerged as the participants acknowledged that a society where there is an expectation to have all needs fulfilled instantaneously will always be unsustainable. From this point of resistance, the participants were able to imagine future urban mobilities beyond the scope of pedestrian, bicycle, car, and public transport.

Another form of resistance that I encountered during the first workshop was the participants' general inability to

conceive of a future without cars. Although each participant was directly or indirectly working against private automobile use, no one could give a clear vision of life unfolding without a car. While everyone could speak generally about limiting car use at a macro scale when discussing a map at a city of neighbourhood scale, this completely changed when they were asked to consider a street level image and describe what it could look like without the associated car infrastructure. This understanding is best summarised by a participant who said,

> So, at a macro scale it seems very smart to limit car use. But the closer to the street you get, the more baffled we became on what it would look it. We did not come up with any amazing ideas. Maybe you could grow some vegetables? I think our brains are blocked because the more concrete it gets [sic], the more it looks unrealistic. Why is this hard for us? It would be great to have more data to help us.

The final sentence in the quote offers significant insight into the challenge faced by planners and policymakers—data has become a crutch for the unimaginative to lean on and justify decisions. Even within the safe space that the future workshop created, the participants were unable to trust their own insights and intuition. This demonstrates that the transition to sustainable urban mobilities will not come from data, because only small and predictable solutions come from data. Instead, the radical transformation needed for sustainability transitions will come from something that data cannot see, because the future has not happened yet. The next section outlines how architectural methods were used to inspire imaginative alternative futures for the workshop participants.

7.4.2   Workshop 2: You Have Not Been Radical Enough!

As mentioned previously, the resistance experienced in the second workshop took another form than that of the first. While the resistance in the first workshop was characterised by scepticism of the idea of a car-free Copenhagen, the resistance in the second was predominantly about the visions of the future not being radical enough. This altered form of resistance likely came from the participants in the second workshop reviewing the visual input proposed by those from the first workshop. For example, in the first workshop participants were hesitant to remove any on-street parking, but

after showing them a visualisation of a street where 70% of on-street parking had been removed, they remarked that this still privileged the car too much. This sentiment was best summarised by a participant who noted that:

> *it needs to be a radical change, you cannot go halfway, you cannot even go 80% or 90%, you need 100% of cars gone. If you allow just one car in, it is going to destroy it and you are not going to get the life that you want in there. Of course, you will have some problems, but they can be solved by bicycles and public transport. If you really think radically, then you could finally have areas where parents are not afraid to let their children play on the street.*

This form of resistance was by far the most unexpected that I encountered. This phenomenon may be best described by what Marteen Hajer calls 'ontological expansion' (2016). Hajer describes this process as the transformative potential of material such as visualisations to help people imagine beyond their existing worldviews. The visualisations gave the workshop participants a glimpse of an alternative future that inspired them to think beyond what they thought was possible.

Furthermore, other forms of experienced resistance helped the participants collectively rally around the challenge of transitioning to a car-free Copenhagen. For example, several participants questioned the possibility of the design proposals based on financial costs. While this could have stalled the imaginative process in the collective discussions, it led the group to generate rich insights. As the discussion progressed, participants proposed methods to finance such a grand scheme, such as one participant who said:

> *I am coming to this discussion with a very pragmatic approach, but this is only because such a project that you are proposing is extremely costly and it is important to take that into reality. There is an enormous amount of infrastructure underneath when you are re-arranging streetscapes, so it becomes very expensive. But I am not scared of big numbers – all large infrastructure projects have big numbers; it is just a matter of financing. We are a rich society, so we can always find the money. It is just a matter of taking the right choices and making the right plan to do it. For instance, I am very pro-congestion charging. That could create they money to realise this project.*

Other participants suggested that existing programmes funded by the municipality could be a means to finance the proposed car-free design:

> *How do we move this project? Well in the municipality we are planning to build thousands of little recycling stations, and it is already financed. So that is a huge infrastructure project that we could combine with your project. We've already discussed the effect of internet trading; well, these recycling stations could act as little hubs to create a community spaces that handle many different daily functions including trash and delivery. That could create a lot of excitement, it is going to be rolled out all over the city.*

7.5 Knowledge needed for sustainability transitions

Despite the different forms of resistance experienced, the two visioning workshops demonstrated a viable method of producing knowledge on the transition towards a car-free Copenhagen. To achieve such a transition, scholars speculate that three kinds of knowledge need to be produced: systems knowledge, target knowledge, and transformational knowledge (Pohl & Hirsch Hadorn, 2007). Systems knowledge entails an understanding of the current state of systems and actors. The aim of target knowledge is to develop alternatives to those systems,, and transformational knowledge regards building pathways from a currently unsustainable present towards a desirable future. According to Pohl and Hirsch Hadorn (2007), traditional forms of scientific study have been successful in producing systems knowledge; however, these forms are not sufficient for the generation of target and transformational knowledge. According to Gaziulusoy and Ryan (2017, p. 1917), visioning workshops have been shown to generate both target and transformational knowledge as they enable the articulation of not only alignment but also contradictory perspectives to demonstrate the viability of alternative futures.

The process of producing systems knowledge began before the two visioning workshops. This involved starting with desktop research to review theories of sustainability transitions (Köhler et al., 2019), the new mobilities paradigm (Sheller & Urry, 2006), urban planning, the landscape of emerging transportation technologies, and data on Copenhagen and its urban development policies. This early phase also involved identifying and engaging relevant stakeholders and project partners to develop an understanding of the diverse array of perspectives important to transition to car-free urban environments in Copenhagen. This process revealed insights on the challenges and opportunities perceived by the stakeholders and particular domains that they found relevant to their own organisations that went beyond generic problems, such as congestion and pollution, associated with transport in most cities. The most pertinent observation from the stakeholders was the growing trend of the Copenhagen 'weekend car'. This unique phenomenon entails that cars, which are not purchased as a primary commuter mode, sit dormant on the street during weekdays and are only used by Copenhagen residents to escape the city on the weekend, to visit their holiday home, or to partake in recreational activities where public transport and cycling are not appropriate. At the individual level this trend may not seem like a problem, but as the phenomenon becomes more common, increasing pressure is placed on the stock of on-street parking where inefficient demand has outgrown supply. A 2016 study of two representative areas of Copenhagen found that one in four cars parked on the street did not move from Monday to Friday (Københavns Kommune, 2017); however, the stakeholders who were interviewed anticipated that the situation had worsened. This phenomenon of the 'weekend car' has led to a system where the limited public space within urban streets is used to store cars that may be used only once or twice during the week.

The insights derived from the production of systems knowledge became the outset for the co-development of a design proposal of a 'car-free' Copenhagen within the two visioning workshops. This design proposal became the main tool to produce target knowledge. Through both workshops, the participants established that the collective target of a 'car-free' Copenhagen should make residents less dependent on the car in the dense inner city as well as in the wider metropolitan area so that transportation challenges are not simply relocated to other areas in the region. Furthermore, 'car-free' should not be equated to a blanket ban on cars, but rather it should describe a transportation system that preferences walking, cycling, and public transit over car-use to create an

urban environment full of life and with less noise, smog, and carbon dioxide. Through design iterations, the participants imagined how new typologies of streets could create arteries of not only public transport and bicycles but also new forms of city nature and unprogrammed public spaces (Figure 7.3). These discussions with the participants developed into the idea of a 'super-boulevard' (Figure 7.4) that not only creates priority streets for bicycles and public transport but also acts as boundary lines for new traffic islands within the city.

Figure 7.3:
Participants drawing over the top of supplied stimulus material.
Robert Martin, 2020.

Participants also suggested that while more restrictive measures could be used to limit car-use within the Copenhagen municipal boundary, strategies such as mobility hubs adjacent to public transportation nodes may work in the outer suburbs (Figure 7.5). These mobility hubs were imagined as an evolution of traditional parking houses, but rather than only being available for privately owned automobiles, they could also house shared cars, electric charging points, different forms of micromobility, and ground floor amenities such as supermarkets, information booths, and waiting areas to encourage the interchange between car and more sustainable modes. The idea of a mobility hub also evolved throughout the workshops as participants suggested that these could also become a form of street

Figure 7.4:
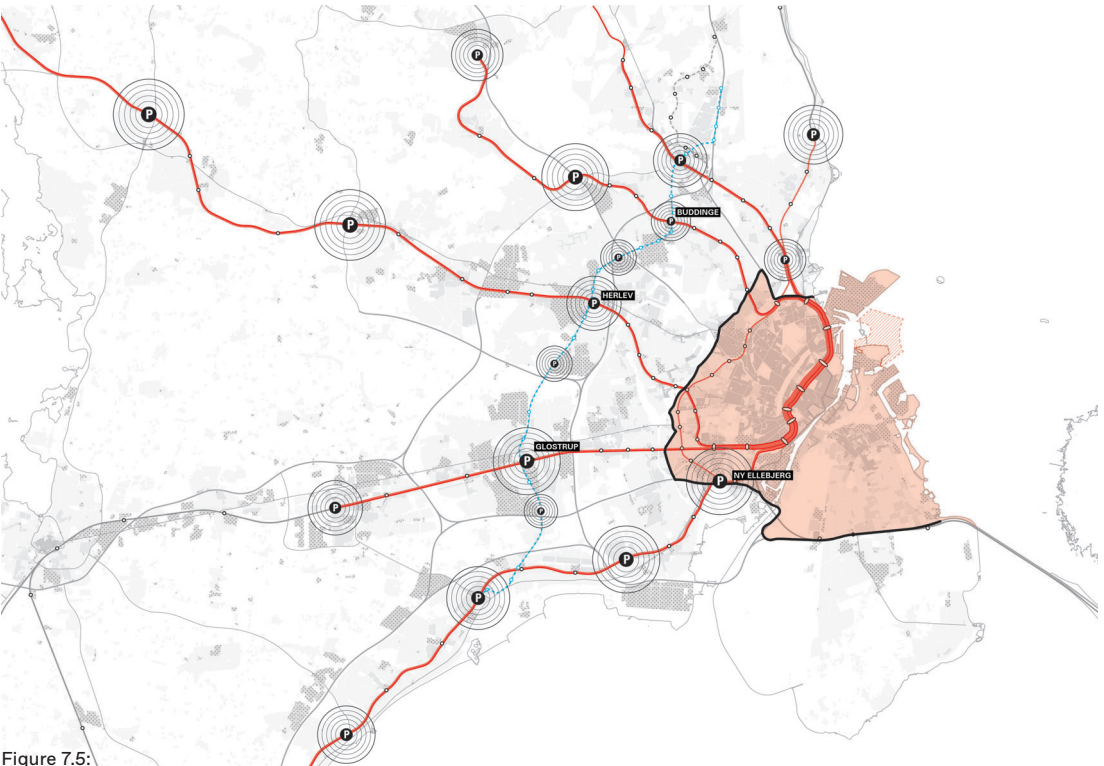Visualiastion of superboulevard.
Robert Martin, 2020.

Figure 7.5:
Copenhagen map showing car-free
zone (highted red), train lines (red line),
and mobility hub locations.
Robert Martin, 2021.

Figure 7.6:
Visualiastion of micro-mobility hubs.
Robert Martin, 2020.

furniture that combines micromobility parking, delivery, and trash collection (Figure 7.6).

The establishment of transformational knowledge was synthesised through the intertwining of systems and target knowledge to build possible pathways between Copenhagen's current and future 'car-free' mobility systems. The pathways that were derived from the participants' responses varied in time and scale as well as in their approach to planning management. While some focused on traditional governmental policy approaches such as increasing parking prices and taxation on vehicles, others created innovative pathways that broke through siloed conceptualisations of transport. These ideas centred less on transport technologies and focused more on socio-spatial pathways. They included strategies such as using climate resilience infrastructure budgets to fund street transformation, socio-political strategies that utilise visualisations of the future as well as pilot projects to shift conversations from what car owners must give up to what society will gain. Furthermore, participants suggested the workshops provided pedagogical approaches that could develop into mobility awareness educational programs for school children to connect the implication of transport choices with lifestyle and quality of life at an early age.

7.6　Conclusion

This paper presents a new methodology for the planning of future urban mobilities which incorporates architectural methods and outlooks towards the future. The methodology was created in the context of an Industrial PhD project that aims to synthesise analytical research with a design proposal of a car-free area of Copenhagen, Denmark, through two visioning workshops. The two workshops were staged to co-create future possible urban developments, and visualisations were developed to evidence the urban spatial implications of the themes that the participants had discussed. These visualisations of urban implications offered an alternative method for approaching the planning of urban mobilities as it moved transport planning away from 'predict and provide' ontologies to planning that consciously shapes pathways towards a better future. This work is pertinent to the field of planning as increasing uncertainty about the future has left planners searching for new methods of knowledge production.

The findings brought forward throughout the workshop are important to both planners and policymakers working in Copenhagen as well as to other academics hoping to utilise visioning workshop in the future. From a methodological standpoint, the workshops demonstrate how visualisations and other architectural methods foster participants to think outside their disciplinary boundaries through a process of ontological expansion. This aspect was most evident through the changing nature of the resistance encountered as participants transitioned from doubting the possibilities of reducing car-use in the first workshop to demanding radical restrictions for cars during the second. I suspect that the visualised ideas of the participants became vessels for socio-technical imaginary that could bridge the intangible idea with the material solution (Jasanoff, 2015). Previously, I have explored how socio-technical imaginaries are able to direct and de-limit what individuals think is possible in the future (Martin, 2021). However, the production of such visualisations requires serious training, time, and resources. Therefore, I recommend that teams hoping to use this methodology either have design capabilities or the ability to hire outsourced help.

In terms of the findings directly applicable to Copenhagen, the two visioning workshops demonstrated a possible method of producing the three types of knowledge mentioned by Pohl

and Hirsch-Hadorn (2007) needed to transition to car-free urban environments—systems, target, and transformational knowledge. While systems knowledge was produced in the preparation of the two workshops to identify participants, set agendas, and prepare toolkits, target and transformational knowledge emerged throughout the two workshops. In one sense, target knowledge, which was expressed and discussed through the visualisations, is considered the most relevant aspect of the project as it becomes a physical artefact of the process and something that everyone can see and discuss. However, its main purpose was to stimulate stakeholder imagination to produce transformational knowledge. I do not wish to reduce the crucial role that target knowledge provided in the process but to highlight that the visualisations were only representational and did not provide pathways to a better future. The transformational knowledge produced through the workshops was more valuable as it gave hints to novel pathways such as educational programs, funding for waste removal, and linkages to climate resilience strategies. Therefore, my recommendation is to ensure that workshop facilitators strive to inspire participants to consider pathways to target knowledge and not stop at the visualisation stage.

In summary, this paper contributes to both mobilities and transitions literature by outlining a new methodology for visioning workshops focused on transitioning to sustainable futures. Although the workshops solely focused on urban transportation, this method may be helpful for other problems where society should look outside of conventional assumptions and approaches to transform socio-technical systems. While producing knowledge that is specific to Copenhagen, this work also enriches the ability of academics to co-create sustainable futures by collaborating with design professionals such as architects, landscape architects, and urban designers in other contexts around the world. Furthermore, the number of workshop participants was limited due to pandemic restrictions, and therefore, this study could not include non-transport professional residents of Copenhagen. To accommodate smaller numbers, professionals were also considered users as they also live, work, and move within the Copenhagen region. In some ways, this framed the workshop discussions around macro issues that the professionals could easily understand and engage with, but further research should involve more users outside of planning and transport professionals. If the SARS-COV 2 virus continues to prevent large numbers of people gathering into the future, online tools such as teleconferencing, surveys, and social media platforms may become useful to reach new user groups. Moreover, this research may give a different understanding of the collective

ambitions of the residents of Copenhagen and provide more insights into transformational knowledge towards the transition to sustainable urban mobilities.

7.7 References

Andersen, I.-E., & Jæger, B. (2001). Scenario workshops and urban planning in Denmark. PLA Notes 50, February, 53–56.

City of Copenhagen. (2016). Copenhagen CPH 2025 - Climate Plan.

City of Copenhagen. (2017). Copenhagen: City of Cyclists.

Cresswell, T. (2011). Mobilities I: Catching up. Progress in Human Geography, 35(4), 550–558. https://doi.org/10.1177/0309132510383348

Duarte, F., & Ratti, C. (2018). The Impact of Autonomous Vehicles on Cities: A Review. Journal of Urban Technology, 0732. https://doi.org/10.1080/10630732.2018.1493883

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2006). Inaccuracy in traffic forecasts. Transport Reviews, 26(1), 1–24. https://doi.org/10.1080/01441640500124779

Freudendal-Pedersen, M. (2009). Mobility in Daily Life: Between Freedom and Unfreedom. In Journal of Chemical Information and Modeling (Vol. 53, Issue 9). Ashgate Publishing.

Freudendal-Pedersen, M., Hartmann-Petersen, K., Friis, F., Lindberg, M. R., & Grindsted, T. S. (2020). Sustainable mobility in the mobile risk society-designing innovative mobility solutions in copenhagen. Sustainability (Switzerland), 12(17). https://doi.org/10.3390/su12177218

Freudendal-Pedersen, M., & Kesselring, S. (2015). Workshop Manual: A Reflexive Methodology for Urban Planning in the Mobile Risk Society.

Gaziulusoy, A. İ., & Ryan, C. (2017). Shifting Conversations for Sustainability Transitions Using Participatory Design Visioning. Design Journal, 20(sup1), S1916–S1926. https://doi.org/10.1080/14606925.2017.1352709

Hajer, M. (2016). Untamed Urbanisms. In A. Allen, A. Lampis, & M. Swilling (Eds.), Untamed Urbanism (1st ed., pp. 50–63). Routlege.

Henderson, J., & Gulsrud, N. M. (2019). Street Fights in Copenhagen: Bicycle and Car Politics in a Green Mobility City (1st ed.). Routledge.

Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power (p. 341). University of Chicago.

Jungk, R., & Mullert, N. (1987). Future workshops : how to create desirable futures. Institute for Social Inventions.

Københavns Kommune. (2016). Kort om København - Analyser og Tal: København får flere personbiler. 2. https://www.kk.dk/sites/default/files/København får flere personbiler A.pdf

Københavns Kommune. (2017). Parkering 2017: Parkeringsredegørelse. 1–24. https://www.kk.dk/sites/default/files/edoc/b57fcc12-373f-4adf-9d8f-fd73ee0969f-c/54aad0d9-27a6-47c7-a45e-1ec2736fa463/Attachments/17729710-23065597-1.PDF

Københavns Kommune. (2019). Københavns Kommuneplan 2019: Verdensby med ansvar. Kommuneplansstrategi 2018 for Københavns Kommune.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2019.01.004

Lyons, G., & Davidson, C. (2016). Guidance for transport planning and policymaking in the face of an uncertain future. Transportation Research Part A: Policy and Practice, 88, 104–116. https://doi.org/10.1016/j.tra.2016.03.012

Martin, R. (2021). AV futures or futures with AVs? Bridging sociotechnical imaginaries and a multi-level perspective of autonomous vehicle visualisations in praxis. Humanities and Social Sciences Communications, 8(1), 1–15. https://doi.org/10.1057/s41599-021-00739-4

Martin, R., Bruck, E. M., & Soteropoulos, A. (2021). Transformations of European Public Spaces with AVs (In Print). In M. Mitteregge, E. Bruck, A. Stoerpoulos, A. Stickler, M. Berger, J. S. Dangschat, R. Sceuvens, & I. Banerjee (Eds.), AVENUE21 Volume 2: Policy and Planning Considerations for Automated Mobility. Springer Vieweg.

Pohl, C., & Hirsch Hadorn, G. (2007). Principles for designing transdisciplinary research. In Principles for Designing Transdisciplinary Research.

Scheurer, J. (2013). Measuring Copenhagen ' s public transport accessibility and network performance in a European context. Annual Transport Conference at Aalborg University, 1–20.

Sevtsuk, A., & Shieh, E. (2019). Los Angeles: Towards an Automated Transitopia.

Sheller, M., & Urry, J. (2006). The new mobilities paradigm. Environment and Planning A, 38(2), 207–226. https://doi.org/10.1068/a37268

The City of Copenhagen Technical and Environmental Administration. (2012). CPH 2025 Climate Plan: A Green, Smart, and Carbon Neutral City. 64.

Transport Construction and Housing Ministry. (2018). Mobilitet for fremtiden.

Urry, J. (2005). The "System" of Automobility. In Automobilities (pp. 25–40). SAGE Publications.

Via Trafik Rådgivning A/S. (2020). Mobility Analysis: Green conversion of traffic - partial delivery 1 - three initative packages.

Chapter 8:

The Exemplar

Copenhagen Car-free(dom)

8.0 Abstract

The exemplar, Copenhagen Car-free(dom) has emerged as the completion of the programmatic design research approach. Throughout this PhD project, a future scenario for a sustainable urban mobilities system in Copenhagen, Denmark has been designed and development with a wide range of stakeholders through interviews, presentations, and two workshops. The following drawings, visualisations, and diagrams are a selection of the total body of work which represent knowledge and insights from the past three years. The following chapter may seem foreign in the context of a PhD thesis, as it is 'text light' and communicates mainly through images. However, as an architect, with an architectural studio as an industrial partner, I believe that it is within the tradition of our profession and supports our attempt to engage the outside world with this research.

8.1   Introduction

Across the globe, car-free cities are becoming a major discussion in urban planning. In Europe, municipal elections are being won across the political spectrum on promises to limit car use, reduce CO_2 emissions, and give back space to the public. Copenhagen is amongst these cities, with an ambitious target to being CO_2 neutral by 2025. However, CO^2 emissions from the transport sector remain a challenge for the municipality's planners, and policymakers who prefer to encourage cycling and public transport modes, over discouraging car use. From 2010-2015 the transport sector's share of the city's total CO_2 emissions increased from 24% in 2010 to 34% in 2015 (The City of Copenhagen 2016a). If Copenhagen is to achieve its ambitious targets, it is necessary to reduce CO_2 producing traffic considerably and look towards car-free strategies seriously.

But where the term 'car-free city' suggests an either-or scenario, where cars are banned in the urban environment, the concept of 'car-free(dom)' suggests a choice. This choice includes all people and modes of transport, where cars are a part of a multimodal mix, but introduces a clear prioritisation where less impactful modes become the easiest and preferred mode of transport. In this scenario, we can transform excessive road infrastructure into better housing quality and a richer city life, while also reducing noise, harmful air pollution, and overall CO_2 emissions in Copenhagen.

I imagine this new mobility system like a food diet: everything allowed in moderation, with more focus on green and sustainable. This way our cities can be happy, healthy, and active. Rather than congested, and fat.

Figure 8.1:
The Mobility Pyramid.
Robert Martin, 2021.

8.2 Vision

The vision of Copenhagen Car-free(dom) is based on the city's unique spatial context combined with insights derived from European cities such as Barcelona, Ghent, and Oslo, which in recent years are working ambitiously with the planning and development of future car-free cities.

Inspired by and based on Copenhagen's Finger Plan from 1947, the project introduces a range of spatial strategies across all scales to shift away from traditional mobility planning.

However, it is my belief that in order to succeed, this project must ultimately make a difference in the everyday life of the residents of Copenhagen: outside their front door, on their way to work, and how they interact with the street.

Therefore, when reading the material on the following pages, it is important to keep in mind that the project's greatest ambition is to improve the human scale, so that it can improve the quality of life in Copenhagen as the basis for future sustainable urban development. Its aim is to showcase what a city's streets and neighbourhoods could look like if we gave much higher priority to sustainable and shared modes of transport, rather than private car ownership.

Figure 8.2:
A living street transformation in
Copenhagen.
Robert Martin/JAJA architects, 2018.

8.3 Boundary

Unlike bureaucratic decision-making processes, mobility cannot be controlled within municipal boundaries as commuters travel from home to work and residents use their free time to explore their surroundings. However, policies to regulate traffic, for example through low-emission zones and traffic islands, will always be defined by internal and external boundaries. In an attempt to discuss car-freedom in the Greater Copenhagen area, this project ignores municipal boundaries to promote collaboration between public authorities, so that strategies to reduce car use in one area, does not simply shift the problem to a neighbouring area.

The scope of this design project lays within the urban core of the city. However, the project's strategies have been developed with a view to incorporate across the entire region (Figure 8.3). It builds on the principles of the Finger Plan, where 'fingers' of train lines extend out from the 'palm' of the inner city to the neighbouring municipalities. Several strategically placed mobility hubs are proposed along these train lines as well as at the intersection with major roads, and the incoming light rail system.

This mobility hub strategy allows the easy interchange for motorists to interchange with sustainable transportation alternatives as close to their departure point as possible, rather than simply having to stop at the car-free boundary. They are also imagined as sites to introduce sustainable modes in local areas through new public transportation routes, and the location of shared cars and micromobility.
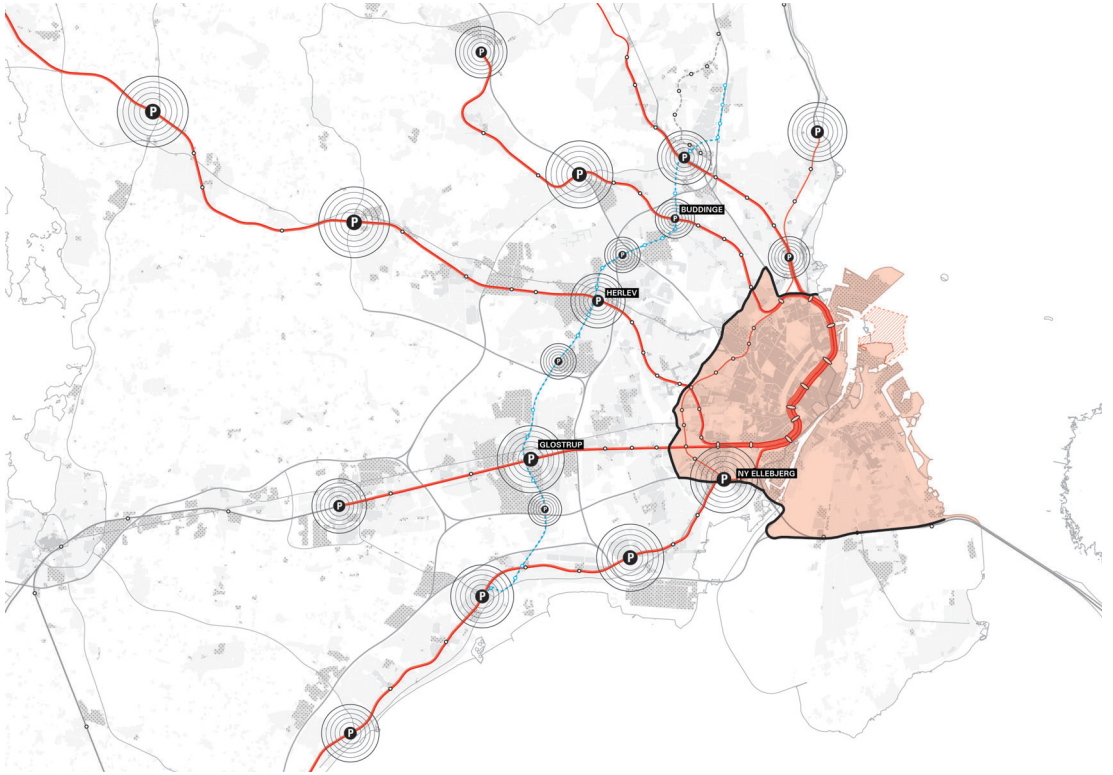
Figure 8.3:
Copenhagen map showing car-free
zone (highted red), train lines (red line),
and mobility hub locations.
Robert Martin, 2021.

8.4 From Vision to Reality

The design project takes two on-going developments in Copenhagen as a starting point. The first is the planned construction of an eastern ring road tunnel around the city, Østlig Ringvej, and the second is the implementation of a 'car-free' zone in the medieval city centre (Via Trafik Rådgivning A/S, Schønherr A/S, and ICP A/S 2019).

Østlig Ringvej is a controversial project, having to rely on funding from the sale of a proposed artificial island built for high-socioeconomic demographics, as well as its projected induced traffic demand (Vejdirektoratet 2020). However, the tunnel's construction, together with the motoring 2 and E20 highway, establish a complete ring road around Copenhagen (Figure 8.4). Insights from chapter 7 demonstrate that a ring road is a valuable tool for establishing car-free zones.

The car-free medieval city will undoubtably create an increased quality of urban life in the city. However, according to the municipality's own studies, the transport sector's CO_2 emissions will only be reduced by 0.7% (Via Trafik Rådgivning A/S, Schønherr A/S, and ICP A/S 2019).

Nevertheless, it is the relationship between the two projects where this design proposal starts. With the newly established ring road, it no longer makes sense to direct traffic through the city. The ring road will also require that several of Copenhagen's main traffic routes be redesigned. Many of the major roads run along the medieval city, and this project therefore imagines using this planned car-free zone as a natural blockade for through traffic, with the exception of public transport, shared transport, and micromobility (Figure 8.5).
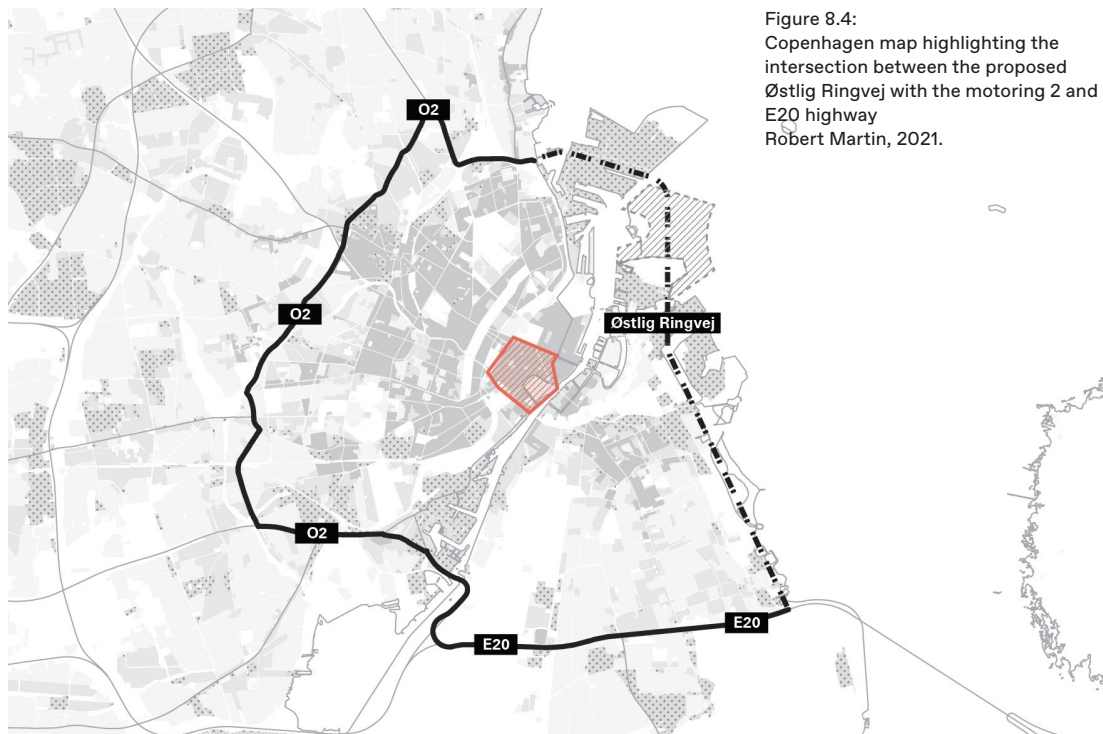
Figure 8.4:
Copenhagen map highlighting the intersection between the proposed Østlig Ringvej with the motoring 2 and E20 highway
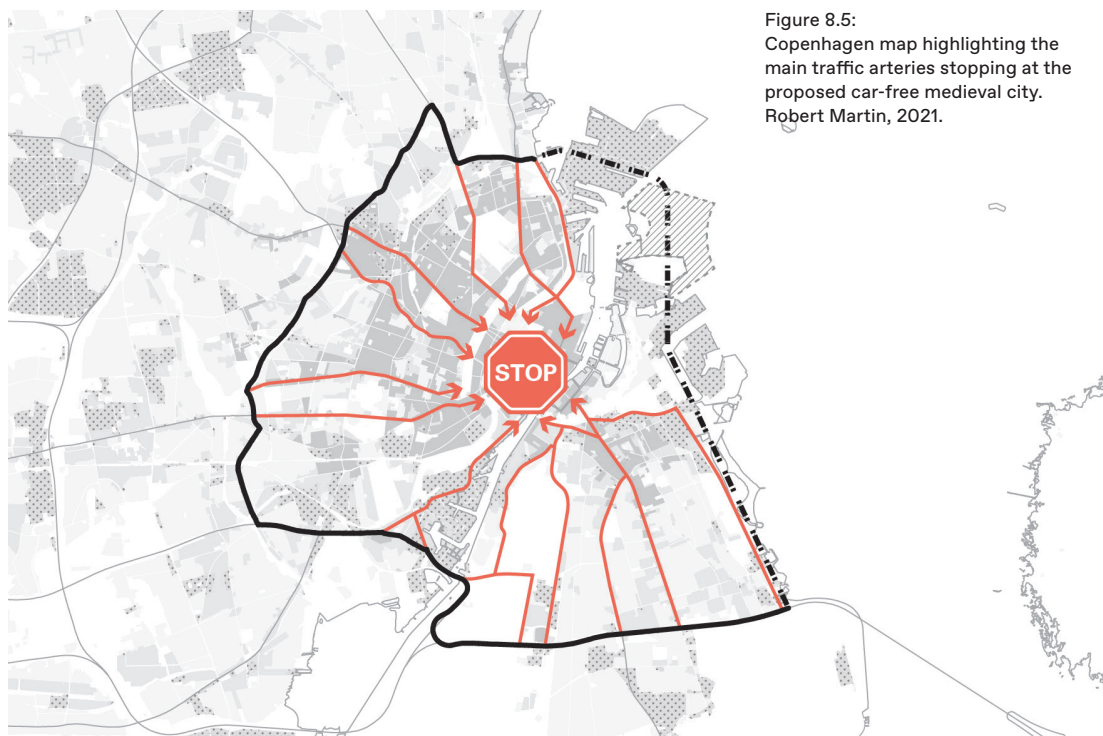Robert Martin, 2021.

Figure 8.5:
Copenhagen map highlighting the main traffic arteries stopping at the proposed car-free medieval city.
Robert Martin, 2021.

The next step in the design proposes that the city's major roads are divided into groups. Every second main road remains an accessway (Section 8.7) road for cars into the city. However, the capacity of the road is reduced as you move towards the medieval centre, ending blindly where the road meets the car-free zone (Figure 8.6).

The remaining main roads are designed as a continuous, green super boulevards (Figure 8.7), which offer fast and attractive connections across the city based on green modes of transport. The Super Boulevards are therefore equipped with wide superbike trails and roadways that exclusively serve public and shared modes of transport (Section 8.6).
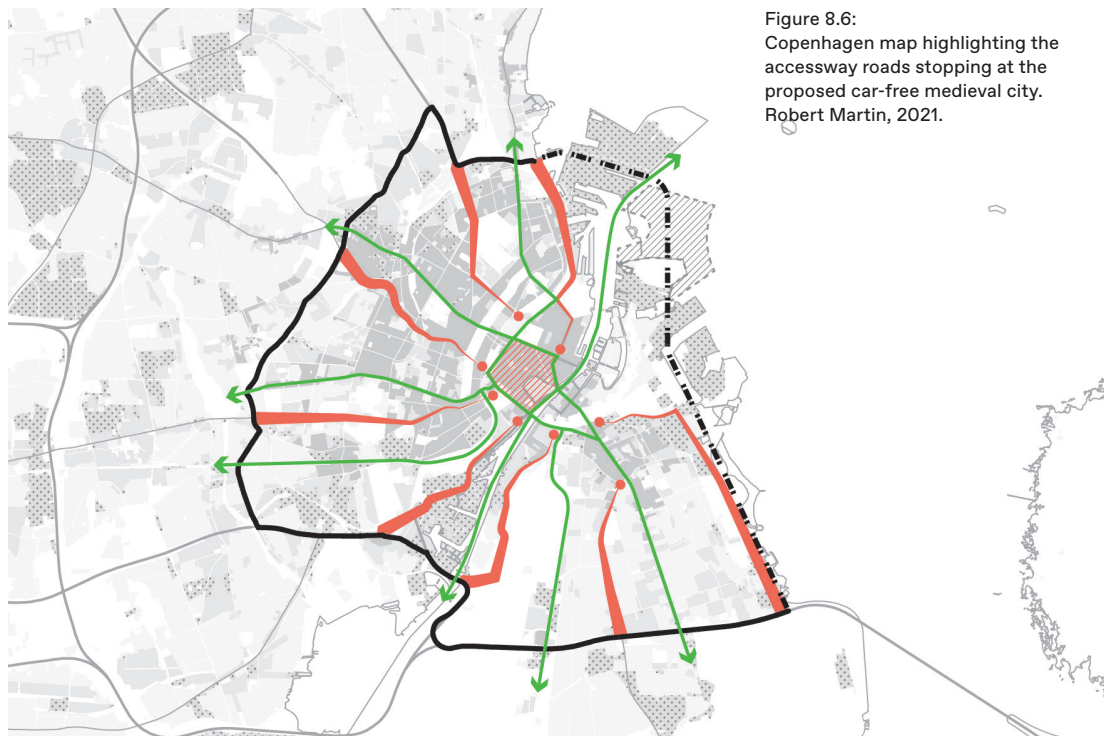
Figure 8.6:
Copenhagen map highlighting the accessway roads stopping at the proposed car-free medieval city. Robert Martin, 2021.
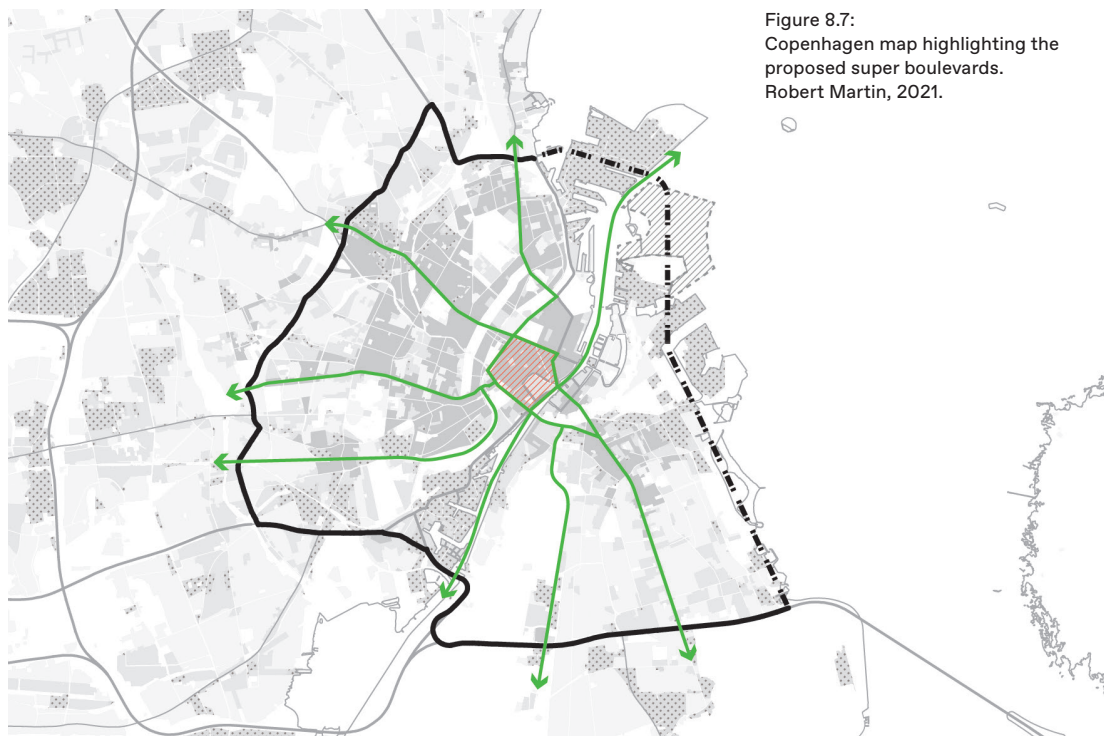

Figure 8.7:
Copenhagen map highlighting the proposed super boulevards. Robert Martin, 2021.

8.5 Traffic Islands

Based on the transformation of Copenhagen's main traffic arteries, I propose that the area within the ring road be divided into eight traffic islands in a radial structure around the medieval city (Figure 8.8).

These traffic islands are bounded by the super boulevards and ring road. Motorists can access and commute between the traffic islands via the ring road and the access roads, which will act as the traffic lanes' backbone. Pedestrians, cyclists, public transport and other priority groups and modes of transport can move freely between the traffic islands. The super boulevards act as a physical boundary to stop car traffic travel between the zones.

In this way, the project's mobility strategy does not prevent car access within Copenhagen. It merely makes it the slowest and least convenient mode, while prioritising pedestrians, cyclists, and public transport over cars. In the following section, I present the individual sub-elements in the project to illustrate the positive spatial and environmental effects of this proposal.
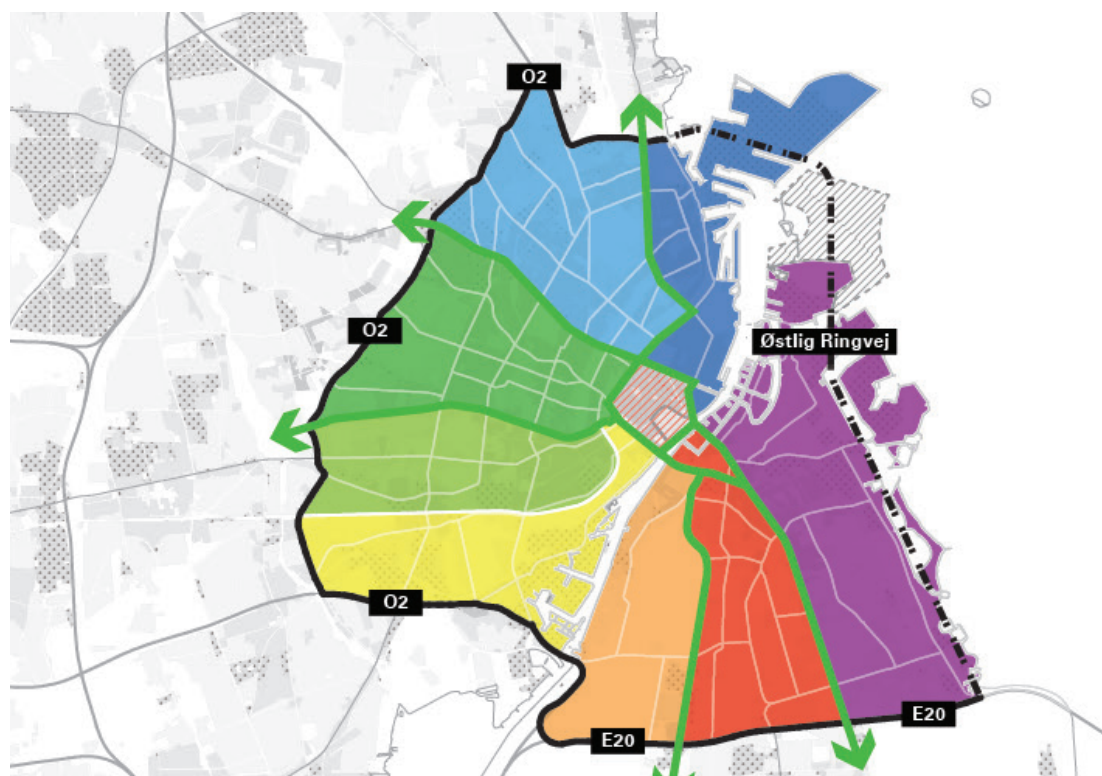
Figure 8.8:
Copenhagen map illustrating the super
boulevards form each traffic island.
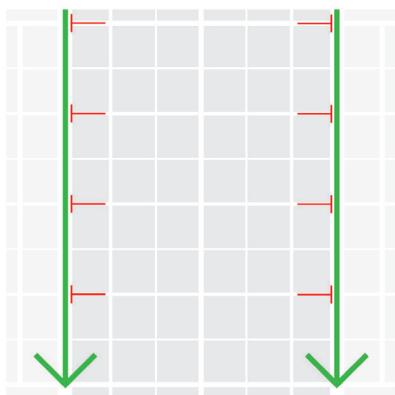Robert Martin, 2021.

8.6 Street Principles

The mobility plan for this proposal consists of four types of roads and streets: Super Boulevards, Accessways, Collectors, and Living Streets. The streets each have a distinct function and character and operate with a clear, inherent hierarchy.

The diagrams on the opposite page describe the relationship between each street. The super boulevards (green) are the boundaries for each traffic islands. They also provide prioritised road for public transport and micromobility as well as streets full of green space and trees. Accessways (red) are the main road in which motorists can access each traffic islands and operate as a spine to distribute cars throughout the islands. Each accessway feeds into a collector road (orange). Collectors are the streets in which cars can navigate through the islands and form superblocks[8.1]. Motorists can only access a living street (yellow) from a collector road. Living streets are most streets in Copenhagen and have been blocked to through traffic. Two thirds of parking have been removed from these streets, while the remaining has been given priority to shared cars. The remaining space is transformed into urban nature and amenities to support city life.
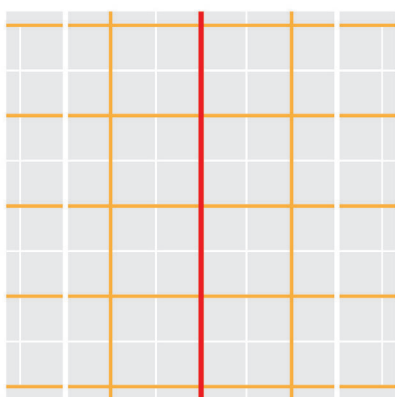
The map on the following page illustrates these principles applied to Copenhagen.
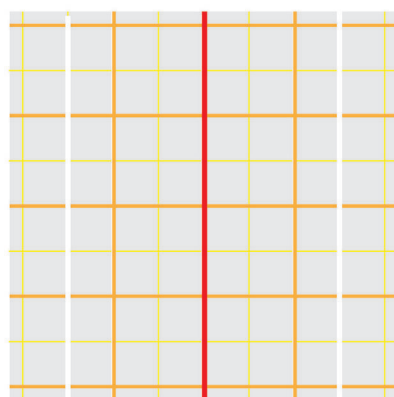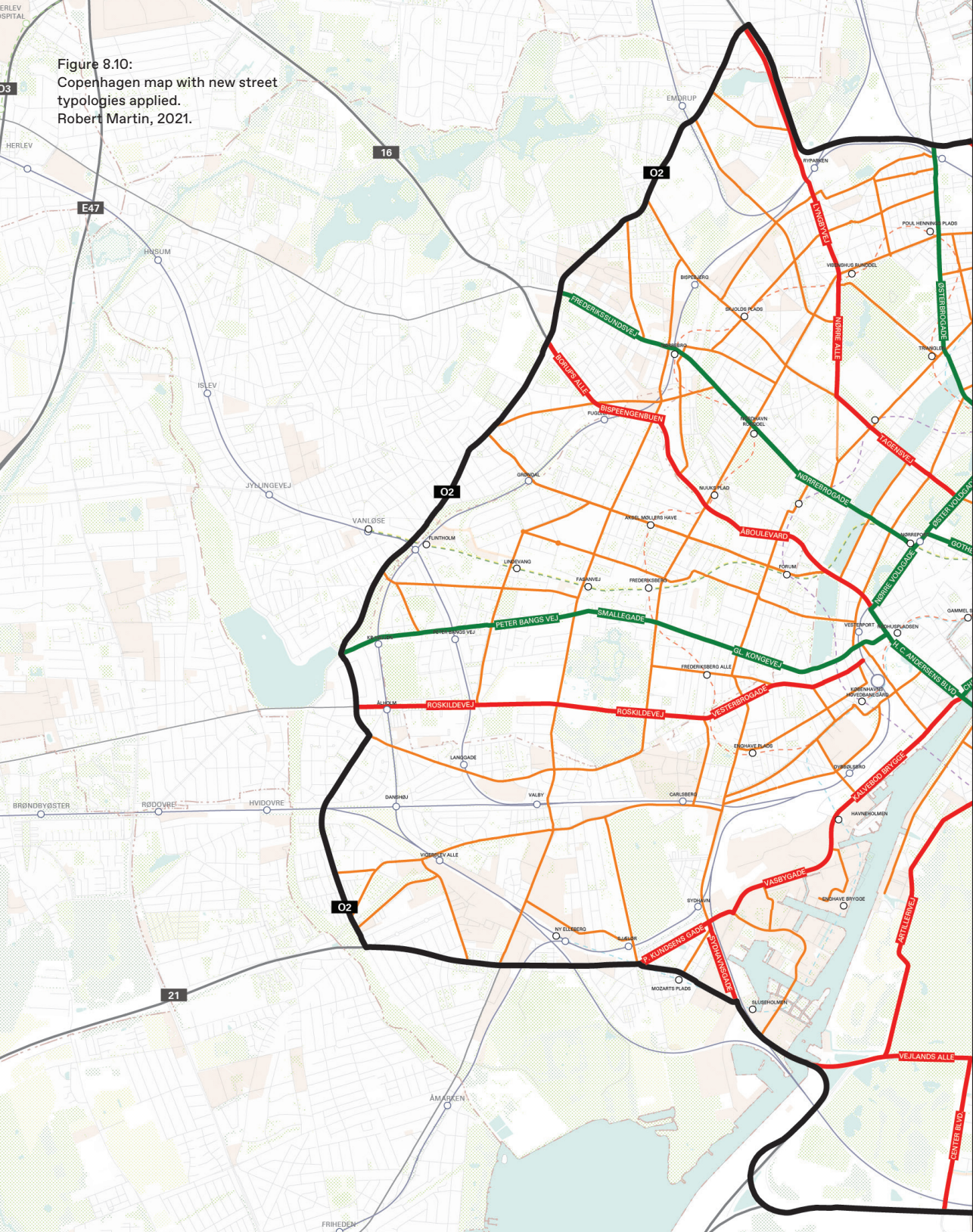
SUPER BOULEVARD
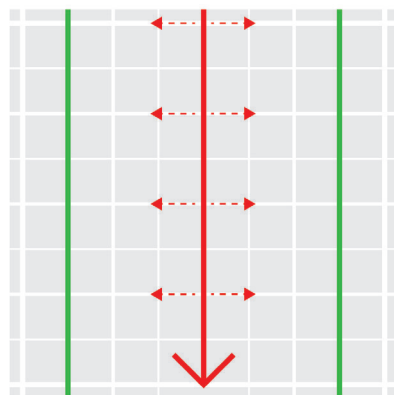
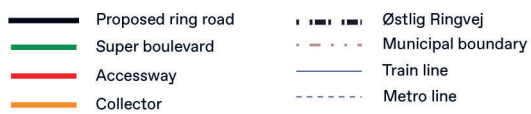ACCESSWAY

COLLECTORS

LIVING STREETS

Figure 8.9:
Principal diagram explaining the role of
each road typology.
Robert Martin, 2021.

Figure 8.10:
Copenhagen map with new street
typologies applied.
Robert Martin, 2021.

COPENHAGEN, DENMARK/
CAR-FREE(DOM)

0   3km

Map labels:
Østlig Ringvej
STRANDVEJEN
ORIENTKAJ
NORDHAVN
KALKBRÆNDERIHAVNSGADE
LYNETTEHOLMEN
ØSTERPORT
MARMORKIRKEN
BREDGADE
REFSHALEØEN
RSGADE
KONGENS NYTORV
STRAND
KLØVERMARKEN
CHRISTIANS BRYGGE
TORVEGADE
CHRISTIANSHAVN
RAFFINADERIVEJ
PRAGS BLVD
AMAGER BLVD.
ISLANDS BRYGGE
AMAGERBRO
LERGRAVSPARKEN
ØRESUND
DR BYEN
AMAGER STRAND
AMAGER STRANDVEJ
Østlig Ringvej
FEMØREN
ØRESTADS BLVD.
SUNDBY
ENGLANDSVEJ
AMAGERBROGADE
BELLA CENTER
KASTRUP
KØBENHAVNS LUFTHAVN
ØRESTAD
TÅRNBY
E20

Legend:
— Proposed ring road
— Super boulevard
— Accessway
— Collector
–·–·– Østlig Ringvej
–·–·– Municipal boundary
— Train line
- - - Metro line

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8.6.1 Intersections

As described in the previous section, the project's mobility plan relies on the blocking of several roads to limit areas in which cars can access. Where super boulevards and access-ways intersect with living streets, existing roads are blocked and transformed into new urban amenities (Figure 8.11).
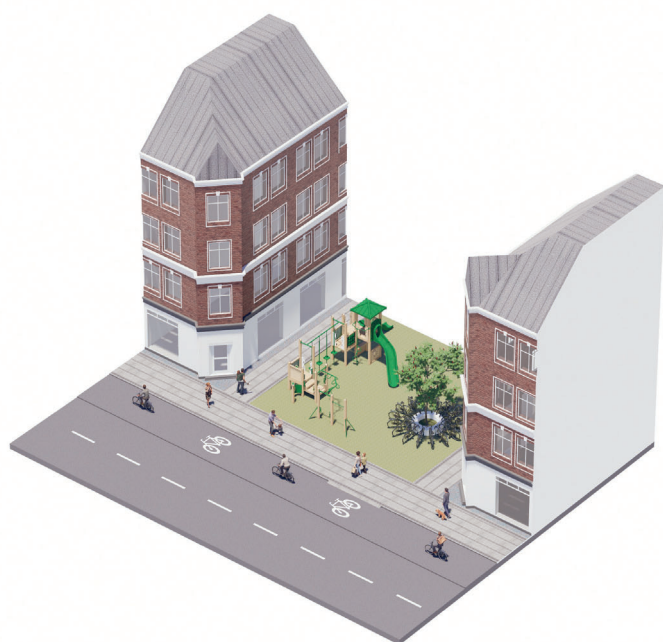
Figure 8.11:
Before and after axonometric of
intersection principle.
Robert Martin, 2021.

8.6.2 Flex zones

On-street parking along super boulevards, accessways, and collectors is removed. The space gained from the removal of intersections and flex zones is then used to support future mobility modes and new urban life (Figure 8.13). Uses include parking and charging for micromobility, outdoor furniture for cafes, protected transit stops, drop off and pick-up zones for taxis, and space for more green areas and city trees (Figure 8.12).

CARGO BIKE PARKING

CHARGING

BICYCLE PARKING

BUS STOP

OUTDOOR FURNITURE

SHARED CARS

CITY TREES
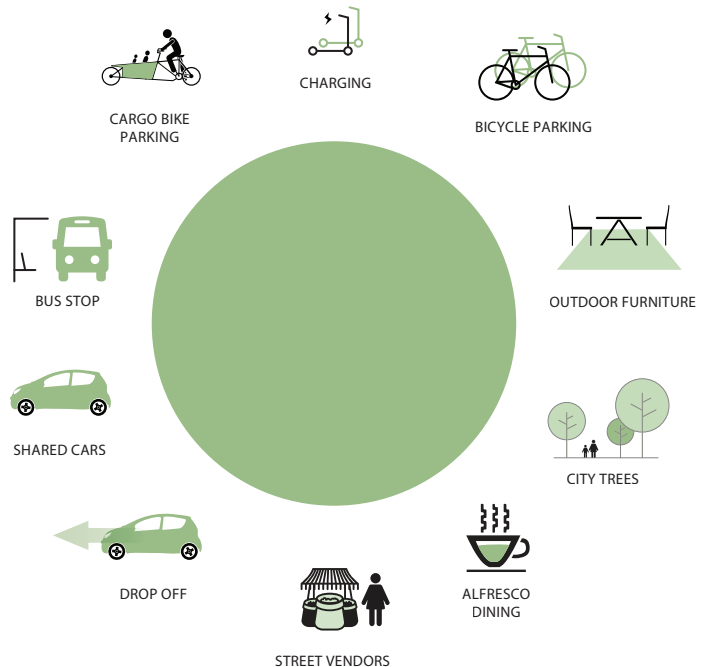
DROP OFF

ALFRESCO DINING

STREET VENDORS

Figure 8.12:
Diagram describing different purposes of the flex zone and intersection space.
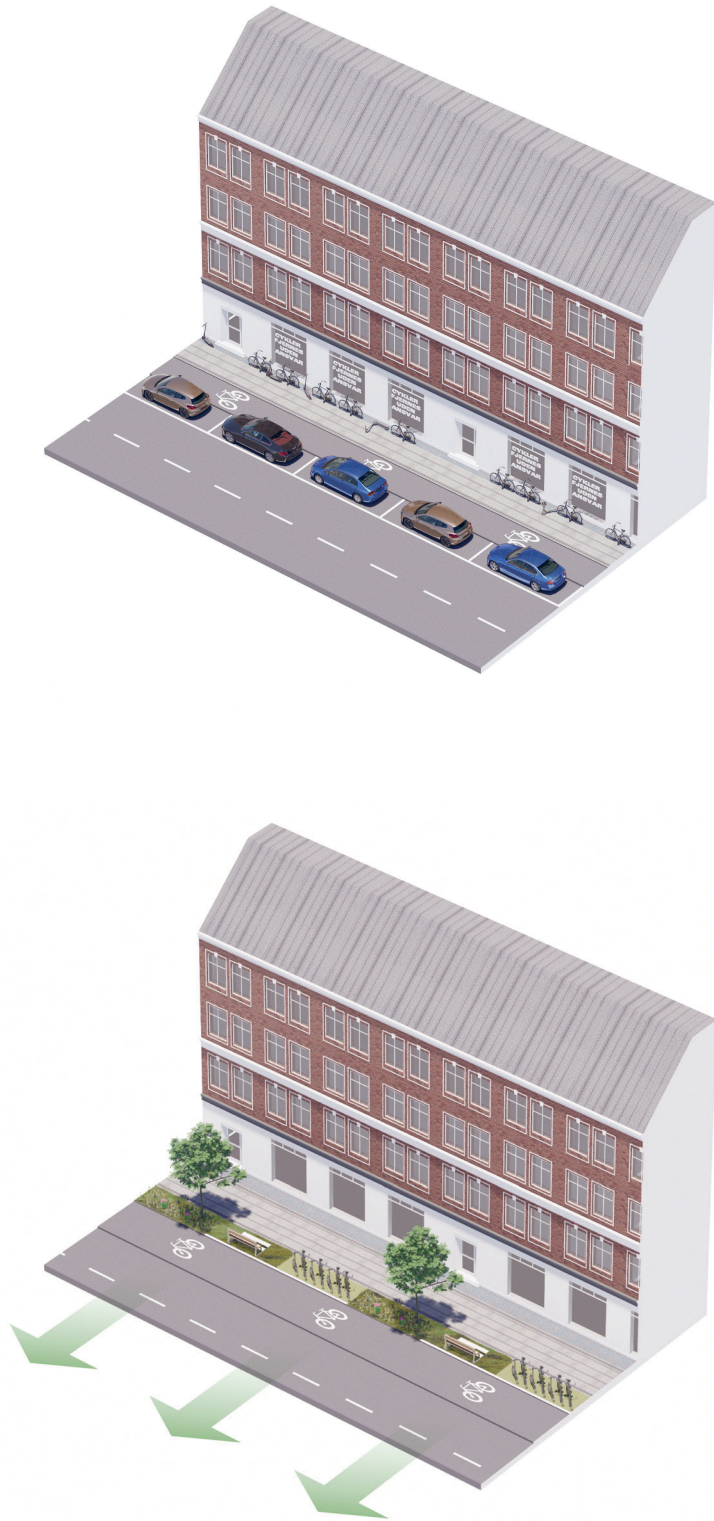Robert Martin, 2021.

Figure 8.13:
Before and after axonometric of flex
zone principle.
Robert Martin, 2021.

8.7   Super Boulevards

Super boulevards have two important functions: they frame the traffic islands while offering an attractive, high-capacity connection through the city designed for bicycles, micromobility, shared, and public transport. At off-peak hours, they may also be utilised by logistic companies to quickly move goods around the city. The two sections on the opposite page illustrate the transformation of a main traffic artery into a super boulevard (Figure 8.15). The drawing shows how seven lanes of traffic are converted into two transitways (yellow), two lanes for shared vehicles (yellow hatch), and two bicycle highways (blue).

The drawing also shows how excess road capacity is transformed into a green terrace that acts as a physical boundary, which prevents car traffic from travelling across traffic islands. The super boulevard therefore has far fewer intersections, which both saves space and provides a basis for an efficient green connection through the city (Figure 8.14).

Figure 8.14:
Super boulevard principal diagram.
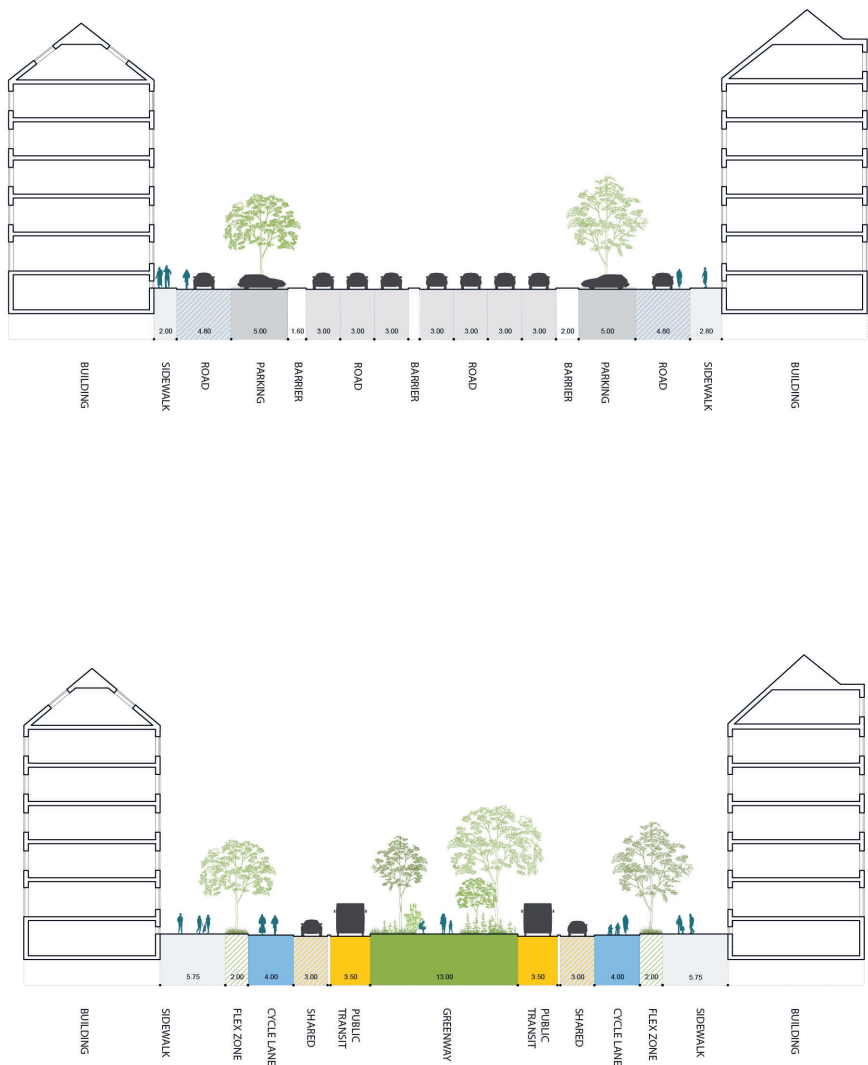Robert Martin, 2021.

Top section labels (before):

BUILDING · SIDEWALK · ROAD · PARKING · BARRIER · ROAD · BARRIER · ROAD · BARRIER · PARKING · ROAD · SIDEWALK · BUILDING

2.00 · 4.60 · 5.00 · 1.60 · 3.00 · 3.00 · 3.00 · 3.00 · 3.00 · 3.00 · 3.00 · 2.00 · 5.00 · 4.60 · 2.80

Bottom section labels (after):

BUILDING · SIDEWALK · FLEX ZONE · CYCLE LANE · SHARED · PUBLIC TRANSIT · GREENWAY · PUBLIC TRANSIT · SHARED · CYCLE LANE · FLEX ZONE · SIDEWALK · BUILDING

5.75 · 2.00 · 4.00 · 3.00 · 3.50 · 13.00 · 3.50 · 3.00 · 4.00 · 2.00 · 5.75

Figure 8.15:
Before and after section drawing of
super boulevard transformation.
Robert Martin, 2020.

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8.7.1　H.C. Andersens Boulevard

H. C. Andersens Boulevard is one of Copenhagen's busiest traffic arteries. It was inspired by the wide boulevards of Paris and was not designed for through traffic. Instead, it was constructed as a green promenade lined with trees. Following World War II, most of the trees were removed and six lanes of traffic were installed.

As the road borders the medieval city, it is imagined as a super boulevard. The opposite page illustrates the transformation of the road, where the green promenade of trees is reintroduced as well as the public transportation corridor (Figure 8.16). The following pages shows the before and after transformation of the road as an eye-height visualisation.
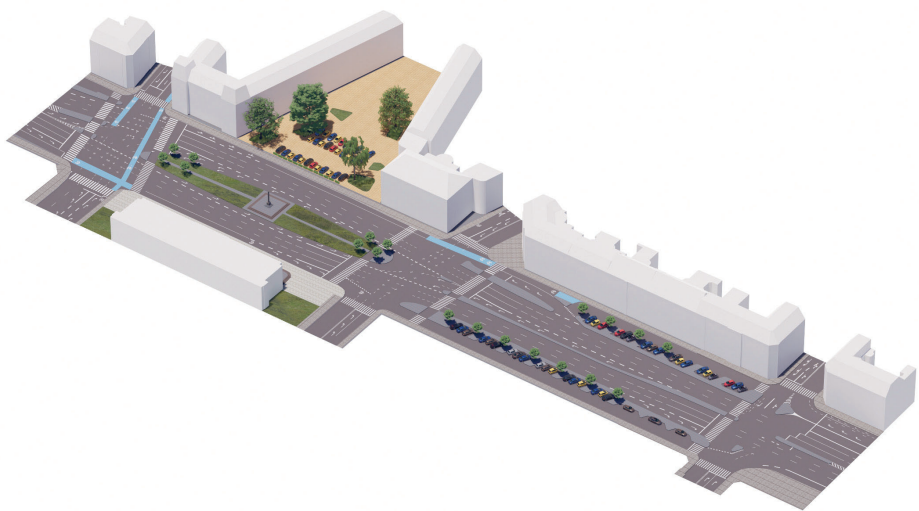
Figure 8.16:
Before and after axonometric of the
super boulevard principles applied to
H.C. Andersens Boulevard.
Robert Martin, 2020.

Figure 8.17:
Eye-height visualisation of the current
situation on H.C. Andersens Boulevard.
Robert Martin, 2020.

Figure 8.18:
Eye-height visualisation of the
proposed super boulevard on H.C.
Andersens Boulevard.
Robert Martin, 2020.

8.8 Accessways

Accessways function as a backbone in each traffic island and serve as a distribution street for car access. Accessways are connected to the zone's ring road and are therefore the only connection in and out of each traffic island (Figure 8.20). Like super boulevards, the intersection between accessways and living streets are blocked. Motorists are able leave the accessway at the intersection between the road and a collector (Figure 8.19).
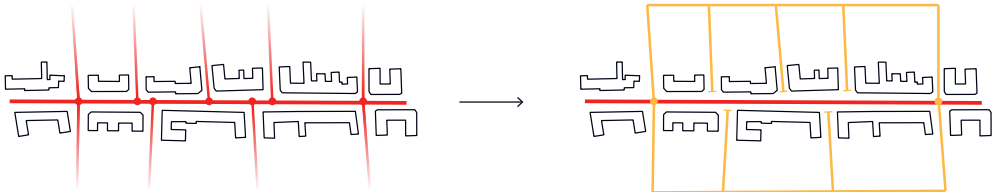
Figure 8.19:
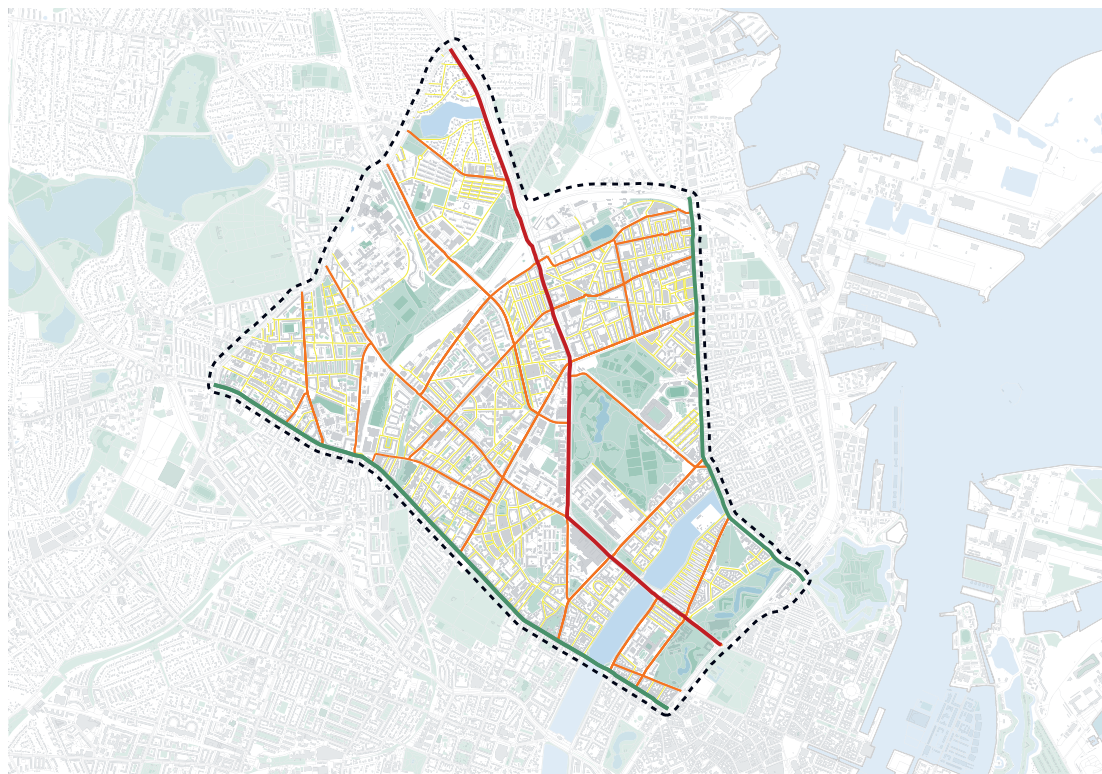Accessway principal diagram.
Robert Martin, 2021.

Figure 8.20:
Siteplan of a proposed traffic island
with street typologies highlighted.
Robert Martin, 2020.

8.8.1   Accessway Examples

Each accessway starts at the ring road and ends at the meeting the medieval city. This means that the closer one travels towards the medieval city, the fewer cars need the service of the accessway. Therefore, rather than having a continuous traffic artery that cuts through the city, the accessway gradually scales down in capacity before meeting a dead end at the intersection with the centre, which forms a new plaza (Figure 8.22).

The idea of a gradual downscaling of the accessway is exemplified here along the roads Bispeengbuen, and Åboulevard which extend from each other. Here I show three sites within the accessway, where the road changes from 4-lanes to 2-lanes before ending in a new public plaza at Jarmers Plads (Figure 8.21).

This particular road has been chosen because there is an on-going discussion within the Copenhagen Municipality of reopening a dormant river that lies underground. In fact, the Å in Åboulevard means river in Danish, which refers to the historical form of the road. To achieve this goal, the city is investigating building a four-lane tunnel to bypass the existing road and redevelop the river (The City of Copenhagen 2016b). Within the project, Copenhagen Car-free(dom), I wish to illustrate how the same goal can be achieved without the economic, environment, and social impact that building a tunnel would bring.

BISPEENGBUEN

JARMERS PLADS

ÅBOULEVARDEN

Figure 8.21:
Situation plan highlighting the location
of the three accessway examples.
Robert Martin, 2021.

Figure 8.22:
Principal diagram of the accessway
downscaling as it meets the medieval
city.
Robert Martin, 2020.

8.8.1.1   Bispeengbuen

Bispeengbuen is the first site of investigation. It is an elevated 6-lane motorway on columns that cuts through a residential area, creating a barrier between the neighbouring housing plots. The bridge was built in 1972 but has been controversial since its inauguration. There have been discussions to dismantle it since 2011.

There is no doubt that the municipality's proposed tunnel is preferable to the current elevated motorway. However, the tunnel proposal still requires the establishment of long descent ramps in the middle of the city, which will splinter the urban environment and will allow tens of thousands of cars to pass through the city.

This project suggests that Bispeengbuen still be taken down, but that the road be placed on the ground instead. Reports from feasibility studies show that four lanes are enough to take up capacity over Bispeengbuen (Åbn Åen 2021). A reduction in the number of lanes from the existing six to four makes room for both road and reopening of the river, as well as new urban nature and amenities and greater cycling infrastructure (Figure 8.24).
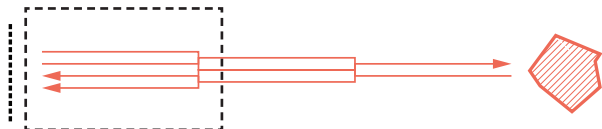
Figure 8.23:
Principal diagram of Bispeengbuen's
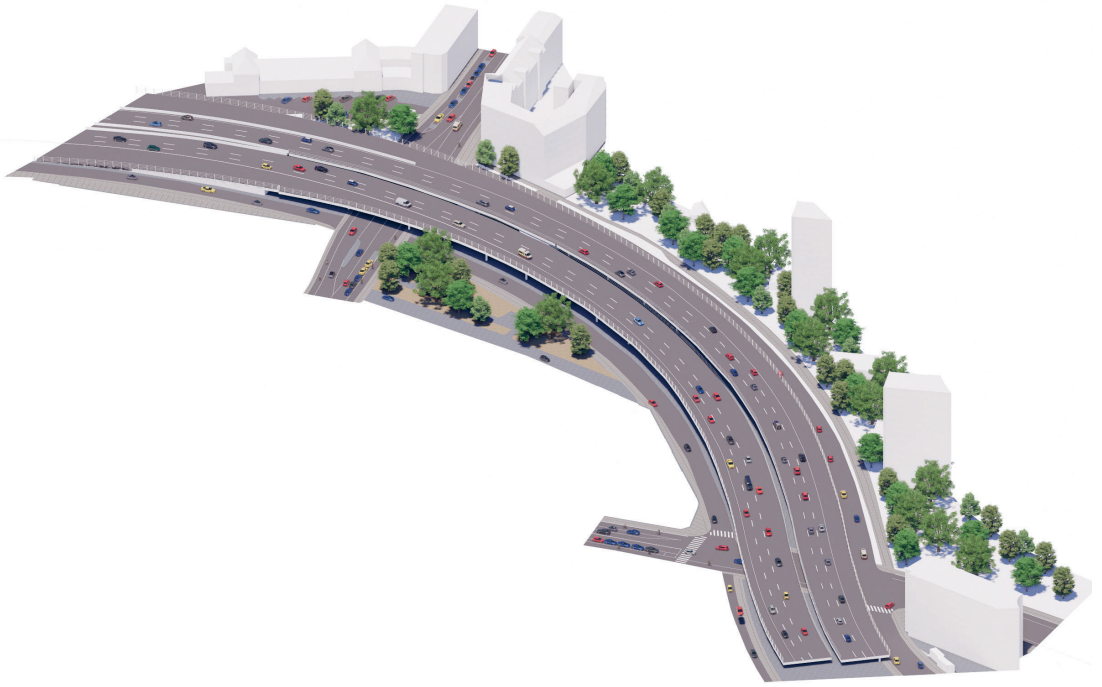location on the accessway.
Robert Martin, 2020.

Figure 8.24:
Before and after axonometric of
the accessway principles applied to
Bispeengbuen.
Robert Martin, 2021.

8.8.1.2   Åboulevard

Åboulevard, which is an extension of Bispeengbuen, is designed according to the principle of downscaling to only two lanes for vehicle traffic. The illustrations on the opposite page (Figure 8.26) show how the street and the reopened river together create a vibrant and attractive recreational space through central parts of the city. The illustration also shows where the accessway intersects with a collector road and is blocked to the adjoining living street.

The following page showcases a before and after visualisation of the Åboulevard transformation.
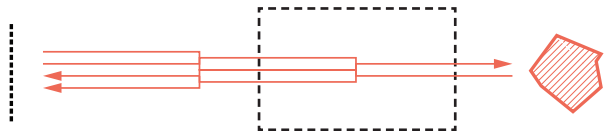
Figure 8.25:
Principal diagram of Åboulevard's location on the accessway.
Robert Martin, 2020.

Figure 8.26:
Before and after axonometric of
the accessway principles applied to
Åboulevard.
Robert Martin, 2021.

Figure 8.27:
Eye-height visualisation of the current
situation on Åboulevard.
Robert Martin, 2021.

Figure 8.28:
Eye-height visualisation of the
proposed accessway and rejuvenated
river on Åboulevard.
Robert Martin, 2021.

8.8.1.3   Jarmers Plads

The final site of investigation is where the accessway ends at the intersection of Jarmers Plads. As this is the final point at which cars can depart the accessway, motorists must either turn left or right. Pedestrians and cyclists may still continue through to the medieval city. The large amount of space released through the blockage of the accessway creates a new public plaza where the re-established river ends in a new public fountain.

The following pages present a before and after site plan of the proposed changes.

Figure 8.29:
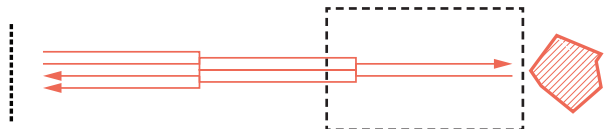Principal diagram of Jarmers Plads'
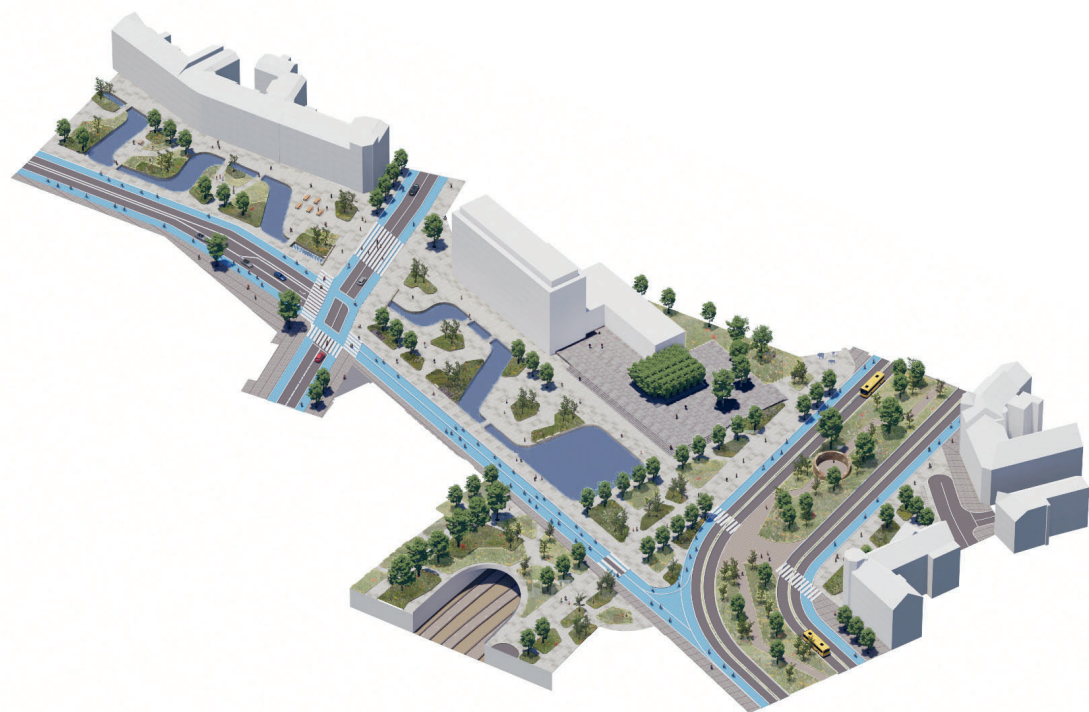location on the accessway.
Robert Martin, 2020.
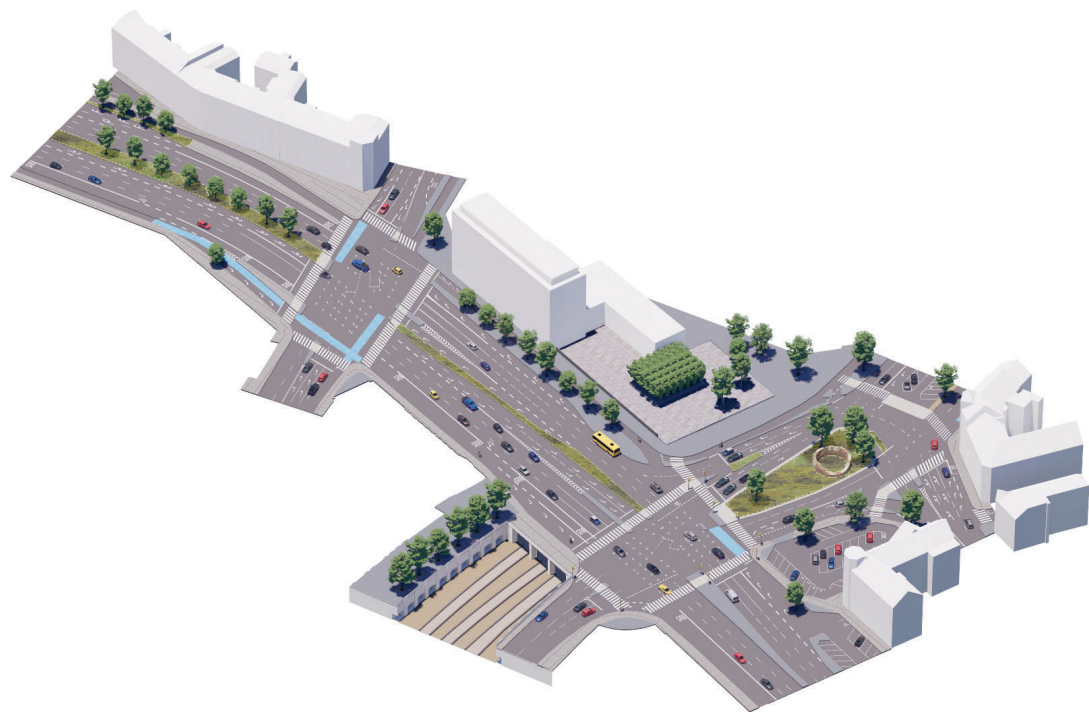
Figure 8.30:
Before and after axonometric of
the accessway principles applied to
Jarmers Plads.
Robert Martin, 2021.
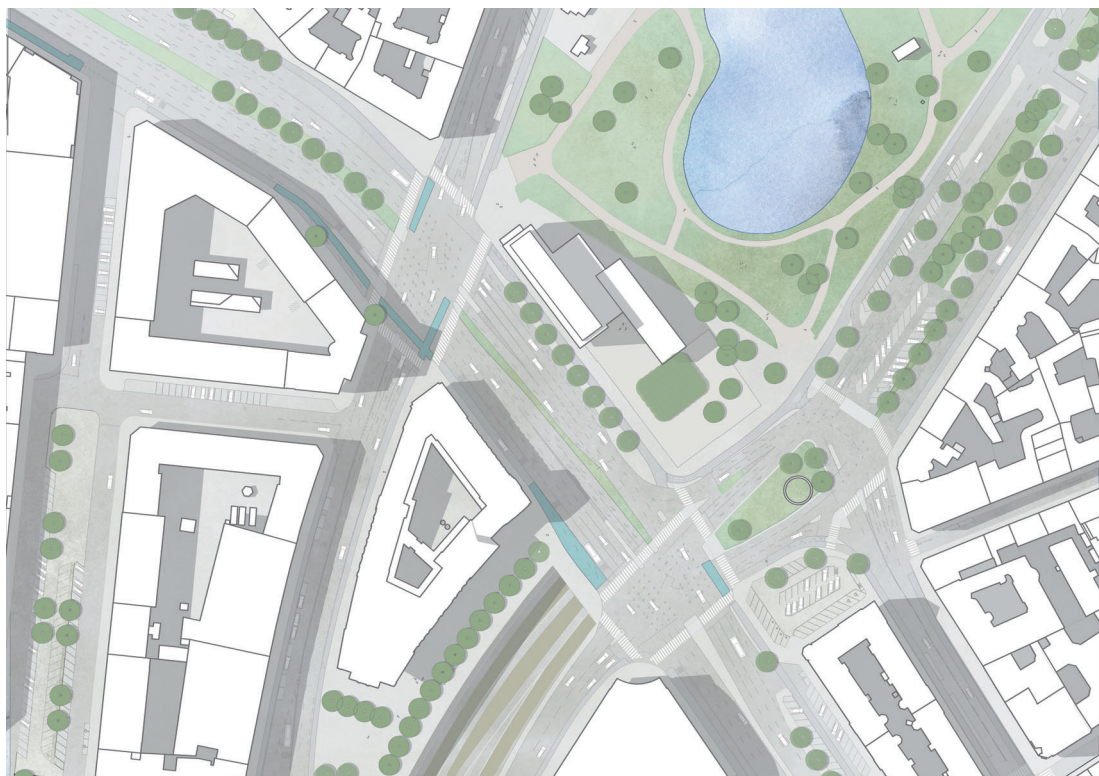
Figure 8.31:
Existing siteplan of Jarmers Plads.
Robert Martin, 2021.
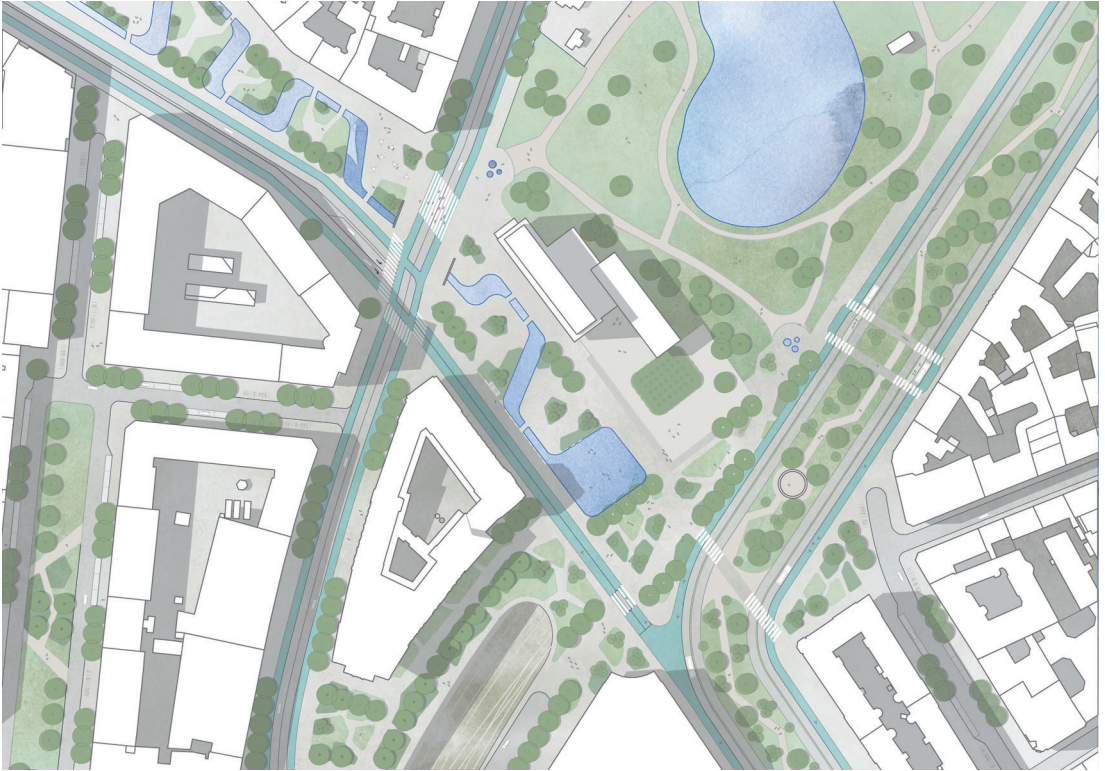
Figure 8.32:
Existing siteplan of Jarmers Plads
illustrating the new public plaza and
end of accessway.
Robert Martin, 2021.

8.8.1.4   A New Rampart

As illustrated with the example of Jarmers Plads, all access-ways, finish as a dead end at the intersection with the medieval city.

This strategy not only adds a number of new, public squares and urban spaces to the city, but also offers the opportunity to re-establish Copenhagen's original ramparts as a green, continuous park that surrounds the medieval city. Several fragmented city parks can be re-established as a whole, where historic layers, transport planning, and urban nature are united in a single move.
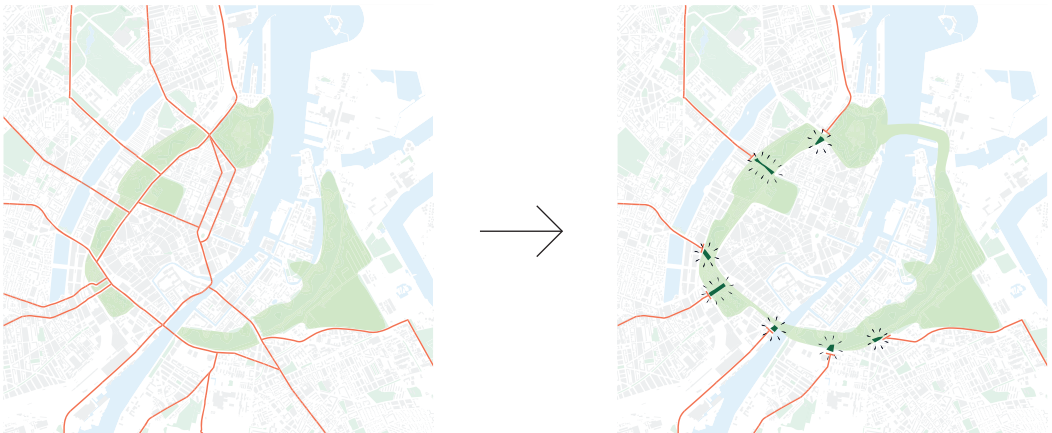
Figure 8.33:
Principal diagram illustrating the establishment of a new green rampart.
Robert Martin, 2021.
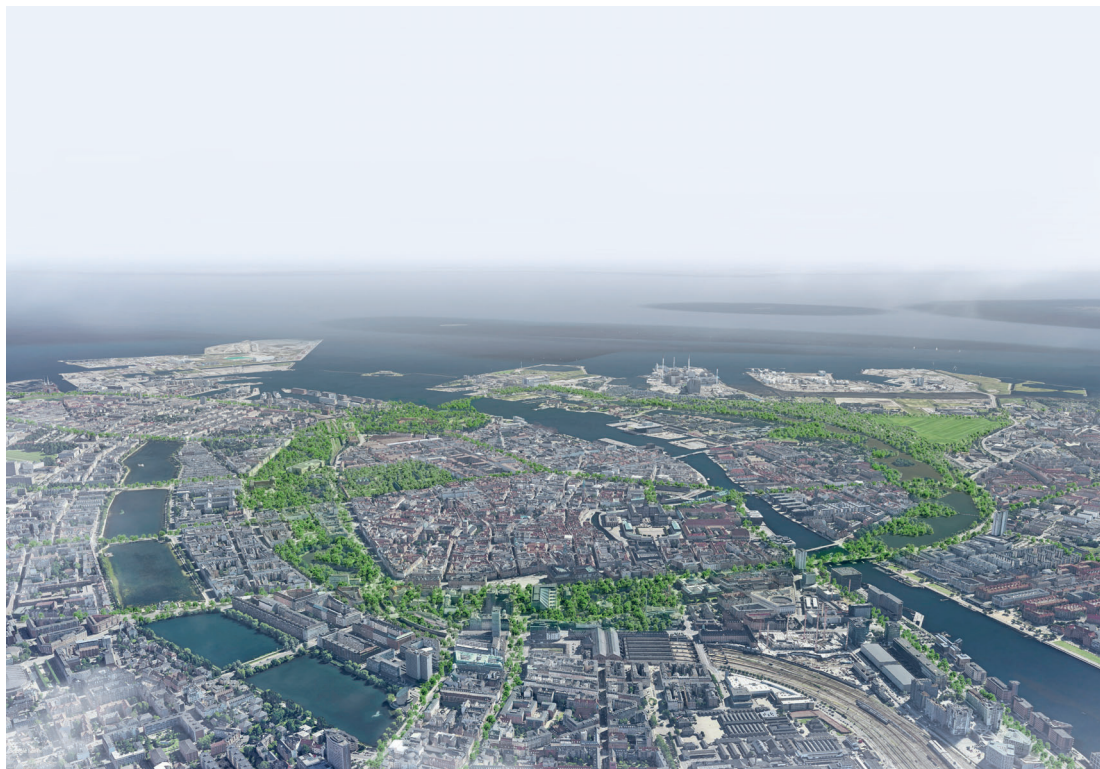
Figure 8.34:
Bird-eye overview of proposed green
rampart surrounding the medieval city.
Robert Martin, 2021.

8.9 Collectors

The accessways branch out into the collector streets that surround small residential neighbourhoods. In principle, this proposal works in the same way as we know it from the Super Blocks project from Barcelona, where through traffic is prevented from travelling within neighbourhood streets (Figure 8.35). Residents may only access their own living street through a collector road.

The two sections on the opposite page illustrate the transformation of a road into a collector (Figure 8.36). The drawing shows how traffic is limited to one lane in each direction. The excess road and parking space is converted expanded cycle lanes and flex zones for new urban amenities.
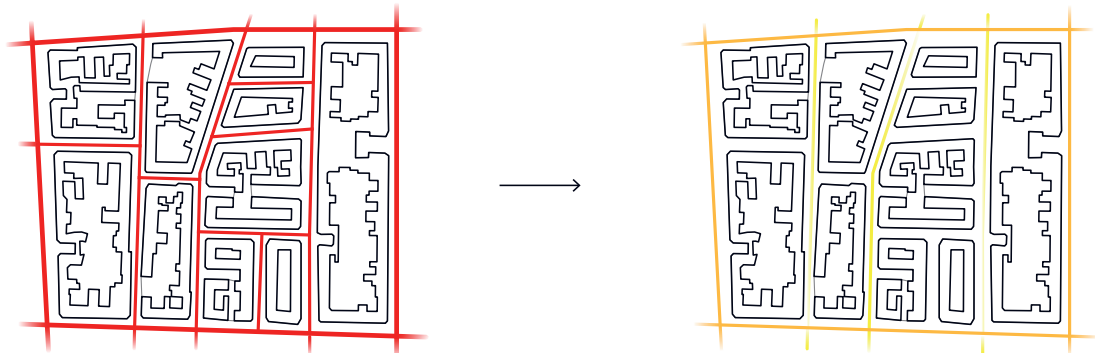
Figure 8.35:
Collector superblock principal diagram.
Robert Martin, 2021.

Upper section labels:

BUILDING — SIDEWALK — CYCLE LANE — ROAD — CYCLE LANE — SIDEWALK — BUILDING

6.33 | 2.50 | 3.00 | 3.00 | 3.00 | 3.00 | 2.50 | 2.61

Lower section labels:

BUILDING — FRONTAGE — SIDEWALK — FLEXZONE — CYCLE LANE — ROAD — CYCLE LANE — SIDEWALK — BUILDING

2.56 | 3.00 | 2.50 | 2.80 | 3.25 | 3.25 | 2.50 | 2.80 | 3.18
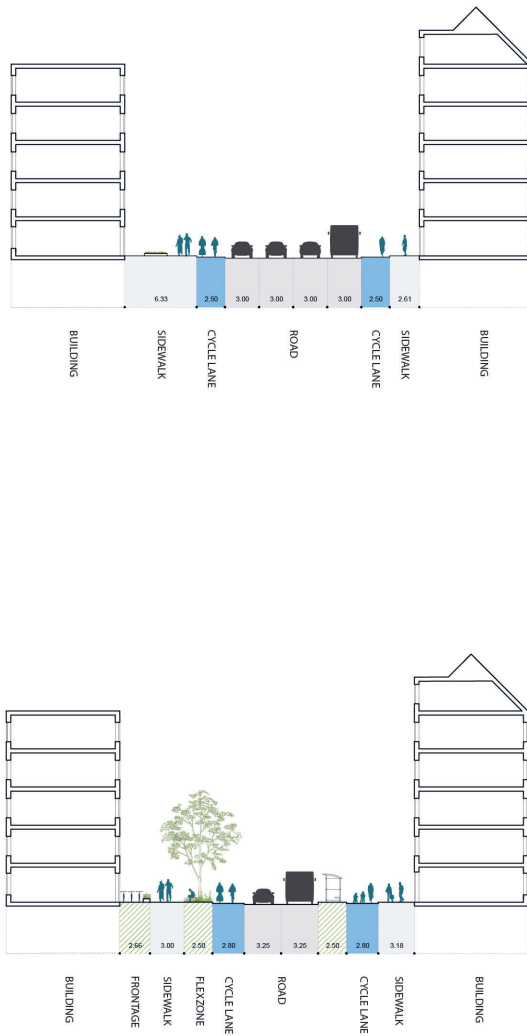
Figure 8.36:
Before and after section drawing of a
collector transformation.
Robert Martin, 2020.

8.9.1 Tagensvej

Tagensvej is a major thoroughfare in the NW part of the city. Although the street is located within a residential area, there can be up to 400m between pedestrian crossing, and therefore, residents must dangerously run across the road amongst traffic to get from one side to the other.

The two axonometric drawings on the right (Figure 8.38) illustrate how the street is transformed from a main thoroughfare for cars into a collector for all road users with an flex zone that includes new covered bus stops, and timed standing zones for pick-up and drop off. At the intersection between living streets and collectors, motorists may only enter or exit a living street with a right-hand turn (Figure 8.37). This creates a simpler and safer traffic flow, where new pedestrian crossings can also be implemented.

The following page visualises a before and after scenario of the street, where the introduction of a new raised pedestrian crossing re-orientates the street to give greater and safer connection for residents moving between living streets.
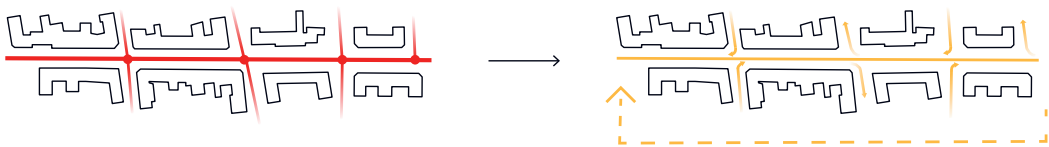
Figure 8.37:
Collector traffic wayfinding diagram.
Robert Martin, 2021.
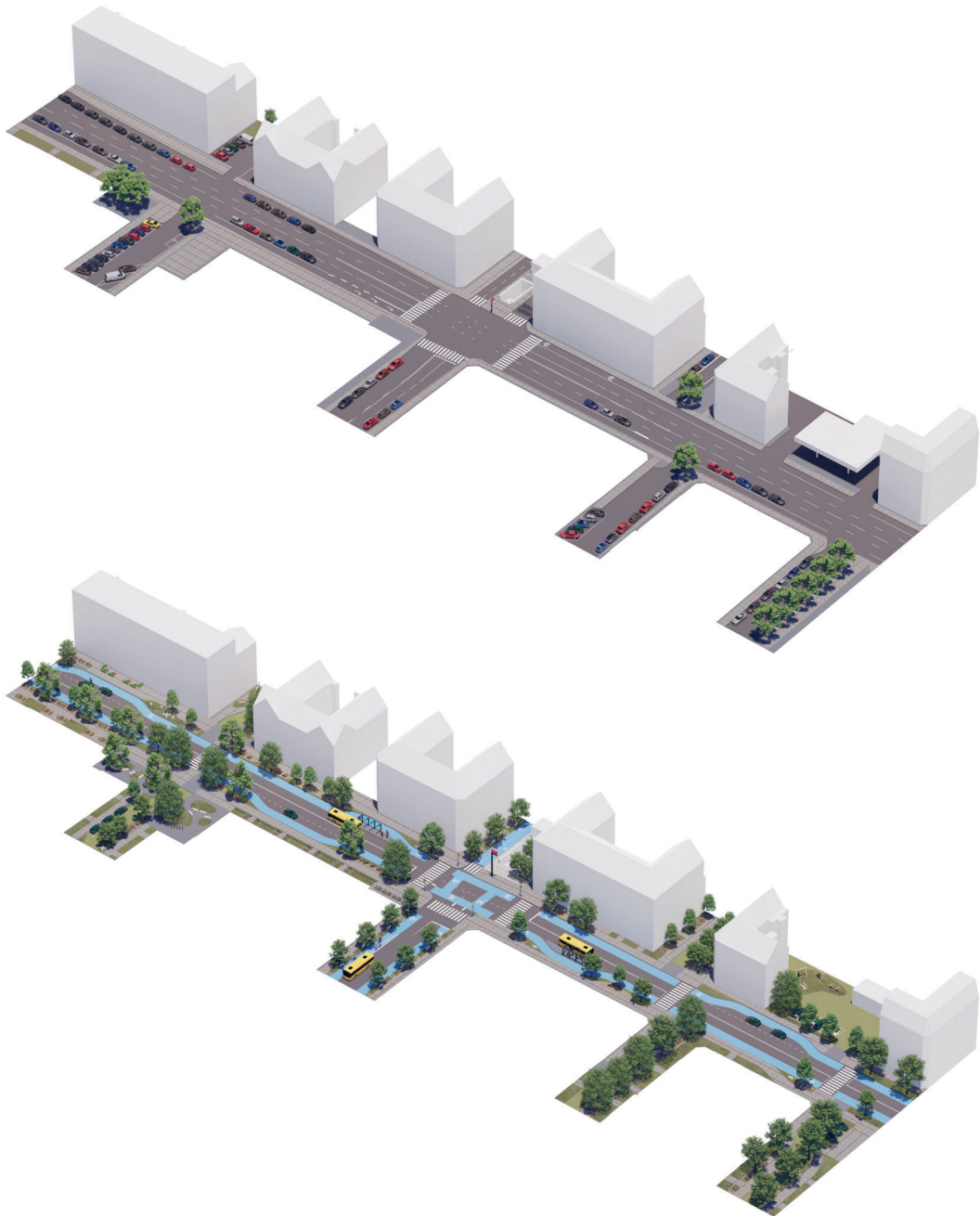
Figure 8.38:
Before and after axonometric of the
collector typology principles applied to
Tagensvej.
Robert Martin, 2020.

Figure 8.39:
Eye-height visualisation of the current
situation on Tagensvej.
Robert Martin, 2021.

Figure 8.40:
Eye-height visualisation of the
proposed collector and new pedestrian
crossing on Tagensvej.
Robert Martin, 2021.

8.10 Living Streets

Within the superblock formed by the collectors are the living streets that ensure access to the homes and are primarily intended for the area's residents. The living streets are only one-direction and have an enforced slow speed limit through changes in the road profile, which provides safety and an experience of peace in the residential areas.

This principle is illustrated in the diagram below (Figure 8.41) and applied to a neighbourhood in the district of Nørrebro in the site plan opposite (Figure 8.42). The residential streets have a natural, low speed limit, which creates security and provides an experience of peace and quiet in the residential areas. To further support this spatial experience, schools, and cultural facilities can work with decidedly closed streets to car traffic.

Figure 8.41:
Diagram describing traffic principles in living street neighbourhood.
Robert Martin, 2021.

Figure 8.42:
Proposed siteplan of living street
principles applied to a Nørrebro
neighbourhood.
Robert Martin, 2021.

By re-thinking our approach to residential streets, living streets provide an increased amount of green space to local areas and new communal areas which can provide climatic protection to extreme rainfall events. The street also provides new infrastructure to support sustainable mobility such as dedicated parking spaces for shared-cars, secure on-street parking for bicycles and cargo-bikes, electric vehicle charging stations.
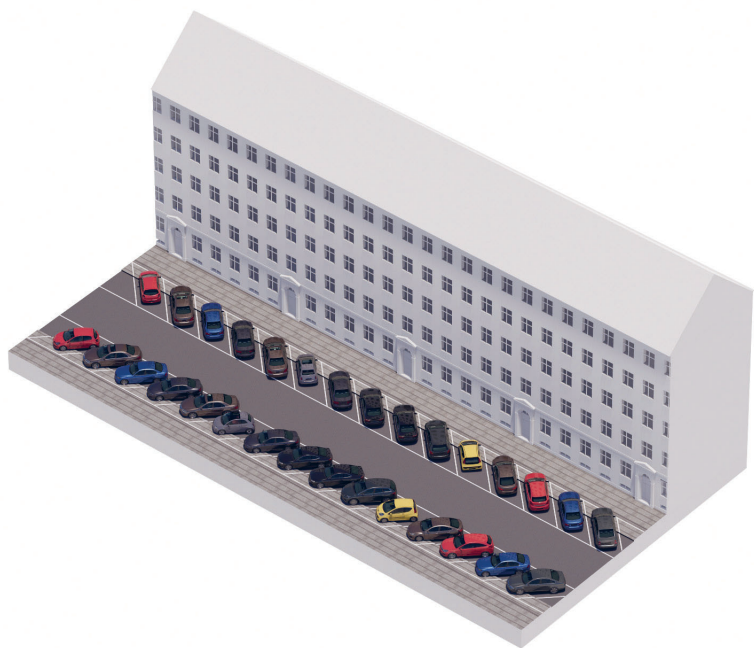
Figure 8.43:
Before and after axonometric of the
living street principles applied to
generic street in Copenhagen.
Robert Martin, 2020.

Elsewhere, the utilisation of one-way living streets allows the opportunity to create spaces rather than intersections where streets meet. These special places can advantageously be arranged as micro-mobility hubs in the neighbourhood which, for example, can handle parcel post, waste sorting, rental of cargo bikes and other shared mobility, etc.

The following pages illustrate several micro-mobility hubs and their integration into a living street.
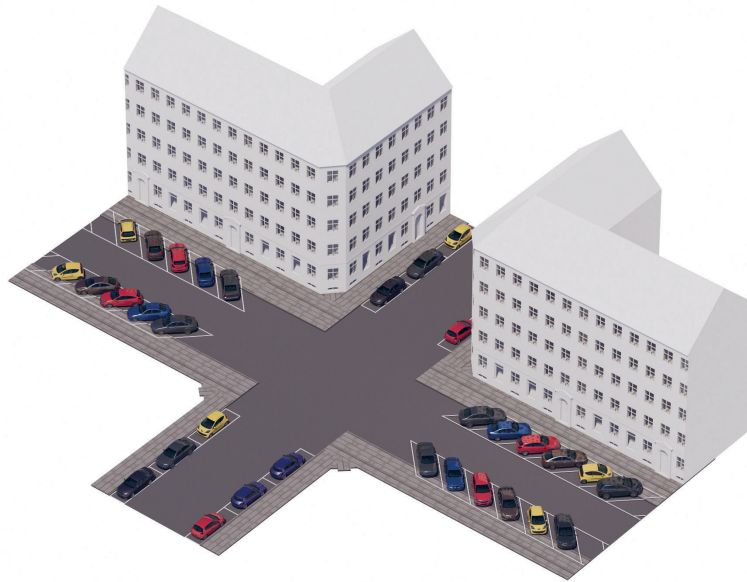
Figure 8.44:
Before and after axonometric of the
living street principles applied to
generic street crossing in Copenhagen.
Robert Martin, 2020.

Figure 8.45:
Eye-height visualisation of a current
street intersection situation on
Struenseegade, Nørrebro.
Robert Martin, 2021.

Figure 8.46:
Eye-height visualisation of several
proposed micro-mobility hubs on
a former street intersection on
Struenseegade, Nørrebro.
Robert Martin, 2021.

8.10.1 Living Street Catalogue

No two streets in Copenhagen are alike: ranging for example in length, width, and adjacent building heights. While this applies to super boulevards, accessways, and collectors, these pale in comparison to the variety and number of living streets. Therefore, this project has prepared a catalogue of different approaches to apply to living streets based on their spatial characteristics. On the opposite page, three examples of the catalogue are presented. The image shows how even if the same principles are applied to a street, the outcome will vary based on the street's dimensions.

In the following pages, two examples of the application of the living street catalogue to neighbourhoods in Copenhagen are presented.

20m   12m

20m   14m

20m   14m
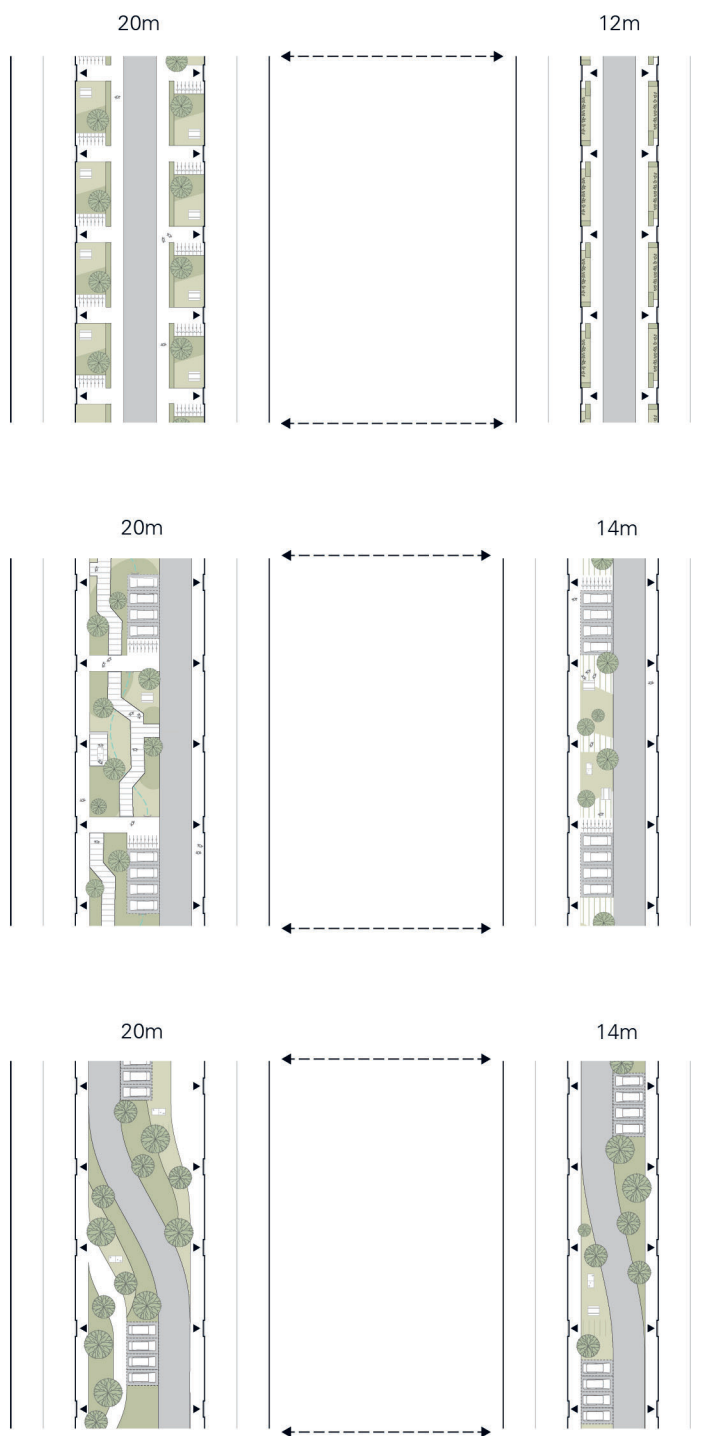
Figure 8.47:
Three examples for the Living Street
Catalogue.
Robert Martin, 2021.

Figure 8.48:
A proposed siteplan of living street
principles applied to residential streets
in Copenhagen.
Robert Martin, 2021.
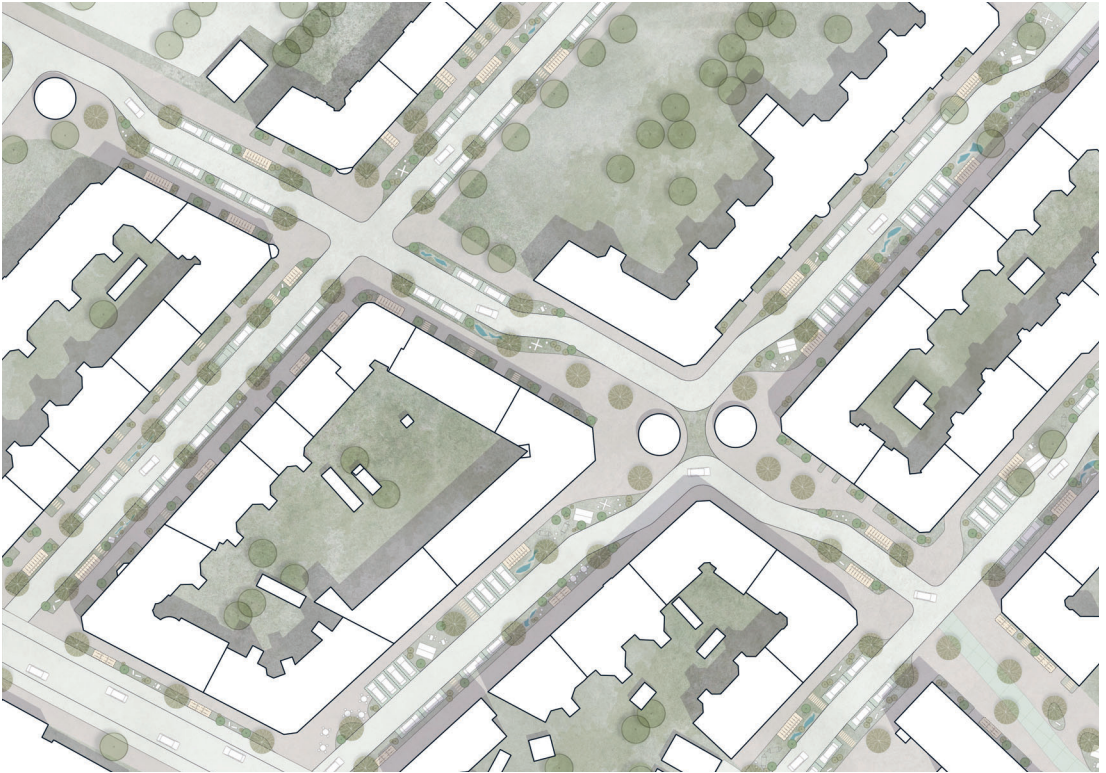
Figure 8.49:
A proposed siteplan of living street
principles applied to residential streets
with an intersection in Copenhagen.
Robert Martin, 2021.

8.11 Chapter Summary

In summary, this chapter has presented the output of the programmatic design research approach as an exemplar project, Copenhagen Car-free(dom). Through a series of short explanatory texts, illustrations, drawings, and diagrams the chapter finalises the research project by contextualising the work as a form of comprehensible dissemination, so that the research can interact with the outside world. The chapter began by outlining an approach to sustainable urban mobilities through the analogy of a mobility diet that preferences smaller, shared, and sustainable modes in the urban environment, while still allowing car access. It then outlined a series of large-scale strategic moves to limit car use, while connecting these strategies to the human-scale through eye-height visualisations to illustrate the spatial, social, and environmental benefits of such a proposal.

8.12 References

Åbn Åen. 2021. "Bispeengbuen – Gylden Middelvej."
Copenhagen.

The City of Copenhagen. 2016a. "Copenhagen CPH 2025 -
Climate Plan." Copenhagen.

———. 2016b. "Omdannelse Af Åboulevard:
Forundersøgelse." Copenhagen.

Vejdirektoratet. 2020. "Forundersøgelse Af Østlig Ringvej
Sammenfattende Rapport." Copenhagen.

Via Trafik Rådgivning A/S, Schønherr A/S, and ICP A/S.
2019. "Mindre Biltrafik i Middelalderbyen: Kortlægn-
ing, Analyse Og Effekter for Trafik, Byrum Og Erhverv."
Copenhagen.

Chapter 9:

Conclusions

9.1　Introduction

The point of departure for the 'Points of Exchange' PhD project was rejection of the dominance of positivistic transport planning approaches to the development of future sustainable urban mobilities. It was inspired and conceived by a company of architects and urban planners who felt a lack of agency to drive the transition towards sustainable urban development in their practice. This thesis took this sentiment as a basis to explore how architects may contribute to the sustainable urban mobilities agenda through their methods of visualisation and unique understanding of space. A significant aspect of this Industrial PhD research is the reconceptualisation of space as an integral aspect of sustainability transitions, facilitated by a research-through-design methodology. This chapter draws on the vast amount of academic and industrial work of the past three years to answer the guiding research questions. To conclude, I propose implications for theory and practice that have derived from this PhD project and provide an afterword to close the work.

9.2　Answering the Supplementary Research Questions

As described in the programmatic design experiment approach to research-through-design, the relationship between the programme, design experiments, and four papers contributed to answering the different research questions. In the following sub-sections, I start by answering each of the supplementary research questions before using these insights to discuss the overall research question of this PhD thesis.

9.2.1 What Is the Role of Emerging Transportation Technologies in Driving a Transition Towards Sustainable Urban Mobility Systems?

9.1 The Peak of Inflated Expectations is one of four stages of the Gartner Hype Cycle of the maturity and adoption of technology. It describes the early enthusiasm for new technologies where a few success stories often shadow many failures. Over time, a new technology will then enter the Trough of Disillusionment, followed by a Slope of Enlightenment, and eventual maturity within the Plateau of Productivity.

This PhD project was conceived of at the peak of inflated expectations[9.1] of AVs. At that time, it appeared that the world was on the verge of a paradigm shift in the way people move around cities. Each day, a new press release would emerge announcing a pilot city, an advancement in the technology, or the acquisition of a new AV start-up, complete with glossy images of the AV 'in the field'. These fictitious (in hindsight), yet capital-attracting depictions were reinforced by trend-analysis reports by the Big Four consulting firms, which announced the imminent arrival of the technology in the next few years, complete with multi-billion-dollar revenue projects. Therefore, the first emerging transport technology that was analysed in this investigation was the AV.

The basis for A1 (Chapter 4), 'Transformations of European Public Spaces with AVs' was a series of design experiments that imagined autonomous driving futures in a Copenhagen context. While studies exist that imagine AV futures, they primarily present conditional scenarios that will be rare in practice. Current thought experiments may depict AVs as a simple substitution for existing monomodal patterns of automobile use, which exacerbates the already destructive implications of congestion, resource consumption, and urban sprawl. Alternatively, they imagine that AVs lead to a utopic future in which shared ownership reduces the negative consequences of automobiles and supports sustainable mobility. These two alternatives simplify the way that AVs will emerge in the world and substantially ignore the possibility of long-term transitional periods and the fact that local social, spatial, and political conditions will affect their use.

What became apparent throughout the design experiments was that AVs alone cannot drive a transition towards sustainable urban mobility systems. This point was further established in A2 (Chapter 5), in which an analysis of AV futures from an incumbent automotive manufacturer showcased a replication

of existing transport systems within a 'system of automobility' (Urry, 2005). Instead, to transition towards sustainable urban mobility systems, the development of AVs should be seen in conjunction with other technological developments that integrate the use of AVs with solutions based on shared mobility, micromobility, and active modes. Mobility as a Service offers one such opportunity to integrate different modes of transport through the exponential uptake of smartphone devices. Accessing a MaaS platform using a smartphone, a user can order transport between two locations, and receive possible travel choices based on different types of transport within an integrated payment system. Transport solutions can consist of public transport, car-sharing, bicycles, or micromobility, depending on what fits the customer and their journey. This allows users to 'match' the vehicle type to their journey type. Therefore, MaaS has the potential to increase modal share to more sustainable modes of transport as users' individual journeys become less reliant on a car to fulfil all transport needs and more tailored to the specific journey's needs. However, as shown through the design experiment 'From Train Station to Mobility Hub', considerable adaptation to existing transportation infrastructure will be required to facilitate such a mobility system.

Although not directly related to emerging transport technology, insights from the two visioning workshops (outlined in Chapter 7) highlighted that low-hanging fruits should not be ignored in the discussion of sustainable urban mobilities. These can include existing transport modes, such as cycling and car-sharing, that do not require huge infrastructure upgrades or investment in technology to reach many of the same ambitions in sustainable urban mobility. In this light, the emergence of new transportation technologies may actually hinder the transition to sustainable urban mobility systems, as they distract investors, companies, planners, and policymakers from tangible solutions that are available today. For instance, a recent publication by the World Economic Forum on the future on urban logistics concluded that the most promising technology to de-carbonise last-mile delivery was autonomous delivery bots (2020). Not once are bots compared to cargo bicycles, despite the current adoption and promotion of this vehicle by international logistic companies attempting to reduce their carbon footprint. This point illustrates that society needs to look beyond the hype of new technologies and evaluate them objectively.

A final insight revealed by the first design experiments was that the introduction of emerging transportation technologies varies significantly according to urban forms and is highly

contextual. This was demonstrated in the different applications of AVs in each of the three scenarios in Chapter 4. For example, in a suburban environment, AVs were imagined as similar to taxi services, with a fundamental aim of re-connecting spatially splintered residential plots to improve social cohesion. However, on dense, inner-city streets, their application resembled bus services, envisioned to create more space for more efficient movement through micromobility. Therefore, I conclude that the role of emerging transportation technologies in the transition towards sustainable urban mobility systems is to shift focus from the monomodal automobile systems that have dominated the twentieth century. Instead, the focus moves towards multimodal systems that best apply new technologies where they can achieve the greatest impact. Furthermore, I suggest that these insights may re-frame the first supplementary research question for future research from 'What is the role of emerging transportation technologies in driving the transition towards sustainable urban mobility systems?' to 'Where is the role of emerging transportation technologies in driving the transition towards sustainable urban mobility systems?'.

9.2.2 How Can Different Spatial Characteristics of the Urban Environment Drive the Transition Towards Sustainable Mobility Systems?

The second sub-research question emerged from a re-framing of the research programme after the first design experiment (described in Chapter 4) and analysis of different visualisations of future mobility systems (presented in Chapter 5). In those chapters, it was established that emerging transport innovations will not alone drive the transition towards sustainable urban mobility systems; they need to be conceived in connection with changes to the built environment. This became obvious in the examples presented by the automotive manufacturer, Daimler, in Chapter 5, in which sustainable mobility modes were not presented with adequate infrastructure to suggest a sustainable urban mobility system. Therefore, the second research question focused on which

spatial characteristics were necessary to transition to sustainable mobility systems.

Current iterations of sustainability transitions theory do not adequately allow for the inclusion of physical space when discussing sustainability transitions. Therefore, a considerable effort was made to reconceptualise the spatial dimensions of sociotechnical landscapes as an essential element enabling transitions to sustainable urban transportation systems. As emerging niche technologies do not yet exist at scale, it was deemed important to determine which spatial characteristics exist that are contributing to limiting car use now within car-free discourses. This effort was documented extensively in Chapter 6 with the formulation of the idea of a sociotechnical-spatial landscape. The findings clearly showed that spatial context was crucial in the transition to sustainable transportation systems and in guiding individual strategic responses by cities. For example, Barcelona's Eixample city grid plan inspired a considerably different response to promoting sustainable transport than the medieval urban fabric of Ghent. This is important to stress, as both cities are currently used as defining examples by other cities that are determining how to limit car use. Therefore, a clear conclusion is that city planners and policymakers should avoid standardised responses to restricting car use and instead consider the unique spatial characteristics of their built environment.

Interestingly, spatial infrastructures built to facilitate automobile transportation systems may also contribute to the transition towards sustainable urban mobility systems. For instance, analysis of the third design experiment showed that ring roads had been used successfully by multiple cities to demarcate car-light areas. Moreover, multistorey carparks located adjacent to ring roads may be converted into interchange points between cars and other, more active, modes of transport. Multistorey carparks also served to consolidate parking in designated areas, providing the option for public authorities to transform on-street parking into other public amenities. Furthermore, the design proposal in Chapter 8 expands on these two typologies by showcasing how excess capacity on main thoroughfare roads can be repurposed to form dedicated public transport lines and to widen cycle paths. These points are not intended to encourage cities to continue building infrastructure for automobiles, anticipating later transformation. Instead, they illustrate that cities can approach the transition to sustainable transportation through the adaptation of existing infrastructure, rather than by building new.

While the discussion so far has focused on unique spatial characteristics found in urban environments, the research also highlighted several overlapping spatial factors found in the case-study cities of Barcelona, Ghent, and Oslo that benefited sustainable transportation. The three most conclusive characteristics were a high population density, a dense network of bicycle lanes, and a highly accessible public transportation system. While these findings may seem banal, I want to reiterate the point that cities considering the transition to sustainable transportation systems must look beyond the hype of new technologies, such as autonomous vehicles and flying drones. Instead, they should consider more proven strategies, such as land-use zoning policies, the construction of bicycle lanes, and investment in public transport. However, I concede that these strategies may be more applicable to wealthy cities in the global north. For cities without the means to invest in such infrastructure projects, there may be other means to achieve sustainable transport beyond the scope of this PhD research.

9.2.3 How Do Visualisations of Future Mobility Systems Affect Stakeholder Input and Planning Processes?

The third sub-research question surfaced from reflecting on the responses I received when presenting the three design scenarios from the first design experiment. The scenarios were presented to a wide range of audiences, including academics, planners, policymakers, members of the transport industry, and the general public, as a form of dissemination to show the work that JAJA and I were doing. While the scenarios were depicted through a range of mediums, such as diagrams, drawings, and visualisations, my experience was that the visualisations usually became the focal point of discussions. I concluded that the visualisations were successful as a catalyst for discussion because they provided a way for the audience to connect a future mobility system with their everyday lives. Too often, the discussion of future mobilities occurs at an abstract and superficial level, whereby spoken or textual debates are far removed from the context in which the changes discussed are supposed to occur. Visualisations, however, take abstract debates and embed the ideas within concrete materialities, so individuals can imagine life within

the ideas presented. With this realisation as a basis, I wanted to test how my own visualisations of future mobility systems might affect planning processes in Copenhagen.

My primary method for investigating this question was two visioning workshops that brought together a range of transportation stakeholders in Copenhagen from the public and private sectors (the method is described in Chapter 7). While the aim proposed to the workshops participants was to co-design a possible scenario for sustainable urban mobilities in Copenhagen, I was also interested in observing how participants interacted with the visualisations that I would produce during the process. From the literature, it appeared that visualisations of future mobility systems may move transport planning processes away from 'predict and provide' ontologies towards a 'decide and provide' approach that consciously shapes transition pathways towards better outcomes (Gaziulusoy & Ryan, 2017; Lyons, 2015). However, I observed that the visualisations allowed the workshop participants to think beyond their disciplinary silos through a process of ontological expansion (Hajer, 2016). This was most evident through the changing nature of resistance I experienced between the two workshops, when visualisations of the ideas discussed in the first workshop were presented in the second. For example, while many participants from the first workshop doubted the possibility of restricting car use as a pathway towards sustainability mobilities, when showed visualisations of a car-light solution, participants from the second workshops demanded that cars be completely banned. Furthermore, the discussions prompted by the visualisations led to novel and imaginative forms of transformational knowledge (Pohl & Hirsch Hadorn, 2007) and possible pathways towards sustainable urban mobility systems. Therefore, I conclude that visualisations of future mobility systems can aid planning processes. They allow stakeholders to imagine beyond existing, path-dependent knowledge regimes and act as catalysts, linking and encouraging discussion between different disciplinary backgrounds.

While the scope of the PhD research only included two visioning workshops, the production of the final exemplar design proposal allowed me to repeatedly engage with the outside world. As outlined in Chapter 2, Section 2.1, I continually attempted to disseminate the knowledge from this PhD project through public lectures and workshops with organisations. This caught the attention of local politicians and media outlets, who wished to discuss the design proposal with me. It takes approximately 45 minutes to explain the design proposal in its entirety. I spend around 30 minutes explaining

the background research and transport strategy at a macro scale through maps, figures, and diagrams. It is only in the last 15 minutes that I begin to explain how such a strategy may positively affect the residents of Copenhagen through the visualisations of streetscapes. I repeatedly experience that the project only makes sense to my audience when they see these visualisations, and they start to become excited about the project's prospects. Previously, I noted that the visualisations predominantly become the focus of discussions. However, I want to reiterate and develop this point by proposing that they also allow those without a background knowledge of transport to engage with the complexity and politics of mobility planning. Therefore, I also suggest that visualisations of future mobility systems may allow planning processes to consult significantly more effectively with the public and those not traditionally involved.

9.3 Answering the Main Research Question

During this PhD research, the following main research question emerged through the continual re-framing of the research programme:

> *How can an architectural approach to spatial knowledge and methods of visualisation help reconceptualise visions for sustainable mobilities futures?*

As posited in the introductory chapter, I believe that architects possess a unique spatial knowledge that stems from our experiences with form, proportion, atmosphere, context, and materiality (Kürtüncü et al., 2008). It has been my proposition that by including this spatial perspective, which prioritises public space and streets as places of living and not only movement, novel methodologies for the planning of future sustainable urban mobilities may arise. In this chapter, three important supplementary research questions were outlined. These arose from a Lefebvrean (1991) position that understands space through the interconnecting of physical space, representations of space, and imaginations of space, which are entry points to answering the main research question.

The first half of this question explores how architects' qualitative epistemological foundations may be applied to the field of transport planning, which is otherwise dominated by a tradition of positivistic methods and principles. Drawing on the findings from the four papers, I propose that architects' spatial knowledge is particularly helpful in the early conceptions of new mobility systems. This is particularly because of its ability to link spatial form, the materialities of mobility practices, and context in the imagining of new mobility systems. This point was established in A1 and A2, in which the design experiments outlined possible trajectories to counteract dependency on automobiles by engaging with liveability. It also highlighted how architectural thinking may conceive of new mobility infrastructures that support emerging technologies. The findings also support the suggestion that architects' spatial knowledge is particularly helpful in the transformation of existing transportation infrastructure. I would like to identify this as the architects' ability to uncover the latent potential of space. All the design experiments were considered within the context of existing cities, rather than imagining new technologies in abstract or generic sites, and identified spatial infrastructures that may contribute to the transition towards sustainable urban mobilities. In particular, Design Experiment 3 identified bypass roads and multistorey carparks as boundaries for car-free areas and excess road capacity as sites for new amenities to support urban life. This point is crucial, as the sunk-cost fallacy for transport infrastructure is often used as an argument against sustainability transitions. Therefore, I encourage planners and policymakers to include architects (either internally or as outsourced assistance) in multidisciplinary teams when considering new transport projects dealing with emerging technologies.

The second half of the question investigates how the architectural method of visualisation can be employed as a tool for future sustainable urban mobilities. Based on the empirical and theoretical evidence present in this thesis, it is the position of this Industrial PhD that the process of architectural visualisation is a valid form of knowledge production within the field of mobilities. First, the production of these images involves an abductive process, whereby the architect moves between the reading of data and theory, 'designerly' ways of knowing, and sketching representations on screens and paper. This process allows the architect to see what is and is not practical before revisiting and reinterpreting the design within a hermeneutic process. Furthermore, these visualisations can enable others to see space as the architect sees it. Throughout the two workshops, visualisations played a key role as a constant reminder of the urban implications of

transportation decisions and their effect on space and quality of life. They also allowed the ideas discussed by workshop participants to be embedded within the concrete materialities of cities to connect them to their everyday life. Finally, and most importantly to the research question, visualisations of future urban mobility systems are a key element of mobility planning processes. They act as mediators between different stakeholders and help them overcome various forms of resistance through a process of ontological expansion that helps them to imagine novel visions for sustainable mobilities in the future.

9.4 Contributions to Theory and Practice

As As an Industrial PhD, the aim of this research project was to contribute to both theory and practice, as stated in my employment contract. In the following sections, I outline these contributions.

9.4.1 Contributions to Theory

This thesis was motivated by a desire to reconceptualise space as an integral aspect of sustainable urban mobilities and challenge prevailing positivistic transport planning approaches. As I am an architect with little to no theoretical foundation, the project initially took a wide scope of theoretical positions before finally arriving at three theoretical perspectives that I present within the published articles. Synthesising the insights from this PhD project, I believe that I have contributed to expanding theoretical perspectives in three key areas.

The first contribution is the theoretical linking between the MLP on sustainability transitions and sociotechnical imaginaries, which was outlined in the second article (Chapter 5). I believe that by connecting sociotechnical imaginaries with transitions, I have created a framework in which visual representations of space can be understood as enablers or constraints on transitions. This is crucial, as it allows the

spatial impact of mobility decisions to be considered before they are realised as physical space. Furthermore, I believe that this contribution enriches the ability of transition scholars to unpack the latent meaning of visual, discursive material by placing it alongside the broader context of sociotechnical systems and the individual layers of the MLP.

The second area in which I believe this PhD research contributes significantly to theory is in the reconceptualisation of space as a critical component enabling transitions to sustainable urban transportation systems. While there have been several recent attempts to address the need for greater spatial sensitivity in transition literature, it often presents a narrow understanding of space as units, such as 'nations', 'cities', 'regions', and 'clusters'. While these terms begin to expand the lexicon of transitions scholars, they do not sufficiently acknowledge the spatial characteristics that vary between spatial units within each category. Through my empirical work (outlined in Chapter 6), I supported the reconceptualisation of the landscape layer of the multi-level perspective as a sociotechnical-spatial landscape. I believe this has widened the lens of transitions researchers and enriched their ability to collaborate across disciplines to include spatial thinkers, such as architects and urban planners.

The final theoretical development that I believe this PhD project has contributed is the empirical evidence that visualisations aid urban mobilities planning processes (outlined in Chapter 7). There is a growing concern about the accuracy of modern-day transport planning tools, such as modelling and simulation, that rely on high levels of certainty to qualify their own projects. As the degree of uncertainty increases, so too does the inaccuracy of these tools to predict the future (Flyvbjerg et al., 2006). The literature suggests that this is due to the ambiguity of the emergence of new transport technologies and the dynamics of socio-economic and cultural-political change (Lyons & Davidson, 2016). Consequently, there is a growing body of scholars that is interested in developing new methodologies and ontologies. The findings from Chapter 7 clearly support a new methodological framework. In this framework, architectural visualisations of future mobility systems foster new forms of collaboration between workshop participants from various disciplinary backgrounds, inspiring them to think of innovative mobilities possibilities beyond their existing worldview. Therefore, this work contributes to the development of applied mobilities research by bridging architecture, practice, and social science to create new planning processes.

9.4.2   Contributions to Practice

The starting point for this PhD research project was an investigation of how architects may contribute to the sustainable urban mobilities agenda. It was conceived by JAJA architects in an effort to expand beyond the traditional boundaries of the architectural profession. It is not uncommon for the most successful architecture firms to venture out into the world and widen the scope of the services that they offer (Klooster, 2013). In the architectural field, technological innovation, cross-disciplinary partnerships, and research collaborations are increasingly consistent with the delivery of successful projects within the built environment. At the commencement of the development of the proposal for this project in 2017, planning future sustainable urban mobilities design was not yet an established field. Therefore, it seemed only necessary that actors from the architecture and planning professions engaged in its formation to balance the dominance of the existing transport planning industry. In the following, I describe the two primary ways in which I believe this research project has contributed to the practice of sustainable urban mobilities design.

Although I have positioned this PhD research in opposition to the dominance of positivistic transport planning approaches, I still acknowledge their role in the design and planning of sustainable urban mobilities. A common question I am posed when presenting the exemplar design project is But have you calculated the effects of your project yet? With a fundamentally different epistemological outset and training as an architect, there is no way that I can answer this question alone. Therefore, I believe that collaboration between architects and engineers will be necessary within multi-disciplinary teams working on sustainable urban mobility projects in the future. However, my experience from attending transportation planning conferences is that there is an ontological divide between architects, with their interest in spatial, material, and formal qualities, and transport engineers, who appear to focus particularly on safety, capacity, and flow. Thus, I believe that the first contribution to practice is that this PhD thesis is relevant to both architects and transport planners. It provides a new platform, tools, and vocabulary for these two professions to understand and collaborate with each other. Moreover, I hope that this thesis engages those outside the realm of architecture and engineering to break down the walls of the disciplinary silos occupied by different stakeholders in transport planning.

The second contribution that I believe this PhD thesis makes is the formalisation of techniques for mobilities design within architectural practice. As mentioned previously, the planning of future sustainable mobilities was still an emerging field at the commencement of this PhD project. Throughout this thesis, I have researched, developed, and outlined a number of different methods that I believe other architects can utilise in their engagement with mobilities projects. They include proposing scenario planning tools; engaging with spatial data applications, such as GIS software; and facilitating visioning workshops that utilise architectural methods of drawing, data synthesisation, and visualisation. Furthermore, I hope that the description and deployment of a programmatic design research approach within the research-through-design methodology may inspire other architects who feel anxious about academic traditions to approach scholarly research with our unique worldview and architectural methods.

9.5 References

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2006). Inaccuracy in traffic forecasts. Transport Reviews, 26(1), 1–24. https://doi.org/10.1080/01441640500124779

Gaziulusoy, A. İ., & Ryan, C. (2017). Shifting Conversations for Sustainability Transitions Using Participatory Design Visioning. Design Journal, 20(sup1), S1916–S1926. https://doi.org/10.1080/14606925.2017.1352709

Hajer, M. (2016). On being smart about cities. In A. Allen, A. Lampis, & M. Swilling (Eds.), Untamed Urbanism (1st ed., pp. 50–63). Routlege.

Klooster, I. van't. (2013). Reactivate!: Innovators of Dutch Architecture. Valiz/Trancity.

Kürtüncü, B., Köknar, S. A., & Dursun, P. (2008). Decoding Spatial Knowledge and Spatial Experience. Design Train Congress, 2.

Lefebvre, H. (1991). The Production of Space (D. Nicholson-Smith (Ed.)). Blackwell.

Lyons, G. (2015). Transport's digital age transition. Journal of Transport and Land Use, 8(2), 1–19. http://www.jstor.org/stable/26202710

Lyons, G., & Davidson, C. (2016). Guidance for transport planning and policymaking in the face of an uncertain future. Transportation Research Part A: Policy and Practice, 88, 104–116. https://doi.org/10.1016/j.tra.2016.03.012

Pohl, C., & Hirsch Hadorn, G. (2007). Principles for designing transdisciplinary research. In Principles for Designing Transdisciplinary Research.

Urry, J. (2005). The "System" of Automobility. In Automobilities (pp. 25–40). SAGE Publications.

World Economic Forum. (2020). The Future of the Last-Mile Ecosystem.

Chapter 10:

Afterword

An Industrial PhD is a unique form of education. While meeting the academic requirements of the Danish Executive Order on PhD Programmes, the research project must also be industrially focused with direct short- or long-term commercial potential. It is also unique in that the PhD student is employed by a company, rather than a university, and therefore often spends much of their time within that commercial workplace, instead of at an academic institution. The aim of these two conditions is to produce what the Innovation Fund Denmark refers to as impact on the host company, which is seen as one of the main purposes of the Industrial PhD programme. However, little space has been allocated in this PhD thesis to discuss how this work has impacted JAJA architects. Therefore, I would like to use this afterword to dwell on how I feel this project has had an impact.

First, I believe that this PhD research project has positioned JAJA at the forefront of the discussion on future sustainable urban mobilities in Denmark. I only take some credit for this, as the project was conceived before I joined the company, and the work has been a collaborative effort with the founding partners and architects at JAJA. When I joined the company, we were all engrossed in the promise of AV technology. It was only through a joint re-framing of the project to focus on tangible sustainability practices, mostly through ideas surrounding car-freeness and urban planning principles, that I believe JAJA has become a leading voice in the mobility world. Throughout the past year, I have witnessed several other architectural firms in Denmark join the debate on mobilities. However, they approach the conversation from a techno-optimistic perspective, similar to our earlier beliefs, that places too much emphasis on technologies such as AVs.

The timing of JAJA's increase in work with mobility has coincided with a global political shift regarding privately owned cars. Local elections are being won across the political spectrum with promises to limit or ban car use in favour of more social and active urban environments. In Copenhagen, which has maintained a policy of not removing a single parking place over the past ten years, politicians are now announcing plans to remove one-third of all parking spaces by 2025. Furthermore, in April 2021 the Copenhagen municipality published an ambitious traffic island plan to become CO_2 neutral by 2025. The findings of this PhD have become extremely relevant to city officials. I have already observed senior members of the Technical and Environment Administration of the Copenhagen Municipality using content from my workshops in their presentations about the future of Copenhagen. This has led to a lot of interest from the media. Together with my industrial

Figure 10.1:
Screenshot of shared tweet of JAJA's Mobility Pyramid.
Source: Twitter, 2021.

supervisor, Jakob Steen Christensen, I have written opinion pieces for national media outlets and given several interviews. Furthermore, Denmark's national architecture magazine, Arkitekten, recently published a special issue on mobility in which JAJA were featured on the cover with several spreads describing our projects inside. The more that the PhD is disseminated in this way (which includes several visualisations), the greater the chance that the work can become a dominant sociotechnical imaginary within the city. I have already seen a former mayor of Copenhagen sharing our work via their social media channels (Figure 10.1), which adds greater weight to our cause and cements JAJA's position as a mobility design forerunner.

Figure 10.2:
Front cover of Arkitekten featuring JAJA's Wooden Mobility Hub project.
Source: Arkitekten, 2020.

The PhD has also had a significant impact on the way in which JAJA approaches their own mobility projects. Through our joint efforts, the PhD has informed a practical methodology that combines backcasting and prototyping when working with mobility planning (Figure 10.3). While the individual components are not novel, their combination has provided an innovative method for design. While forecasting tries to predict the future, backcasting does the opposite. It is a technique that focuses on designing a desirable future situation and then imagining the steps and strategies to reach it. Prototyping balances this process by working on smaller scale inventions which represent that desirable future in the present. Therefore, backcasting provides the vision and long-term masterplan while prototyping develops knowledge, experience, and user feedback for a more sustainable future. In relation to JAJA's work, my PhD has functioned as the backcasting element and the long-term vision, which has informed JAJA's work on smaller pilot projects in cities such as Copenhagen and Aalborg, Denmark.

Figure 10.3:
Backcasting/
Prototyping framework diagram.
Robert Martin/ JAJA Architects, 2020.
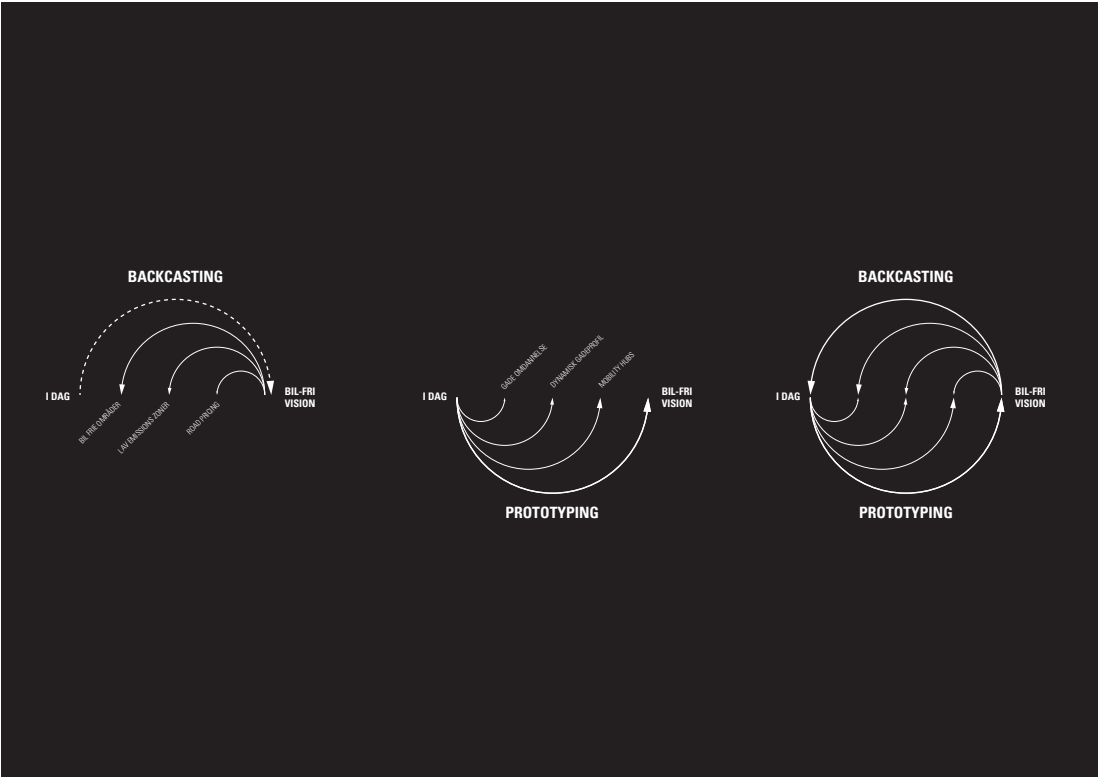
The final impact that I wish to highlight, to close this PhD thesis, is the transdisciplinary knowledge that this Industrial PhD has imparted to JAJA and hopefully to the wider architectural community. I believe that through the engagement with mobilities and transitions literature, architectural perspectives on transport planning can extend beyond the hype of new transportation technologies to see them objectively. This research also enriches the ability of architects to engage in and collaborate with disciplines outside the traditional realm of the construction industry. Considering the acceleration of planetary urbanisation and the impact of current mobility practices, this work provides a timely foundation for JAJA and other architectural practices. My experience is that architects keep entering the discussion on the future of sustainable urban mobilities from the same starting point. Let us use this PhD to start somewhere else.