Datafication of Cycling: tensions between cycling policy and mobility justice

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A thesis submitted in partial fulfilment of the requires of the University of Brighton for the degree of Doctor of Philosophy

Abstract

This thesis investigates how the "datafication" of cycling and policy can exacerbate the existing mobility injustices associated with the privileging of efficiency and individual freedom over diversity. The thesis synthesises theories of mobility justice and data justice, with critical scholarship from mobilities, critical data studies, and public policy to develop an original understanding of how "datafication" processes are influencing the delivery of cycling policy plans. It makes a transnational comparison of two government departments: Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA. Data from fitness apps, such as Strava, are being used to evaluate transport planning and cycling-relevant policies at TfL and ODOT. These Strava data generally capture journeys made by younger males for commuting and recreational purposes. Despite some academic interest in exploring the statistical representativeness of Strava Metro samples compared to other data sources such as cycle counters, there are few contributions that have critically reflected upon the applied uses of Strava Metro data within public administrations. In response to this research gap, this thesis critiques the collection and analysis of commercial cycling data such as Strava Metro by transport policy practitioners. Through the analysis of cycling policy plans and of semi-structured interviews with professionals at TfL and ODOT, this thesis argues that whilst cycling is perceived as a sustainable mode of transport, cycling efficiency and speeds are privileged. I thus argue that policy ambitions to support more inclusive cycling are positioned as secondary ambitions to increasing total numbers of cyclists. To move towards more egalitarian and mobility just futures, this thesis demonstrates that cycling policies must address both problems by moving away from measures to increase cycling mode share as their core priority and questioning the use of data. Rather, cycling policy plans should start with an ethical imperative to diversify participation in cycling, which is fundamental to sustainability. Without a re-evaluation of cycling policies and plans, uses of commercial data such as Strava Metro will benefit and unfairly privilege those who are already highly mobile, and who may cycle out of choice, not necessity. As I emphasis throughout, the benefits of more cycling across society are numerous, yet there is no guarantee these will materialise without transformative policy that aligns inclusive cycling provision with data practices that focus on mobility needs and affordances, rather than observable data and estimated demand.

Key words: Datafication. Cycling. TfL. ODOT. Strava. Mobility justice.

List of acronyms

A&E – Accident and Emergency

AADBT - Annual Average Daily Bicycle Traffic

ADA - The American with Disabilities Act (USA)

APBP - Association of Pedestrian and Bicycle Professionals (USA)

ATNM – Active Travel Network Map (Welsh Government)

AVT – Automated Vehicle Travel

CA – Capabilities Approach

CBA – Cost Benefit Appraisal

CDS – Critical Data Studies

cLOS – Cycling Level of Service

CYNEMON – Cycling Network Model for London (TfL)

DfT – Department for Transport (United Kingdom)

ECF – European Cyclists' Federation

ERSI - Environmental Systems Research Institute

ESRC - European Social Research Council

ESRI – Environmental Systems Research Institute

EU – European Union

GDPR - Data Protection Regulation (EU)

GPS – Geographical Positioning Systems

GUI - Graphical User Interface

HEAT – Health Economic Assessment Tool (WHO)

HGV - Heavy Goods Vehicles

IoT – Internet of Things

KSI – Killed or Seriously Injured

LASSO - Least Absolute Shrinkage and Selection Operator

LCDS - London Cycling Design Standards (TfL)

LTDS - London Travel Demand Survey (TfL)

LTNs – Low Traffic Neighbourhoods

MAMILs – Middle Aged Men in Lycra

NCN - National Cycle Network (UK)

OD – Origin and Destination

ODOT – Oregon Department of Transportation

ONS – Office for National Statistics (UK)

OSM – Open Street Map

PBOT – Portland Bureau of Transportation

PCF - Participant Consent Form

PcT – Propensity to Cycle Tool (DfT)

PIS – Participant Information Sheet

PPP – Public Private Partnerships

PSU – Portland State University

QGIS – Quantum Geographic Information System

QS – Quantified Self

SCDTP – South Coast Doctoral Training Partnership

sDNA – Spatial Density Network Analysis

STARS - Sustainable Travel: Active, Responsible, Safe (TfL)

STS – Science and Technology Studies

TAG – Transport Analysis Guidance (UK)

TfL – Transport for London

TLRN - Transport for London Road Network (TfL)

TREC – Transport Research & Education Center (PSU)

UBDC – Urban Big Data Centre (ESRC)

UK – United Kingdom

UoB - University of Brighton (UK)

USA - United States of America

USDOT – United States Department of Transportation

WIMD – Welsh Index of Multiple Deprivation

Preface

Hello, I'm a transportation student and professional based in the UK who has an interest in spending time outdoors. This interest probably emerged at same time as one of my favourite childhood memories with my brother, that involved venturing beyond Margam with an inventive bicycle-rope-scooter assembly to visit our nanna.

Acknowledgements

A special and dedicated thanks to Dr Frauke Behrendt, Professor Lesley Murray, and Professor Phil Haynes for supervising this doctoral study. Thanks for the endless supervision support. An extended recognition to Dr Mark Erickson, who offered time to support this thesis when there was no requirement to do so. Thanks to all the administration and library staff at Brighton University and Southampton University, particularly Fiona Sutton and Glenn Millar. Thanks also to Professor Jennifer Dill, and Dr Joseph Broach, and everyone in Portland Oregon who also offered their time. Thanks to Dr Aristea Fotopoulou and Dr Carl Walker for their critical and supportive feedback as internal examiners for this work. Many thanks also my external reader, Professor Peter Cox, whose work and critical feedback has inspired much of this thesis; and many thanks to Dr Roxanna Cavalcanti for chairing the examination of this work. Thanks also to my master's supervisor, Dr Justin Spinney, for the initial intellectual steer. A huge thanks to all the highly skilled and enthusiastic transportation and software experts at various organisations who offered their time for this project. Thanks to all my close friends and their families: James Morgan, Chloe Morgan, Hayleigh Thorn, Adam Thorn, Bethan Russ, Chelsea Saunders, Tom Cole, Jordan David; Anthony Craig, Natalia Bonilla Porras, Tattiana Hernández Madrigal, Edith Rojo Zazueta, Andrea Guati Rojo,; Phil Wells, Carwyn Price, Ffion Price, Tom Dunn; Jason Preston, Hannah Preston, Matthew C. Smith, Chloë Porter, Lucy Menzies, Gigi Hennessy, Toby Collingwood, Alberto Pavano, Mijke van der Zee, Elliot Batty, Bethan Prosser, Naz Biggs, Hannah Selby, Amartey Golding, and Emily Robinson; Lyndsey Stoodley, Charlotte Gaughan, Patrick Lee; Isabella Kremer and Rachel Moras; Jo Pope; also, everyone who went to midday lunch at Falmer, played afternoon table tennis, or managed a Saturday Morning Parkrun before the pandemic times; to everyone who went for a walk, or for a breakfast, around Neath and Port Talbot during pandemic times; everyone at work, especially to Tim John; and to everyone else who has been a social support, you'll know who you are. To my parents and their partners; my brother Dale; and my whippet nephew, Wil Williams. To all the Williams' and Johns' and extended family, especially to the many cousins; and, for my nannas and aunties. And finally, to you, the reader. I hope you enjoy reading this thesis as much as I enjoyed researching and writing it.

Funding

This thesis was funded by the Economic and Social Research Council (ESRC) South Coast Doctoral Training Partnership (Grant Number ES/R501025). The findings of this work are targeted at students and researchers interested in mobilities, transportation planning and policy, and the politics of "big data". It will also appeal to transportation professionals and decision makers that are interesting in supporting non-motorised travel and mobility.

Declaration

Declaration I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree and does not incorporate any material already submitted for a degree.

Signed Shaun Williams

Dated 28th February 2023

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Chapter 1: Introduction

1.1 The need to promote cycling

Cycling is increasingly promoted as sustainable and healthy by transportation policies, a solution to the negative externalities generated by mass automobile societies. As the analysis of policy documents within this thesis will show, cycling specific policies, such as the Transport for London *Cycling Action Plan* (2018), promote cycling to reduce traffic congestion, air pollution, assist in creating healthier and happier places and people. Cycling thus contributes to complex policy challenges, especially related to the decarbonisation of global transportation, and the transport sector's contribution to human-induced climate change. Indeed, more cycling has been positioned by academic (Zuev et al., 2021; Whitelegg, 2020) and policy advocates (ECF, 2022; Sustrans, 2022; Cycling UK) as both logical and necessary to support transitions away from the environmentally and ecological damaging impacts caused by mass motorised travel. To emphasise the need for more cycling in society, there too has been an upsurge in academic writing across varying disciplines, and political support to fund cycling. Cities across the world, particularly across northern Europe, have set about becoming associated with cycling (Popan, 2019). Particularly cities such as Amsterdam (Netherlands) and Copenhagen (Denmark) which are viewed as exemplars of urban cycling and transportation, boasting estimated cycling mode shares that exceed 10% (Parkin, 2018). Furthermore, as of May 2021, 54 countries across Europe adopted the *Pan-European Master Plan for Cycling Promotion* to develop or update national cycling strategies by 2030 (ECF, 2022), further illustrating international political interest in supporting cycling.

Cycling has a long history, pre-dating the invention of the automobile, and its practice has evolved over time since its early (and contested) origin (see Oldenziel et al., 2016). Cycling today is increasingly being seen by many western governments as necessary transportation mode for cities to promote alongside the automobiles, trains, and buses. It is also seen as a recreational endeavour for exercise and enjoyment. Globally, cycling is also seen as professional entertainment with major international road races such as the Tour de France and the Ronde van Vlaanderen, and multiple disciplines of cycling at the Olympic Games. From a manufacturing perspective, cycling is big business, and technologies for cycling are as diverse as the varying and overlapping reasons for cycling. For this thesis, whilst recognising that the meanings of cycling are diverse and varied, the focus remains on assessing cycling for everyday mobility and transportation, and not competitive or leisure cycling.

Nevertheless, for all the perceived benefits and positive claims for more cycling, participation rates are very low in many cities and countries (Parkin, 2018; ECF, 2022). This is also true in across the United Kingdom and the United States, which have estimated cycling mode shares that are less than 2% across the adult population (Parkin, 2018). Despite the numerous benefits associated with more cycling in society, cycling has been marginalised as a mode of mobility through historic transportation policies that have privileged the private car. Cycling is thus seen to exist within a dominant "system of automobilities" (Urry, 2004). To promote cycling in society, cycling policy advocates, such as Cycling UK (2021) and the European Cyclists' Federation (2022) have called for a challenge to the homogeny and political dominance of motorised vehicles. To overcome the low participation is to overcome one challenge of cycling: encouraging more people to participate. Several strategies have been raised to meet this challenge, especially through the installation of physical cycle-specific infrastructures to create safer and more convenient environments in which to cycle.

As discussed in subsequent chapters of this thesis, cycling has also been identified as having a historic "data problem" that has hampered the ability of transportation professionals to demonstrate existing practices and latent demand of cycling, which could otherwise make evidence driven cases for inward investment for supportive infrastructures. In recent years, the increasing "datafication of society", through the mass availability of digital infrastructures, including public access to mobile GPS technologies such as mobile phones and fitness trackers, has led to excitement amongst transportation professionals and researchers that have asked whether "big data" sources could support data transport planning efforts (Romanillos et al., 2016; Musaka & Selala, 2016) to demonstrate and enhance cycling within "lower cycling" contexts. Within this broader context of "big data" sources for cycling, this thesis focuses specifically on one commercial software company called Strava, which has repurposed, and shared fitness data volunteered by app users with public administrations to support transportation planning efforts.

1.2. The perceived need for more data

Whilst an increased data availability, such as Strava Metro, may help to overcome the perception of limited data related to cycling, a key concern is raised in relation to who is captured within samples, and who is not. This issue related to sample representativeness will be revisited throughout this thesis to critically reflect upon how Strava Metro has influenced policy and delivery of cycling specific schemes at two public administrations, Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA. For now, it is next relevant to provide context to the software company, Strava. Initially, the Strava app was principally developed as a social media platform in 2009 for cyclists to voluntarily record, upload, and share cycling activities to other online followers. Following a request for data from the Oregon Department of Transportation (ODOT) in 2014, Strava started to repurpose their data for transportation planning purposes. According to the incumbent Bicycle and Pedestrian Program Coordinator at ODOT at the time, the rationale for requesting data from Strava related to cycling was clear:

> *"It [manual cycle counts] was very haphazard, two-hour counts done once a year. Volunteers sitting on the street corners because they wanted better bike facilities. Pathetic, really."* **(Quoted in Walker, 2016)**

In response, the Oregon Department for Transportation (ODOT) approached Strava for data to address a "haphazard" approach to data collection and a general lack of data related to cycling. Following this initial partnership between public and private sectors for access to crowdsourced data to support planning and governance of cycling, the Strava Metro project has expanded transnationally, with partnerships established with transportation authorities across Australia, Brazil, Norway, the United States, and the United Kingdom. Since 2016, Strava Metro data have been utilised by the Transport for London (TfL) in the UK, another regional sized government administration alongside ODOT in the USA. According to the Strava Metro website, the company has collaborated with over 100 public administrations around the world (Strava Metro, 2019). In an article entitled "The New Human-Powered Era" published in 2020, Strava claimed that 4 billion fitness related activities had been uploaded to their servers (Strava Metro, 2020), and that the company had over 50 million global app users (The Telegraph, 2020), giving context to the scale and global impact the app has had since it first launched in 2009. The geographical scale of Strava Metro is demonstrated within Figure 1 which displays a "heatmap" of trillions of data points of aggregated Strava user data across the globe. As Figure 1 illustrates, the Strava app is used across the globe, but particularly across Western Europe and North America. According to Strava Metro, this sheer volume of Strava users thus supports the generation of significant data available to public transportation administrations:

> *"The Strava dataset is the largest collection of human-powered transport information in the world. Metro aggregates, de-identifies and contextualizes this dataset to help make cities better for anyone on foot or on a bike. We work with urban planners, city governments and safe-infrastructure advocates to understand mobility patterns, identify opportunities for investment and evaluate the impact of infrastructure changes."* **(Strava Metro, 2021)**

In this sense, Strava Metro proclaim to have a monopoly share of data related to cycling which public administrations could leverage to understand cycling activities within their jurisdictions. However, as the commercial company notes, above, Strava Metro data are pre-processed as aggregated datasets before being shared with public administrations. In other words, public administrations may acquire Strava Metro datasets, but not unprocessed (or "raw") Strava data. Throughout this thesis, the aggregation of data will be further discussed, but this brings us to one significant query regarding Strava Metro data: exactly who are captured within Strava Metro datasets, and what are the potential issues of this?

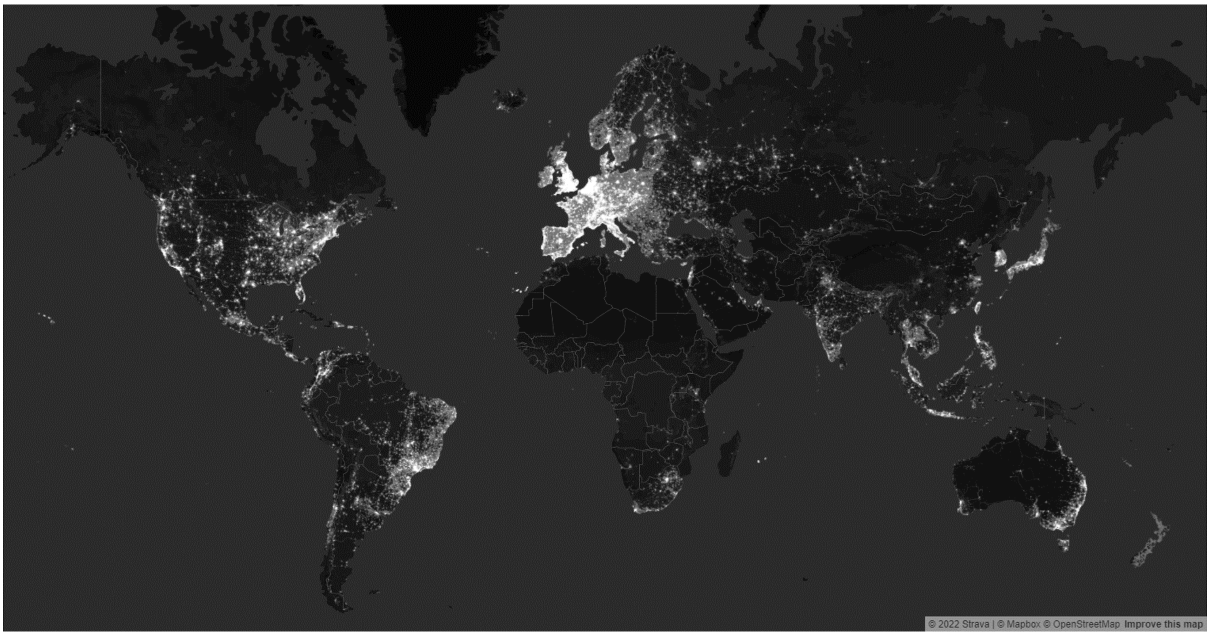

Figure 1: Heatmap of all public Strava activities during 2021 (Strava, 2022)

1.3. The issue of unrepresentative cycling data

The questions raised above are significant in the context of cycling observations across specific contexts within western societies. Indeed, as this thesis will demonstrate, cycling is one of the most unequal, unrepresentative modes of surface transportation and mobility, particularly within certain contexts such as the UK and the USA. Furthermore, Strava app users are equally understood to be highly unrepresentative of society. Academic reviews of Strava Metro data, that are detailed within this thesis, emphasise how samples are largely comprised of young male riders. Furthermore, Strava app uses are also recognised to ride for pleasure, competition, or to record commuter journeys to work, thus Strava Metro data samples are largely unrepresentative of other trips such as journeys to school, healthcare facilities, and to shops. This is problematic from a social sustainability and social justice perspective; as an increasing collective of critical voices emphasise (Zuev et al., 2021). Indeed, as scholars have noted in recent reviews of cycling in the cities such as London, an increase in the cycling rate is no guarantee of more diversity in cycling (Aldred et al., 2016), and equally, lessons such as those from San Francisco in the United States show how more cycling may benefit some whilst continuing to marginalise others (Stehlin, 2014; 2019). This means that in addition to promoting cycling in society, there is also an imperative need to diversify one of the most unequal modes of mobility in society. In the next section, I outline the need to critically appraise Strava Metro data uses.

1.4. Original contribution to research

This thesis provides an original understanding of how "datafication" processes, such as the collection, processing, and sharing of "big data" generated by smart devices, influence the delivery of cycling policy plans. Whilst there is a growing body of literature that is responding to the needs of social sustainability and social justice when evaluating cycling in societies, there are considerably fewer that have reflected upon how "datafication" processes and applied uses of "big data" may support or hinder efforts to support more inclusive cycling practices. Equally, there are several contributions that have assessed how statistically representative sources of Strava Metro are of cycling, without critically reflecting upon how "big data" uses may exacerbate existing issues observed in contemporary western society. Specifically, there are few contributions that have addressed how and why Strava Metro data are being used by public administrations, and what this may mean for sustainability and social justice in cycling.

To address this significant gap in knowledge, this thesis explores how profound changes brought about by the datafication of society are influencing the delivery of cycling policies at two regional sized transportation authorities: Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA. Specifically, I synthesise theories of mobility justice and data justice, with critical scholarship from mobilities, critical data studies, and public policy to understand how datafication processes are influencing the delivery of cycling policy plans (and thus cycling futures) at TfL and ODOT. Through the analysis of cycling policy plans and of semi-structured interviews with professionals at TfL and ODOT, this thesis argues that whilst cycling is framed as a sustainable mode of transport, cycling efficiency and speeds are privileged over the need to diversity, thus exacerbating existing mobilities injustices.

To move towards more egalitarian and mobility just futures, this thesis demonstrates that cycling policies, such as the *TfL Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016), must move away from measures to increase cycling mode share as their core priority. Rather, cycling policy plans should start with an ethical imperative to diversify participation in cycling, which is fundamental to sustainability. Thus, a key policy recommendation of this work concerns a call to revise transport policy plans. Without a re-evaluation of cycling policies and plans, uses of commercial data such as Strava Metro will benefit and unfairly privilege those who are already highly mobile, and who may cycle out of choice, not necessity. As is emphasised throughout, the benefits of more cycling across society are numerous, yet there is no guarantee these will materialise without transformative policy that aligns inclusive cycling provision with data practices that focus on mobility needs and affordances, rather than observable data and estimated demand. The debates discussed within this thesis contribute to the research fields of mobilities and critical data studies. The thesis will be of particular interest to cycling researchers, transportation planners, and social scientists interested in public policy.

1.5. Research objective and research questions

The overarching objective of this thesis is to understand how Strava Metro data has been used by UK and US transportation planners, specifically in London and Portland, and to reflect upon the consequences of these data uses for sustainability and social justice, with a view to supporting cycling futures that are responsive to equitable and mobility just societies in an increasingly datafied world. Indeed, as this thesis emphasises within the accompanying literature review, there are very few critical reflections within the academic literature which question how public-private partnerships impact the delivery of public cycling plans and policies. Specifically, this thesis conducts an international comparative analysis that critically reflects upon Strava Metro data uses at two regional sized government administrations: the Oregon Department of Transportation (ODOT) in the United States, and Transport for London (TfL) in the United Kingdom. The rationale for choosing these organisations is based on reported uses of Strava Metro data through journalist accounts of Strava Metro data acquisition by the two transportation authorities (The Guardian, 2016; Financial Times, 2019; Walker, 2017).

To move toward the thesis objective, I address four guiding research questions throughout this thesis.

The first research question asks: *what is the transport policy "problem" – at the regional scale – that determines injustices in cycling and cycling data?* To critically reflect and address this research question, I draw upon transportation policies and plans published by the two regional government departments. Specifically, I focus upon two cycling plans: the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), and the *TfL Cycling Action Plan* (2018) to reflect upon the cycling "problems" both documents seek to address issues of related to cycling, and to ascertain how both cycling plans anticipate uses of "data" related to cycling. By utilising Bacchi and Goodwin's (2016) "*What's the problem represented to be?*" (WPR), I show policy plans recognise a need to increase the rate of cycling, whilst also seeking to diversify. However, I critically emphasise how these policy ambitions and brought into tension, due to the prioritisation of supporting overall cycling numbers above a need to diversify.

The second research question asks*: how is Strava Metro data used by transportation authorities at regional scale of government, and across different national contexts?* To address this research question, I draw upon a set of interviews conducted with transportation professionals at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) that have utilised Strava Metro to assess how commercial data uses are leveraged in support of the cycling policy plans at the two regional government departments. I draw comparison between the two regional government approaches and outline the main motivations and policy relevance for Strava Metro data uses at each public transportation department.

The third research question asks: *how does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?* To emphasise concerns for social sustainability and mobility justice, I introduce additional voices of transportation professionals that have not utilised Strava Metro data to emphasise how their concerns remain unaddressed through the reported uses of Strava Metro data at Transport for London (TfL) and the Oregon Department of Transportation (ODOT). I show how tensions which arise due to the policy prioritisation of supporting more people to cycle, above a need to diversify leads to the perpetuation of mobility injustices.

The fourth research question of this thesis is: *how can Strava Metro data use by transportation professionals be rethought to deliver more equitable and socially just velomobile futures?* To address this final research question, I draw upon all research material presented across all chapters to re-analyse how the concerns for mobility justice may be resolved. By addressing these four research questions, I outline how the research questions work together to address the central objective of this study, that seeks to support more socially sustainable and mobility just cycling societies in an increasingly datafied world.

1.6. Structure of thesis

This thesis is divided into seven chapters, which work together to address the four main research questions and overall research objective of supporting more equitable and mobility just cycling in an increasingly datafied world. As discussed above, these work together to explain why cycling policy plans should start with an ethical imperative to diversify participation in cycling, which is fundamental to sustainability.

To begin this journey, this first section, *Chapter 1: introduction*, I provided a very brief overview to what I see as two main challenges in the delivery of cycling futures. These challenges include encouraging more people to cycle, whilst simultaneously addressing observed marginalisation and exclusion. Furthermore, I have also provided context to one commercial software company, Strava, which has repurposed fitness and health data to share with public transportation administrations. Whilst public-private partnerships with regional government organisations such as the Oregon Department of Transportation (ODOT) and Transport for London (TfL) have led to the acquisition of Strava Metro data, there are few critical reflections by academic voices that have questioned how the "datafication" of cycling impacts upon cycling plans and policies (and thus cycling futures). To address this gap, four guiding research questions which are answered throughout this thesis. Before doing so, I outline the existing body of knowledge through two literature review chapters to further emphasise: (1) the need for cycling, and (2) the need for more diversity in cycling.

The review of literatures in *Chapter 2: cycling futures in the age of "datafication"* offers an overview to the exponential rise of "big data" which are associated with "datafication" processes. Working definitions for these terms are outlined before a discussion on how these technological developments and the privatisation of data influence policy. Following this, the emerging research field of critical data studies (CDS) is outlined, including the "quantified self'" movement and how pervasive smart technologies impact upon social lives. As the chapter discusses, digital technologies do not simply reflect social worlds, but have an active role in their construction. This leads to a focused discussion on "datafied" cyclists, such as Strava app users, who are predominately younger males that ride for recreational or commuting purposes. Following a review of academic papers (published before 2022) which have sought to test the statistical representativeness of Strava data compared with other data sources, such as cycle counters, this chapter's focus switches to why "big data" sources such as Strava have been considered as transportation planning resource. At this point, consideration is afforded to work on the "system of automobilities" (Urry, 2004), a conceptual framework which provides context to the historical marginalisation of cycling as a mode of transportation. With consideration to his, I suggest that the increasing "datafication" of cycling is being presented as a solution cycling's historical "small data" problem, by both scholars and policy advocates. To conclude the chapter, I express a cautionary note regarding Strava data uses by public administrations may unfairly privilege cyclists who are already highly mobile, who may cycle out of choice, and not necessity.

The review of the literature continues in *Chapter 3: Interweaving mobility justice with the "datafication" of cycling*. Picking up from the previous chapter, this chapter merges discusses related to digital inequalities associated with "big data" and "datafication" processes, with observed inequalities of contemporary cycling. Drawing upon mobility justice and data justice, I outline the need for an interwoven approach of social justice. I then introduce further conceptual work of "staging" to make conceptual sense of how "datafication" processes contribute to the "scripting" of cycling. Following this, I emphasise these concerns with reference to a growing body of critical literature that questions the assumption that cycling is an automatic good for society. This critical scholarship does not seek to discourage cycling, but it brings our focus directly to who benefits from this mode of transport – and who does not. I show how "lower-cycling" contexts such as London (UK) have failed to diversify cycling due to policy function and implementation. I conclude the chapter with concerns related to the" datafication" of cycling and the need to critically appraise its policy impact. I utilise these emerging debates of justice to provide the analytical framework to answer the four research questions and the central objective of this thesis, which are addressed across chapters 5 and 6.

In *Chapter 4: mobilising literatures for comparative analysis*, I detail and justify the qualitative research design and methods that I used to address the four research questions of this thesis. I outline the use of a "mobile" ontological framework that is developed from mobilities and mobility justice scholarship which suggests reality should be understood as an ongoing and entangled "process" which is not "fixed" but rather socially produced. Basing this conceptual view of reality upon this premise, I then discuss and justify the use of "static" (non-mobile) methods, including policy document and semi-structured interview data collection and analysis. Following this, I provide greater context to Transport for London (TfL) and the Oregon Department of Transportation (ODOT) and outline the rationale for conducting an international comparative analysis to address the study research questions. I also outline the data collection and analytical process before critically reflecting upon my positionality as an academic researcher and transportation professional, and the consequential impact this has on the analytical directions of this study. I conclude the fourth chapter with an overview to the ethical considerations of this study.

Chapter 5: *representing and contesting cycling's policy "problems"* offers the first analytical chapter of this thesis. It answers the first research question that asks: *what is the transport policy "problem" – at the regional scales – that determines injustices in cycling and cycling data?* To answer this question, I draw upon analytical guidance on post-structural policy analysis framework to compare regional and national cycling policies relevant to the cities of London (UK) and Portland (Oregon, USA). By utilising Bacchi and Goodwin's (2016) framework "*what's the policy problem represented to be?*" (WPR), I show how cycling policy plans present two, unevenly weighted, policy "problems" of cycling: (1) increase the total number of cyclists, and (2) diversifying cycling. I argue that there is an inherent social injustice in policy framings of the "problems" related to cycling, which result in the prioritisation of capitalist accumulation and individual freedom over diversity. Proposed data collection and appraisal mechanisms, I argue, risk contributing to and accelerating tensions of this unequal weighting.

Chapter 6: *challenging technocratically driven mobility justice* addresses the remaining research questions of this thesis. I emphasise how the unevenly weighted policy "problems" are exacerbated by the "datafication" of cycling, thus accelerating tensions between the (1) increasing the total number of cyclists, and (2) diversifying. By drawing upon a set of interviews with professionals at Transport for London and the Oregon Department of Transport, I address the question: *how is Strava Metro data used by transportation authorities at regional scale of government, and across different national contexts?* By assessing "big data" uses in relation to the cycling plans and policies published by TfL and ODOT, I discuss how data innovation and exploration is predominately shaped by policy agendas. Next, I suggest that data innovation is taken further by one of the regional government departments due to an explicit licence to do so by cycling plans. Despite creative explorations of Strava Metro data at both Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I outline data efficacy concerns related to the pre-processing of datasets by the commercial vendor, Strava. Due to restricted access to "raw" (unprocessed) data, I outline genuine risks of data dependency upon commercial companies such as Strava to support policy evaluation.

I then address the third research question of this thesis: *how does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?* Here I emphasise how the unevenly weighted "policy" problems are brought into tension. I emphasise how the privileging of cycling that is made "visible" through data sources are based on an existing cohort of cyclists, that may have very different needs to future cyclists. By basing cycling futures on commercial data that is evidently unrepresentative of society, there is a clear risk that cycling futures will fail to unlock the benefits of cycling equally across society for all people. To conclude the chapter, I then facilitate a discussion: *how can Strava Metro data use by transportation professionals be rethought to deliver more equitable and just velomobile futures?* I argue that privileging of cycling that is made "visible" through the "datafication" of cycling and related sources does so based on an existing cohort of cyclists, that may have very different needs to future cyclists. By basing cycling futures on commercial data that is evidently unrepresentative of society, there is a clear risk that cycling futures will fail to unlock the benefits of cycling equally across society for all people. Unless policy "problems" are reconceptualised to afford equal weight to the imperative need to diversify, the "datafication" of cycling will contribute to socially unjust cycling futures.

In Chapter 7: conclusion I provide a summary of the key findings, with a focus on research objective of this thesis by outlining how policy recommendations can support cycling futures that are responsive to equitable and mobility just societies in an increasingly datafied world. I close the chapter with a critical reflection for future research opportunities.

Chapter 2: Cycling futures in the age of "datafication"

2.1. Introduction

This chapter contextualises the thesis within the rise of "big data" which are associated with "datafication" processes. Working definitions for these terms are outlined, leading to a discussion on how "datafication" influences policy. Following this, the emerging research field of critical data studies (CDS) is outlined, including the "quantified self" movement and the role of pervasive smart technologies has upon everyday social lives. As the chapter discusses, digital technologies do not simply reflect social worlds, but have an active role in their construction. This leads to a focused discussion on "datafied" cyclists, such as Strava app users, who are predominately younger males that ride for recreational or commuting purposes. Following a review of academic papers (published before 2022) which have sought to test the representativeness of Strava data compared with other data sources, such as cycle counters, this chapter's focus switches to why "big data" sources such as Strava have been considered as transportation planning resource. At this point, consideration is afforded to work on the "system of automobilities" (Urry, 2004), a conceptual framework which provides context to the marginalisation of cycling as a mode of transportation within western contexts such as the UK and the USA. With consideration to his, I suggest that the increasing "datafication" of cycling is being presented as a solution cycling's historical problem, by both scholars and policy advocates. To conclude the chapter, I express a cautionary note regarding Strava data – due to dominant framings of cycling within policy – that may unfairly privilege cyclists who are already highly mobile, who may cycle out of choice, and not necessity.

2.2. The rise of "big data" and "datafication" processes

In this section, I outline emerging debates regarding "big data" and "datafication" to provide an overview to how these phenomena have contributed to profound changes across western societies, including governance. For Kitchin (2014: 1) "big data" share characteristics such as the 3Vs: "Huge in *volume*, consisting of terabytes or petabytes of data; high in *velocity,* being created in near real-time; diverse in *variety,* being structured and unstructured in nature." These 3Vs are also shared by commercial software giants, such as Amazon Web Services (2022). However, Kitchin (2014:1) notes additional "big data" characteristics, including sources as being *exhaustive* in their scope (striving to capture entire populations), and *flexible* so that data may be combined with other data sets (see also Kitchin, 2013, 2014; boyd & Crawford, 2012). Whilst there is no singular definition of "big data", it can be understood as one by-product of high-powered computation and technological innovation. As Dencik (2020: 769) observes, these data are not simply a commodity, but rather can be seen as a form a capital, "that is accumulated through extraction and exploited for value." This abundance of computational "big data" since the emergence of the internet, coupled with smart technologies such as mobile phones, has also contributed to academic reflection upon how lives are impacted through their collection, analysis, and storage – which is discussed next.

To make conceptual sense of the influence "big data" is having across societies, it is relevant to introduce the term "datafication". For Mejias & Couldry (2019:1) "The term "datafication implies *something* is made into data." Powell (2014) offers a working definition in relation to governance, which is adopted and developed for the purposes of this research. For Powell (2014) "The 'datafication' of societies refers to the role of communication technology companies and the collection of user data for understanding aspects of social behaviour". Although a relatively new concept (Mayer-Schönberger & Cukier, 2013), there is an active debate regarding questions of political sovereignty and the role of corporations in the governance of societies. Equally, there are critical questions for social justice and equalities, particularly concerns regarding digital discrimination and disproportionately distributed benefits of "datafication" across societies (Heeks & Shekar, 2019). Numerous scholars have brought attention to data inequalities and discrimination for certain user groups (Dencik, 2020; Taylor, 2017). A key area of focus and debate regarding data inequalities has surrounded the ethics of artificial intelligence (Andrejevic, 2019; Dencik, 2018; Dencik, 2019) and algorithmic governance and decision making (Mittelstadt et al., 2016). For example, automation of "profiling" has received significant critical attention due to inadvertent harms they may generate (Barocas & Selbst, 2015; Mann & Matzner, 2019). To address concerns regarding algorithmic data bias, attention has been afforded by researchers and software engineers to incorporate fairness into coding practices (Barocas et al., 2018). For Denick (2020), although there is a need for researchers to critically appraise algorithms, the search for solutions to technical problems somewhat overlooks "datafication's" political complexity. In other words, algorithms, that raise profound ethical questions regarding their role in autonomous decision making, cannot be isolated in purely mathematical terms (Mittelstadt et al., 2020).

Indeed, controversies regarding "datafication" are not limited to the collection of user data, but also of the ways "big data" are processed and presented as information, with further questions regarding user rights to privacy. As Micheli et al. (2020: 1) note, there a multiple stakeholders involved with the governance of "big data", which extends beyond these technology giants. Additional actors, such as public administrations, also play a significant role within the governance of personal data generated by digital technologies. This raises critical questions regarding significant ethical concerns, particularly as users of media technologies may not consciously be aware of their "digital traces" (Breiter & Hepp, 2018: 387). For Nissenbaum (2017) the collection of personal data has become so pervasive, policy regulation should exclusively focus on the *uses* of data (and not necessarily collection) by different actors. Termed as "big data exceptionalism" (Nissenbaum, 2017), this has been contested by others such as Couldry & Yu (2018: 4473) for "naturalising" flows of data by corporations at the expense of individual right to privacy and human freedoms. In chapter 3, I will expand upon this discussion in relation to questions of user privacy, data exclusions, and data justice, but for now I next wish to reflect upon how processes of "datafication" have emerged as a significant opportunity and challenge for the governance of public administration of everyday life. As such, it is important to emphasise that the processes of "datafication" are far from being a technical issue, but one that is increasingly being woven into the social fabric of everyday lives and governance of policy, which I discuss next.

The impact of "datafication" has been felt across multiple sectors, including education, health, policing, and transport (see Couldry & Yu, 2018). As Banerjee et al. (2021) observe, these processes offer a potential to support complex policy challenges, such as understanding and improving public health. Yet, there is also cause for critical reflection regarding the governance and legal regulation of the digital sector's agency and influence regarding public policy (Micheli et al., 2020). For example, these "datafication" processes may also be read as an extension of marketisation of public administrations and outsourcing of roles previously conducted by the state (Haynes, 2015; Hill & Varone, 2017). Indeed, as Redden (2018: 8) notes: "The infrastructure, data science skills and access issues… as well as a desire to reduce costs, increase efficiency and improve services are motivating government bodies to develop public-private partnerships in this area." Haynes (2015) warns of the risks of private-public partnerships (PPP) in the delivery of public policy, including the standardisation of digital technologies in administration of government, that may lessen professionality and diversity of opinions. Taking the example of care management, Haynes (2015) notes that whilst commercial software may offer some consistencies in applications for state care, the standardisation of digital technologies may undermine professional opinion that cannot easily be entered numerically to a standardised needs-based assessment. This may be further compounded by digital dependency upon private sector partners, where issues cannot be easily resolved by a government partner. Examples include technological and digital illiteracy and lack of skills within the public sectors, and restrictions to proprietary software and data, that may result in additional resources to resolve. Marketisation of public administration tasks may support a dominant narrative where the state has moved toward a more "efficient" model, yet quality of service is not guaranteed. Haynes (2015) emphasises this critique taking the example of education and health provision, where financial gain for private sector actors may override complex social issues. Haynes (2015: 12) outlines the example of private schools that may reject admission of pupils with challenging needs, and of private hospitals that may not be willing to treat a patient that has an unclear diagnosis when there is no clear financial funding attached. Using these examples, Haynes (2015) brings attention to the weakened position of governments that may not be able to raise the quality of services beyond contractual obligations. Where profit and resource efficiency drive an agenda for the delivery of public administration, governments may be at risk of depending upon the priorities and performance of private sector partners. For example, there are risks that public-private partnership contracts could fail. In the UK, a recent case includes the collapse of the Carillon Group of companies that were awarded and responsible for over 400 public sector contracts, including transportation services (National Audit Office, 2018: 4). These themes, I argue, extend to the privatisation of data governance and debates in the age of "datafication" (Micheli et al., 2020), all of which are of central interest to this thesis.

As discussed above, much of the technological innovation is motivated and driven by the monetisation of user data, which is controlled by a few American technology giants, including Alphabet and Amazon. As this section has illustrated, whilst "datafication" processes are influencing the governance of societies globally, the parameters for defining it conceptually is as complex. There are active and relevant discussions regarding the "parameters of debate" (Dencik, 2020), thus for the purposes of this thesis, I draw upon Powell's (2014) and Mejias & Couldry's (2019) working definitions. Whilst these definitions are not free from critique (see Denick, 2020), they offer a conceptual framework in which to conduct empirical study on the "datafication" of cycling. Indeed, the impact of "datafication" has had a profound impact on multiple areas, including policy. However, as Flensburg and Lomborg (2021) observe, "datafication" related research has been dominated by theoretical contributions. As such, there are considerably fewer empirical contributions to critically appraise these profound changes to their specific contexts. In response to this, this thesis seeks to contribute to these debates by exploring how "big data" related to the "datafication" of cycling are used to support policy ambitions by organisations such as Transport for London (TfL) and the Oregon Department of Transportation (ODOT). Building upon these discussions, I next introduce the research field of critical data studies (CDS), and the associated discussions related to smart technology "tracking" and the "datafication" of health (Lupton, 2018), which is fundamental for this research.

2.3. Critical data studies and the "quantified self" movement

Next, I return attention to the politics of "big data" and concerns of digital inequalities that arise through digital "tracking". Drawing upon the research field of critical data studies (CDS), I first situate how commercial software is transforming everyday social lives, and the challenge this has presented from a data governance perspective. According to Kitchin (2014) suggests, commercial software and algorithms do not simply reflect social worlds, but rather actively constructs it. This includes discussions of "persuasiveness" of digital app technologies by prompting actions by users (Fotopoulou & O'Riordan, 2017), rather than simply measuring user activities using devices such as smart "trackers". This broader process has been discussed as the "quantified self" (QS) movement and is summarised by Pink & Fors (2017):

> *"Self-tracking involves people using and engaging creatively and analytically with wearable, digital, mobile, and locative sensor, and computer technologies to record and quantify and analyse various aspects of human activity. This includes walking, running, cycling and other forms of movement, heart rate, sleep, calorie intake and expenditure, stress levels and much more".* **Pink & Fors (2017: 376)**

The "quantified self" (QS) movement thus allows digital tracking devices to monitor various biometric data, allowing users to engage and reflect upon the data generated (Lupton, 2018). These tracker-generated data by "smart" watches and phones are thus volunteered to a software "apps", such as Strava (Barrett, 2016), and FitBit (Fotopoulou & O'Riordan, 2017). They may, depending on the application, allow users to visualise fitness and health information through the medium of data (Smith & Vonthethoff, 2017). Uses include personal and recreational fitness, such as Strava user's ability to record physical activities such as cycling, along with medical applications to support people with monitoring their physical health (Smith & Vonthethoff, 2017; Lupton, 2018). Capturing sensory biometric information has also been used to explore the research potential of smart trackers, including experiences of cycling (Cox, 2019; Jones et al., 2016). At first glance, the "quantified self" (QS) movement is viewed somewhat favourably, given its potential to support people in managing their health. There is also policy and commercial relevance to private health insurance companies, such as Vitality in the UK, which offer discounted premiums to customers willing to volunteer data as evidence of living "active" lifestyles (see Walker, 2021). However, such benefits may only be realised by selective communities that have access to smart technology and who can afford the financial premiums for private medical cover. Fotopoulou & O'Riordan (2017) also raise concern that wearable "tracking" devices, such as FitBit, have become framed by policy as an enabler of individual health that also places the onus upon these individuals to take responsibility for healthier, more active lifestyles. Through an auto-ethnography of using a FitBit, Fotopoulou & O'Riordan (2017) suggest that activity data (such as number of daily steps) teaches users to become "good consumers" and "bio-citizens" through self-responsibility. These responsibilities, they argue, includes ensuring that FitBit devices are charged and regularly worn to sustain more accurate records of fitness activities. Related work by Carter et al. (2018) shows how the "quantified self" (QS) phenomena has percolated into transportation debates by reframing activities such as cycling as a public health solution to address complex policy issues such as inactivity and obesity. Writing on the fitness app, Strava, Carter et al. (2018) suggest that the app supports "biomedical citizens" that seek to prioritise physical fitness above all factors, such as wellbeing.

Though users can track their health and fitness activities using apps, the medium of digital data has also been observed for prompting action. As such, fitness trackers and apps are not just reflections of the social world, but also, to an extent, architects of it. Discussed as "nudges" to prompt action, devices may notify users (through notifications, such as vibrations) to encourage movement (Lupton, 2018) or to prompt actions related to health and monitoring (Smith and Vonthethoff, 2017). This was the case in research by Fotopoulou & O'Riordan's (2017) autoethnography, which are also present in the behaviours of participants in a study by Pink & Fors (2017). Pink & Fors (2017) discuss how displays of smart watches and phones assisted study participants' progress toward a sense of fulfilment of achieving ten thousand daily steps; participants behind their target step noted how they would elect to walk further to reach a daily step target. In another study that utilised "running interviews" with women who identified as "self-trackers" in the USA, Esmonde (2020) details how participants both accommodate and resist "datafication" by using strategies such as not tracking every run and "valuing" feelings over visually displayed data to overcome "disappointing" or "unfavourable" data.

Yet, there is also a social element to fitness tracking and the "quantified self'" which further blurs the boundaries between individual autonomy and prompted health action through tracking devices. In a study with twenty club cyclists, Barrett (2017) brings attention to the "gamification of cycling" brought about due to Strava app being a social media platform, where users may choose to make their physical activities public. Participants of club cycling are likely to ride a road cycle designed for speed and aerodynamic efficiency, and wear performance enhancing clothing, including lyrca clothing and specialist cycling shoes (Spinney, 2006). Whilst this generalisation may not apply to all club cyclists, I would keep in mind Cox's (2019: 76) observation that "Practices of cycling are recursively related to cycle technologies." Due to a culture of "sharing" activities with others, Barrett (2017) found that Strava use led to app users overtraining and risking overexertion due to perceived social surveillance from other Strava users. Participants in Barrett's (2017) study also reported a willingness to perform risky manoeuvres, such as "run a red light", to maintain higher average speeds and therefore higher performance metrics related to tracked rides. There are instances where "running a red light" might be done so from a safety perspective, such as Popan's (2020), account of cycling amongst motorised traffic in the UK city of London. The difference with Barrett's (2017) findings relates to how Strava app use actively led cyclists to ignore traffic signalling due to individually "tracked" performance statistics. Furthermore, Barrett (2017) emphasises that Strava app use had a negative impact upon social and family relations for app users, who dedicated ever increasing training time and energy to maximising their performance of cycling. Couture (2021) sees this as the "Strava-sphere", where users are "connected" to virtual communities. The role of Strava "segments" also contributed to this "gamification of cycling" culture. A segment, according to the Strava website (2020):

> *"You can use segments to compare your own times or to compare with other users' times who have also completed the segment. Segments are a great way to keep track of your performance and progress and to see how your training compares to others."* **Strava (2020)**

Barrett (2017) notes how this comparative element of public Strava segment leader boards (for those that wish to participate) generates a highly competitive environment (also see Smith & Treem's (2017) review on: Striving to become king of mobile mountains). Rather than simply "tracking" performance, the Strava app use is seen to actively "push" users into performing different behaviours on (risky behaviours, overtraining) and off the bike (diet, monitoring of Strava segment leader boards, cycle equipment). Based on the research reviewed here, it becomes evident that many or most of the journeys captured on Strava are unlikely to be representative of practices of everyday cycling, such as journeys to shops or schools. Individuals that use the Strava app may be encouraged, motivated, pressured to do so for several reasons, including self-responsibilities of their individual health (Carter et al., 2018; Fotopoulou & O'Riordan, 2017), but also through the socialisation and pressures of sharing digital data (Barrett, 2017).

2.4. Datafied cyclists and the promise of "big data"

In this section, I outline discussions within the academic literature that are related to the use of "big data" in cycling research, followed by a detailed overview of research involving Strava Metro app data. Before doing so, it is necessary to first show how discussions related to cycling data has shifted from "small" to "big". As van Dijk (2014) has noted, the mass availability of GPS enabled technologies has proliferated in western societies. Through access to hardware, such as smart phones and other wearable devices, GPS technologies (Holmes, 2017) have allowed users to track (wittingly or otherwise) their everyday activities, including data related to mobility. Romanillos et al. (2016) offers a useful starting point to make sense of how "tracked" devices, and the data they generate, have started to impact research related to cycling:

> *"Big data will drive the assessment of cycling infrastructure at different levels, analysing the use of local infrastructures, (such as lanes or bike parking), identifying the main cycling routes over the course of a day, or understanding the obstacles, delays and dangers that slow or hinder their journeys."* **(Romanillos et al., 2016: 128)**

For this thesis, the focus is on commercial "big data" sources that are generated using apps, with an emphasis upon Strava Metro data, which is used both specific contexts within the UK and USA. Though there is increasing attention regarding "big data" and its potential to support the governance and planning for cycling (Romanillos et al., 2016), its definition remains ambiguous, however the "Vs" offers a useful point of reference. As discussed above, for Kitchin (2014) "big data" are large in volume (size), velocity (speed of generation), and variety (generated by multiple sources). As an example, Strava Metro "raw" data shares similar characteristics to the "big data" definition. After approximately a decade (2009-2018) of Strava being released, the software company (Strava) claimed that over 84 million activities had been volunteered by app users (Strava, 2020). The velocity of "big data" concerns data being generated and communicated in "real-time"; however, at the time of writing, Strava Metro data is shared only historically and not in real-time, and therefore is not considered a "big data" example by some scholarly definitions (Kitchin, 2014; Romanillos et al., 2016). Whilst real-time "tracking"[1] of Strava user activities are available for individual uses, these data are not available for analytical purposes. Variety for "big data" concerns data being actively produced, by logging its use to app developers, including autonomous interactions (Kitchin, 2014). Given that data such as Strava Metro is volunteered by app users, it may also fail to stand up to a variety indicator.

Whilst Strava Metro data may not meet definitions proposed by theorists such as Kitchin (2014), for this thesis, I continue to regard Strava Metro data as a "big data" source principally upon its size (or volume). This also represents an everyday understanding of the term "big data" that is likely shared by policy makers. If we are to treat Strava Metro data as an example of "big data", it is important to switch attention to the quality of these data, especially if they are used to make decisions that impact upon people's lives and everyday mobilities. Kitchin (2014) asserts that data should also have veracity, ensuring that there is at least confidence of data accuracy. As the next section, elaborates, attempts to explore the data veracity (or the representativeness of data)

[1] However, real-time presentation of Strava activities is available to app users, called Strava "Beacon". This feature is presented as a safety feature which allows contacts to receive live updates of the Strava user's location (see Strava, 2021).

has been a major driving force in the assessment of Strava Metro data sources. Over the next section, I review how transportation researchers have approached the issue of veracity in their assessments of Strava Metro data.

Strava Metro data are an increasingly researched source of GPS data related to cycling. Due to the availability of "big data" sources, such as Strava Metro, Lee & Sener (2021: 27) proclaim that the "Monitoring of bicycle trips is no longer limited to traditional sources, such as travel surveys and counts." One of the earliest articles advocating the use of Strava Metro data was published by Musaka & Selala (2016) after purchasing 2014 Strava user origin-destination data for the city of Johannesburg, South Africa. Using Strava Metro data, Musaka & Selala (2016) noted that the sample included a total of 85,297 trips during 2014, 80% of which were recorded as recreational rides, and 20% as commuting. As expected, the highest number of trips was recorded in the summer months, with annual peak hours for ridership occurring between the hours 04:00 – 09:00 and 15:00 – 17:00. In addition to the temporal descriptive statistics of Strava rides within the sample, Musaka and Selala used ArcGIS[2] software to map the spatial coverage of Strava user cycling, noting that "cold spots" were identified within the south of Johannesburg. Corroborating the Strava Metro data with household official income statistics, the authors suggested that the Strava represented cyclists are found in relation to affluent households. Using Strava data, the authors suggest that cycle traffic provision could be targeted in "hot spots" where there is evidence of Strava cycling but offer limited consideration to the limitations of individual access to GPS enabled technology. Following these recommendations made by the authors, the "cold spots" of cycling that display limited Strava activity are at risk of remaining "cold". Whilst Musaka & Selala's (2016) offer a descriptive account of Strava Metro data, along with visualisation of Strava data use in the city of Johannesburg, the review leaves the issue of veracity (Kitchin, 2014) largely unaddressed. There is also a problematic assumption that recorded journeys reflect route preferences, without consideration to other motivations such as avoidance strategies.

To review questions related to veracity of Strava Metro data, McArthur & Hong (2019) assessed a sample for the UK city of Glasgow. To do this, McArthur & Hong (2019) compared Strava Metro (origin-and-destination) data to a traffic assessment model, based on "if" commuter[3] cyclists had taken the shortest possible route. McArthur & Hong (2019) noted that actual distances (718,798km) ridden by Strava commuters in Glasgow

[2] ArcGIS software is a graphical user interface (GUI) mapping software written in the programming language Python. It is a proprietary commercial software product developed by the Environmental Systems Research Institute (ERSI). Open-source (free to use) GIS alternatives are also available, including Quantum GIS (QGIS) and Geocomputation with R (see Lovelace et al., 2019).

[3] The Strava app allows its members to "tag" their cycling activities as "commutes" to differentiate between journeys to work and other activities, such as recreational trips.

were only 0.3% different to shortest alternative modelled distances (716,907km). This contrasts substantially to Broach et al.'s (2012) smaller sample of GPS findings for the US city of Portland, who found that cyclists travelled approximately 11% further compared to the shortest possible distance. Whilst these findings suggest that Strava app cyclists in the city of Glasgow may take the most direct route, McArthur & Hong (2019) make several assumptions, principally that the shortest route is always the most desirable for cyclists. Furthermore, McArthur & Hong (2019) leave the question of sample bias largely unaddressed, though do acknowledge Strava samples should not be seen as representative of all cycling journeys. McArthur and Hong (2019) note within their article that the sample are dominated by males, and Strava supply basic demographic information to confirm this. For the Glasgow data sample, McArthur & Hong state that the gender demographics of the sample included 13,085 males and 2207 females. Hence the Glasgow Strava Metro sample comprised approximately 86% male ridership, with the average trip distance approximately 23km, and a median trip distance of 14km. Other transportation researchers have also recognised sample bias as the key issue of Strava data (Nelson et al., 2021; Roy et al., 2019; Jestico et al., 2016). A review of a Strava Metro data sample from the UK city of Manchester adds further illustration of data bias, as displayed in Figure 2. For the sample illustrated, below, it shows how the Strava Metro data includes disproportionately includes younger male cyclists.

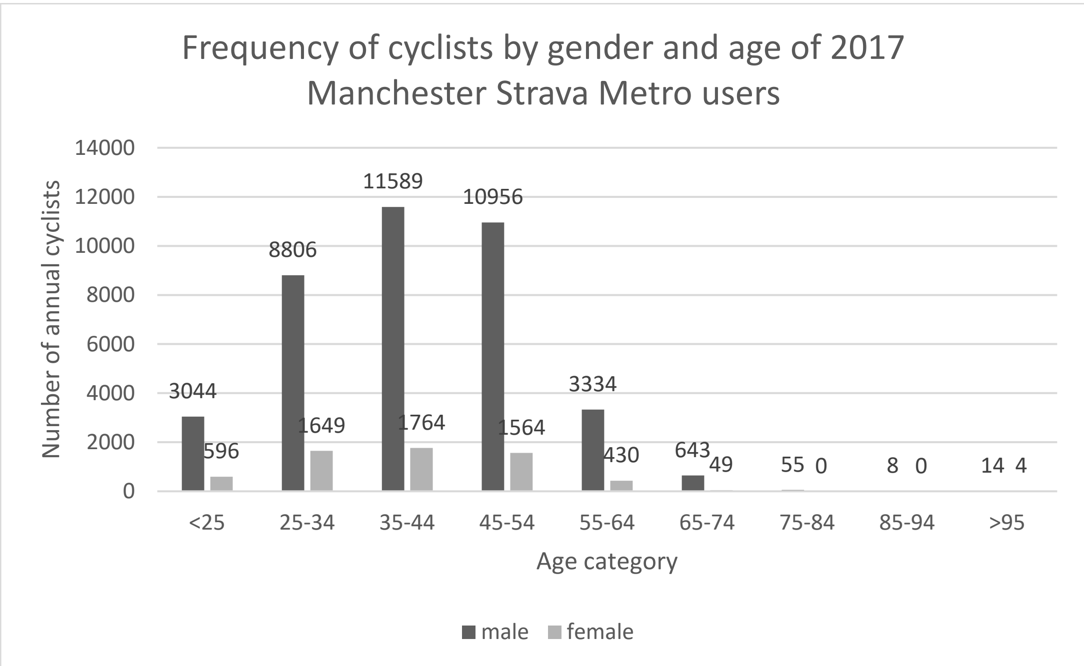

Figure 2: Frequency of Strava Metro uses by gender and age in Manchester (Jan - Dec 2017) (Data licenced by Strava, 2019)

In response, transportation research teams have sought to interrogate Strava samples by developing machine-learning models to integrate Strava data with multiple data sources, such as official cycle count data, to predict a more "representative" view of cycling activity. For example, Roy et al. (2019) sought to correct 2016 Strava data bias in the city of Tempe, Arizona (USA). Roy et al. (2019) observed that "nearly 76.5% of Strava riders… were male, 17.6% were female, and 5.9% did not specify a gender." Due to a lack of representativeness of Strava users, Roy et al. (2019) sought to correct for these biases using a three-step LASSO (least absolute shrinkage and selection operator) model. The researchers concluded that transportation authorities could approach research departments to support informed, "evidence-driven" decision making regarding the future installation of additional cycle counters that could enhance modelled predictions. Furthermore, Nelson et al. (2021) proposed that Strava Metro data could be leveraged to predict "all" bicycling ridership. Utilising Strava Metro data, Nelson et al. (2021) also developed a LASSO machine-learning model to identify the key variables required to predict cycling across five US and Canadian cities: Boulder, Ottawa, Phoenix, San Francisco, and Victoria. Using LASSO variable selection, they were able to identify the most important variables required to test and correct bias. The results by Nelson et al. (2021) suggest that the total number of Strava users was the most important variable required across the five cities, followed by the percentage of journeys reported as commute data, bicycle crash density, and median household equity.

Furthermore, Conrow et al. (2018) set out to assess whether crowdsourced Strava Metro data are spatially representative of all bicyclist behaviours at the regional scale in Greater Sydney Australia. Comparing automated count data with Strava Metro data, they noted that there are advantages to using crowdsourced data due to its spatial and temporal coverage, yet there are important considerations to note. Conrow et al. (2018) emphasise that Strava Metro data are compared with non-random official counts for validation. These counts are installed by public administrations at strategic locations only, which may influence spatial results of estimated cycle counts across city-regions. Conrow et al. (2018) also add that Strava Metro data offer limited information regarding how samples are generated, and that official counter data offers no insight into socio-economic information. Further research is required to understand the relationship between crowdsourced data sources and cyclists, and thus the authors note that Strava Metro data should not be taken as an authoritative source of data for understanding cycling.

In addition to testing and correcting for bias in Strava Metro data, samples have also been reviewed to understand safety risk (Ferster et al., 2021). Using Strava Metro data for 2015 and 2016 with official and crowdsourced accident data for the city of Ottawa, Canada, Ferester et al. (2021) observed that there are differences between (1) the raw data incident hotspots and (2) incident hotspots when normalised using Strava Metro data. This analysis thus suggests that incident hotspots move away from protected infrastructures in

Ottawa's city centre, to commercial streets outside of the city's centre. In other words, by comparing official count data with Strava Metro data, Ferester et al. (2021) could infer ridership between the 12 official counters in the city of Ottawa. By understanding estimates of bicycling on streets without counters, Ferester et al. (2021) could estimate and quantify cyclist's exposure to safety risk. In this scenario, the results by Ferester et al. (2021) called for greater attention to install supportive provision where there are limited cycling infrastructures. Since the earliest reviews of crowdsourced Strava Metro data (see Romanillos et al., 2016), research teams that have reviewed Strava Metro data emphasise that these commercial sources should enhance, not replace, official cycle counting programmes. Yet there is an assumption made by proponents of statistical modelling that through the integration of Strava Metro data with other sources of data can help mitigate or eliminate bias in terms of "representativeness" of sample characteristics. Fundamentally, however, the modellers are limited to seemingly purposeful journeys, such as commuting data to work. In response to this limitation, Nelson et al. (2021) stress that results from their models offer representations of average conditions of cycling, and not the actual conditions. Given that the availability of data related to cycling offers new ways of researching and understanding cycling, it appears at first glance to be a logical and viable option for transportation professionals. Continuing with the focus upon "data" related to cycling, I next outline the perceived limitations of "small data" sources.

2.5. Cycling's historic "small data" problem

Thus far, I have reviewed critical appraisals of Strava Metro samples by transportation researchers. In this next section, I unpack the policy relevance these "big data" sources in relation to the discipline of transportation planning. According to Black (2018) in *Urban Transport Planning: Theory and Practice*, the discipline of transport planning concerns the pragmatic "search" for the "best solutions" to support decisions. For Black (2018), only through vigorous analysis of these solutions will make any decisions regarding alterations to land-use acceptable to the public. There are several points of interest here. There first concerns the use of "search", as if there is knowledge "out there" about people and their travel habits and desires. The problem for Black (2018) concerns accessing of this knowledge. The second concerns the belief that only a thorough analysis of evidence will suffice to facilitate changes to the urban environment. But what is "evidence", and who owns it (Grauberg & Coxhead, 2008; Parsons, 2008)? In the context of this thesis, the interest is placed upon how evidence supports decisions related that support cycling specific infrastructures. As a discipline that is used to support policy, Koglin & Rye (2014) note that transportation planning initially emerged during the 20th century to support and optimise car travel (also see Brezina et al., 2020). The approach to do so has relied, predominately, upon positivist methodologies with claims saturated in scientific rationality (Koglin & Rye, 2014). Assumptions regarding the future of transport plans were supposedly rationalised, objective, and value-free (Koglin & Rye, 2014). However, the planning of transportation has been loaded with prescribed values, including aspirations to reduce travel times (Banister, 2008), promote an illusion of "freedom" and to facilitate neoliberal agendas (Doughty & Murray, 2016). Most importantly, spaces were made and remade with modelled projections reflecting the assumption that cars are both necessary and desirable. As motorised vehicles require more physical space to accommodate uninterrupted travel for higher mass, volume, and velocity, non-motorised transport such as cycling are pushed to the "margins" (Cox, 2020) of physical spaces and policies. Thus, transport and mobility, and policies that govern them, are "embedded into spaces" (Koglin, 2020).

Transportation within a "system of automobilities" (Urry, 2004) has thus continued to rely upon "predict and provide" (Whitelegg, 2020), and therefore remains a hyper-rationalised and quantifiable profession. In addition to estimating future capacity, modelled forecasts of transport seek to ascertain estimated monetary benefits of infrastructure provision, including time-savings for people by supporting them to move quickly and efficiently through transportation spaces. This is discussed as cost benefit-analysis, and it remains an important method for supporting transport experts and policy makers to arrive at infrastructural decisions (see Boardman et al., 2011; Mackie et al., 2014). Indeed, the cost benefit analysis methodology has become so entrenched as a forecasting mechanism, there have been attempts by policy administrations and researchers to replicate similar models for emphasising the financial benefits of more cycling. As Ruffino & Jarre (2021) observe, cost benefit analysis is based on economic theories and the quantification of intervention. Applied to transportation, this might include modelled projections of travel times, modal shifts, and associated transport emissions. The results of a cost benefit analysis are thus "measured in monetary terms and compared to the cost of the intervention" (Ruffino & Jarre, 2021: 172). For Mackie et al. (2014: 4) the rationale for taking a cost benefit analysis directly relates to the "formalisation" of decision making, removing human error and biases. In recent years, there has been a vested interest to apply cost benefit analysis methodologies to schemes related to walking and cycling (compare Brown et al., 2016; Mueller et al., 2015).

The most widely recognised and cited approach to walking and cycling schemes has been commissioned by the World Health Organisation (WHO) and the development of the Health Economic Assessment Tool (HEAT) (Kahlmeier et al., 2017). This tool can be used to estimate potential the economic benefits of improvements to population wide public health compared to no intervention. By providing estimates to the Health Economic

Assessment Tool (WHO, 2018), transportation professionals obtain a cost benefit ratio to review how investment in cycling could lead to long-term estimated savings in public health, for example (see Parkin, 2018: 26 for an illustration of how the HEAT model works). Despite an interest in cost benefit analysis' potential as a planning tool to support walking and cycling, several authors have raised critique, particularly in relation to difficulties quantifying variables such as the quality of the environment and issues of inequity (see Beukers et al., 2012)." Using the statistical appraisal mechanisms, transportation professionals can obtain estimates on how improvements in physical health from increased cycling *commuting* amongst the *adult* population might benefit the state in the future.

As the HEAT model suggests, numerical data are seen to strengthen cycling's economic credentials and policy relevance. By "replicating" the system that brought such dominance to "automobility", such as the availability and analysis of data related to motoring, Koglin & Rye (2014) suggest that this may pragmatically help bring cycling into a more visible position within transport policy. Writing on "sustainability" in the public sectors, Owens & Cowell (2011) note how quantified data are offered a privileged position within planning processes. They add that in the search for implementing sustainable development there is an assumption that quantified data, "technical rationality" and knowledge will inherently lead to better decision making. These claims echo work by cycling researchers, that suggest data is (increasingly) essential for safeguarding cycling in the future. According to Behrendt (2021), the visibility of modes of transport and mobility (in planning) is increasingly related to the availability of data related to these modes. Without data, modes such as cycling would cease to exist from a transport policy perspective. The lack of historic data related to cycling, especially when compared to "automobility", for many writers such as Behrendt (2021), has prevented the mode from establishing a more privileged position within the dominant existing "system of automobilities" (Urry, 2004). Many scholars posit that an increase of data related to cycling may therefore lead to greater policy opportunities that will help to support cycling (Behrendt, 2021; Broach et al., 2012; Romanillos et al., 2016; Jestico et al., 2016; Parkin, 2018). This is also identified by transportation practitioners as one of the key barriers of obtaining cycling investment. In an online survey with over 400 transportation professionals across England (UK), Aldred et al. (2017) found that whilst only 4.1% ranked "transportation planning tools" as the top barrier to cycling investment, 19.4% placed a general lack of data related to cycling in their "top three" barriers, which ranked 5th out of 8 pre-defined options. To make sense of the "problem" of cycling-related data, I next discuss the limitations of what have become known as "traditional" data.

A claim repeated by several researchers (Roy et al., 2019; Conrow et al., 2018; Jestico et al., 2016; Musaka and Selala, 2016; McArthur and Hong, 2019; Sun, 2019) concerns the issues of the problem of "traditional" (also discussed as "conventional") cycle-related data available to support transportation policy and planning. These "traditional" sources include "manual" or "automated" counts of cycling activity at specific sites. Taking the example of manual counts of cycling activity, researchers record instances of cycling at strategically placed sites, such as a road junction. Such an approach offers an insight to the popularity of cycling at selected locations, allowing comparison with manual counts from previous years. An alternative approach to manual counts involves the use of automatic counters. Transport for London (2018), for example, installed sixty automatic cycle counters during 2018 to sample cyclist activity on the Transport for London (TfL) road network. Automatic counters have the advantage of providing greater temporality as they can collect data daily, and therefore collect greater volumes of cycling activity. However, these methods are not without limitations, especially regarding data quality and error. No data are collected for cycling activity performed outside the range of sensors, for example. Romanillos et al. (2016) have also added that automatic counts are expensive to set-up and operate and require maintenance to ensure cycle traffic is counted. The most frequently sited critique of automated counts concerns the spatiality of data (McArthur & Hong, 2019; Parkin, 2018; Romanillos et al., 2016). As discussed above, automatic counters only record in locations where they are installed, and volunteers only count where they are instructed to count.

Alternative data sources to cycle traffic counting techniques include origin-destination flow data that are collected during some national census surveys, such as the UK 2011 and 2021 censuses (UK Office for National Statistics, 2019), and travel diary research such as the *National Travel Survey* (DfT, 2018), and the *Personal Travel in Oregon* report (ODOT, 2019). Using journey to work data from the UK 2011 census, Lovelace et al. (2017) assigned future demand of four cycling scenarios (UK Government target of doubling the number of trips, UK to Dutch propensity, E-Cycle propensity, and gender equal propensity) and mapped this propensity based the on open-source CycleStreet journey planner. The CycleStreet algorithm enabled the researchers to map the assignments of demand to illustrate "desire lines" of potential demand. Using the maps, the authors claimed that it may be possible to identify areas where local authorities may wish to build cycling infrastructure. Similarly, Parkin et al. (2008) used 2001 aggregate UK census data related to cycling to measure cycling potential by using a logistic regression model for wards within England and Wales. Parkin et al. (2008) found that lower levels of cycling were attributed to factors such as road defects, hilliness, and temperature. However, as discussed above, national statistics on cycling focus predominately on the commute to work and therefore misses other cycling non-commute journeys. For example, data from the UK census asks for postcode data (home and work address) and "main" mode of travel. The UK census thus privileges both the needs of the commuter and most popular mode of mobility by "distance". Aspirational ways of mobility remain invisible from UK census statistics, as are multi-modal journeys, which may include short to medium distances travelled by foot, wheelchair, or cycle. Due to the constraint of these data sources and methods for counting, Musakwa & Selala (2016) go as far to state that reliance upon these traditional data may "hamper" efforts to promote and increase cycling.

Resolving the issue of data related to cycling, could lead to the issue of historic underfunding and lack of dedicated cycle-infrastructure becoming an issue of the past. Broach et al. (2012) argue that a general lack of quality data related to cycling behaviours has hindered cycling's policy potential. A systematic approach to data related to cycling, according to Broach et al. (2012) should thus be embraced, including the use of geographic positioning system[4] (GPS) data to understand "revealed preferences" of cycling. In a study of 164 participants in the city of Portland (Oregon, USA), Broach et al. (2012) utilised GPS technology attached to cycles to understand preferences for utilitarian journeys. Using the "revealed preference" data, Broach et al. (2012) concluded that cycling journeys are shaped by multiple factors, including distances, slopes, and turning frequencies. Since Broach et al.'s (2012) contribution, there has been a surge in academic (and policy) attention to the potential of GPS data in supporting cycling, expressing the claim that geographical positioning systems (GPS) has the potential to alleviate issues associated with "traditional" data. Experimental uses of GPS have also been used in cycling research, including Jones et al.'s (2016) attempt to corroborate GPS data with galvanic skin response data to understand where cycle participants in Cardiff (UK) experienced "unconscious" moments of stress in relation to the built environment. Results from Jones et al.'s (2016) experiment suggested that cycling amongst motorised traffic and illegible infrastructure contributed to higher levels of stress amongst participants. In another study related to an electric assist cycling experiment in the UK city of Brighton, Behrendt et al. (2021) (also see Behrendt, 2016; Cairns et al., 2017; Kiefer and Behrendt, 2016) sought to assess where and how study participants interacted with a loaned e-bike. By using GPS data in conjunction with interviews and sensor data about the levels of assistance used Behrendt et al. (2021) illustrated how e-bikes enabled cycling in hilly locations in various ways. Whilst examples of GPS related research by Broach et al. (2012), Jones et al. (2016), and

[4] Geographical Positioning Systems work by triangulating an estimated position of a GPS-tracking device, such as a smartphone or smartwatch with three satellites that orbit the Earth. For a summary overview on how this technology works by correcting satellite atomic clocks in orbit see: *Time* by Stuart (2021: 60).

Behrendt et al. (2021) offer an insight into how "tracking" devices may help understand cycling activities, they can all be understood as what I would call "small data" studies. In the next section, I switch attention to the specific contexts of cycling within a dominant "system of automobilities" (Urry, 2007) to further emphasise the need for data related to cycling.

2.6. Cycling within the dominant "system of automobilities"

To make conceptual sense of why data are required to support cycling, especially in specific "lower cycling" contexts with parts of the United Kingdom and the United States, it is next essential to reflect upon how private motor vehicles have shaped and governed everyday lives. For Urry (2004), the private vehicle has not only led to changes in how people travel, but also upon how societies operate. Urry (2004) convincingly argued that this "system of automobilities" emerges as a:

> *"Self-organising autopoietic, non-linear system that spreads worldwide, and includes cars, car-drivers, roads, petroleum supplies… technologies and signs. The system creates the preconditions for its own self-expansion."* **Urry (2004: 27)**

Thinking about this in practical terms, Urry (2004) suggests that the private automobilities have led to a systematic change in how people live their lives. Not only are social lives transformed by these changes and the ability to travel, but also in terms of governance. (Urry, 2004). Since the globalisation of private cars, traffic signal engineering, road taxing, out of town developments, driving standards, physical infrastructures that afford automobility travel (Featherstone et al., 2005) have all followed. Linked closely to spatial and infrastructural changes to urban environments was the idea of "freedom", with car ownership the ticket to participating in visions of modernity for those able to participate. Doughty & Murray (2016) outline how autonomous car travel has been at the heart of neoliberal policy to support individual expression and culture. In this sense, the car is more than a car; it's deeply entrenched in everyday lifestyles and expression. Removal of infrastructures, such as parking spaces (Leyendecker, 2020; Jensen & Lanng, 2017), therefore becomes more than physical, but also as a restriction of individual rights to mobility (Merriman, 2007). The contradiction here relates to how such individual rights to (auto)mobility impinge and restrict the mobility propensity of others: communities displaced by automobility road provision; physical severance of communities from access to basic amenities; physical and emotional harms caused by disproportionate traffic injuries and fatalities to people that walk and cycle; proximity to toxic particles for communities, which again disproportionally affects the most marginalised in societies (Sheller & Urry, 2006; Sheller, 2018).

The catalyst in achieving the self-sustaining "system of automobilities" (Urry, 2004; 2007) has been public policy, which has accelerated the position of private vehicles to the top of transportation policy agendas. Alternative modes of mobility, including public transport use, have subsequently been pushed down the prioritisation of transportation policy. Indeed, the problematic use of "alternative" for non-motorised mobility initiatives gives some indication of automobiles' seemingly natural position as "mainstream". Articulating how the car has emerged as the most dominant mode of surface transportation in some parts of western societies lays beyond the scope of this thesis, yet policy has unquestionably shaped how contemporary societies travel, and equally of how societies are in turn are (unequally) shaped by this travel. Whilst the numerous factors contributed to the "system of automobilities" (Urry, 2004), such as lobbying from manufacturers, it is policy which can steer hopeful ambitions and more egalitarian future mobilities (Leyendecker, 2020). As such, I next bring attention to automobilities to provide context to how surface travel and mobility has developed since the late 19th Century (Urry, 2004).

Although, as stated above, a comprehensive overview sits outside the scope of this thesis this section provides a snapshot of automobility policy that has contributed to car dominated societies in parts of the UK and USA. In the United Kingdom, for example, motorised transport increased over the twentieth century, growing exponentially between the 1950s and 1960s (Gunn, 2011). In response in increasing congestion that was generated by mass motorisation, the solution of the UK Conservative Government was not to reduce the appeal of the private car, but rather to make room for it and to create the conditions for a car owning and using society (Gunn, 2011). Efforts to accommodate motorised vehicles in the UK were made explicitly clear in *Traffic in Towns: A Study of the Long-Term Problems of Traffic in Urban Areas* (Buchanan, 1963), that sought to address the environmental and social challenges of mass availability of private car use. Whilst many of Buchanan's recommendations failed to materialise, including the modernist and aspirational "multiple-deck" city, the report generated significant media and political traction that would lead to substantial increases in road building. However, for both the UK and USA, it is inaccurate to suggest that the private car has been embraced openly by all people in society since its introduction. Social issues related to the car extended beyond traffic and included environmental concerns (which the 1963 Buchanan Report also noted); however, despite such concerns, the car has evidently been privileged by public administrations. Explicitly coupled to the car was the idea of economic growth and prosperity. In other words, by enhancing the car mobility in towns and cities, financial prosperity would ensue. Combining these benefits with ideas of freedom of expression and individualism (Doughty & Murray, 2016), the car became an object that is symbolic of a largely unquestioned "natural order" (Urry, 2004; 2007) of mobility.

The political incentive to accommodate motorised travel, combined with varying policies to realise the potential of the car, led to transportation becoming seen as a scientific endeavour. By calculating future demand of the car, governments could keep pace and provide necessary road infrastructures to allow (future) car drivers to travel. This approach has been conceptualised as "predict and provide" but is now largely out of favour in many national transportation policies (although this is contested, see Whitelegg, 2020). Bannister (2008) identified two issues with forecasting, whereby models to predict automobile traffic ultimately value time as a "derived demand", that assumes that travel time is a burden. In this sense, journeys are not seen as inherently valuable, rather it is important for (higher earning and tax-paying) travellers (Sheller, 2018) to move from A-to-B as quickly and conveniently as possible (also see section 2.5. on the critique of cost benefit analysis of calculating economic benefits). Perreira et al. (2017) warn that such a utilitarian perspective toward transport provision risks positioning the mobility of motorised drivers and passengers above communities. Historically, particularly in parts of the UK and USA, poorer communities have been displaced to make way for the car (Sheller, 2018). Motorised car infrastructures thus treat spaces as an "empty" container (Sheller, 2018), privileging the needs of automobility users over all other surface transport and mobility needs. Another issue with "predict-and-provide" concerns the now widely accepted fact that building roads does not achieve its ambition of easing traffic, as new road building actively encourages it (Urry, 2004).

In the United Kingdom, "new-realism" policies of the 1980s saw an end to major road building policy (Docherty and Shaw, 2011). This coincided with a general increase in environmental consciousness regarding transport related emissions that accelerate human induced climate change. *A New Deal for Transport: Better for Everyone* was published in 1997 by the UK Government to manage existing demand of transport, rather than simply building more infrastructure to enable automobility (Docherty and Shaw, 2011). Though limits were placed upon car driving, the mode was not entirely disregarded. For marginalised modes such as cycling, new realism policies sought to embrace multi-modality, and to encourage cycling through traffic calming measures and through dedicated cycling infrastructures (Goodwin, 1999; Goodwin et al., 1991; Docherty & Shaw, 2011). Despite new realism policies, and general recognition that mobility of the car must have some restrictions, the legacy of automobilities means that non-motorised modes of mobility (such as cycling) remain in the background of transportation priorities. Furthermore, observations by Whitelegg (2020) suggest less reason to be optimistic. Drawing upon Miola (2008), Whitelegg (2020: 99) details how Governments around western Europe, including Sweden, Germany, and the UK, continue to rely on predicted traffic growth, producing a "self-fulfilling prophecy" to justify road building. For Whitelegg (2020), the inability to reject automobility growth defines the dominance of the "system of automobilities".

2.7. Cycling as transport revival

As the above brief overview on the "system of automobilities" (Urry, 2004) suggests, motorised transport has become the most dominant mode of surface transportation in recent decades. In response to the socially and environmentally destructive "automobilities" paradigm, there has been a significant surge in academic writing on cycling (see Dill, 2017), and why more cycling should be promoted by policy (Popan, 2021). And according to several scholars, cycling is making a comeback; with hopes that "cycling can save the world" (Walker, 2019). In some western contexts several cities are reporting gradual increases of cycle commuting (journeys made by cycle to work). For example, in USA, according to estimates by the New York Department of Transport, cycling experienced an 80 per cent increase in cycle commuting between 2010 and 2015 (Sutton, 2016 in Spinney, 2021). Several policy interventions are observed as contributing to this increase, including the increase of dedicated cycling infrastructure and public bike share facilities. The success of the city has been attributed to the vision of Janette Sadik-Khan, former New York City transportation commissioner, who oversaw the implementation of over 200 miles of "bike lanes" between 2007-2009 (see Sadik-Khan and Solomonow's (2017) *Streetfight: Handbook for an Urban Revolution*). The city of Portland (Oregon) in the USA, one of the research sites of this thesis, also reports of increases in the total number of cyclists. According to the Portland Bureau of Transport (2022), cycling uses over four bridges has increased by 322% since 1991, and cycle-specific infrastructure along these bridges are accredited (by the Portland Bureau of Transport) to be responsible for this trend.

Similar trends are observed in the city of London in the United Kingdom, which the other research site of this thesis. According to Will Norman, the Walking and Cycling Commission for Transport for London (TfL), "some places" in London have witnessed a 50% increase in the total number of daily cycling journeys where cycle-specific infrastructures have been installed to support cycling (Transport for London, 2017: 4). Across the entire city of London, Transport for London (2017: 22), monitoring of cycling suggests that cycling increased by 24 per cent between 2012 and 2017. Whilst all statistics are estimates of cycling increase, the take home message is that cycling is undoubtedly on the rise within policy and through statistical observations. This has also generated international and competitive comparison (Popan, 2019). As Popan (2019) suggests, cities across the world not only seek to obtain a "cycling city" status, but also to obtain the title of "number one" cycle city. Whilst these efforts are perhaps necessary to address complex policy problems, such as reduction of transportation's contribution of human-induced climate change and public inactivity, there is a need for caution regarding "successes" of cycling. In the next chapter, I introduce conceptual work on social justice with empirical observations of social inequalities to stress concerns regarding contemporary cycling because of its dominant policy framings.

2.8. Conclusion

Within this chapter, I have provided working definitions for "big data" and "datafication", technological advancements which has generated significant discussion regarding the governance of societies, including controversies and concerns of social justice. Following this, I provided a brief overview to the historic development to private public partnerships within the UK and USA, to provide context to how corporations support the delivery of policy. The emerging field of critical data studies (CDS) was then discussed, particularly the "quantified-self" movement, whereby users of smart technologies may volunteer data to software companies to monitor and track aspects of their lives. This led to focused discussion of "datafied" cyclists, including Strava app users, who are understood to be representative of younger males who ride for recreational or commuting purposes. Building upon this, I outlined how "big data" generated by Strava app users has been utilised as a source to support transportation planning, including a review of academic papers that have sought to test to statistical representativeness of these data. To make conceptual sense of why "big data" sources such as Strava Metro have been considered as a transportation planning resource, I afforded consideration to the dominant "system of automobilities" (Urry, 2004) and how cycling has been historically marginalised as a mode of transportation. I then argued that the "datafication" of cycling has thus been presented as a solution to historic "small data" problems, supporting efforts to increase cycling as a legitimate mode of transport across cities within the UK and USA. Despite this, in the next chapter I will express a further cautionary note regarding "big data" sources as Strava from a social justice perspective. I emphasise how the "datafication" of cycling must be critically appraised to ensure its contribution to policy does not exacerbate any inequalities of cycling.

Chapter 3: Interweaving mobility justice with the "datafication" of cycling

3.1. Introduction

In this chapter, I merge discussions related to digital inequalities associated with "big data" and "datafication" processes, with observed inequalities of contemporary cycling within specific contexts. As the previous chapter discussed, unrepresentative app data, such as Strava Metro, are being studied to evaluate a mode of mobility that is by and large unrepresentative of society in specific "lower-cycling" contexts. This raises critical questions for social justice, which this chapter engages with. Drawing upon mobility justice and data justice, I outline the need for an interwoven approach of social justice. I then introduce further conceptual work of "staging" to make conceptual sense of how "datafication" processes contribute to the "scripting" of cycling. Following this, I emphasise these concerns with reference to a growing body of critical literature that questions the assumption that cycling is an automatic good for society. This critical scholarship does not seek to discourage cycling, but it brings our focus directly to who may benefit from this mode of transport – and who does not. What connects these literatures is a concern for historic and contemporary exclusions in cycling, and a demand for attention to the needs of marginalised and excluded cyclists to move toward more socially inclusive and just cycling futures. To emphasise how social exclusions have emerged within specific "lower-cycling" cycling contexts, I draw upon critical mobilities scholarship to demonstrate how a perception of cycling has emerged that is highly gendered, ageist, disabling, classed, and racialised due to its dominant "scripting" of cycling as a mode transportation. Whilst I emphasise that contemporary cycling is not inherently unjust, the benefits of cycling are felt unequally across societies, particularly in some specific "lower-cycling" contexts. By drawing upon works such as Horton, Rosen & Cox (2007), it is suggested that there is a need to move beyond understanding cyclists as one homogeneous collective, and to move toward one that pays attention to issues of marginalisation, and to a heterogeneity to unlock cycling's transformative potential. Whilst I do not use this section to provide an exhaustive list of all challenges present within some contemporary contexts of cycling; this chapter offers a critical springboard to assess how mobility injustices and social inequalities related to cycling are researched.

3.2. Beyond sedentary approaches of social justice

In this section, I present a summary of Sheller's (2018) call to move toward an emerging socially driven mobility justice. For Sheller (2018), concepts such as "transportation justice" and "spatial justice" fail to incorporate how mobilities emerge as *processes* rather than being understood as static, fixed entities which suddenly emerge after people enter a particular space. Whilst the application of these theories of justice (which I expand upon throughout this section) may help to overcome some challenges within society, there will remain a risk that the most marginalised communities will continue to face disadvantage. Relating Sheller's (2018) call for a mobile ontology to an example from urban cycling, a cyclist is not placed in an unjust transportation "space" or "infrastructure" when they perform cycling; rather, unequal spatial conditions are a "process" that gives rise to unequal cycling subjects. As Sheller (2018: 20) emphasises:

> *"…most theories of justice have been sedentary, meaning that they treat their object as an ontologically stable or pre-existing thing, which stands still before it is put in motion. In contrast, the new mobilities paradigm enables the development of a mobile ontology which not only tracks the effects of inequalities in mobility across various connected sites and scales, but also shows how justice itself is a mobile assemblage of contingent subjects, enacted contexts, and fleeting moments of practice and political engagement."*

As a starting point, Sheller (2018) reviews how transportation scholars such as Perreira et al. (2017) have applied various approaches to justice to a transportation lens. Perreira et al. (2017) draw upon a Rawlsian approach toward distributive justice developed by Rawls (1971), with a capabilities approach (CA) developed by Sen & Nussbaum (1993). Indeed, by drawing upon Rawls' *A Theory of Justice* (1971, 1999), Perreira et al. (2017) consider how distributive concerns of personal freedoms in society should apply equally across society on the condition that these freedoms to not negatively impact others, thus addressing questions of transportation inequalities related to transportation provision. For Perreira et al. (2017) this includes the distribution of resources, access, and opportunities to make use of transportation options for all people within society. To supplement these distributive concerns toward transportation justice, Perreira et al. (2017) also combine a capabilities approach that asserts that people should have freedoms and autonomy in aspects of their everyday lives, which I discussed next.

The capabilities approach, developed by theorists, such as Sen & Nussbaum (1993), affords central consideration to quality of life and wellbeing, and the capacity for humans to perform actions such as being able to access healthcare services. For Sen & Nussbaum (1993), having the "right" or "freedom" to access provisions to support human welfare is insufficient. Rather, the emphasis is placed upon the actual capacity of people to make use of these freedoms. Applied to transportation, Perreira et al. suggest that these capabilities should therefore enable people to access transportation resources to support their everyday needs. In relation to cycling and dock less shared cycles schemes across Greater Manchester, UK, Sheriff et al. (2020) have also shown how emerging micro-mobility technologies become unevenly experienced using a capabilities approach. As Sherriff et al. (2020) highlight, the (geographically restricted) availability of shared bikes is no guarantee of increasing the total number of communities which cycle. Although availability of dock less shared use bikes may increase access to cycling, people's capabilities are differently impacted. Coupled with perceptions of safety and limited dedicated and separated cycling provision, for example, people's encounters with dock less bike share within Greater Manchester emphasised how capabilities to cycle were unevenly experienced. This includes consideration to the "datafication" of cycling, as Sherriff et al. (2020) note how exclusions arise "related to gender, age, and income, which are in turn connected to existing levels of smartphone and data accessibility" (Sheriff, 2020: 9).

By embracing such an approach toward transportation justice, Perreira et al. (2017) observe their proposal is a significant departure from social and ecologically destructive historical approaches such as utilitarianism, which is linked to economic appraisal approaches such as predict and provide and cost benefit analysis discussed in chapter 2. Perreira et al. (2017) reason that utilitarianism should not be embraced due to the discounting of needs for the most vulnerable in society. Indeed, transportation planning approaches have been highly quantified, drawing upon cost benefit appraisals to support decisions regarding transportation. This approach toward transportation has privileged the "system of automobilities" (Urry, 2007), supporting automobile transport as quickly and efficiently as possible, without fuller consideration to how people and communities may be disproportionately and negatively impacted upon by motorised transportation. Equally, Perreira et al. (2017) remain critical of libertarian, economic market-based approaches toward justice, which are also likely to result in equities in transportation provision as market decisions will likely be dominated by the most powerful in society.

Whilst Perreira et al.'s (2017) approach toward transportation justice indeed goes beyond historically destructive approaches of thinking about justice, such as utilitarianism that has historically dominated transportation planning and governance, Sheller (2018) observes how Perreira et al.'s (2017) approach toward transportation justice alone cannot sufficiently deal with complex mobility issues experienced across society. Sheller (2018) notes how distributive approaches toward transportation justice may overlook wider considerations of human capabilities as the focus is narrowed to the distribution and access related to questions of transportation only. To emphasise this point, Sheller (2018) summarises an extract of the Equity Statement published by the Slow Roll Chicago Bicycle Movement, which lambasts the structural, institutional, systematic racism that contributes to observed inequalities related to cycling within the US city:

> *"It is about far more than distributive questions of access and demands more than an egalitarian approach. Instead, it concerns overturning marginalisation and disadvantage*

through intentional inclusion of the excluded in decision making and elimination of unfair advantage. It puts "oppressed" and "disenfranchised" groups front and center." **(Quoted in Sheller, 2018: 29)**

As the Slow Roll Chicago Bicycle Movement emphasises, demands for social equality for people in the United States, distributive elements alone such as access to transportation resources, are insufficient. There is an emphasis on injustices that remain unaddressed even when distributive concerns, such as access to transportation services, are addressed. Sheller (2018: 27) goes further to argue that the focus on access means that spaces for travel are conceptualised as a "means to an end." By thinking in this way, Sheller (2018) brings attention to how distributive concerns fail to tackle issues such as exposure to harms generated by transportation, such as proximity to traffic pollution and incidents. Furthermore, Sheller (2018) asserts that dominant narratives of how transportation operate are also left unaddressed, including an uncritical focus on bicycling policies that privilege notions of active travel based on "health" and "fitness" at the expense of other potential meanings of cycling in society.

By bringing attention to social and mobility inequities that exist within the USA, Sheller (2018) thus demonstrates that transportation justice is not capacious enough to deal with issues of mobility and immobility. As briefly discussed above, part of the issue for Sheller (2018) concerns ideas of theories related to transportation and movement (including cycling) as being "spatially contained", rending them as ontologically "fixed". Related to cycling, there are numerous examples of seemingly "a-mobile" policy recommendations, including by well-cited cycling researchers. For example, basing policy recommendations of best practice around the world, academics such as Pucher and Buehler (2008) often fall into a mindset of promoting infrastructures that are (1) distributive in their aspirations, which are complemented by (2) measures to support people's capacity to participate in cycling. Cycle-specific infrastructures are suggested as a means of enhancing cyclists' physical safety and therefore regarded as mechanism to support cycling. Additional "soft" infrastructures are also recommended, including cycling training for children and adults and policy support to access cycles (through loan, rent, or purchase). As successful as cycling policies and programmes may be, without serious consideration of how cyclists (existing or potential) may become marginalised, there runs a risk of leaving issues of social equality and justice unaddressed. Whilst there remains a role to deliver infrastructures and training programmes as part of a move toward mobility justice, Sheller (2018) asserts that a far more holistic approach is required that moves toward an ontological perspective that breaks away from being fixed to one that is mobile.

Sheller (2018) further outlines how, in addition to Rawls' distributive justice (which debates such as transportation justice have drawn upon), other approaches toward socail justice also struggle to sufficiently deal with issues of mobilities. These understandings of how justice might be "put into practice", include deliberative justice, procedural justice, restorative justice, and epistemic justice. Sheller (2018) summarises these as concerns for who is included in decision making related to transport (deliberation); who is given meaningful participation regarding decisions (procedural), who is responsible for harms generated by excessive mobilities (restorative) and recognising new ways of knowledge generation (epistemic). Collectively, Sheller (2018) thus sees these more traditional theories as an "nested approaches to justice". By embracing these approaches, Sheller (2018) asserts that none address the fundamental issue of moving beyond seeing spaces as ontologically "fixed" entities. By having a non-spatial or a-spatial underpinning, these philosophies alone do not sufficiently deal with social inequalities and injustices. In other words, whilst these conceptualisations assist in our understanding of how justice may be pragmatically utilised to assess mobility, Sheller (2018) asserts they cannot alone sufficiently deal with the complex and uneven struggles of mobility injustices when treated in isolation.

Whilst theories such as Edward Soja's "spatial justice" may be seen as a potential resolution regarding this, Sheller (2018) asserts that it too relies upon an immobile ontological grounding that does not address (im)mobilities that arise due to interactions across different scales and sites. Reflecting the ontological limitations observed for Perreira et al.'s (2017) transportation justice, Sheller (2018) notes how Soja's spatial justice too sees transportation as connecting people to places only. In other words, journeys are not in themselves valuable, but rather it is the outcome of transportation that has value. To move beyond sedentary understandings of justice, Sheller (2018) thus proposes that there is a need to draw upon theories such as transportation justice and spatial justice whilst also going beyond them to understand how mobile lives are brought into being at different "scales". By developing a theory for mobility justice, Sheller (2018) thus seeks to develop a mobile ontology that can deal with complex social and ecological issues that are experienced by contemporary society at varying "scales". These include "scales" that are directly related to this thesis: the body, transportation systems, and city-scale environments. In the next section, I briefly outline these scales, and reflect upon how these scales proposed by Sheller (2018) responds to "datafication" processes and its impact upon people, transportation systems, and governance of city environments.

3.3. Interweaving mobility & data justice

In this section, I next outline Sheller's (2018) use of mobility "scales" to critically conceptualise unpack how social inequalities and injustices may arise across societies. Building upon this, I outline how Sheller (2018) discusses the role of data at these "scales" before introducing additional theories of data justice that have developed from critical data studies. The section ends with a proposal of how to support the emerging development of mobility justice, and how this emerging conceptualisation may support appraisals of "big data" app appraisals related to policy. The first of Sheller's (2018) "scales" that is necessary for mobility justice concerns the bodily scale. The human body plays a significant role in the assemblage of a cyclist and therefore is of significant relevance for this thesis. To move toward mobility justice at the bodily scale, Sheller (2018) outlines several principles that are necessary to achieve, including inclusion of all people within public space, universal design within public spaces to support accessibility to transportation facilities, and mobility rights for marginalised populations such as children. Secondly, Sheller (2018) moves attention toward transportation system scales, drawing upon infrastructural justice concerns. At the transportation system scale, Sheller (2018) notes the need for equitable transportation provision, and greater attention to transportation decision-making and participation of people regarding policy decisions that impact or impinge upon their everyday mobilities.

Recognising that transportation planning is traditionally highly technocratic, Sheller (2018) suggests that this may close the possibilities for "collaborative planning" with communities. Focusing upon people, and the impact that transportation has upon people and communities with the first two scales of Sheller's (2018) emerging mobility justice, Sheller does not, however, bring the role of digital data collection and analysis to the centre stage until the third scale toward mobility justice. Pertaining to data mobilities, Sheller (2018) suggests that the third scale toward mobility justice, at the city-scale: data and information for public transport infrastructures should be made public; with legal protection for data privacy; and net neutrality and open data repositories for publicly funded research. Specifically, at this city scale, Sheller (2018) evokes discussion regarding the impact of digital infrastructures and how these permeate policy decisions related to the physical realm. Specifically, the flows of digital data may disrupt and increasingly govern embodied interactions and the organisation of spatial infrastructures. Indeed, whilst Sheller (2018) brings data and data systems into focus at the city-scale, the emerging mobility justice approach proposed concerns the entanglement of all "scales" of mobility that cannot be easily separated and dissected as an individual entity. Rather, by moving toward a more mobile ontology of justice, Sheller (2018) thus demands full consideration to how "scales" (including bodily, transportation systems, city-scales) are inextricably interlinked and co-dependent.

As discussed earlier within Chapter 2, location aware "tracking" technology use and social media data sharing, such as Strava, have not only changed how cycling practice is communicated, but also of how persuasive technologies may prompt physical activities and influence practices of cycling (e.g., increased risk taking and over-exertion, see Barrett, 2016). In the case regarding Strava Metro data generation, mobility "scales" are seen to run parallel, whereby data related to cycling emerges through an assemblage of "scales" that include individual app users, cycling within urban transportation systems, and through the governance of ever-increasing autonomous data flows within cities. Consequently, future mobilities are at risk of being determined by the flows and circulation of people, cycle technology, and digital data, that may exacerbate the fundamental mobility equalities and injustices. To support Sheller's (2018) mobility justice theorisation, I next introduce additional literature from the emerging field of critical data studies, along with demands for data justice. To move toward more egalitarian visions of mobility justice, Sheller (2018) outlines a need to critique digital data, bringing a focus to how data mobilities are entangled together with other "scales" of mobilities, including the body and systems of transportation. As discussed within Chapter 2, digital data (or "big data") are not simply technical (Kitchin, 2014), nor are data simply an economic commodity (Richterich, 2018). Rather, "big data" sources and the increasing "datafication" of society is an entangled concern for mobilities and mobility justice. In response to increasing "big data" and algorithmic governance across societies, including western (Kitchin, 2014) and developing contexts (Heeks & Shekhar, 2019; Taylor, 2014), researchers such as Dalton & Thatcher (2014) offer a critical framework to assess these impacts, which I outline next.

For Dalton & Thatcher (2014), critical data scholars are encouraged to situate data regimes in time and spaces, to reflect upon how data are geographically situated. This includes access to the internet, network coverage, and access to digital technologies. Indeed, this is particularly relevant for mobility justice due to the observed "digital divide" in societies such as the UK and USA (Sourbati & Behrendt, 2020; Lyons, 2015; Kitchin, 2014). Regarding Strava Metro data, as Chapter 2 reflected upon, there are significant generational issues regarding who are captured by the commercial app. For many older people in society, their cycling journeys and preferences may not be included within Strava Metro data samples as smart computational technologies (GPS trackers) are not universally available to all, or desired. This issue also applies to younger generations, who again are recognised as marginalised within a cycling context. Though children may have access to GPS "tracking" technologies, apps such as Strava are unlikely to include independent journeys they make due to age restricted access to the Strava app. Thus, the reason it is important to emphasise missing journeys relates to how "scales" of mobilities

(Sheller, 2018) interact and impact upon the mobilities of others, and this is irrespective of whether people engage with digital technologies or not. This leads to the second and third points for Dalton & Thatcher's (2014) call for researchers to "expose" data as inherently political, and to "unpack" the relationship between "big data" and society. Writing on community mapping within international development contexts, Heeks & Shekhar (2019) demonstrate how new data flows may help to address the "invisibility" of previously "hidden" populations whilst simultaneously creating conditions for disproportionate benefits and power relations that emerge due to data availability. This applies again to the concerns regarding sources of data such as Strava Metro. As the existing literature on Strava Metro data suggests, there are limited contributions that have addressed questions regarding who the "main" beneficiaries are when Strava Metro data are used by public administrations.

Dalton & Thatcher's (2014) fourth recommendation calls for academic researchers to illustrate the ways in which commercial "big data" sources are "never" raw. In contrast, following Kitchin (2014), privatised sources of "big data" should be recognised as "cooked", or pre-prepared. In other words, how data are prepared may have significant ramifications relating to sample characteristics. Indeed, as discussed within Chapter 2, Strava Metro data are pre-processed by the company Strava before being shared with government departments due to privacy legislation, such as the European Union GDPR (Couldry & Yu, 2018). This links to the fifth recommendation by Dalton & Thatcher (2014) who call for researchers to "expose" the fallacy that "big data" sources will "speak for themselves" and in turn replace "small data" (see discussion in Section 2.5 on "small data" related to cycling). These two points are especially relevant as is the need to assess how Strava data are understood and used within regional transportation departments. The role of data was emphasised in the previous chapter with reference to "traditional" sources of data such as cycle counters that, for many commentators such as Musaka & Selala (2016), have hampered transportation planning for cycling. This also evokes concerns for certain approaches of justice, especially related to deliberative practices and "collaborative planning" (see Sheller, 2018). Thus, there is not only a concern regarding who may be captured within Strava Metro data samples, but also of how these data may be leveraged over other forms of data and other ways of generating knowledge (or epistemic justice concerns). Furthermore, procedural concerns arise regarding how people may support or contest any decisions that arise due to the utilisation of data sources such as Strava Metro.

In their sixth and seventh recommendations for conducting a critical data study, Dalton & Thatcher (2014) support a shift toward more socially progressive approaches to "big data" uses within society. Sheller's (2018) mobility justice demands echoes these recommendations. In her discussion of data related to the city-scale (which is entangled and impacts upon other "scales", such as bodies and systems of transportation), there too is a demand for just data practices, especially when commercial "big data" are used by public administrations. As discussed above, Sheller (2018) does not call for the exclusion of data uses in the governance of mobilities, but rather greater sensitivity to how these uses of data unevenly impact upon mobilities of people across society. Sheller (2018) thus calls for open data repositories for publicly funded research, with legal protection for data privacy, and to include people within decisions when "big data" sources are utilised. Whilst these principles echo calls by critical data scholars for rights to data protection and privacy (Andrejevic, 2014; Taylor, 2017; Iliadis & Russo, 2016), there are however tensions in ensuring full privacy for people whilst allowing open access of data for public research. As the example of Strava Metro data shows, commercial data cannot be entirely "open source" when these sources are used by public administrations, as this would in turn violate individual Strava user's legal rights to privacy (also see "big data exceptionalism" discussion by Nissenbaum, 2017), Furthermore, the privatisation of data adds a further layer of legislative complexity and risk for both private and public partners that share sources such as aggregated data related to cycling. Rather than a demand for "open" data repositories, which may undermine a right to individual privacy, a data justice perspective which is critically aware of risks of "datafication" becomes important. Indeed, as Dalton et al. (2016) observe, the uses of data and algorithms may do less to interpret the world, and rather to actively frame people and their preferences (also see Mittelstadt et al., 2016).

The urgency and rationale of emphasising data justice is underpinned by contemporary observations of social inequalities of contemporary cycling within some "lower-cycling" contexts, which is later emphasised throughout this chapter. Bringing together social equalities observed within specific "lower-cycling" contexts, with the "datafication" of cycling, it thus becomes imperative to research how "big data" sources such as Strava Metro are being utilised by public administrations. Though privacy and access to data will (and should) mean restrictions to "raw" data sources such as Strava Metro data, this does not prohibit a critical assessment of how "big data" sources are being leveraged to actively "script" cycling. By understanding how cyclists are imagined and governed through data uses, it then becomes possible to actively toward more egalitarian futures for cycling mobilities.

From an interwoven mobility and data justice perspective, the question regarding Strava Metro data uses turn to a consideration of exactly who the main mobility beneficiaries from the sharing of Strava Metro data are. As

Chapter 2 outlined, there are several contributions regarding the potential of Strava Metro data uses, including assessments on representativeness and comparison with other sources of data related to cycling (see section 2.4). However, there are comparatively few contributions that have assessed exactly how, where, and why Strava Metro data are being used by public administrations. As a result of this research gap, it is not possible, using the existing literature alone, to ascertain how Strava Metro data uses in transportation planning and governance may support or derail efforts to achieve more egalitarian futures for cycling. Most importantly, from an interwoven mobility and data justice perspective, addressing this gap in turn will help to ascertain whose cycling becomes "scripted" via Strava Metro data use, and what might this mean for future cycling mobilities. To make conceptual sense of "scripting" the cycling subject, I next outline work on the "staging of mobilities."

3.4. "Scripting" the cyclist

Jensen & Lanng (2017) offer a useful starting point to help analyse and address the multiple and intersecting inequities that have emerged in urban cycling because of its normative policy framing. In Jensen & Lanng's (2017) *Mobilities Design*, the authors review how mobile situations, such as crossing a road, are "staged" by those who interact with urban environments and those who are involved in the design of the built environment. In other words, Jensen & Lanng (2017) see everyday mobilities as an outcome of the urban design and how people interact with these designed spaces. Earlier work by Jensen (2013) proposed a "staging of mobilities" framework that considers how mobilities are planned, designed, and governed in certain ways over other alternatives. Jensen's (2013) framework regards mobilities as being (1) staged from above, and (2) staged from below. To make conceptual sense of how mobilities are "staged from above", Jensen (2013) asserts that mobile situations emerge beyond the physical, and therefore arise due to policies, plans, designs, data, engineers, regulations. Taking the example of cycling specific infrastructures, by considering how cycling becomes "staged" suggests that they are more than physical assemblages (raised kerbs, asphalt surfaces, and paint) of urban environments, but are also the outcome of many unseen actors. For example, policies may offer design guidance over infrastructural recommendations, and these recommendations may be optional or statutory. Histories of recommended "best practice" may also shape policy implementation, which in turn determine the funding priorities for planners, designers, engineers, software developers, who will have a significant bearing on the final design of cycling infrastructures.

The collective influence of actors and non-human actors (including digital software and data) have in shaping mobilities from above can be said to determine the "scripts" (Akrich, 1992; Akrich and Latour, 1992) upon how mobilities are “staged from below” (Jensen, 2013). Developed from theories of science and technology (STS), “scripts” may not necessarily be “written” yet are shaped by the intentions of designers; the meaning of designed objects is therefore “inscribed” into objects (Akrich, 1992). Taking the example of a bicycle, for example, the design assumes the ability of a user to use momentum to sustain balance for travel. Fallon (2008) goes further and encourages thinking beyond the intentionality of designers, to consider whether users of a designed object will subscribe, re-inscribe, or ignore the “purpose” of a designed object. Continuing with the example of a bicycle, its designed purpose might be seen as a transportation technology, whilst for others it may be a displayed work of art, or as a means of generating electricity (when connected to a generator). Thus, an idealised “script” that is staged “from above” may influence how people may interact with a designed object, but they do not dictate human-object interactions (Cox, 2019). The same principle applies to the urban design of infrastructures; indeed, well-intentioned cycling infrastructure might encourage people to participate, whilst others may, for numerous reasons, choose to ignore or reject the mobility “script” that has been written.

Rather than seeing design as an isolated “neutral” process, the focus is shifted toward thinking about how designs shape and reshape how people move (Spinney et al., 2017). The outcome of urban design thus, for Jensen & Lanng (2017), has significant bearing upon the “affordances” of mobility. The term affordance emerged from writing by environmental psychologists, such as Gibson (1986), and concerns the different perceptions of environments for different animals and people. For Gibson (1986: 128), affordances of the environment cannot be quantified or measured numerically as they are dependent upon the perceiver. Related to cycling, infrastructures that are not related to motorised vehicles may afford cycling mobility for some, but not all may take up the offer that such provision “affords”. Williams (2016), for example, conducted a study with disabled cyclists to highlight how features of the Welsh Government Active Travel Design Guidance (2013) offered insufficient consideration to the needs of people that used adapted cycles. Whilst turning widths in design guidance, for example, acknowledges the turning needs to manoeuvre several different adapted cycles, a lack of consideration for universal dropped kerbs restricted access to “up-to-standard” cycling infrastructures. Whilst disabled cyclists had been considered by the designs, participants within Williams’ (2016) study reported being unwilling to use specific infrastructures even though existing design guidance standards at the time were met. Thus, cycling infrastructures did not afford cycling to all users, despite recognition that design guidance should be sensitive to the needs of all cyclists. For this thesis, I place greater attention to the analysis of how mobilities are “staged from above”; focusing on how policies, guidance, plans, and professionals, contribute to the planning, design, and redesign of cycling mobilities. Most importantly, I seek to understand how the "staging from above" may produce or exacerbate issues that exist within some "lower cycling" contexts. Understanding how the design of mobilities gives rise to social inequalities may in turn help address the social injustices that may inadvertently be "scripted" into urban cycling. In the next section, I provide an overview to the observations of social inequalities that have arisen in some "lower-cycling" contexts as a function of their policy design and implementation, starting with a focus on gender inequalities. Indeed, the purpose of this next section is not to provide an exhaustive account of all social inequalities that may arise due to normative understandings of cycling by policy, but to bring attention to how specific contexts may "script" cycling for some at the expense of others.

3.5. The observed gender-imbalance of "lower-cycling" contexts

One of the clearest indicators of social inequalities arises from a review of gender divisions of urban cycling in some western contexts where significantly more men are seen to participate in contemporary cycling compared to women. This arises due to a function of specific policies and their implementation, rather cycling being inherently gendered. Indeed, in many northern European cities, such as Copenhagen, gender imbalances are not observed (Feddes et al., 2020), and as such contemporary cycling is far from being intrinsically socially unjust. However, equally it must be emphasised that increases of funding to support cycling in no guarantee of ensuring gender parity. For example, in the "lower cycling" context of London, despite a tenfold increase in cycle commuting between 2001 and 2011, Aldred et al. (2016) observed that there was an overall decrease in gender and age diversity. This means that whilst the total numbers of women who cycle increased between the two UK censuses, the greatest beneficiaries of investments in London's cycling infrastructure were younger males. This brings into question claims of cycling successes within London, a city that has been praised for its policies on cycling as a higher cycling city within a "lower-cycling" national context (see Spinney, 2021). Lam (2018) emphasises this in a critical review of Hackney, a borough of London, that has the highest share of cyclist mode share within England's capital city. Despite these figures, Lam (2018) asks how growth of cycling within London can be considered as successful when approximately three quarters of all of London's cyclists are men (including "hipsters" and "MAMILs'"– middle aged men in lyrca). Part of Lam's (2018) concern relates to deliberate "blindness" of cycling experiences within London, whereby all users are seen as being given equal cycling provision. Drawing upon Sen's (1990) work on human capabilities (which is also discussed in Section 3.2.), Lam (2018) outlines how disparities of cycling, such as significant differences of cycling participation between men and women, will likely continue unless all potential users have access and freedom to make use of cycling provision. In other words, whilst cycling infrastructures may be available to everyone, infrastructures will likely advantage men if understandings of cyclists (and cyclist's needs) are "imagined" as being predominately male. Again, this privileging of some users must be understood as the outcome of policy design, and not inherently gendered as a mode of transport. For example, compare observations from "lower-cycling" contexts, such as London, with Norther European cities such as Amsterdam, Copenhagen, Utrecht that see gender parity between the percentages of men and women who cycle (Feddes et al., 2020; Spinney, 2021; Popan, 2021).

Regarding barriers to cycling, Twaddle et al. (2010) suggest that concerns related to safety feature more for women than men, and that segregated provision may help to promote cycle commuting. Despite this, segregated infrastructure is not a guarantee to promote gender diversity, as the case of London shows. Implemented initially as "cycle superhighways" (now cycleways), new cycle only routes in London offered separated provision from motorised vehicles yet were planned as strategic arterial routes to support continuous cycling to and from London's commercial business centre. These routes privilege a certain type of user, interested predominately in quicker access to and from work, relating only to a certain type of employee that values journeys to workplaces. This reflects the radial provision related to public transportation that has been long critiqued as failing to serve the needs of a range of users (see Church et al. 2000). These routes privilege values such as speed and efficiency, echoing a long-standing critique of cycling (and transportation systems more generally) as highly gendered. In a study related to the Scottish city Glasgow, Motherwell (2018) notes how, due to cultural and historical legacies of gender division, women are more likely to work-part time, have additional caring and family responsibilities compared to men. Not only do these gender divisions reduce free time, but women are also more likely to "chain-trip", making multiple journeys during a given day. These observations are also observed by authors such as Pooley et al. (2013) who noted examples of multiple journeys such as journeys related to the school-run with children, food shopping, prescription collections; thus, women are more likely than men to make journeys that are "encumbered". Continuous cycling infrastructures that fail to support multi-modal journeys may instead benefit journeys made by (presumably tax-paying, economically active) men (Sheller, 2018).

To address issues of gender inequalities of cycling within London, Transport for London (TfL) proposed a separate 60-kilometre infrastructural plan, initially called Quietways (now also cycleways) to support a wider range of journeys made by bicycle (Lam, 2018). Whilst Quietways in London were conceptualised as facilitating community cycling, Lam (2018) critiques the programme of infrastructural interventions that do not address issues such as physical modal separation away from motorised vehicles, but rather focused on less intensive infrastructural work such as implementing low-traffic neighbourhoods (LTNs). Low traffic neighbourhoods focus on reducing the convenience of motorised car use by reducing overall traffic speeds to 20 miles per hour, combining minor infrastructural interventions such as modal filters to privilege walking and cycling. These interventions are also seen in US cities, such as residential areas within Portland, Oregon (Portland Bureau of Transportation, 2016). In addition to designing "on road" cycling shared with motorised vehicles (Lam, 2018), their spatial Implementation has been slower than the implementation of strategic linear cycleways in London (i.e., "cycle superhighways"). Spinney (2021: 94) identified that the Quietways programme (albeit now also "cycleways") took considerably longer to implement compared to London cycle superhighways, that thus "speaks volumes about what its policy priorities are."

The main issue, for critics such as Lam (2018) and Spinney (2021), concerns the overall prioritisation of providing cycling provisions to separate and support utility cycling journeys, such as cycle commuting. These journeys aren't exclusively made by men, but research (such as Aldred et al., 2015) suggests that men are, statistically speaking, the greatest beneficiaries of policy interventions when infrastructures are designed with utilitarian perspectives in mind. Some of the qualities of utilitarian mobility regard cycling (as well as other modes) as purposeful and rational, echoing the assumptions of transportation planning that time is a burden, and has limited instrumental value beyond trying to move as quickly as possible from one place to another (Sheller, 2018; Perreira et al., 2017). Seeing time as a cost thus gives more agency to velomobilities that are faster and more efficient, at the expense of slower cycling (Popan, 2019). For Spinney (2021), accommodating utilitarian values of cycling supports what are seen by policy as "desirable variants" that feed the idea of economic growth (also see Stehlin, 2014). By accommodating these variants with the most "visible" and "supportive" infrastructures to encourage the cycling commute, other values such as sociability (side-by-side cycling), exploration, and playfulness become marginalised. Thus, as recent research has shown in the UK and USA, increases in cycling mode share is no guarantee for more diversity in cycling. However, statistical data from northern European cities such as Amsterdam (The Netherlands) and Copenhagen (Denmark) show that there can be greater parity between men and women cyclists (Feddes et al., 2020). In relation to the city of Copenhagen, Freudendal-Pedersen (2020), who quotes Aldred & Jungnickel (2013), offers a useful summary of how these successes are achieved within the Danish capital:

> "*Aldred and Jungnickel (2014) point out that cycling is associated with social identities such as those of class and gender, and discourses guiding practice and subcultures. They suggest*

that for cycling practices to be sustained they need to be related to other practices, such as shopping, commuting to work or taking children to school. This is the reason why cycling plays the role it does in Copenhagen, when cycling in the same way as other works of transport in the city is linked to everyday practices". **(Freudendal-Pedersen, 2020: 186)**

Freudendal-Pedersen's (2020) observations suggest that promoting cycling within urban environments must accommodate "all" types of journeys. Whilst this includes commuting, economic productivity and utility is only one part of this. As discussed earlier in this section, this approach of accommodating non-economic journeys is more likely to be disregarded in transportation policy and infrastructural provision in the UK and USA. Thus, whilst "higher-cycling" cities are often presented as "benchmarks" for cities across the world to replicate, cycling is far from being a guaranteed and uncontested mode. In the next section, I next turn our attention to issues related to cycling injustices related to age; issues that are experienced by both "lower-cycling" contexts of the UK and USA, and in the "high-cycling" contexts in northern Europe.

3.6. Marginalisation of children's and older people's cycling needs

Although contested (Murray and Cortés-Morales, 2019), it is broadly assumed that across both the UK and USA, children's independent mobility has declined over the 20th and 21st centuries (Whitelegg, 2020; Barker et al., 2009; Walker, 2020). As children's independent mobility declined, the level of car ownership in both countries increased. Again, physical safety and concerns related to transport incidents gave the impression that roads were for cars, and not spaces for children (Spinney, 2021). Policies and media campaigns in "lower-cycling" contexts has further reinforced this message as Aldred (2012: 97) notes, including UK examples whereby a lack of attention by children and parents could cause traffic incidents:

"The Central Office of Information's short road safety film 'Sewing Machine' (1973) begins with a mother saying 'I'll just be a minute' – but that is too long, the lugubrious voice-over tells us. The child runs out of the house and onto the road to see her friend and does not see the car that kills her; according to the film, this is the fault of her mother." **Aldred (2012: 97).**

As the example by Aldred (2012) suggests, streets were regarded as unsafe places for mobility, and that accidents which occurred in them would not be the sole responsibility of motorists. In addition to being marginalised by the needs of automobilities over the 20th and 21st centuries, findings from Horton et al.'s (2007) study with children (ages 9-16) in the UK suggest that the mobility needs are often assumed by existing policies to promote cycling. Horton et al. (2007) note how non-purposeful meanings such as playfulness and exploration hardly feature in transport planning discussions. Instead, the mobility aspirations of children are overwhelmingly determined by instrumental thinking, of moving from A to B, the same as an adult who may wish to travel by cycle.

Taking a historic perspective, lessons of "higher-cycling" cities in northern Europe stem from the demand for safety considerations for children. In the city of Amsterdam, protests across the city erupted from 1973 following fatalities involving motor vehicles and children. In a highly emotive campaign following several child fatalities involving automobile drivers during the 1970s (Feddes et al., 2020), citizens protested the dominant position afforded to motorists and motorised vehicles. Alongside over citizen and political movements in the Netherlands, the "Stop de Kindermoord" ("Stop child murder") movement mobilised campaigners across political divisions to take seriously the need for safety measures to curb automobilities and ensure safer streets for children to play (Feddes et al., 2020). Indeed, referring to Freudendal-Pedersen's (2020) observation that cycling practices in the city of Copenhagen link neatly to other activities, the examples are again largely based on adult mobilities. Children's mobilities, such as non-purposeful trips, do not feature largely in infrastructural provision even in 'high-cycling' cities. Participants of Freudendal-Pedersen's (2020) study emphasised this as being a significant concern regarding the limited provision of cycling infrastructures which generated concerns regarding children's safety whilst cycling. However, as with Horton et al.'s (2007) study that explored how children value mobility, there is certainly some element of this even within the 'high-cycling' exemplars of northern Europe. Spinney (2021) takes this critique even further, suggesting that even in the Dutch CROW Manual (2007) (which is seen by many as being an example of best practice of cycling infrastructure delivery; see Parkin, 2018) makes little mention of the independent mobility needs of children. Rather, children are assumed to share the similar qualities as adult cyclists, apart from having less predictable cycling behaviours (such as "zigzagging") which designers should be mindful of (see Spinney, 2021: 64). As such, the assumption holds that whatever is important for adult cyclists, will be of value to children that cycle.

The assumption also holds for older cyclists, as research on the UK *Cycle Boom* (2016) project suggests. Speaking to older participants (aged over 50), Jones et al. (2016) found that the cycling infrastructural needs of people changed as they aged. Many of these needs included an inability to perform what had previously been "taken-for-granted" abilities when cycling, including looking over shoulders to review motorised traffic when cycling along highway (road) infrastructures. Through interactions between road surfaces, cycles (experienced when wheels connect with surfaces), and older cyclists' bodies, Jones et al. (2016) observed how these combined to exacerbate physical discomfort of cycling, particularly related to wrist and back pains. Rather than the urban environment adapting to the needs of older cyclists, Jones et al. (2016) assert, older cyclists are required to adapt to the needs of mainstream cycling and highway infrastructures. These adaptations included, requiring gloves and wrist supports to absorb shocks from uneven surfaces, to attaching a mirror to support older cyclists turn their necks. Many of Jones et al.'s (2016) participants who failed to successfully "re-adapt" to urban cycling environments were less likely to continue cycling into older age. Whilst new technologies, such as e-cycles with battery assist may help support older cyclists prolong their ability and enjoyment of cycling, they too are expected to adhere to a built environment largely designed for commuter cycling.

3.7. Disabling aspects of cycling infrastructures

Following on from the critical literature on how older cyclist's experience of cycling may be diminished by unsupportive environments that assume "taken-for-granted" manoeuvres (Jones et al., 2016) within "lower-cycling" contexts, the same concern has been expressed for disabled cyclists. In a detailed policy brief, Andrews & Clement (2021) stress the need for inclusive design standards that is universal across national contexts, in addition to enhanced recognition for the needs for disabled cyclists. These needs include recognition of cycle technologies as mobility aids, and not just as transportation technologies. Andrews & Clement (2021) also call for the development of a "Blue Badge" scheme that would grant disabled cyclists the permission to ride in non-cycling areas. As Spinney (2021) discusses, disabled cyclists may require adaptable cycle technologies (which again are likely to be used by older people) to perform a wide range of "taken-for-granted" manoeuvres. The turning circles for adapted cycles, such as upright or recumbent tricycles, which have very different geometries, require different turning widths to manoeuvring an upright bicycle with two wheels. Physical boundaries, such as kerbs and physical barriers to separate cyclists from motorised vehicles, are often lauded for the safety they offer. However, in a study entitled *Thinking Beyond Two Wheels* that researched the cycling perspectives of disabled cyclists in the city of Cardiff (UK), Williams' (2016) participants noted how separated cycling provision led to some concerns related to a sense of "entrapment". As this example suggests, there is an imperative to avoid any assumptions of what constitutes as "good" cycling infrastructure, as this will always be context dependent upon the interactions between different cycling environments, cycle technologies, and cyclists.

In recent years, Andrews et al. (2018) note that there are improvements to design guidance across London and England (UK). And this had been a long time coming, as Hickman (2016) observes. In a detailed analysis of cycling related policies in England between 2013-2014, Hickman (2016) notes that out of approximately 350 images that contained cycles, less than 15 included a representation other than an upright bicycle. As Hickman (2016) emphasises, the idea of a cyclist, has for years been one that rides an upright, two-wheeled bicycle. In a follow up paper that assessed the visual images of cyclists in London, Andrews et al. (2018) found that out of 56 documents related to cycling and policy, only 3.6% (13 out of 364) contained images that were non-standard (i.e., not bicycles). As Andrews et al. (2018) and Hickman (2016) demonstrate, disabled cyclists are underrepresented in the conceptualisation of cycling and of cyclists, especially in "lower-cycling" policy contexts. In the next section, I move the focus toward how implementation of cycling infrastructures may overlook the needs of minority populations and exacerbate isolated issues of social injustice.

3.8. Uneven classed and racialised cycling

In recent years, researchers such as Stehlin (2014; 2019) and Hoffman (2016) bring our attention to unintended social injustices that arise alongside the delivery of cycling infrastructural provision. As discussed in the opening section of this chapter, cycling is viewed as a more sustainable form of transportation that may support healthier and happier lifestyles, both for individual and for communities. Despite these aspirations for future mobilities, a stern caution is attached. Steinbach et al (2011: 1123) argues that for the city London "cycling is disproportionately an activity of affluent, White, men." Similar concerns are also observed from research across the USA. For example, Stehlin (2019) outlines how the development of cycling provision has been experienced unequally by communities. Not only has cycling provision been observed to be of most benefit for white Americans (who are predominately male), their implementation has also been coupled with gentrification[5] to the benefit of those that can afford to cycle out of choice, and not necessity. To emphasise this, Stehlin (2019) adds:

> *"Though bike lanes do not cause gentrification in isolation, support for bicycle infrastructure comes from the same social bloc that gentrification empowers and makes visible in urban space: young, mostly white, upwardly mobile professionals. And the economic contributions that bicycle advocates now celebrate are the products of the reworking of race, space, and capital."* **Stehlin (2019).**

As Stehlin (2019) above notes, cycling provision across the USA has been extremely racialised and has benefitted a very narrow population, that arguably do not see the cycle as an essential mobility technology.

[5] "Gentrification" is linked, albeit not exclusively, to inward investment and increasing property prices (Lees et al., 2008). Whilst this is very basic summary, gentrified areas impact significantly upon the existing populations who may be forced (evicted or priced out through increases in property rental) of staying within that area. For additional overview in relation to cycling see Stehlin (2019).

Hoffman (2016) outlines these concerns in *Bike Lanes Are White Lanes*, in which existing social injustices in the USA are seen to be exacerbated by cycling advocacy. For example, Stehlin (2019) notes how "Silicon Valley" companies (where a concentration of major software giants, such as Google, are headquartered) have called upon the government officials to support cycling to allow employees to commute by cycle. This focus on supporting the "creative classes"[6] (Florida, 2002; 2014) is not limited to the Silicon Valley. In London, a coalition of major corporations (that operate transnationally) called the CyclingWorks Campaign (2014) expressed the need for Cycle Superhighways to attract and retain skill labourers within the UK capital (see Transport for London, 2018). As these specific studies suggest, policies to support cycling have historically benefited majority populations. Whilst these histories of spatialised inequalities are not the same regardless of location (i.e., London and Silicon Valley cannot stand as proxy for the UK and USA), there are critical policy lessons to learn from the building of cycling provision that principally supports wealthier populations that cycle out of choice, not necessity. Furthermore, these specific cases of "lower-cycling" contexts do not suggest that cycling is universally linked to processes of gentrification, as lessons from "higher-cycling" contexts may suggest. As discussed above (see Section 3.6), cities across northern Europe have experienced increases of total numbers of cycling without significant displacements of populations.

3.9. Conclusion

This chapter has called for critical attention to an interwoven approach to mobility and data justice. Building upon Chapter 2, and discussions related to digital inequalities associated with "big data" and "datafication" processes, this chapter outlines observed contemporary cycling inequalities within specific "lower-cycling" (albeit higher compared to national) contexts such as London (UK) and Portland, Oregon (USA). Following an overview to critical discussions related to social justice, I then outline the conceptual work on "scripting". I argued that through an understanding how cyclists are imagined and governed through data uses, it then becomes possible to actively toward more egalitarian futures for cycling mobilities. As this chapter has emphasised, echoing the work of critical scholars that also seek to support more people participating in cycling, there are critical issues that must be considered to ensure more socially just futures for cycling (Spinney, 2021). More cycling in society is by no means an automatic good for society (Cox & Koglin, 2020), despite all the calculable and non-calculable benefits of riding a bicycle. As discussed within this chapter, cycle-specific

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[6] The term "creative class" emerged following the publication of Florida's (2002; 2014) work on gentrification and regeneration. In this account, Florida called for greater investment to support an emerging technological class. However, this has been met with significant critique following displacements of people that have subsequently been priced out of neighbourhoods in which the greatest beneficiaries are white middle-class populations (see Wainwright, 2017)."

infrastructures are presented as the most valuable means of "unlocking" urban cycling by addressing issues of safety within automobility dominant spaces, yet alone these are not sufficient at resolving the social injustices which may arise through investments to support contemporary cycling. Within some "lower-cycling" contexts, the main beneficiaries of existing dominant forms of cycle-specific infrastructures (albeit not exclusively) are economically active male cyclists, especially in cities such as London. I have argued that the "datafication" of cycling problematises existing tensions to cycling inequalities within "lower-cycling" contexts, as "big data" may valorise (Stehlin, 2014: 27) cycling journeys made by a narrow proportion of society. In the next chapter, drawing upon these critical foundations, I outline my research design to critically assess relationships between "datafication" of cycling and cycling related policy within "lower-cycling" contexts of London (UK) and across Oregon (USA).

Chapter 4: Mobilising literatures for comparative analysis

4.1. Introduction

In this chapter, I outline my use of a "mobile" ontology research that directly draws upon the literatures of mobilities to critically assess how "datafication" processes are influencing the delivery of cycling policy plans. I then outline and justify my use of "static" methods, including policy document analysis and semi-structured interviews within a mobile ontology. Next, I outline an international comparative analysis approach to review cycling policies and Strava Metro data uses at two regional sized government departments: Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA. I then discuss my approach to collecting policy documents related to cycling at TfL and ODOT. Following this, I detail the sampling of research participants to review how Strava Metro data have been utilised at TfL and ODOT. This is accompanied with a thorough overview of two data collection windows of this thesis, and assumptions of semi-structured interviews. Next, I outline how the literatures of mobilities and critical data studies (outlined within Chapters 2 and 3) are operationalised to analyse the policy document and interview data to address the research objective of this thesis that seeks to support cycling futures that are responsive to equitable and mobility just societies in an increasingly datafied world. I then critically reflect upon a three-month pilot study, and upon my own positionality as a cyclist and experiences working as a transportation professional responsible for the planning of walking and cycling infrastructures that influenced the analysis of the research data. I close the chapter with a discussion of the ethical considerations of this this thesis.

4.2. Research philosophy

Following on from Sheller's (2018) call to move away from sedentary ontologies, and to move toward a view of reality as complex and entangled, this research also takes "mobilities" as an ontological and epistemological position. In other words, by treating reality as a "process", and not a fixed entity, I treat all phenomena as socially produced. Thus, by moving beyond sedentary notions, I treat the reality as subjectively experienced. From this perspective, if I were to ride a cycle, I would consider my experience of doing so entirely different from someone else's emotional and embodied experience. Indeed, by employing a mobilities ontology to review data collected for this thesis, I hold the view for this research that the nature of reality cannot be treated as universally experienced by all people or captured as a single or isolated entity. By taking a mobilities perspective of the world, I understand realities as "brought into being" through complex social systems at multiple sites and scales that afford mobility for some, whilst shutting down the mobility propensity for others. Sheller (2018: 10) provides a concise summary:

> *"Rather than beginning social analysis from the sedentary perspectives of nation-states and societies, or even of individuals and groups, as if these were pre-formed objects bouncing into each other like billiard balls, we can begin by trying to detect the relations, resonances, connections, continuities, and disruptions that organize the world into ongoing yet temporary mobile formations. Everything, including movement, is contingent on other moves."*

As a multiple-disciplinary research thesis, there is recognition of a range of philosophical approaches, including transportation science (which often treats reality as fixed, orderly, and quantifiable); however, to write about mobility justice demands beyond thinking of social reality as a natural or universally experienced phenomenon.

4.3. Reconciling a mobile ontology with static methods

In addition to a theoretical impact of the "mobilities" paradigm (see Sheller & Urry, 2006), its influence has also contributed to critical debates regarding methods of researching mobile worlds. By critiquing the historical and static ontological and epistemological assumptions of researching movement, this led to the questions of how "mobile methods" (methods on the move) might bring researchers closer to understanding mobile lives. This has led to a departure away from reliance upon quantitative surveys and statistical measurement alone, to include non-quantifiable aspects of everyday mobilities, such as stillness (Bissell, 2008) and meanings of embodied performance (Spinney, 2006). Researchers such as Jungnickel & Aldred (2014), for example, explored how participants in their study utilised personal media devices to modify their sensory engagement with cycling environments. By engaging with the sensory, Jungnickel & Aldred (2014) bring attention to how senses, such as sounds, intersect with how cycling mobilities are experienced. For others, such as Spinney (2011), researching cycling "in-situ" has sought to review embodied aspects including the kinaesthetic (or sense of movement). Multiple strategies have been deployed by researchers to review this, including the use of video (auto)ethnographies (Spinney, 2011; Popan, 2020; Cox, 2019), "ride-along" methods (Brown & Spinney, 2010; Spinney, 2011; Spinney & Jungnickel, 2019; Steffánsdottir, 2014), and experimental uses of digital equipment to capture the "unconscious" bodily experiences of cycling (see Spinney, 2015; and Jones et al., 2016, for experimental uses of galvanic skin response data).

Whilst there has been a surge in academic interest to explore mobile method innovation, authors such as Dewsbury (2010) and Merriman (2014) encourage mobilities scholars to reconsider the need for mobile methods. In a paper entitled *Rethinking Mobile Methods*, Merriman (2014: 168) challenges work by economic geographers, such as Spinney (2011) and his use of cameras to record cycling in-situ, arguing that technological and methodological innovation of social science methods must not be viewed as neither natural nor necessary for understanding present-tense performances of mobile subjects. For Dewsbury (2010), recording present-tense mobility using technological means, such as using cameras, places too much emphasis on capturing "performances" of mobility when existing, well-established methods, such as interviewing, may suffice or even offer a more effective means of recalling mobility practices. In response to these critiques that suggest mobile methods may over-aminate research subjects, Spinney (2015) accepts Merriman's (2014) concerns and suggests that rather than seeing mobile methods as a replacement of more traditional methods, such as interviewing and archival studies, innovation should remain supplementary to new opportunities of understanding and ever-increasing mobile world. The idea of seeing mobile methods as supplementary echoes Urry's initial call for mobile methods, where mobile methods were not argued as a "replacement" for understanding a mobile world (see edited work by Fincham et al., 2010, and Büscher et al., 2011).

There are also, like any methods, practical limitations in the use of mobile methods. As discussed above, collecting data regarding utilisation of Strava Metro data by transportation professionals was imperative in addressing the research questions and objective of this thesis. Due to time and resource pressures faced by professional practitioners interviewed for this thesis, moving with the participants was deemed unfeasible. However, a key aspect of mobile methods is "being with" and so the desk-based nature of transport professionals also called for a more static approach. Whilst there are exceptions where researchers have successfully included mobile methods in cycling research with professionals (see Steffánsdottir, 2014), the decision was taken to employ wholly static methods, such as policy document analysis and semi-structured interview analysis to attain insights of Strava Metro data use. Furthermore, due to resource limitations of this thesis, whereby the researcher developed rapports with participants for two 12-week data collection windows, methods such as a walk-along or cycle-along would have added additional resource pressures for both researcher and participants. These resources would have included: requesting additional participant time, asking participants to obtain permission from organisations to leave work to participate in this study, and placing the onus upon participants to acquire access to relevant mobility devices, such as a cycle. Safety considerations also featured strongly in the decision not to move around with participants. Whilst I, the researcher, had over twenty-five years of cycling experience, I had never cycled in mega-city environments, such as London, nor in different national contexts, such as Portland, Oregon's city grid system of transportation. Furthermore, this thesis concerned how transportation policies determine and shape professional uses of app data sources such as Strava Metro, and how these in turn impacted decisions regarding data use. It did not seek to research how transportation professional participants experience cycling, but rather to critically reflect upon how policies and practices of using Strava Metro data might impact upon mobilities and mobility justice.

Whilst this thesis did not utilise "moving with" methods, it is important to acknowledge that very different results may have emerged. Asking transportation professionals to perform cycling manoeuvres in urban spaces that they had some (or considerable) impact in "staging from above" (Jensen, 2013), would have required entirely different research questions. Thus, the approach taken was to undertake semi-structured interviews with transportation professionals. Whilst other important actors, such as those who are affected by the decisions made by transportation experts was considered as part of this thesis, it too sits outside the scope of this work. For example, this work sets out to ascertain how policy and related to cycling supports decisions related to transport planning in London and across Oregon. This thesis is nonetheless heavily influenced by mobile methods as it is principally influenced by the field of mobilities and mobility justice; supplemented by research fields of critical data studies and public policy (as outlined with Chapter 2). The field of mobilities therefore underpins the thesis, and limitations to static methods are acknowledged.

The approach taken is qualitative. Statistical approaches that are positivist in design were not considered for this study as the standardisation of questioning may have restricted deeper insight into the views of participants. This research did not seek to test a research hypothesis, but rather to develop an understanding of how "datafication" processes are influencing the delivery of cycling policy plans. As a deeper understanding of the policies, practices, and perspectives of transportation experts was required to address the research questions and objective, a qualitative research design based on an international comparative analysis study was selected. The chapter next outlines this study's use of an international comparative analysis to address the four guiding research questions (which are recapped in the next section).

4.4. International comparative analysis

International comparisons feature prominently in research related to cycling as a mode of transport (Buehler and Pucher, 2012; Popan, 2019. As discussed in Chapter 2, examples of "best practice" are attributed to the "higher-cycling" observed in countries such as Denmark, Germany, and the Netherlands. Cases of "high cycling" are thus viewed by many as a suitable template to aspire to. This is evident in the number of cycling policies across the world[7] that now assess the suitability of cycling infrastructures based on indicators such as: attractiveness, cohesion, directness, comfort, and safety which derive from the CROW Manual (Spinney, 2021). Following with this trend, this study focuses on the governance of cycling through policy and data uses in two bounded locations: London (UK), and across Oregon (USA). Data collected for this thesis only exist and relate to their bounded and defined locations. As such, data related to specific contexts cannot be generalised for national contexts (e.g., London is not representative of conditions across the UK, and Oregon is not representative of the USA). This is further underpinned by conditions of cycling being relatively "higher cycling" contexts in "low cycling" national contexts, especially given the positive policy plans and autonomy to support cycling across London and Oregon.

As discussed in Chapters 1 and 2, software companies such as Strava have a transnational market share (see Chapter 1, Figure 1 for a visual "heat map" overview of the global use of the Strava app), and therefore their impact is also transnational. Due to the globalisation of data, this study compares how policies shape cycling and data use, and how Strava uses within public transport administrations actively "stages" (Jensen, 2013) of cycling. As a starting point for this comparison, I made use of media sources that mentioned Strava Metro uses in public administrations. Media journalists writing for UK audiences (see Walker, 2019), therefore, offered an appropriate starting point for this research, and this had significant ramifications for where the research would take place. As Transport for London (TfL) and the Oregon Department of Transportation (ODOT) had purchased Strava Metro data, I made the decision to base this study around these two regional transportation departments for comparative analysis. Additional departments were considered for inclusion if they could be studied within project costs, and mitigation was considered to collect data virtually, such as tele-meetings, if additional opportunities arose. Interview data was collected in two 12-week windows. Expanding upon the summary outline, above, I next provide an overview to the two organisations that I structured this thesis upon: Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA.

Transport for London (TfL)

Overseeing transport in UK capital, London, this transportation authority is responsible for the management of the Transport for London Road Network (TLRN), London Buses, London Rail and Underground services.

[7] The success of the CROW (2007) Manual's approach to assessing cycling infrastructure has been imported to countries in the UK (see Welsh Government design guidance, 2021) and cycling strategies in Colombia (van Laake and Peña, 2021).

Whilst TfL are responsible for the regional governance of mobility, London also shares the management of roads with London Boroughs. As such, TfL does not hold autonomy over London Boroughs, and must work in collaboration with local councils to deliver mobility infrastructures, particularly those that are outside of the Transport for London Road Network (TLRN). According to official statistics, between 2001 - 2011 census data saw a significant increase in commuter cycling within London. As discussed in Chapter 3, despite observed increases in the total number of commuter cyclists, and a concerted policy and funding to promote cycling to London's populace, London also exhibited a decline in age and gender diversity between UK census data collection (Aldred et al., 2016).

The Oregon Department of Transportation (ODOT)

The Oregon Department of Transport (ODOT) were the first department in the world to request access to Strava app data to support planning and administration of cycling with the state of Oregon (Walker, 2017). Like Transport for London (TfL), the Oregon Department of Transportation (ODOT) is also responsible for managing some road networks in the US State of Oregon. However, in contrast, ODOT does not oversee the management or delivery of transportation services such as bus networks or train services. For example, in the Oregon city of Portland, a regional planning body called Portland Metro are responsible for the delivery of light rail services within the city region. To further complicate the administration of mobility across Oregon, infrastructures are managed by numerous departments (ODOT, 2016). For example, the transportation road networks within the US city of Portland are managed by the Portland Bureau of Transport (PBOT), whilst roads outside the city boundary are managed by the Oregon Department of Transportation (ODOT), and interstate highways are managed by the US Department of Transportation (USDOT). This means that unlike London, transport policies in Portland lack integration and oversight and this may have an impact on planning for socially sustainable cycling. Thus, although both sites have similarities in that they are relatively affluent western cities, they also have significant differences in terms of governance and policy development.

The use of "regional" for the purposes of this thesis, concerns transportation administrations that work within the national contexts, and above local contexts. For example, Transport of London (TfL) has devolved administration of transportation related matters, such as the Transport for London Road Network (TLRN) and the London Underground, yet also exists within the UK national context (e.g., UK Department of Transport). Although the DfT have limited direct governance over some devolved matters within London, there is also national guidance related to cycling provision, such as the DfT Publication of *Gear Change* (2020) and *Local*

Transport Note 1/20 (2020). Furthermore, TfL must work in collaboration with local levels of government to deliver schemes, including London Boroughs. For the purposes of this thesis, I also classify the Oregon Department of Transportation (ODOT) as a regional government body. The rationale for this, like TfL, is that the administration also sits within a larger national context, such as the United States Department for Transportation. Furthermore, ODOT, do not have fully political autonomy regarding transport decisions. This includes working with city authorities, such as the Portland Bureau of Transportation (PBOT) and planning Metros, including Portland Metro. Although this thesis is predominately concerned with the regional scale of governance by TfL and ODOT, consideration to wider governance structures must be considered. Indeed, whilst the regional administrations viewed for this thesis have some political autonomy to support cycling, I emphasise that these administrations work within a governance structure alongside both national and local contexts.

4.5. Data collection process

In this next section, I outline the steps taken to collect research data to address the four research questions of this thesis. As a reminder, these four questions seek to address the following:

- What is the transport policy "problem" – at the regional scale – that determines injustices in cycling and cycling data?
- How is Strava Metro data used by transportation authorities at regional scale of government, and across different national contexts?
- How does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?
- How can Strava Metro data use by transportation professionals be thought to deliver more equitable and just velomobile futures?

These four questions echo the objectives of the thesis and the main objective to understand the impact of the "datafication" of cycling in reimagining more equitable and just velomobility futures. To move toward answering these questions, the methodological strategy was based on different methods. Research question 1 is necessary to set the scene for the following research questions and was approached through a document analysis of documents published by TfL and ODOT. Research questions 2 and 3 were addressed by holding semi-structured interviews with transport professionals and collecting material regarding Strava Metro uses by transportation professionals at regional government departments. Research Question 4 provides a re-analysis of the previous three research questions to address the central objective of this thesis, that seeks to support cycling futures that are responsive to equitable and mobility just societies in an increasingly datafied world. The outcomes of this combined approach are given in the remainder of the thesis. First, however the rest of this chapter outlines the process taken in terms of data collection using document analysis and interviews.

Policy document collection

As discussed above, policy documents were required to address Research Question 1 of this thesis, to set the context to cycling and data use at the two regional governments: Transport for London (TfL) and the Oregon Department of Transport (ODOT). By articulating the transport policy context at the regional government scale, and how these determine injustices in cycling, the research question thus provides the analytical foundations to critically assess Research Questions 2, 3, and 4 (outlined, above in Section 4.5.). Policy documents were included for analysis based on the three criteria. First, policy documents had to published by (or on behalf of) Transportation for London (TfL) or the Oregon Department of Transportation (ODOT) regional governments. Secondly, policies did not explicitly need to mention cycling or cycling data but were included only if they were related to surface transportation with the regional governments. Thirdly, documents published after 2009 were considered for analysis, coinciding with the launch of the social media and fitness app, Strava. A list of documents analysed is displayed in Appendix A. To search for the policy documents, I first explored the regional government websites of Transport for London (TfL) and the Oregon Department of Transportation (ODOT). For the Transport for London (TfL) website, I first reviewed the TfL website page entitled *Publications & Reports* (see Transport for London, 2022) and filtered by the mode "cycling". Though this search query, I was directed to all Transport for London (TfL) publications, including the TfL *Cycling Action Plan* (2018).

Upon review of these documents, I noted how these standards and plans directly supported an overarching Transport for London policy, entitled the *Mayor's Transport Strategy* (2018). All documents related to this strategy were thus included for analysis, including specific plans for Vision Zero and safety, walking, and a "Healthy Streets" approach. For the Oregon Department of Transportation (ODOT), I followed a similar procedure, starting with an exploratory review of policies and publications available on the regional government website. To start this search, I reviewed the ODOT *Programs* webpage that provided resources related to *The Oregon Bicycle and Pedestrian Program.* Following a review of this page, I observed how a cycling plan, entitled the ODOT *Bicycle and Pedestrian Plan* (2016) formed one part of the overarching *Oregon Transportation Plan* (2016). As part of this plan, additional plans such as *Safety Action Plan* (2016) and the *Public Transport Plan* (2016). As these plans supported the delivery of a central plan, they were also included for analysis along with the ODOT *Bicycle and Pedestrian Plan* (2016). To identify additional publications for inclusion, I used search terms such as "cycling"; "cycling data"; and "Strava" on both the Transport for London (TfL) and Oregon Department of Transportation (ODOT) websites. This latter approach did not lead to the identification of additional publications for inclusion.

The publication of cycling policy plans indicates that there is policy appetite to support more people to cycle across London and Oregon. Indeed, as Brezina et al. (2020) observe, in contexts from Austria where strategic plans are published, cycling provision implementation was perceived as more likely by transportation professionals in scenarios where a strategic vision had been published. These cycling policy plans therefore cannot be treated as an isolated phenomenon, rather as a dynamic process which will likely be redrafted, revaluated, and refined over time. Furthermore, personnel responsible for the drafting and implementation of the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), are also assumed to change over time. This will likely have significant ramifications over the implementation of the he TfL and ODOT cycling policy plans. For example, there is an increasing body of literature that discuss the role of beliefs and values held by transportation professionals, which are shaped by their educational training (compare Rose, 2018; Dill & Weigand, 2008). Data related to professional experience (e.g., number of years) were not collected as part of this thesis, and therefore must be accepted as a limitation. An overview of all policy documents reviewed for this thesis is presented in Appendix A. I next discuss the inclusion criteria for semi-structured interview data collection.

Sampling interview participants

Participants were sampled through purposeful and snowball sampling techniques (Bryman, 2016). Participants were specialist experts that had used Strava Metro products within their existing or previous work as a public servant. The participants of the research include experts only with a vested interested in the delivery of transportation policy. The views of Strava app users were not included as part of this study (for a review of Strava app user perspectives, see Barrett, 2017). Thus, the main inclusion criteria for participation within the study require actors to have worked with Strava Metro data for a government institution, or have a direct influence, within a professional capacity, over its use (e.g., the software company Strava). Interviews with transportation professionals that did not use Strava Metro data were also conducted if participants were key stakeholders.

As an international comparative analysis, which included a broad scope of transportation professionals, the aim was to recruit a range of professionals including data scientists, transportation researchers, and software developers. However, civil servants or politicians (i.e., law makers) were not included as part of the study, as research focused policy implementation rather than policy formulation. Bryman, (2016: 416) acknowledged that it is impossible to predict how many participants are required to reach theoretical saturation; and guidance by Adler and Adler (2012) in Bryman (2016), recommends setting a target between 12 interviews to a maximum of 60. However, in this research it was found that holding eight semi-structured but extended interviews with transportation professionals was sufficient as their experiences and perspectives directly related to the research objective and questions. Participants were representatives of the following organisations: Oregon Department of Transportation (ODOT), Portland Bureau of Transport (PBOT), Strava, Sustrans, and Transport for London (TfL).

The semi-structured interviews were informed by the researcher's exploratory review of Strava Metro data acquired through the European Social Research Council (ESRC) data repositories. Based on an exploratory review of Strava Metro data, which I discuss in Section 4.7., I obtained an understanding of how Strava Metro data samples are aggregated and observed how samples contain bias toward younger male app users. This initial review of Strava Metro data provided the researcher with a greater understanding of sample characteristics and an insight to how Strava Metro data samples are aggregated before being shared with public administrations. Following this, I forwarded a provisional interview guide to topics directly related to the research objective to research participants ahead of interview. For transportation professionals at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I focused my interview questions around three core topics, (1) the policy needs for Strava Metro data, (2) uses of Strava Metro data, and (3) perspectives, challenges, and issues of using Strava Metro. The first topic concerned the policy context regarding why regional government departments required Strava Metro data. The second core topic centred on how Strava Metro data uses responded to the cycling plans and policies at Transport for London (TfL) and the Oregon Department of Transportation (ODOT). The third core topic concerned perspectives regarding Strava Metro data samples, challenges of using Strava Metro data and of working with Strava. Whilst semi-structured interviews sought to discuss these three core topics, rigid interview questions were not used. This decision was based upon the experiences of pilot interviewing for this thesis, which I also discuss further in Section 4.10. For interviews conducted with research professionals outside of regional government departments, including Strava, Sustrans, and the Portland Bureau of Transportation (PBOT) a different format was utilised. Rather than follow a three-topic guide, I instead focused upon perspectives of Strava Metro data only.

Interviews were employed to place an emphasis upon the perspectives of the interviewee (Bryman, 2016) and were used here to obtain professional perspectives and insights of using commercial Strava Metro data for the governance and planning of cycling. The interviews were designed to be semi-structured and were based upon key debates that emerged from the review of literature. Semi-structured interviews were designed to allow participants to elaborate and emphasise key debates, and to provide insight into what they see as important and relevant (Bryman, 2016: 467). Structured interviews and surveys with little or no deviation in participant responses were not considered for this research. Rational and factual responses (Bryman, 2016) were sought from interviewees, thus unstructured ("open") interviews were not considered for this research, as some structure was required to ensure cross-compatibility for international comparative analysis. Participants were representatives of professional organisations and may have time restrictions, and therefore some structure was important to ensure the "core" topics were addressed during interviewing. These included discussions regarding Strava Metro data need and acquisition, and to unpack how Strava Metro data were used by transportation professionals to support government plans and policy. An example of questions asked during semi-structured interviewing are presented on the interview guide (Appendix B). Participants were informed of the study via the participant information sheet (Appendix C) and participant consent form (Appendix D). During interviewing efforts were made to minimise researcher bias by sustaining non-judgement to participant responses to minimise researcher influence upon answers (Bryman, 2016: 472). Efforts to avoid agreeing and disagreeing with participants are also important to minimise researcher influence. Interviews were conducted in person and were recorded with the permission of the interviewee. Participants were not coerced into providing a verbal recording for interview, and their participation was entirely voluntary. Notes were taken during interviewing to allow for further elaboration and quality control. Upon interview completion, written and recorded data were imported into proprietary f4Transkript software for transcription. Transcripts were completed within one week of the initial recording. Transcriptions were conducted by the lead researcher to ensure familiarity with qualitative data and were discussed with the research supervision team. Participants were also asked if they could be contacted for follow-up interview (Bryman, 2016: 468).

All interviews were supported by additional discussions and email correspondence with other professionals at the organisations listed above. No interviews were conducted with organisations that did not have a vested interest in Strava Metro data, as identified through discussions with Strava, pilot research, and through policy document analysis. Interviews were conducted at a regional scale, at Transport for London, and ODOT, rather than national level of government level (i.e., UK Department of Transport, and United States Department of Transportation). To recruit participants for this study, I was required to communicate my research objective directly with transport professionals. Prior to starting the research, I had no previous connections with any transportation professionals that had used Strava Metro data to support decision making related to cycling. Although participants were not a "hidden" population, they are classified as a "rare" population as few transportation professionals had used Strava data sources within scope of the study, and therefore recruitment for this study was time intensive. The most successful strategy for sampling was through a snowball sampling technique (Bryman, 2016), including introductions to transportation professionals from individuals at organisations such as the Transportation Research & Education Center (TREC), Portland State University (PSU), and the Portland Metro Government. Furthermore, purposeful sampling was also utilised through contacting organisations directly using telephone and email information noted on websites, such as Transport for London's (TfL) CYNEMON model that referenced Strava Metro data use. Snowball sampling also applied here where transportation professionals recommended other participants, including the identification of use at Transport for London (TfL) Operations, for example. Interviews were conducted face-to-face in the cities of London and Portland at participant's choice of location. Typically, meetings were held at the workplaces of professionals, though a couple of interviews were conducted in public cafés. All interviews were scheduled for one-hour using Microsoft Office meeting scheduler; the minimum interview time lasted 42 minutes with a maximum interview time of 1 hour and 27 minutes.

As discussed above, the researcher had no direct connections prior to commencing the project and thus employed multiple strategies to promote the research, and to recruit additional participants that met the inclusion criteria. Attempts to recruit participants included attending transportation research and policy conferences. During the study, two interviews with transportation experts were agreed in principle but did not materialise. Reasons for this were both personal and work-related. Efforts to reschedule interview times were attempted via telephone communication and were not pursued if the researcher did not hear a response after a second email attempt. Furthermore, two potential interviewees were identified and contacted during the data collection window, though changed job roles after being recommended through snowball sampling. In the next section, I outline the use of data collection windows, starting with interviews conducted in the US city of Portland.

Data collection in Portland (Oregon), United States of America

For study participants based in the United States, I was fortunate to be offered a visiting scholar status at the Portland State University (PSU) to research this thesis. After the Oregon Department of Transportation (ODOT) was selected for research, I worked with my supervision team to explore options of attaining access and travel funding. On my behalf, Dr Behrendt, who had supported this project as a lead supervisor, contacted Professor Dill, head of the Transportation Research and Education Center based in Portland State University (PSU), regarding opportunities for visiting status. Professor Dill accepted and offered a visiting scholar position to work from PSU. As part of this, I was also offered the opportunity to support a recent cycling data project which sought to evaluate commercial sources of data such as Strava Metro. However, I was unable to work simultaneously on two separate projects and therefore was required to dedicate energy to collecting data for this thesis. My position at Portland State University (PSU) as a visiting scholar offered valuable access to transportation professionals in various government institutions based in the city of Portland. Prior to travelling to the US, I had contacted individuals based in organisations such as the Oregon Department of Transportation (ODOT) and the Portland Bureau of Transport (PBOT), however, this project benefitted considerably from access to transportation professionals that worked in collaboration with researchers at Portland State University.

To recruit additional participants, I also attended the American Pedestrian and Bicycle Professionals (APBP) conference (Portland, Oregon, 25-28 August 2019). At the latter, I met two Strava Metro representatives who were in attendance, who had also been working across the Portland city area to promote Strava data to transportation professionals from transportation organisations including Portland Metro, Portland Bureau of Transport (PBOT), Portland State University, and the Oregon Department of Transportation (ODOT). Due to work commitments, these Strava representatives were unavailable for formal interview but did meet for lunch to discuss future products and offered suggested contacts who I could contact. In a final attempt to recruit participants in the US, I prepared an online seminar based on this research at the Portland State University's Transportation Research & Education Centre (TREC). This platform offered an opportunity to share research with transportation researchers and professionals across the USA, however, the opportunity did not result in any additional recruitment.

Data collection in London, United Kingdom

Upon returning from fieldwork in the US, I then focused attention on collecting data from participants based in London. Recruitment in the UK was seemingly easier than recruitment in the US. There are several observations that assist in explaining this. I had gained additional experience of recruiting participants from time spent in the US. I had learnt what worked well, and what didn't. Recruitment through advertisement via conference webinars, for example, were not effective. Reflecting the lessons from the pilot research (see Section 4.7.), the most useful approach I had observed was recruitment through snowballing and recommendations from other professionals for introductions. As such, once I had returned to work following data collection in the US, I compiled a list of all connections I had with Transport for London (TfL) and other transportation professionals based in the city of London. Whilst I had made connections with TfL colleagues from attendances at conferences such as the Hackney Cycling Conference (2016) and the London Walking and Cycling Conference (2019), I did not have previous connections with professionals that had used Strava Metro data. To resolve this, I referred to an article published by the *Financial Times* (2019) which included interviews with several transportation professionals related to Transport for London's decision to renew a contract to purchase Strava data for the next four years. Upon reviewing this article, I subsequently contacted each transportation professional that had commented on this contract renewal. To gather the perspectives from representatives from Strava, I contacted two UK-based Strava employees who I had contact details for following discussions with Strava employees based in the USA. The data collection window for this thesis closed in March 2020, coinciding with the SARs COVID-19 pandemic which resulted in significant mobility and lifestyle disruption at a global scale. In the next section, I discuss the approach to critically analyse research data collected for this thesis.

4.6. Data analysis process

In this section, I outline the analytical steps taken to review the research data to address the four research questions. As a first step, following the collection of policy document and interview data, backup copies were uploaded directly to NVivo 12 analytical software. As a preliminary step before analysing data, I first read through all the data, adding annotations to assess topics of interest. Harnessing NVivo 12 software, I also queried policy documents and semi-structured interview data using a word frequency search to familiarise myself with the research data. Drawing upon Braun & Clarke (2006) I first used a thematic analysis approach to support the comparative assessment of cycling plans and policies and interview data across the two regional governments assessed for this thesis. Following the initial review of all data included for this thesis, I then explored the use of manual coding to explore and interrogate the data with direct reference to the literature review material presented in Chapters 2 and 3. Specifically, using an abductive approach to coding where codes were generated with reference to the existing literatures and also "bottom-up" from the data, I sought to specifically assess how all research data addressed issues of cycling inequalities, which I discussed within Chapter 3. I explored the commonalities and differences between Transport for London (TfL) and the Oregon Department of Transportation (ODOT) to ascertain how social inequalities and injustices in cycling were acknowledged and addressed by the regional government departments.

This is complemented by literatures on the "staging of mobilities" model (Jensen, 2013), with related working on "scripting" (Akrich, 1992; Akrich and Latour, 1992). The analytical lens was added following the collection of data, following a cycling crash that I experienced whilst researching this thesis. I explore the impact of researcher positionality further in Section, 4.8. Whilst I had generated a provisional codebook to support the generation of codes, to support the identification of themes across international contexts, I did not rely entirely upon analytical software such as NVivo 12. Rather, the use of analytical software served a role only to comprehensively explore policy document and interview data. Instead, the thematic analysis emerged through the writing process, of drafting and redrafting analytical thoughts regarding justice and injustice. Through the process of writing, I explored the missing and overlooked debates of social justice that an interwoven approach toward mobility justice and data justice demands.

Following the generation of initial themes through thematic analysis, I next reviewed initial findings through a critical discourse analysis lens to critically reflect upon why policy plans at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) "script" certain variants of cyclists above others. Discourse analysis has been applied to cycling policy research by authors such as Caimotto (2020), Balkmar (2020), Tschoerner-Budde (2020) to critically reflect upon the "doing" of politics. Thus, to support the analysis of cycling policy plans published by TfL and ODOT, I offer consideration to poststructuralist analysis guidance developed by Bacchi & Goodwin (2016) termed "*what's the problem represented to be?*" (WPR). The WPR has been applied directly across varying research disciplines, including education policy (Tawell & McCluskey, 2021). By utilising the WPR approach, initially developed by Bacchi (2009), I critically reflected upon questions of "why" cycling policies construct specific "problem(s)" which require policy intervention to resolve. As such, for the first data analysis chapter, which draws upon guiding questions posed by Bacchi & Goodwin (2016), I critically reflect upon why TfL and ODOT frame "problems" related to cycling, which in turn have significant ramifications regarding the implementation of policies (which I review during the second data analysis chapter on interview data with transportation professionals). To support this analysis, I selected four guiding questions developed by Bacchi & Goodwin (2016):

- what's the policy "problem" represented to be? (WPR)
- What deep seated assumptions underlie these representations?
- how has the representation of this "problem" come about?
- what is left unproblematic in this representation?

As a final analytical step, I adopt Bacchi & Goodwin's (2016) recommendation to reflect upon my own biases and assumptions as a researcher, to acknowledge how the analysis of data is shaped by my reading of literatures (such as social justice) and personal experience. In the next section, I provide detail of a pilot study conducted in 2018, which influenced the methodological and analytical approach of this study.

4.7. Impact of three-month pilot study

During 2018, a pilot study was conducted to test the proposed use of semi-structured interviews for the main study. Whilst qualifying as a "pilot" or "test-run" for the main data collection windows, the pilot study significantly impacted upon the overall design of the project, in addition to the researcher's understanding of Strava Metro data and its potential uses. In this next section, I reflect upon the exploratory analysis of a Strava Metro sample, and pilot interviews, which influenced decisions made to critically assess Strava Metro data use within public administrations. To do this, I first start with a detailed reflection of an exploratory analysis of a Strava Metro data sample of one UK city.

Reflections on Strava Metro data

Before conducting any semi-structured interviews (pilot and main study), I held the belief that (at a minimum) a basic understanding of Strava Metro dataset's characteristics was essential for this thesis research. Thus, I acquired a sample of Strava Metro to conduct an exploratory statistical analysis to support the generation of research questions. Specifically, I sought to ascertain Strava Metro data samples characteristics such as aggregate number of trips, trip length, and distribution over times of day and year. Initially, I attempted to acquire data relating to London or Oregon; however, due to the contractual agreements Strava agree with public administrations, access to these data was not available to the public. To get around this issue, I thus acquired a Strava Metro sample from the ERSC Urban Big Data Centre (UBDC), hosted at Glasgow University. After signing contractual agreements with the UBDC, I was granted access to a Strava Metro dataset for the UK city of Manchester. As part of these agreements, I confirmed that I would not use Strava Metro data for any commercial purposes, nor would I share the data without prior consent. I also confirmed that I would encrypt (password protect) the data for additional security, and I agreed that only the lead researcher or main supervisor could review these data directly. Due to the time taken to acquire a Strava Metro data sample (which exceeded three months), I did not seek to acquire an additional sample. Comparisons with other research papers reflected similar results, and thus the view was taken that limited insights would be acquired by assessing the sample characteristics for a different city. Notably, the results of the exploratory analysis confirmed existing studies insights regarding Strava users (see Musaka and Selala, 2016; McArthur and Hong, 2019). As shown in Table 1, the Strava Metro data sample for Manchester (October – December 2018) included 23583 unique users, but notably the average distance of cyclist trips exceeded 23 kilometres, with a median of 14 kilometres. This report is consistent with the findings reported by researchers such as McArthur and Hong (2019), who noted that the average distance of trips for Strava users exceeded 20 kilometres.

Age	Male	Female		
< 25	1160	238	Cyclists	23583
25 - 34	3192	625	Trips	251809
35 - 44	4886	717	Average Distance (metres)	23545.788519061409
45 - 54	5277	663	Median Distance (metres)	14366
55 - 64	1973	241	Average time (seconds)	5018.8937463077052916
65 – 74	440	32	Median time (seconds)	2852
75 - 84	37	0	Average Uploads	443.3813
85 – 94	3	0	Commute Counts	163304
>95	7	2		
Age Unknown	2805	510		

Total	19780	3028	**Gender Unknown** 775	Total 23583

Table 1: Strava Metro age demographic data in the city of Manchester (UK) 10/10/2018 – 31/12/18 (Data licenced by Strava, 2019)

The demographic figures presented for the city of Manchester are consistent with findings for male sample skewness noted in studies in Australia, Canada (Boss et al., 2018), South Africa (Musaka and Selala, 2016), and other UK studies (McArthur and Hong, 2019). Though comparison between the Manchester data is not possible as the demographic reports are collated for periods of 3 months (i.e., there is no indication for understanding the total number of cyclists for 2018 using Strava Metro data alone). However, the samples are largely representative of male users, more than 80%. Table 2, below, outlines a comparison of different time scales, which provide an indication of gender differences.

	Male	Female	Gender Unknown	Total
January – December 2017 (12 months)	47241 (82.10%)	7755	2542	57538
January – March 2018 (3 months)	18424 (84.61%)	2633	719	21776
April – June 2018 (3 months)	31616 (82.24%)	5331	1475	38422
July – September 2018 (3 months)	31684 (82.46%)	5476	1364	38524
October – December 2018 (3 months)	19780 (83.87%)	3028	775	23583

Table 2: Strava Metro gender demographic data in the city of Manchester (UK) 10/10/2018 – 31/12/18 (Data licenced by Strava, 2019)

Strava supplied three types of data in comma separate value (.csv) format to accompany demographic summaries of: (1) "origin-and-destination" data; (2) "node" data; and (3) "edge" data. The first relates to origin-and-destination data that indicates where a journey starts and ends. The Strava data are rounded up to the nearest 5 riders, so 8 riders with the same origin-destination data are rounded to 10, for example. Resulting from pre-processing, Strava Metro samples are aggregated to comply with data protection laws, such as the

European Union General Data Protection Regulation (GDPR) implemented in May 2018 that requires businesses to protect personal data. This aggregation applies to samples in both the UK and USA. Consequently, the data of Strava users who have "opted-in" and volunteered data to the Metro project, which permits Strava to share journey data with other parties, cannot be disaggregated[8]. For example, samples cannot be analysed by demographic information such as age or gender. Although samples are aggregated, Strava supply a demographic table to accompany these data products. Summaries for demographic information for 2017 Manchester users are illustrated in Tables 1 and 2.

The second is node data which indicates average estimated and aggregated cyclist waiting times at junctions, and the third type of data are edge, which provides a total estimated number of cyclists on a segment (such as a street) on a given hour. I use the word 'estimates' as volunteered Strava data are assigned to specific geographies by Strava regarding how to match rider data with spatial data (i.e., processing of data). Other variables, such as type of cycle (optional volunteered user data), and other data that may be viewed redundant or compliant with existing data privacy legislation (such as volunteered heart rate data) are not shared. Though demographic summaries are supplied with the Strava Metro data, the demographic aspects are not included within any of the three types of spatial data. Therefore, data cannot be filtered or compared based on rider demographics. For example, the differences between male and female riders within datasets cannot be compared, and equally the characteristics of riders based on age cannot be compared. As such, variables including total ride distance, or route preferences cannot be ascertained for male only cyclists, female only cyclists, younger / older cyclists. This is important, as the literature suggests, there are many types of cyclists who will experience cycling differently. These concerns may involve sense of safety, or differently abled abilities and manoeuvres (decisions and actions during rides) and tactics (decisions about routes prior to rides). Indication of whether different Strava cyclists share ride preferences, for example, avoidance strategies of certain infrastructures cannot be determined. It can only be achieved using samples that include 'all' Strava cyclists that contribute to the Strava Metro project. Significantly then, it is not possible to disaggregate data. This aggregation by the company Strava seeks to ensure that individual user privacy is protected, but because of quantitative aggregation, Strava Metro data treats all cyclists as one collective group, in terms of age and gender, therefore individual characteristics of the sample are lost by the process of "cooking" of data (Kitchin, 2014). Taking these observations forward, I next outline the analytical lessons learnt from conducting pilot interviews with participants.

[8] At least not directly. Researchers such as Huber and Lißner (2019) outline their multi-step methodology to disaggregate Strava Metro samples based by comparing observed origin-and-destination samples.

4.8. Researcher positionality

Over the course of this thesis, my personal experiences had a significant ramification upon the analytical decisions made. Whilst I have received training in "scientific method" and "objectivity" from a background in physical sciences, it is important to recognise how the researcher's own values and experiences throughout the course of this study had changed; and thereby influencing (at least indirectly) the prioritisation and analysis of data contained within this study. This is not only limited to encounters with critical literatures presented within *this thesis,* but also directly related to experiences encountered over the five years of this study. Indeed, had I submitted this thesis sooner (say within three years), the analysis of data would have been different. Life experiences thus contributed to this study, and thus selected experiences that impacted upon this study are discussed. In the next section, I discuss two life events which influenced this study. After introducing these experiences, I then outline how these relate to (1) organisational practices, which would be relevant to professionals working across different contexts such as TfL and ODOT, and (2) a reflection upon the limited traction "big data", and thus "datafication" has in capturing emotional and embodied experiences.

Reflections on cycle accident, July 2020

In March 2020, the UK Prime Minister announced the closure of non-essential retail and enforced local lockdowns to prevent the spread of Coronavirus (COVID-19), a highly infectious SARs disease that necessitated the slowing down and restriction of mobilities to prevent its spread. As a result, local authorities and boroughs were also charged with changing their strategic transportation priorities to support "socially distant" walking and cycling. Emergency funding was supplied by relevant transportation administrations to empower local authorities and boroughs to build pop-up cycle lanes to support cycling (Walker, 2021). Using one of these "pop-up" pieces of cycling infrastructures, I experienced a significant cycle accident after my body had flipped over the handlebars of a road cycle. Whilst indicating to turn left with my left arm outstretched, the front wheel of the road-bike briefly contacted a raised kerb, and I subsequently lost control of the cycle. Shortly after, the briefest of moments, I landed onto an asphalt surface. Physical recovery for this took approximately four weeks, yet I have since become a far more cautious and nervous cyclist. However, whilst my attitudes toward safety had changed, my analytical perspective also shifted. Retracing my memories of that incident, I asked how did this incident occur? I've replayed the parts I can recall, to help make sense of this.

First, there's a moment of indecision. I've followed a cycle lane and have ended up on a road with motorised traffic. Second, I've panicked and increased my cadence and power to travel up to 30 kilometres an hour to maintain comparative speeds with motorised traffic. Third, I've reached a velocity which I cannot easily manoeuvre with. Fourth, another indecision moment: leave the road now, or join a dual carriageway (two-lanes of motorised traffic in one direction) in approximately 200 metres. I elected to try and leave the road to avoid mixing further with motorised traffic. The front wheel of the road bike touched a raised kerb and I've gone, according to a GPS "tracker", from 25km/h to 0km/h in about 3 seconds. There is no blame; this was an accident. It is also, however, a combination of my own (in)competence and skill, cycle lane designers, planners, engineers, politicians. All these factors, however subtle, contributed to this accident. After (physically) recovering from this incident, I started to pay far more attention to theorising infrastructure, particularly concerning how these design velomobilities. As already discussed with Chapter 3, conceptual approaches such as Jensen's (2013) "staging" model features predominately within this thesis. The experience of a cycle accident played a significant part in this. Next, I discuss the role of professional experience and how this has impacted upon the analytical decisions made.

Reflections on working as an active travel practitioner, February 2021

In December 2020, I applied for a role which would support local authorities in Wales audit and plan for future walking and cycling networks as part of the Welsh Government Active Travel (Wales) Act 2013. For the first time in a short career researching and critiquing policy related cycling, I became an active travel practitioner who actively relied upon technical guidance as outlined in policy. Becoming a transportation practitioner had a significant, and perhaps the most influential impact upon my relationship with the research data collected for this thesis. In summary, upon collection and initial drafting of the data collected for this thesis, I started work as a Network Development Officer, working in collaboration with local authorities in Wales to draft future walking and cycling networks. The task for this work involved creating an Active Travel Network Map (ATNM) which outlined both Existing and Future walking and cycling routes. Existing routes would be added to the ATNM after passing an audit, designed by the Welsh Government, but based on the Dutch CROW manual and other leading guidance. Future routes, once approved by the Welsh Government following statutory consultation with the public, are then eligible for funding. This process sought to support consistency of design across local authorities, and to prevent ad hoc infrastructures being implemented. Critically, future routes must adhere to a set of standards to ensure designs support inclusivity, for example, including the use of dropped kerbs and tactile paving throughout. Whilst the ATNM process is a significant step forward in the delivery of high-quality, walking and cycling infrastructures and provision, teething issues with the design guidance are visible. It is these teething issues working with policy guidance that helped reformulate my thesis research design. To elaborate this, I expand upon the steps taken to develop an ANTM for one local authority in Wales. The process of development of ATNM maps did not occur in a linear approach, but are outlined as steps for clarification:

1. Map key locations within local authority boundaries, such as schools, healthcare facilities, and employment zones.
2. Review future local development plans, including new residential areas.
3. Review official statistics, such as the Welsh Index of Multiple Deprivation (WIMD) data, reported traffic accident data, and car ownership data.
4. Review potential for modal shift using forecasted projections, such as the Propensity to Cycle Tool (PcT) based on 2011 census commute data.
5. Review pre-statutory and statutory public consultation data for strategic and infrastructural comments.
6. Create and propose future walking and cycling routes based on the corroboration of data sources, including sources outlined in the previous steps.
7. Assign new future routes with unique route identifiers, route descriptions, and route type (for example: primary, secondary, local; and walking, cycling, shared use).
8. Assess routes for funding and delivery prioritisation (short-term, medium-term, long-term) based on geospatial analysis of data, developed using an ArcGIS model that considered route proximity to key sites of interest and deprivation data.

Focusing on the final step of prioritisation, however, is worth elaborating as it directly impacts upon the allocation of future funding of walking and cycling infrastructures. For the Welsh Government Active Travel Network Map (ATNM) process, all future routes for investment must be ranked for prioritisation of funding, short-term, medium-term, and long-term. Routes that are identified for short-term investment are therefore routes that should be considered first for investment, based on a prioritisation matrix. Examples of the matrix include route proximity to "purposeful" sites of interest, such as schools, healthcare facilities, and employment zones; Welsh Index of Multiple Deprivation (WIMD) data; modelled forecasts of mode shift toward active modes. Data available to create a model to determine prioritisation are thus dependent upon available data, and of the transportation professional's decisions of what data to include. For example, in my role creating routes for one local authority, I (depending on circumstance) proposed routes that exceeded 5km as primary, strategic routes upon which to connect secondary and local routes to. This strategic routing system would form the "spine" of a cycling and walking transportation network. However, given its length, these routes would also likely score highly on a geospatial model I had co-designed (based on Welsh Government guidance) to prioritise routes. For example, longer routes are more likely to be near strategic sites of interest and cover a larger population. Thus, decisions that are taken to design a network may therefore inadvertently have a significant impact upon how future routes are prioritised. Regarding the geospatial model used to generate scores, the parameters of how scores should translate into descriptions of prioritisation also needed to be determined. Scores for prioritisation ranged from 0-12, and routes that scored 9-12 would therefore be considered for short-term priority for investment and infrastructural provision.

Relevance of the experiences

As the example above regarding prioritisation shows, the statutory requirements of design guidance are flexible to the ambition, skills, and resources of the local authority or consultant. For example, in the prioritisation of future routes, the approach taken is flexible. There are two key issues here. Firstly, a highly quantified process is outlined by design guidance, however it is a highly subjective process. The scoring used in modelling is also highly subjective and will inevitably vary across local authorities in Wales. Secondly, whilst design guidance outlines the recommended steps, it is ultimately guidance only. For example, the common response to meetings remains: "what does the guidance say?" In cases of ambiguity, the decision is left with transportation professionals to interpret guidance which thus affect decisions. Overall, official design guidance supports the required steps to deliver policies, such as the Active Travel (Wales) Act 2013. Nonetheless, my experience working with government guidance offered personal insight to the position of the practitioner. My values, experiences, and skills ultimately shaped the ATNMs I helped to create on behalf of local authorities. Based on this experience, it became apparent that policies and practices of delivering policies were two very different things. As a result, I became considerably more interested in the "interface" of policies and practice, rather than seeing them as separate. This includes greater consideration to the governance capacities and role of professionals within organisations. From my experience, active travel policies guide practice, but often they do not dictate. Policies offer a hopeful outcome for future mobilities, but how these outcomes arise also, to varying degrees, depend on the practitioners of policy. Transportation professionals may thus have more (or less) agency than expected. For this thesis, questions around how practitioners support policy thus became more centre stage for me, including how professionals at TfL and ODOT worked with relevant organisation policies and legislation within their specific contexts.

Taking all these experiences together, I developed a more thorough (albeit interpersonal) understanding how policies and delivery of policies "stage" mobilities "from above'" (Jensen, 2013; Jensen and Lanng, 2017). Indeed, in the first instance, my cycling accident was influenced by my lack of skill and confidence, but also due to the "intentionality" of engineers, designers, planners, and policy makers (and amongst many others) that supported the creation of the cycle lane. The second instance, I have demonstrated how my own 'intentionality' supported the generation of Active Travel Network Maps (ATNMs) in my role as a transportation professional. Whilst adhering to supporting guidance, my understanding of cycling would have certainly influenced how ATNMs developed, despite drawing upon an array of data driven exercises. Taking these experiences together, I argue that the decision to analyse all data through this lens (which I detail above) are thus offered further justification. As personal experiences that span the entire length of this thesis suggest, the scientific and the personal are not easily separated.

Furthermore, these experiences are perhaps the most significant factors in shaping the analytical decisions of this thesis. Indeed, it is highly unlikely that another researcher will review the data presented in this thesis and share the same analytical thoughts. For example, the cycling incident experienced during the research of this project brought my attention to how data, including "big data" sources, have limited or no traction to the emotional or embodied experiences of cycling. Although this journey was "tracked", as discussed above, any interpersonal experiences would not feature directly in the planning of future cycling provision. Therefore, I am arguing that through this experience, I now view the performative aspects of cycling as almost entirely separated from the "datafication" processes that are increasingly shaping planning and policy of cycling. "Big data", I am arguing, cannot provide transportation planners or data scientists context to certain insights into the performance of cycling, including sense of safety or cycling route preferences. For example, are higher volume of activities related to cyclist's preferred route, or avoidance strategies? It is not possible to provide one answer to this question, as, I discovered after crashing a cycle, everyone's motivations are subject to experience and are never fixed. Thus, in the analysis of policy documents and interviews for this thesis, I maintain this line of thought where "big data" (and the "datafication" of cycling activities) are limited in that they reveal very little about social and emotional experiences. Before moving onto a discussion of the data collected and analysed for this thesis, I next outline the ethical approval granted for this study.

4.9. Ethical approval for data collection and retention

The study was awarded a favourable ethical opinion by the Tier 1 Research Ethics Committee of the University of Brighton, School of Applied Social Science, on 27th August 2018, chaired by Professor Squires. No ethical issues were anticipated in the collection of publicly available transportation policy document data. Regarding the collection and analysis of interview data with transportation professionals that worked with Strava Metro data, their personal identity was not a key factor for the project and thus limited information was requested from participants, which included age range, gender, profession, and limited contact details. These details were kept optional should any participant prefer not to disclose this information. Participants were kept anonymised by default, and they would instead obtain a pseudonym (for instance, a Data Scientist at Transport for London). Though, participants were reminded that complete anonymity could not be guaranteed as they may be identifiable to work colleagues, for example. Participants were asked if their interview could be recorded using a voice recorder, though offline discussions would take place could participants preferred not to be recorded. Participants were required to sign and date a Participant Consent Form (PCF) that confirms they have had the opportunity to review the Participant Information Sheet (PIS) and were offered the opportunity to ask the researcher for additional information. All participants were offered a full transcript of their interview data to check for accuracy. Only data directly related to the research objective and research questions were collected. To ensure that comprehensive review of ethical considerations was also considered prior to submission, the researcher also reviewed a Tier 2 Research Ethics form to assess and mitigate against any ethical concerns related to this study. This optional form was attached as part of the Tier 1 Research Form to show how ethical concerns were thoroughly considered prior to the collection of any research data.

Approval was also afforded to the collection of Strava Metro data from European Social Research Council (ESRC) data repositories (UBDC, 2020), which was not used for in-depth analysis. These data were instead used to support the generation of interview questions and to assist the researcher's understanding of the characteristics of the Strava Metro data samples. These data were licenced by Strava Incorporated and were freely available to university researchers and were protected by ethical and legal agreements outlined by the ESRC UK Data Service policy and guidance. In accordance with these agreements, these data could not be shared freely, used for educational and research purposes only. All data collected for this research project adhered to the University of Brighton (UoB) Data Protection Policy in adherence to the European Union (EU) General Data Protection Regulation (GDPR). Personal information, such as email contacts, was used to contact participants directly and not shared widely. All personal information was stored in an anonymised format and stored on the University of Brighton Microsoft One Drive storage. Any data stored on external drives, during data back-ups for instance, were kept in a password encrypted file using software such as 7-Zip, as recommended by the University of Brighton, and would be kept in a safe location, such as a lockable drawer. Finally, the research data methods and collection did not deviate away for its original purpose: to develop an original understanding of how "datafication" processes are influencing the delivery of cycling policy plans.

4.10. Conclusion

In this chapter I articulated my use of a "mobile" ontology, drawing upon the work of Sheller and other mobilities scholars. Following this, I outlined my approach toward using "static" methods, including policy documentary and semi-structured interview data collection and analysis to understand critically appraise the role commercial sources of data have in support planning for cycling. I then discussed my rationale for conducting an international comparative analysis at two regional sized governments: Transport for London (TfL) in the UK, and the Oregon Department of Transportation (ODOT) in the USA. This rationale was based upon researching government departments that had purchased and utilised Strava Metro data. I then discussed my approach to collecting policy documents related to cycling at the two regional government departments. Following this I provided an outline to the inclusion criteria for participant semi-structured interviews and detailed the two data collection windows for collecting interview data. Moreover, I discussed the analytical framework used to analyse research data which drew principally from existing literatures of mobilities and critical data studies (that are also detailed within Chapters 2 and 3). To provide more context regarding my methodological and analytical decisions, I also offered a reflective account of a pilot study, including a review of one Strava Metro data sample for a city in the UK. Furthermore, I detailed how my personal experiences, combined with my professional experiences planning for walking and cycling, shaped the analytical steps to address the research questions of this thesis. The next chapter presents a detailed analysis of cycling plans and policies published by Transport for London (TfL) and the Oregon Department of Transportation (ODOT) that set the agenda for cycling provision.

Chapter 5: Representing and contesting cycling's policy "problems"

5.1. Introduction

In Chapter 1, I outlined four research questions that help address the research objective of this thesis to understand how Strava Metro has been used by UK and US transportation planners, and to reflect upon the consequences of these data uses for social justice and policy. This is done to critically examine how equitable and mobility just societies in an increasingly datafied world can be made possible. In the first of these research questions, I ask: *what is the transport policy "problem" – at the regional scale – that determines injustices in cycling and cycling data?* To critically address this first research question, I draw upon Bacchi & Goodwin's (2016) guidance on post-structural policy analysis framework to compare regional and national cycling policies relevant to the cities of London (UK) and Portland (Oregon, USA). By utilising Bacchi & Goodwin's (2016) framework, entitled "*what's the policy problem represented to be?*" (WPR), the critical analysis in this chapter explores the conceptual foundations (Bacchi, 2009) upon which cycling policies are based. The concern of this policy analysis chapter therefore is not to focus on the actual implementation of cycling policy at regional government departments, but rather to identify the specific construction of the "problem(s)" that official cycling related policy documents seek to address, which are often framed around efficiency and increasing modal share rather than diversifying. In doing this, I critically examine how "taken-for-granted" (Bacchi, 2009) assumptions embedded within cycling policy documents risk narrowing the potential for equitable and inclusive cycling futures.

Following the WPR framework, I first show how these cycling policy plans published by Transport for London (2016) and the Oregon Department of Transportation (2016) position the cycling "problem" as one where not enough people cycle; this is considered detrimental to public health, the "environment", and the "economy". Furthermore, I discuss how these policy plans seek to address a second policy "problem" of addressing a lack of diversity of cyclists across London and Oregon. Although two policy problems are observed, I argue that there are tensions between these policy "problems". Rather than working in equal tandem, the privileging of dominant normative forms of cycling which focus on efficiency and individual freedoms inadvertently hampers efforts to diversity. To arrive at this argument, following a discussion of the two policy "problems", I explore how these assumptions have emerged. I argue that representation of this "problem" arises due to assumptions of cycling as an inherent good for society. This representation has come about to address negative externalities associated with the "system of automobilities", that has emerged through a combination of unsupportive infrastructural provision for cycling. However, critically, the policy instruments to support this representation are left unproblematic, which in turn unfairly privileges more cycling over the need to diversity. In other words, the role of data to evidence cycling provision is seen as politically neutral, which in turn exacerbates tensions between the two policy "problems" of supporting more people to cycle, whilst seeking to diversify. As such, this chapter illustrates the inherent injustice in policy framings of the "problems".

5.2. What's the TfL and ODOT cycling policy "problem" represented to be?

In this section, I first outline two regional cycling policy plans at Transport for London (2018) and the Oregon Department of Transportation (2016). Guided by Bacchi & Goodwin's (2016) post-structural policy analysis framework, I address the question: "*what's the cycling policy 'problem' represented to be?*" (WPR). I argue that both these regional policy documents present two problems. The first "problem" of representation concerns a lack of cycling, where not enough people within either London or Oregon participate. This is viewed as detrimental to individual and public health, the "environment", and the "economy." The second "problem" concerns an observed lack of diversity of cycling, which constrains the mode's potential as a transformative mode of mobility. Specifically, both the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) recognise "barriers" to cycling for marginalised and excluded groups across London and Oregon. Thus, there are two "problems" for TfL and ODOT: supporting more people to cycle, whilst simultaneously diversifying cycling. Whilst these problems are considered by both TfL and ODOT, I also discuss how these policy problems are not granted equal weighting, but rather are assumed to work in tandem. As such, tensions between these policy ambitions are observed. I begin this analysis by reviewing the first "problem" represented: that not enough people cycle.

The strategic requirement of both the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) concerns increasing the total numbers of people who cycle over a longer-term. For example, Transport for London (TfL) state a target year of 2041 by which 80% of all journeys will be made by active means, such as walking, cycling, and public transportation. Similarly, the ODOT Oregon Bicycle and Pedestrian Plan (2016) presents 2040 as the target year for supporting more people to participate in cycling, although the regional government department refrain from presenting a measurable target. The reasons for maintaining that more cycling is required stem from cycling's contribution toward addressing cross-cutting and complex policy challenges. Cross-cutting benefits are raised within cycling policy plans published by Transport for London (TfL) and the Oregon Department of Transport (ODOT).

"We are committed to creating a fairer, greener, healthier, and more prosperous city. The Mayor's Transport Strategy sets a target for 80 per cent of all journeys to be made on foot, by cycle or using public transport by 2041. To make this a reality, we prioritise health and the quality of people's experience in everything we do."	"Specifically, by 2040, the Plan envisions that: In Oregon, people of all ages, incomes, and abilities can access destinations in urban and rural areas on comfortable, safe, well-connected biking and walking routes. People can enjoy Oregon's scenic beauty by walking and biking on a transportation system that respects the needs of its users and their sense of safety. Bicycle and pedestrian networks are recognized as integral, interconnected elements of the Oregon transportation system that contribute to our diverse and vibrant communities and the health and quality of life enjoyed by Oregonians."
TfL Cycling Action Plan (2018: 3)	**ODOT Bicycle and Pedestrian Plan (2016: 6)**

As part of supporting more people to cycling within London and across Oregon, there is also a policy ambition to address a recognised lack a diversity in cycling. In addition to supporting more people to cycle, both the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) outline an issue of representativeness in cycling.

"We will target new initiatives where there is most potential for more cycling, with a particular focus on supporting those who experience the greatest barriers to cycling, including currently underrepresented groups such as women, BAME people and families. The funding will also be used to boost the level of resource provided to boroughs to deliver these activities, helping them reach as many Londoners as possible."	"Concerns over equity and equality also features within the Oregon walking and biking options should be made equally available to all, without regard to age, race, income, or other demographic or community interest. The policies and strategies under this goal are designed to understand the issues that may prevent certain portions of Oregon's population from walking and biking, locating, and targeting transportation disadvantaged populations, and helping to close the gap between areas served, and not served, today and into the future."
TfL Cycling Action Plan (2018: 85)	**ODOT Bicycle and Pedestrian Plan (2016)**

The policy plans and guidance seek to do this by addressing "barriers" to cycling, including safety (encompassing perception of risk). Safety is viewed as a significant barrier that needs to be resolved to support more people to cycle and to address issues of marginalisation and exclusion. Physical barriers include providing cycle provision that is sensitive to a wider range of people, including cyclists that may use an adapted cycle (including a three-wheeled recumbent). However, not all barriers are physical. Social infrastructure provisions are also noted by the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016). These 'soft' social provisions, include cycling proficiency training with people to equip them with skills and competencies required to cycle. Overall, there are two principal policy "problems" represented by the TfL (2018) and ODOT (2016). The bullet points, below, summarises the policy "problems" noted within the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016):

TfL Cycling Action Plan (2018)	ODOT Bicycle and Pedestrian Plan (2016)
• 80% of all travel made by foot, cycle, or public transport by 2041. • Emphasis on supporting underrepresented groups to cycle.	• Support more cycling by 2040 (no measurable target). • Emphasis on making cycling options equally to all people.

However, whilst there is recognition of these two complementary policy "problems" across both cycling policy plans, I argue that these policy problems are not granted equal weighting. As opposed to being twin policy challenges, they are seemingly in conflict as the challenge of supporting more people to cycling is presented as the primary policy ambition. Although both policy problems afforded genuine consideration, tensions between these policy problems arise due to assumption that supporting more people to cycle will work in tandem with ambitions to diversify simultaneously. To emphasise this point further, I next discuss the deep-seated presuppositions and assumptions that shape the observed two "problems" which are represented within cycling policy plans.

5.3. Unpacking the assumptions of cycling policy "problem" representations

To make conceptual sense of the policy problems, I next critically outline underlying assumptions that influence how these problems have been constructed. In doing this, I continue with Bacchi & Goodwin's (2016) guidance on post-structural analysis, considering the question: What deep seated assumptions underlie these representations? Specifically, I am arguing that there are deep-seated presuppositions that have influenced how the policy "problems" of cycling have been represented. As the previous section emphasises, the cycling policy plans analysed present two "problems", with the dominant "problem" as one which seeks to support more people to cycle. However, it is important to reflect upon why cycling as transport has been framed in this way. Thus, for this section, I next outline a descriptive account of how supporting more people to cycle in society is coupled with ideas of sustainability. I show how cycling is assumed to be a 'sustainable alternative' of transportation within a dominant 'system of automobilities'. Particularly, as the following quotes outline, the issue of public and individual health is brought into sharp focus:

"London faces an inactivity crisis, and active travel is at the heart of the solution: walking and cycling are the best ways for Londoners to build physical activity into their daily routines. However, just 31 per cent of people report having walked or cycled for two 10-minute periods on the previous day. Encouraging more active travel would make	"The main health benefits of physical activity include improved personal health and increased life expectancy. Investing in pedestrian and bicycle infrastructure, supporting educational and encouragement programs, and supporting active transportation options help to encourage physical activity for better health may reduce

"...a huge contribution to public health in the Capital: if every Londoner walked or cycled for 20 minutes each day, it would contribute at least 60,000 additional years of healthy life."

TfL Cycling Action Plan (2018: 12)

health care costs by decreasing rates of chronic disease. This can be particularly beneficial when educating and encouraging youth to participate in these activities so they can learn to be more active at an early age."

ODOT Bicycle and Pedestrian Plan (2016: 10)

Across both the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) cycling is positioned as a healthy solution to addressing issues of inactivity. The reported benefits of supporting more people to cycle across London and Oregon extend beyond the individual, however. As the quotations above emphasise, the promotion of cycling is seen to contribute to improved public health. In these cases, cycling is more than a transportation issue, but rather one which contributes to a healthier population. And these benefits are viewed as quantifiable: increased activity, decreased chronic illness, couple with a reduction in health care costs. The focus upon active lifestyles extends beyond the cycling policy plans and is also observed across national policy. For example, although published *after* the TfL *Cycling Action Plan* (2018), the UK Department of Transport's (DfT) *Gear Change: A bold vision for cycling and walking* too brings into focus cycling's potential in supporting healthier lifestyles. The UK DfT national guidance suggests that "20 minutes of exercise per day cuts risk of developing depression by 31% and increases the productivity of workers" (DfT, 2020: 9). Though national guidance documents have limited statutory relevance to the TfL and ODOT cycling policy plans (e.g., DfT guidance not enacted directly within London), international lessons on making the case for cycling in relation to health are observed. Continuing with the theme of health, links are drawn to the positive role cycling has in relation to pollutants. The following quotations from the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) provide an example of this:

"As a non-polluting mode of transport, cycling is part of the solution to London's poor air quality. Cycle schemes do not generate motorised traffic and encourage mode shift away from the private car, which will lead to reduced emissions and less noise."

TfL Cycling Action Plan (2018: 12)

"Walking and biking are zero emission modes that play an important role in reducing fuel consumption, air and noise pollution, and carbon emissions. Increasing walking and biking for transportation is a key strategy in helping Oregon achieve its greenhouse gas (GHG) reduction goals. As transportation is one of the highest emitting sectors, contributing to about one third of all GHG emission in the state, approaches for reducing transportation-related emissions are essential."

ODOT Bicycle and Pedestrian Plan (2016: 11)

As the quotations above emphasise, increases in cycling within London and across Oregon, that are coupled with reductions in motorised transportation, is expected to improve local air and noise pollution. A divergence between the two policy documents concerns the role of reducing transportation's overall contribution to human-induced climate change. As the quotation taken from the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) emphasises, an existing system of transportation across Oregon is recognised as a significant contributor to the state's total carbon emissions. By encouraging more people to cycle, the ODOT cycling policy plan situates cycling as a holistic means toward addressing transportation's significant contribution to overall greenhouse gas (GHG) emissions. Thus, links are drawn to external policies, including the *Oregon State-wide Transportation Strategy: A 2050 Vision for Greenhouse Gas Emissions Reduction* (ODOT, 2013); a policy drafted in response to national and international agreements regarding decarbonisation commitments. By aligning policies to their wider context, the key priority within transportation policies concerns transitioning society away from less carbon intensive forms of (auto)mobility toward modes such as cycling, irrespective of who cycles or for what purpose.

In contrast, the TfL *Cycle Action Plan* (2018) makes no *direct* reference to human-induced climate change, but rather focuses upon the specific context of localised pollutants generated by motorised vehicles. That is not to suggest the TfL cycling policy plan does not consider climate change as a significant policy issue, instead there is a clear emphasis on pollution as a public health issue above a global environmental challenge. It would, however, be naïve to assume that these environmental concerns are not major drivers in the formulation of the TfL *Cycling Action Plan* (2018). Indeed, the TfL's *Mayor's Transport Strategy* (2018), which the TfL *Cycling Action Plan* (2018) was drafted to support, observes the need to mitigate the negative impacts generated by forecasted climate change. Again, the policy formulation from national and international agreements of decarbonisation agendas underscores an imperative to promote modes such as cycling despite its limited reference within the TfL *Cycling Action Plan* (2018). This is logical, given a need to publicly emphasise and address local issues of motorised transportation congestion and associated emissions, above global environmental policy ambitions. Although the cycling policy plans at TfL and ODOT consider cross-cutting policy benefits of increased cycling (coupled with a reduction in motorised traffic), the economic benefits of more cycling are especially emphasised. The quotations, below, provide an insight to the potential cycling has for individuals and businesses:

"In the face of many challenges, it is vital that London remains an appealing place for major global businesses, and that the city is able to maintain the strong talent pool required to sustain its place as a world-leading economic and cultural destination. Cycling can help keep the city moving for business, improve the motivation and

"A growing body of research has shown that walking and biking can contribute to a healthy economy. Benefits range from relatively direct impacts for users, such as reductions in travel costs, to more indirect impacts, such as growth in businesses related to the bike industry or congestion relief for converting short trips to walking or productivity of employees, and boost the all-round quality of life that London offers."

TfL Cycling Action Plan (2018: 13)

biking. Increases in walking and biking have potential direct and indirect impacts to the state or local economy."

ODOT Bicycle and Pedestrian Plan (2016: 9)

As the quotations above indicate, the benefits of supporting more cycling for Transport for London (TfL) and the Oregon Department of Transportation (ODOT) are inextricably tied with an economic and financial gain. In addition to individual finances, the economic case for cycling extends to the businesses which are seen to benefit through the circulation of an active workforce. As the TfL *Cycling Action Plan* (2018) suggests, above, cycling is discussed for its potential role in creating the conditions for a more seamless commuting. Not only can major employers attract workers by supporting journeys made by cycle, but also social and cultural benefits are assumed to arise. The quote above concludes with a statement regarding the benefits for these economically active people including individual motivation to work, productivity at work, and enhanced quality of life available to those that participate. There is an emphasis within the TfL *Cycling Action Plan* (2018) whereby for businesses to flourish, capital must circulate, and cycling is certainly seen to support this doctrine. A similar assumption is noted within the ODOT *Oregon Bicycle and Pedestrian Plan* (2016).

In the example presented by ODOT, above, the "health" of the economy is seen to benefit from increases in cycling. Reflecting the statements made within the TfL *Cycling Action Plan* (2018), individuals that participate in cycling are believed to directly benefit financially. This benefit is also believed to extend beyond the individual, supporting growth of the cycling sector and reducing traffic congestion generated by automobile travel. As the potential costs of cycling may be quantified, the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) therefore stresses that the promotion of cycling will result in tangible (financial) impact. In contrast to the "system of automobilities", cycling is treated as a more environmentally, economically, and socially sustainable mode of transportation. Cycling is presented within the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) as a good for society, and as necessary to move toward more sustainable variants of transportation. In other words, the more people who participate in cycling, the more health, environmental, and economic benefits are predicted to materialise.

5.4. Scripting the "productive" cyclist subject

By framing cycling in this way that focuses heavily on the economic benefits of more cycling, I suggest that cycling policies actively "script" and anticipate economically productive cyclists. I will critically reflect upon the historical perceptions of cycling which helps to make sense of why policies do this, but for the emphasis is on how the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) both script productive cycling subjects. Indeed, through the promotion of (predominantly economic) values at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I suggest that whilst other (non-economic) values are acknowledged by cycling policies, these (non-economic) values are at risk of being overlooked by policy ambitions that seek to promote cycling. Specifically, though cross-cutting benefits are aspirational and hoped for, there is an assumption that financially "fixing" transportation through cycling will help to realise a range of social and environmental benefits. The cycling policy plans published by Transport for London (TfL) and the Oregon Department of Transportation (ODOT) are not unique in this sense, and reflect arguments made by national governments of the UK and the USA. Aspirations to attain financial reward from more cycling are also seen within national policy contexts. For example, the UK Department of Transportation (DfT) outlines the many financial benefits for the consumers of urban cycling. These benefits include healthier, happier people who are seen as less burdensome upon health services, and more productive at work through average fewer sick days with more attentiveness which translates to enhanced economic productivity. Not only are cyclists seen as more economically productive by national guidance such as the DfT *Gear Change* (2020), but policy plans view cycling to deliver more productive and efficient transportation systems, helping to address traffic congestion that is caused by mass automobility use.

Returning to theories developed from mobilities and design (Jensen, 2013) and infrastructure research (see edited work in Cox & Koglin, 2020), I next draw upon these theories to unpack how highly individualised values contained within cycling plans effectively write the "script" of economically productive "variants" of cycling. This resonates with an existing (and growing) body of literature that discusses the promotion of cycling that is inextricably linked to a broader neoliberal agenda of capital accumulation (Spinney, 2021; Aldred, 2012). By metaphorically "scripting" the transport cyclist in this way, one that is efficient, rational, and (most likely) employed, cycling policies assume a largely homogenous collective which share a lot of the same qualities for cycling. These qualities include supporting active lifestyles, which in turn will help people live happier and healthier lives. There is an issue with these highly individualised values, in that they mirror the very same system responsible for the marginalisation of cycling: the environmentally and socially destructive "system of automobilities" (Urry, 2004). As discussed in Chapter 2, the "system of automobilities2 has been seen as an expression of neoliberalism, including the belief of unfettered mobility and individual freedom (Doughty & Murray, 2016) and capitalist expansion (Spinney, 2021). This automobilities system thus privileged and advantaged certain people's needs over others. In theory, everyone is invited to participate in the system of automobilities, but crucially, the benefits of the system are unevenly distributed. As such, I am arguing that the cycling policy plans at TfL and ODOT, which are reflective of transport policy in other cities, are also principally motivated by highly individualised values that risk discounting the needs of some people and communities at the expense of a preconceived idea of who cycles and for what purpose.

Contrary to the observed need to diversify cycling, as discussed by the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Action Plan* (2016), a narrowed definition of "cyclist" emerges. For example, children and older people are recognised to have different cycling abilities to economically active adults yet the imagined cyclists within TfL and ODOT cycling policy plans largely (1) assume cycling as a mode of transport, in which (2) cyclists share similar motivations and needs. Crucially, cycling is not regarded as a mode of mobility, a wheeled technology to support social capital accumulation, happiness or life fulfilment and satisfaction. Indeed, there are no examples in either the TfL *Cycling Action Plan* (2018) or the ODOT *Bicycle and Pedestrian Plan* (2016) regarding the meanings of cycling or life satisfaction (with the exception that people can expect fewer sick days through cycling and be more energised to perform during working hours).

Viewed in this way, I contend that cycling policy plans by both TfL and ODOT present cycling as a vehicle toward enhanced economic growth. This is not new for cycling (as discussed in Chapter 2) as there is a dominant assumption that cycling should contribute to economic sustainability. To address the 'challenge' of automobilities, evidence for the need of cycling within London and Oregon is seemingly premised upon the extension of an existing system of transportation, albeit one that generates benefits such as economic efficiency through time and transport cost reductions. As this analysis highlights, cycling policy and ambitions are deeply embedded within complex policy challenges beyond the realm of transport. Whilst the cross-cutting benefits are noted by cycling policy plans at TfL and ODOT, with reference to policy learning from national and international contexts, the financial incentives of more cycling are emphasised. Although these cycling policy plans at Transport for London (TfL) and the Oregon Department of Transport (ODOT) can be read as scripting a particular variant of cycling, it is important next to critically reflect upon the reasons this may have occurred. In the next section, I outline how the conflicting "problems" of cycling have emerged, and why these overlapping problems are observed by policy plans which exist in very different policy and political contexts.

5.5. The emergence of cycling's policy "problem" representation

In the previous section, I stated that both cycling policy plans at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) script an "economically productive" cyclist, akin to a lighter form of 'automobilities'. In this next section, I take a critical "step back" to reflect upon the reasons why this "scripting" has occurred. To achieve this, I continue this analysis using Bacchi & Goodwin's (2016) "*what's the 'problem' represented to be?"* (WPR), to consider *how has the representation of this "problem" come about?* As such, in this next section I am arguing that the rationale for this scripting cannot be assumed as entirely ideological but must also be read with consideration to pragmatic political leverage to promote cycling. Particularly with context to the historical marginalisation of cycling within the system of automobilities.

In Chapter 2 of this thesis, I discussed conceptual work by Urry (2004) regarding the dominant "system of automobilities", which has led to an exponential rise in motorised vehicle ownership and the (predominately) negative externalities motorised traffic has generated across societies, including London and across Oregon. Within this dominant "system of automobilities", cycling as a mode has been marginalised, spatially with respect to supportive provision, but also politically (see Chapter 2). Indeed, only in recent decades has cycling began to receive political and media attention as an increasingly mainstream mode of transportation. As such, policy plans like the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) do not have an extensive history of localised cycling policy implementation, with dedicated funding streams, to draw upon in the same way motorised traffic has. Thus, through a critical reflection and reading of the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), it becomes clearer why progression toward higher cycling contexts are presented as longer-term strategies. Given the structural dominance of the system of "automobilities" (Urry, 2004), there are examples of cycling policy plans which present cycling's wider relevance in transportation futures. The clearest example of this, observed within both the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), concerns cycling's direct policy relevance to 'Vision Zero' societies as the quotations, below, demonstrate:

"Achieving the outcomes of the Cycling action plan will rely not only on the actions set out in the remainder of this Plan, but also on the wider delivery of the proposals set out in the Mayor's Transport Strategy. Adopting Vision Zero for road danger will make it safer and more attractive to cycle. Traffic reduction, both through the next generation of pan-London road pricing, and locally via boroughs' traffic reduction strategies, will be fundamental to creating the conditions where cycling becomes a real option for everyone."

TfL Cycling Action Plan (2018: 49)

"Eliminate pedestrian and bicyclist fatalities and serious injuries, and improve the overall sense of safety of those who bike or walk."

"Goal language to "eliminate bicycle and pedestrian fatalities and serious injuries" encapsulates the principles of "Vision Zero" and "Toward Zero Death" initiatives at the federal and local levels."

ODOT Bicycle and Pedestrian Plan (2016: 30)

As the quotations above indicate, cycling ambitions at Transport for London (TfL) and the Oregon Department of Transport (ODOT) contribute to a wider policy to address physical safety issues of transportation. Crucially, both Transport for London (TfL) and the Oregon Department of Transportation (ODOT) both recognise a policy stance first developed by the Swedish Parliament in 1997 called "Vision Zero" (Whitelegg, 2020). As discussed within Chapter 2, there is a general collective consensus amongst transportation researchers, policy makers, and cycling advocates that the issue of "physical safety" and "fear of cycling" are among the main barriers that prevents and marginalises people from participating. Thus, by eliminating danger and risk, the idea holds that more people will be encouraged to cycle. However, what distinguishes "Vision Zero" ambitions apart from making transportation systems safer relates to an ethical imperative that all lives are valuable, and therefore no one should expect to be killed or seriously injured (KSI) whilst moving through transportation networks. By adopting "Vision Zero" principles, both TfL and ODOT regard physical safety as a significant barrier to cycling.

To resolve this challenge at Transport for London (TfL), the problem therefore is not regarded as an isolated issue for cycling policy, but rather a system rethink of the role of motorised transportation within London. In other words, for cycling to "become a real option for everyone" (TfL, 2018: 49), the hemogenic power of the "system of automobilities" must be confronted head on. However, this challenge to automobilities does not come directly from the TfL *Cycling Action Plan* (2018) or the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), but rather from complementary policies and plans. For example, within the Transport for London (TfL) *Mayor's Transport Strategy* (2018) – which the TfL *Cycling Action Plan* (2018) supports, the role of motorised transportation is critically appraised:

> *"Lowering speeds is one of the most important things we can do to make our streets safer. This is because a person is about five times less likely to be fatally injured if hit at 20mph than at 30mph. We have developed a progressive speed limit policy for the Transport for London Road Network."* **(TfL Mayor's Transport Strategy, 2018: 6)**

As the quotation above emphasises, vehicles that travel at faster speeds exacerbate the risk of fatality or serious injury for individuals involved. Thus, the quote emphasises that speeds for motorised traffic should be reduced to mitigate and reduce this risk, and as such set out a target to strategically reduce speed limits across the Transport for London Road Network (TLRN). Going further than this, Transport for London (TfL) developed a dedicated plan to eliminate all transportation related deaths and serious injuries by the target year of 2041 (along with a target of 80% mode share for public transport, walking and cycling by 2041). This plan published by Transport for London (TfL) is entitled *Vision Zero action plan: Taking forward the Mayor's Transport Strategy* (2018). Rather than see road fatalities or serious injuries on London's roads as "accidents", the policy plan emphasises that traffic collisions are 'incidents' that are neither natural nor inevitable. Rather incidents emerge from complex interactions between built environments that afford motorised transportation, transportation technology manufacturers, highway governance, and other public sectors including the health sector. Road incidents are thus viewed as a public health issue and is not limited as a public transportation problem.

In contrast to TfL's holistic approach, the Oregon Department of Transport (ODOT) refrain from explicitly confronting a 'system of automobilities', but instead focus on the provision of safer cycling infrastructures. Rather than seek to actively restrict motorised transportation, the ODOT *Bicycle and Pedestrian Plan* (2016) with complementary documents such as the ODOT *Oregon Transportation Safety Action Plan* (2016) places an emphasis on the provision of "safe and well-designed streets and highways for pedestrian and bicycle users" (ODOT, 2016: 30). In addition to junction redesign and reducing pedestrians' and cyclists' exposure and proximity to motorised traffic, the ODOT cycling plan, makes clear reference to a need for more data and data sharing to help understanding of risks to mitigate traffic incidents. Specifically, these policies are detailed below in Table 3.

Description
Use pedestrian and bicycle crash and proxy data to identify high crash corridors and crash typologies for further analysis and prioritization. Build upon the Oregon Pedestrian and Bicycle Safety Implementation Plan, highway safety improvement plan criteria, emerging best practices, and other resources.
Explore opportunities to develop and share data for all types of pedestrian and bicycle related crashes and near misses in order to better understand the type and location of safety issues and to prioritize addressing them accordingly.
Gather data on pedestrian and bicycle safety risk by better estimating exposure (use of the system). Develop an approach for capturing pedestrian and bicycle miles travelled and implement accordingly.

Table 3: Policies related to safety detailed within the Oregon Bicycle and Pedestrian Plan (2016)

In the next section, I continue the discussion regarding the observed need for more "data"; for now, I retain attention regarding the role of cycle-specific infrastructures. Based on the cycling plans at TfL and ODOT, I am arguing that the principal mechanism to support cycling is presented as through cycle-specific infrastructural provision. Within the current dominant system of automobilities in "lower cycling" (albeit higher compared to national) contexts such as London and across Oregon, the cycling policy plans refrain from directly promoting radically transformative changes within present transport conditions. The approach taken draws upon tackling an immediate barrier to cycling, related to "making space" for journeys made by cycles in transportation systems that have historically privileged motorised transport. Although, complementary policies across Transport for London (TfL) actively discourage journeys made by motorised vehicles, such as the reduction in traffic speeds across London, the cycling policy plan does not actively discourage car use. I am arguing the rationale for this emerges due to an assumption that the "problems" are resolvable through a technical means, akin to a build it (cycle-specific infrastructure) and they will come approach to supporting cycling. But why do the TfL and ODOT encourage infrastructure as the solution to cycling's "problems"? In part, this is done because it reflects the same messages represented by national and international guidance, including policy learning from higher cycling contexts.

As such, neither the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) cannot be read in isolation, and recognition must be directed toward (inter)national comparison of cycling policies and experiences. Indeed, there are also direct references to international documents of "best practice", including the CROW Manual from the Netherlands. The documents suggest that the main approach to resolving infrastructure is by building provision that will encourage modal shift toward cycling. Thus, policy plans are the accumulation of years of global policy learning, which include lessons on working within the entrenched "system of automobilities". Therefore, from a post-structural analysis reading, there is no "tidy" linear policy process that can be detailed. Part of the policy "problem", representations (that privileges the promotion of more cycling over diversifying) is due to complementary policies that are seen across varying levels of governance in the UK and USA, which are relevant to specific regional contexts within London and across Oregon. For example, these "problems" are also seen in complementary (inter)national policies and guidance, such as the Department of Transport's (DfT) *Gear Change* (2020) and *Local Transport Note 1/20* (2020) where not enough people cycle in society.

Furthermore, the role of activists and political opportunists, is not detailed within either the TfL *Cycling Action Plan* (2018) or the ODOT *Bicycle and Pedestrian Plan* (2016). For example, the TfL *Cycling Action Plan* (2018) supports the *Mayor's Transport Strategy* (2018), but it is important here to ask: who is the Mayor of London, and what political motivations underpin their Mayorship? In the case of London, it was during Mayor Boris Johnson's (later Conversative leader and Prime Minister of the United Kingdom) Mayorship (2008-2016) that saw significant policy and media attention toward cycling, with the planning and implementation of cycling highways across London. Therefore, the motivations and political career ambitions of individuals such as Boris Johnson, transport officials, and civil servants, have contributed to cycling's policy development beyond their administrations. Detailing the policy development of specific policies such as the *Mayor's Transport Plan* (2018) sits outside the scope of this analysis, however it is important to recognise and emphasise that policies and plans to promote cycling cannot be read truly in isolation from their wider context. This also includes international contexts, including the UK Government's adoption of the *Pan-European Master Plan for Cycling Promotion* (2021) to double overall cycling across 54 countries, despite being published after the adoption of the *Mayor's Transport Plan* (2018). Also, as the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) sit within broader policy contexts, in line with policy guidance and directives, these policy plans must also be understood as subject to constant revision and modification rather than as static representations of policy ambitions. Building upon this discussion, continuing with Bacchi & Goodwin's "*what's the policy problem represented to be?*" (WPR), I next outline data and appraisal issues that are left unproblematic by the conceptual construction of these cycling "problems".

5.6. Data & policy appraisal left as unproblematic

I next shift the focus on Bacchi & Goodwin's (2016) consideration of *what is left unproblematic in this representation?* And consider issues which are left unproblematic by cycling policy plans relevant to London (TfL) and Oregon (ODOT). Specifically, I bring the attention to the role of data and policy appraisal mechanisms. As discussed at the start of this chapter, there are two main policy "problems" represented by the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016). These "problem" representations suggest that (1) not enough people cycle, and (2) more diversity in cycling is required. However, in this section, I emphasise how tensions between these two priorities arise in relation to data and appraisal mechanisms. By presenting the issue in this way, I am arguing that the "problem" representations of cycling at both TfL and ODOT can be reduced to numbers, which in turn consolidate and exacerbate dominant framings of capitalist accumulation and individual freedom over diversity. Thus, to address "problems" of cycling, the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) both emphasise a need for sustained data collection efforts. The role of data is outlined in the quotations, below:

> "There is a huge opportunity for innovative solutions from the private sector, and we are working with tech companies, app developers, bike retailers and others to help achieve these goals. We are not just engaging with the industry, but actively challenging it to do more…"
>
> **TfL Cycling Action Plan (2018: 75)**

> "Opportunities identified consisted of better sharing of data between agencies, private and public alike, and using technological advancements to improve data collection. Technology is changing at a rapid rate, and as new and emerging technology improves, the availability of data will better inform system needs."
>
> **ODOT Bicycle and Pedestrian Plan (2016: 25)**

Several concerns are raised regarding data by the Oregon Department of Transportation (ODOT) in the quotation, above. The first relates to a continued search of "appropriate use and context" of measures related to cycling. As this suggests, ODOT concede that a best practice for understanding and evaluating cycling (and walking) remains outstanding. However, what is clear for ODOT relates to the assumption that it is a lack of data, not the analysis of data, that are responsible for the difficulties of measuring cycling. The constraints of this perception of immeasurability means that ODOT are unable to assess cycling across the state of Oregon; resource limitations are thus seen as the culprit. To address this issue of immeasurability, the *Oregon Bicycle and Pedestrian Plan* (2016) encourages active sharing of data, between different state departments within Oregon, but also between public and private partners. Technologies to capture cycling are also recognised as a solution to the problem of missing or inconsistent data, concluding that the availability of data "will better inform system needs." This final, highly ambiguous statement suggests that needs for cycling, and therefore cyclists, are expected to emerge through the collection and analysis of data, which includes private sources. In other words, data is expected to guide the needs for cycling, in contrast to being value driven. The needs for cycling are thus treated as outstanding and unknown; data may help ODOT to identify and respond to this issue. The need and aspirations for more data are also expressed within Transport for London's (TfL) *Cycling Action Plan* (2018).

In addition to expressing a need to collect more data, Transport for London (TfL) "actively" encourage and call for private enterprises to explore opportunities to develop new approaches to understanding cycling. As the TfL *Cycling Action Plan* (2018) and ODOT *Oregon Bicycle and Pedestrian Plan (2016)* both emphasise, cycling needs more data to support its monitoring and its evaluation. Indeed, as Behrendt (2021) asserts, only those modes of transportation that have data at their heart will be considered as important. In other words, for cycling to remain on the transportation agenda, data are not just a good idea, it is an imperative. Indeed, without data, cycling as transportation within the dominant "system of automobilities" would likely cease to exist within contemporary policy which is driven heavily by assumptions of "evidence-based" decision making (Grauberg & Coxhead, 2008; Parsons, 2008), based on the analysis of quantifiable measurements. Moreover, both cycling plans outline the need for creativity and innovation for understanding and evidencing cycling, and both cycling plans published by TfL and ODOT suggest a role of data sharing between different sectors to support cycling efforts. Specifically, the technological innovation in understanding cycling is discussed, and both present the private sector as an important partner in gathering data related to cycling.

Whilst an increase of data related to cycling is expected by Transport for London (TfL) and the Oregon Department of Transportation (ODOT) through data sharing efforts with private partners, the two regional government departments offer a very limited insight to how data might be collected, for what purpose, and which partners may be involved in data collection and analysis. Rather than explicitly state which partners will support the regional government departments with data related to cycling, the door is left ajar to the possibility for future collaboration. Terms such as "innovative solutions" and "technological advancements" certainly provide an indication that data related to cycling is somehow out there, ready to be collected, but the public sector do not have the means to access it. This assumption reflects much of the cycling transportation literature which emphasised that much of the "traditional methods" that captured data related to cycling ultimately hampered efforts to plan for the mode. Furthermore, the extracts from the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycle and Pedestrian Plan* (2016) also reflects arguments by several researchers (see Chapter 2) who assert technological advancements in geographical positioning systems (GPS) will help address and overcome the historic, spatial, and temporal limitations of understanding and planning for cycling.

The focus upon data is not intrinsically problematic; however, as the quotes above suggest, the issues associated with data relate to their availability but not their quality. For cycling to exist as a legitimate mode of mobility and transportation, data are required. However, the focus on cycling data by Transport for London (TfL) and the Oregon Department of Transport (ODOT) to elevate the status of cycling narrows the "problem" to one that can be measured and evaluated numerically. Furthermore, there is problematic evidence form this analysis that policy instruments (such as data collection, data monitoring, and data evaluation) to support cycling are largely based on similar policy instruments that supported a "system of automobilities" in the UK and USA. More cycling is no guarantee of more diversity in cycling, as lessons from London have shown. Yes, policies recognise the need to support inclusive cycling, but when it comes to data and planning for cycling, it becomes possible to separate issues of mode share and diversity.

By framing data in this way, the representation of the "problem" leaves the role of data as largely unproblematic. This includes all types of data related to cycling, including commercial software data. By actively encouraging data uses, irrespective of the data source, all sources as regarded as somewhat politically neutral. As such, the policies actively promote the collection and analysis of data from commercial sources without critically appraising social harms this may inadvertently generate. More cycling in society may help transition to more environmentally sustainable "variants" of cycling (Spinney, 2021), but there is no guarantee that these will be socially sustainable. These visions for privatised data, I am arguing, thereby reflect Spinney's (2021: 210) assertion that "there is a tendency to count what you value and value what you count".

5.7. Discussion: reflecting upon the author's "problem" representations

As a final step of Bacchi and Goodwin's (2016) "*what's the problem represented to be?*" (WPR), researchers are encouraged to critically reflect upon their own "problem" representations. Why, for example, do I, as the researcher and author of this work, view financial capital accumulation as being at odds with social justice? In terms of my own biases, this analysis is shaped by influences from writings by authors such as Sheller (2018) who has argued for an interwoven approach to mobility justice, moving away from static and isolated issues such as distributive justice. To move toward a more comprehensive approach to social justice, there must be deliberation, participation, and inclusion, but current cycling policies at TfL and ODOT (which are themselves shaped by comparative and complementary policies) separate these. During the planning stages, policies ask for data but offer limited guidance on communicating or collaboratively agreeing data driven decisions with the public. These decisions will therefore be left to professional judgement.

Pragmatically, as discussed in this chapter, I have argued that it makes sense why policies do not call for a radically transformative shift away from the "system of automobilities". Cycling has historically been marginalised as a mainstream mode of mobility in "lower-cycling" contexts such as London and across Oregon, and therefore a gradual implementation of cycling policies will likely support a gradual shift toward pro-cycling futures. For example, work by Brezina et al. (2020: 85) in Austria has shown that interventions to support cycling are almost twice as likely when there a strategic document in place. Thus, the existence of the cycling policy plans at TfL and ODOT brings into focus the need for cycling provision yet does so with ideas of incremental change (Brezina et al., 2020).

However, I argue that any idealist values should be brought to the centre, not hidden beneath the surface purely to take advantage of possibilities within a deeply entrenched "automobilities" power structure. I agree that the two core "problems" of increasing cycling mode share with more diversity, are necessary to resolve, but these policy challenges are not evenly weighted. As such, the focus and privileging of efficiency and individual freedoms inadvertently hampers efforts to diversity. Indeed, the policy and appraisal instruments to move toward pro-cycling futures, which depend upon data, leave the door ajar for unintended consequences. For example, the lack of guidance regarding data to plan, monitor, and evaluate cycling leaves policy and guidance open to interpretation and reinterpretation. I am not arguing that the "problem" representations are intrinsically unjust, but rather that cycling futures which are entirely dependent upon data for action limits the potentially transformative impact cycling may have.

5.8. Conclusion

This chapter has illustrated the inherent injustice in policy framings of the "problems". I have argued that there is scope to conceptualise the cycling policy "problem" differently. It argues that the focus needs to be shifted away from increasing the total number of cyclists, to one driven by collective values, that extend beyond instrumental and individualised benefits. Focusing predominately on supporting marginalised and excluded communities, including non-quantifiable values of such as exploration and playfulness. Without critical revision, of cycling plans and policies in "lower cycling" contexts such as London and Oregon, cycling will remain locked into a data "competition" with the "system of automobilities". Thus, making cycling futures akin to a lighter form of automobilities. Cycling policy may always need to balance tensions between pragmatic political leverage and idealism, but there is nonetheless considerable scope to bring awareness to the potential (albeit inadvertent) harms cycling may generate without careful consideration to who benefits most from policy intervention. As discussed in the opening of this chapter, there are two, unevenly weighted, policy "problems" of cycling, (1) increase the total number of cyclists, and (2) diversifying cycling. The concern raised through this analysis, particularly in relation to data collection and policy appraisal mechanisms, is that there is no safeguard or no guarantee that work to increase the total numbers of people cycling which works directly in tandem with the complementary policy work to diversify cycling. As such, I am arguing that these twin-policy problems need to be brought together. Although these two problems may reflect different funding sources and priorities, they are seemingly treated as separated issues which threatens to undo the potential transformative impact cycling could have in contexts such as London and across Oregon. In the next chapter, I shift attention away from the conceptual construction of these policy two, unevenly weighted, "problems" observed within the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Department of Transport* (2016), toward the actual implementation of cycling policy in cases of commercial data use. I will outline interviews with transportation professionals and software developers to illustrate how the policy "problems" presented within the TfL and ODOT policy plans are worked toward, and how data practices may lead to the unfolding of unintended consequences.

Chapter 6: Challenging technocratically driven mobility justice

6.1. Introduction

In the previous chapter, I suggested there is an inherent injustice in policy framings of the "problems" related to cycling, which result in the prioritisation of capitalist accumulation and individual freedom over diversity. Proposed data collection and appraisal mechanisms, I argued, risk contributing to this unequal weighting. In this chapter, I explore this risk further, by addressing the second research question of this thesis: *how Strava Metro data is used by transportation authorities at regional scale of government, and across different national contexts?* Building upon the critical discussion of cycling plans published by Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I next review how certain forms of Strava Metro data analysis occur at the regional government transportation departments. Drawing upon a set of interviews conducted with transportation professionals at TfL and ODOT, I first explore the emergence of *Big Data Innovation and Exploration* in relation to Strava Metro data, and map differences between the two regional government departments. Specifically, I outline the importance and relevance of cycling plans in guiding how commercial data sources are analysed and suggest that innovation has been taken further at one department compared to the other due to cycling plans and policies. Following this, I explore reported issues experienced by transportation professionals that have utilised Strava Metro data within the section entitled *Raising Data Efficacy Concerns.* Within this section, I focus on the technical challenges faced by transportation professionals that prevent certain research efforts from being conducted. More significantly, I discuss how restricted access to "raw" data places public administrations in a position of data dependency, particularly when data are being leveraged to support public policy ambitions.

In the section on *Challenging Technocracy*, I draw upon additional voices, including critical perspectives from transportation charities that call for a re-evaluation of Strava Metro data use. By doing so, I address the third research question of the thesis: *how does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?* Building upon the observed uses of Strava Metro data at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I argue that a technocratically driven form of mobility justice is advanced or sought using commercial sources. Drawing upon additional critiques from transportation professionals that are sceptical of the uses of Strava Metro data for the governance of cycling, I argue that contemporary cycling risks being determined by existing forms of unjust cycling that are understood to be highly unrepresentative of cycling in society. I do not suggest that this approach to data use is inherently unjust, which will give rise socially unjust futures; however, I do suggest that these futures are most likely. To conclude the chapter, I address the final research question of this thesis: *how can Strava Metro data use by transportation professionals be rethought to deliver more equitable and just velomobile futures?* To open this chapter, I thus start with a comparison between innovative and explorative uses of Strava Metro data at Transport for London (TfL) and the Oregon Department of Transportation (ODOT).

6.2. "Big data" innovation and exploration

In this next section, I discuss how Strava Metro data is subjected to detailed analyses at both Transport for London (TfL) and the Oregon Department of Transportation (ODOT) to support cycling plans published by the regional governments. Starting with uses at Transport for London (TfL), I outline how Strava Metro data have been reviewed by data scientists and transportation planners to quantify and review cycling within London. I outline how Strava Metro data are considered across different departments across regional government but are afforded greater attention by an operational department that is responsible for the management of traffic signalling. I then switch attention toward uses at the Oregon Department of Transportation (ODOT), where Strava Metro data have been assessed to support crash prediction modelling to support the delivery of dedicated cycling infrastructures across Oregon. Whilst this section does not outline an exhaustive list of all uses of Strava Metro data at TfL and ODOT, it does outline specific links to how "big data" innovation and exploration are specifically seen to support cycling plans published by Transport for London (TfL) and the Oregon Department of Transportation (ODOT). I conclude the section with a review of how and why the two approaches differ, and I suggest that one of the two regional government departments is seen to have developed greater dependency upon the commercial data to report on "scorecard" metrics. To start this critique, I next review the uses of Strava Metro data at Transport for London (TfL).

Strava Metro uses by Transport for London

As discussed within Chapter 3, Transport for London (TfL) is an integrated transportation authority which is responsible for the governance of the Transport for London Road Network (TLRN) and public transportation within the UK capital. The regional government is thus split into several departments to manage and deliver different aspects of TfL's work. Two TfL departments are seen to have reviewed Strava Metro data extensively. These Strava Metro data reviews are seen at (1) *City Planning*, and (2) *Network Management*, which are discussed in turn. Starting with the TfL City Planning team, TfL transportation planners have developed a strategic model called CYNEMON (Cycling Network Model for London) to estimate cycling activity across

London, and to estimate how cycling might increase following the introduction of dedicated cycling infrastructures. Indeed, as discussed in Chapter 4, the need for this sort of model is emphasised by the TfL *Cycling Action Plan* (2018: 39), which called for "An evidence-driven approach to cycling." Following this example, if there is a demand for cycling that can be empirically measured, then analytical tools such as CYNEMON may help to 'unlock' the potential for cycling by determining future forecasts and demand. When building the CYNEMON statistical model, the team at TfL City Planning drew upon a range of sources related to cycling, including London Travel Demand Survey (LTDS), Origin and Destination (OD) data from public cycle hire data within London. These core data sources provided planners at TfL with an estimated percentage of "switchable" trips to cycling in the future, combined with existing data on actual uses (see Davies, 2017). According to Transport for London:

> *"CYNEMON is designed to address the questions related to the routes that cyclists choose as they travel around London, taking into account aspects such as gradient, road type, cycle lanes and other traffic. It gives the user the ability to quantify the impacts of investment in cycling infrastructure and identify the locations where cycle infrastructure should be considered."* **(Transport for London, London's Strategic Transport Models)**

In addition to these core data sources that are used to predict future growth of cycling across London, the CYNEMON modellers at TfL also explored whether Strava Metro data could be leveraged to support the prediction of future cycling across London. However, due to the pre-processing of Strava Metro data, whereby samples are aggregated prior to being shared with Transport for London (TfL), the team working on CYNEMON model were unable to use the commercial data due to the loss of detailed routing, which a transportation planner at TfL describes:

> *"For the CYNEMON model we made relatively light use of Strava data. We needed detailed routing data so it wasn't something we could get from fitness apps due to privacy / data protection."* **(Transport for London, Transportation Planner)**

As a result of this, Strava Metro data was utilised only as a reference to "sense-check"(Davies, 2017) the observed cycle counts across the city of London to review, and to validate a count database. In other words, Strava Metro data did not feature in the analysis stages of predicting future cycling activity. However, the commercial data source was used to assess and validate cycling counts that were included within the CYNEMON model. Thus, whilst the Strava Metro data were not leveraged to predict future cycling, these data were used to check for accuracy and to confirm existing practices. Irrespective of how subtle or impactful Strava Metro data is for the prediction of future cycling across London, there is seemingly still a role for commercial data, even if that role is to confirm and approve that the characteristics of London's cycling are what they seem.

Next, I discuss how Strava Metro data uses at TfL *Network Management* have taken a considerably more active role in both supporting the plans *and* delivery of strategic policy at TfL. Discussing a model built within the Network Management (or "Operations") team at TfL, a Data Scientist discussed how Strava Metro data are used to try and predict cycling activity across the Transport for London Road Network (TLRN):

> *"that takes all that information in and estimates a total cycle flow. So, it's all taken from the dataset where it's all joined together. You've got your manual cycle count column and that is the target variable which you're trying to predict when it comes to machine learning and stuff. You're trying to predict that column [i.e., the manual cycle count data] based on all the other columns."* **(Transport for London, Data Scientist)**

Using this model to predict population wide cycling within London, the Operations team at Transport for London (TfL) have been able to conduct a review of cycling timing "benefits" along the Transport for London Road Network (TLRN) at specific sites. A Data Scientist at TfL outlines a summary of how these benefits of predicting cycling journeys are calculated:

> *"For each edge you get the journey time before, say 10 seconds, the journey time afterwards 9.8 seconds, the difference, the estimated flow along that edge through the model and then how many times the journey times difference by the [original] count, this is in seconds, and this is in hours but that's like 10 minutes saved to cyclists along that edge."* **(Transport for London, Data Scientist)**

The word "edge" within the quote by the data scientist at TfL refers to a specific geographic location in London (for a recap of Strava Metro products, also refer to Chapter 4). As the quotation above emphasises, time savings for all cyclists are calculated and added together to provide an overall (estimated) travel-time saving for all cyclists. Measured for a given period (such as over the course of one month), the total time difference before and after altering traffic signalling may then demonstrate whether cyclists experience time saving benefits. As a reminder of the discussion in Chapter 5, there is an emphasis noted in the TfL *Cycling Action Plan* (2018) that actively encourages the use of innovative data sources, and to explore how the plans could support cycling efforts. Innovation within professional practice, and the potential for creative forms of analysis of Strava Metro data are thus actively endorsed. For example, the *Cycling Action Plan* (2018) does not state that commercial sources of data should be leveraged to enhance and optimise traffic signalling; rather, this has emerged because of intellectual and technical ability combined with a licence to explore the potential of Strava Metro data. As a result of this creative freedom and technical capabilities, the impact of this work has not been limited to providing evidence for cycling alone but has also had a direct impact upon assessment of strategic policy at Transport for London (TfL). The lead data scientist responsible for this TfL project adds:

> *"Healthy Streets is TfL's, since Sadiq Khan became the Mayor, it's kind of his flagship policy at TfL really… In our department, the way we've kind of, as the department that does traffic lights, the way we've adapted to this is develop this metric which says, as a result of any changes, they make to traffic lights, and their timings, how much time have you saved to buses, pedestrians, and cyclists… But the cycling part of this metric was missing so as of Friday just gone, the first cycling benefits have been reported now as part of this metric."*
> **(Transport for London, Data Scientist)**

Justified and necessitated by the delivery of *Mayor's Transport Strategy* (2018), which underpins the TfL *Cycling Action Plan* (2018), the data scientist outlines how operational work within TfL is appraised against internal Transport for London (TfL) "scorecards" that reviews departmental impact. As the Data Scientist notes, the availability and creative application of Strava Metro data has thus enabled Transportation for London, for the first time, to quantify and evidence estimated time-savings (thus efficiency) for cyclists travelling along the Transport for London Road Network (TLRN). Because of this work, TfL now utilise Strava Metro to report on an internal department scorecard entitled "Traffic Signal Changes to Support Healthy Streets" metric that has been amended to review how work at TfL Operations (Network Management) minimise journeys made by public transportation users and cyclists. Using GPS data on the Transportation for London (TfL) bus fleet, data related to buses previously had been the only mode of transport that contributed to this Healthy Street Scorecard. Since the successful application of Strava Metro data to review time saving benefits, reviews of cycling journeys are added to this metric. Note that this applies to 'all' cyclists, not just Strava app users as Strava Metro data to support the prediction the total number of cyclists across London. From a policy perspective, this is quite a significant step toward quantifying cycling activity through the calculation of estimated travel times. Prior to the availability of Strava Metro data, the lack of spatial and temporal data related to cyclist activity could not have led to this development. In other words, without Strava Metro data (or a "big data" equivalent), Transport for London (TfL) would not be able to estimate time saving benefits to cyclists.

At Transport for London (TfL) then, leveraging "big data" sources such as Strava Metro has enabled Transport for London (TfL) to create a detailed model to estimate and understand how quickly cyclists travel through the Transport for London Road Network (TLRN). Whilst other sources of data (such as automated cycle counts) are required to validate and understand the characteristics of cyclists within London, Strava data thus plays a significant role how cycling is being researched and understood at TfL. Therefore, the world of cycling within London, however subtle, is increasingly being based upon algorithmic governance and social media data. Later in this chapter I will return to this discussion, to reflect upon the potential risks for regional governments, as well as for (existing and future) cyclists. Before discussing these risks, which include data dependency, I next switch the focus to discuss and compare how Strava Metro data have been utilised to support policy ambitions contained within the ODOT *Bicycle and Pedestrian Plan* (2016).

Strava Metro uses by the Oregon Department of Transportation

The Oregon Department of Transportation (ODOT) were the first public administration in the world to approach Strava for access to their data, which eventually led to the creation of a subsidiary company for data sharing called Strava Metro. Following the acquisition of Strava data in 2014, the Oregon Department of Transport (ODOT) reviewed Strava data to inform discussions regarding the locations for new cycle counters to monitor cycling activity. By reflecting on "heat maps", that provide an indication of intensity (the more riders, the brighter this may be displayed on an interactive map) ODOT used Strava data to support decisions on the geographic locations of counters in a geographical region called ODOT Region 1. Following this, researchers at ODOT started to explore the representativeness of Strava data by comparing it with permanent counters that recorded cyclists' journeys across Oregon. At this time, Strava had yet to be explored by numerous transportation researchers (as discussed in Chapter 2) and thus ODOT employees and researchers were amongst the first to critically appraise Strava commercial data for comparison between "observed" cyclists and Strava-tracked cyclists. In one of the earliest reviews of Strava data, the Oregon Department of Transportation (ODOT) found that there was a very high correlation between counter data and Strava data within the US city of Portland along one of the major bridges, but Strava data accounted for a very low proportion of all cyclists. Whilst the uses of Strava Metro during these initial assessments did not lead to significant changes in cycling investment, the availability of "big data" has had some subtle influence in supporting (or deliberation) where cycle counters should be installed to understand cycling. In these cases, sites of high-volume cycle traffic were afforded preference to evidence cycling activity. Following these initial reviews of Strava data, one of the first significant assessments of Strava Metro data by a public administration, that reflects the strategic priorities outlined within the ODOT *Bicycle and Pedestrian Plan* (2016), reviewed the commercial source to support safety and risk analysis of cycling. The application and approach taken for this research are discussed below by a Researcher at ODOT:

> *"[We] created safety performance functions which are very disaggregate, engineering level crash prediction models. Like at an intersection, based on vehicle volume and bike volume entering that intersection, and some other characteristics, what are the expected number of crashes, and you can do that across a whole system, and really see places that are having more crashes than you'd expect based on those geometric and traffic conditions."*

> *"One of the things I've focused on is trying to make a higher-level argument of like if there's a disparity in the crash risk for vehicle travel vs bike travel."* **(Oregon Department of Transportation, Researcher)**

As the Oregon Department of Transportation (ODOT) Researcher emphasises, the purpose of conducting a detailed analysis of crash risk derives from the need to understand where cycling incidents are most likely to occur based on the built environment and traffic conditions. The need for this work stems from observation that there are "disparities" between cycling and motorised transportation. In other words, cyclists are at far greater risk of fatality or serious injury compared to motorists and passengers, and thus there is a need for ODOT to identify and help to mitigate this risk through proxy measures. By estimating the sites of highest risk, ODOT seek to emphasise where cycle-specific or supportive highway infrastructures should be installed. As discussed within Chapter 5, data related to safety is directly referenced as a requirement to support the ODOT *Bicycle and Pedestrian Plan* (2016) and thus Strava Metro data is assessed for its potential in supporting this analysis and understanding of cycling safety. Despite demonstrating initial promise during the analysis of Strava Metro data, the ODOT Researcher noted that the commercial data source could not be successfully utilised to support the detailed crash prediction modelling efforts, as discussed below:

> *"I did some work with Strava using direct demand modelling… but it does improve the direct demand model. The problem was I didn't have Strava accurately assigned to the whole network, so I couldn't apply it to the whole network, but it improves things by a few percentage points in error."* **(Oregon Department of Transportation, Researcher)**

As the ODOT Researcher notes, the availability of Strava Metro was useful in analysis of direct demand model to estimate the annual average daily bicycle traffic (AADBT) along links within Oregon. Compared to cycling estimates derived from cycle count data, the commercial Strava Metro data source thus improved the model accuracy of cycling estimates across Oregon. Whilst models that were calibrated using Strava Metro data produced the least amount of error in validation tests, the commercial data source was not utilised by ODOT due to a technicality whereby the Strava Metro data could not be matched accurately to the spatial network (such as roads). Without this accuracy, ODOT did not utilise Strava Metro to perform a crash analysis or health analysis, that is required to make the "higher-level argument" for safer cycling. I will return to this technical issue reported by the ODOT Researcher within the section on *Raising Data Efficacy Concerns.* For now, I wish to keep the focus on data use, and emphasise why Strava Metro were considered by the Oregon Department of Transportation (ODOT).

Unlike Transport for London (TfL) which introduced a Healthy Streets programme that TfL should work toward, the Oregon Department of Transport (ODOT) specifically outline why data is required to support specific safety and equity using individual strategies with their *Oregon Bicycle and Pedestrian Plan* (2016). As such, the uses of Strava data reported by ODOT are seen to directly support evaluation of existing policies contained within the *Oregon Bicycle and Pedestrian Plan* (2016). The policies include specific data collection needs, including better data sharing to support safety analysis. Indeed, as the exploratory uses of Strava Metro at ODOT suggest, the availability of commercial sources did not change or predetermine how a safety analysis should be conducted. By using existing sources of "traditional" data, such as cycle count data, the review of safety would have been conducted with or without the availability of Strava Metro data due to the strategic direction outlined within the ODOT *Oregon Bicycle and Pedestrian Plan* (2016). For ODOT then, data such as Strava Metro do have scientific and analytic interest, but there is very limited reliance upon the commercial resource. This is emphasised by the Researcher at the Oregon Department of Transportation (ODOT) who stressed that:

> *"we're trying to be more agnostic about it and entertaining data from any source. It's about knowing what is the sample-size you need to make it reliable, and where does the deficiency in sample size cost the network for a given dataset, and what are the implications of those problems? Is a safety analysis just no good or does our bounds or air just expand but maybe to a reasonable point? I don't know."* **(Oregon Department of Transportation, Researcher)**

As the quotation from the ODOT researcher stresses, the need for data is not restricted to one source. Instead, there is a need, as emphasised within the *Oregon Bicycle and Pedestrian Plan* (2016) for data collection to understand safety, but these could, or rather should, be from a diverse mix of sources to help understand cycling. This includes sustained collection of data and information that is already collected by public administrations, and not necessarily commercial data sources related to cycling. In a departure away from the calls to embrace cycling through technical innovation and big sources, the researcher at ODOT focuses on a seemingly untapped potential of public data sharing across government departments, including the sharing of health, ambulance, and traffic accident data collected by emergency services to support crash modelling predictions. In other words, understanding cycling is not simply about understanding "existing" cycling, but rather understanding the conditions of how cycling risk is brought into being through a combination of complex factors, such as proximity to estimated risk. Again, this is reinforced by the *Oregon Bicycle and Pedestrian Plan* (2016) that calls upon public administrations to share data, in addition to understanding proxy estimates of risk and how people in society are disproportionally affected by transportation. Furthermore, the quotation above provides insight to the pressures experienced by the transportation researcher of working within the dominant "system of automobilities" (Urry, 2004). Consequently, the is a potential role for Strava Metro within ODOT, as professionals have sought to deepen their understanding of cycling safety risk, but the commercial source (and similar sources) are not privileged above any other sources. In other words, the analysis is not about Strava Metro data at ODOT; instead, the analysis is primarily about understanding safe cycling to evidence a need for supportive cycling infrastructures. In the next section, I offer suggestions as to why certain forms of analysis emerged at the two regional governments.

Cycling policies direct the analysis agenda

By critically reviewing uses of Strava Metro data at both Transport for London (TfL) and the Oregon Department of Transportation (ODOT), I argue that both regional governments anticipated the use of commercial sources, drawing upon guidance set out within their respective cycling plans. However, a significant point of difference between TfL and ODOT derives directly from the stated needs for collecting commercial data sources. As discussed within Chapter 5, whilst the Oregon Department of Transportation (ODOT) expressed a need for more data collection related to cycling, the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) also details strategic policies that require data, including the need for supportive data for safety and crash analyses. Whilst data innovation is suggested within the *Oregon Bicycle and Pedestrian Plan* (2016), there is clear guidance regarding data collection needs, and this has resulted in Strava Metro data uses that directly respond to the strategic priorities. Furthermore, the Oregon Department of Transportation (ODOT) do not only emphasise a need for commercial sources, but also for the collection of public data that is not presently shared effectively across government departments. As a result of this prioritisation of data needs, Strava Metro data has been reviewed by researchers at ODOT to directly support and assess specific research problems. Yes, the data analysis of Strava Metro has been exploratory, but it is in response to a very clear and articulated research aim. In other words, Strava Metro data have been used at the Oregon Department of Transportation (ODOT) to support and answer specific research questions. Following a technical issue whereby Strava Metro could not be accurately assigned to an underlying road network (which I will discuss further in the next section), the commercial data were not assessed for detailed high-level crash prediction modelling efforts, and thus the researchers at ODOT continued with "traditional" sources of data such as cycle counts.

This contrasts considerably with the approach to data collection and analysis that is promoted by the Transport for London (TfL) *Cycling Action Plan* (2018). Whilst Strava Metro data has also been subjected to exploratory analysis to assess how it may support and validate existing programmes of work, such as the TfL CYNEMON analysis, the data have also been used to directly support policy innovation. This is a significant departure from

ODOT, where Strava Metro data were used only to research and understand risks to cyclists. Indeed, as discussed above, by re-imagining how Strava Metro data could be used, the operational team now use the commercial source to predict and quantify time savings made to cyclists at sections of the Transport for London (TLRN) through traffic signalling changes. Note that these estimated time savings apply to "all" cyclists, and not just cyclists that use the Strava app to record their cycling journeys. By engineering traffic signals to support the flow of cyclists through central London, and thus by reducing journey times and efficiency, the health of highway cycling is seen to be directly calculable. Whilst these may be small or subtle policy changes, they are nonetheless have emerged because of the availability of Strava Metro data supplied by a commercial data vendor.

I therefore argue that there appears to be more emphasis on "innovation" at TfL to explore how Strava Metro data could be leveraged to support cycling. This is not to suggest that there is limited innovation at ODOT, particularly as Strava Metro data have been reviewed to support highly complex modelling efforts at the regional government. The difference regarding innovation stems from the respective cycling plans whereby actions taken by professionals at the regional governments are largely a direct *response* to the needs articulated within the TfL *Cycling Action Plan* (2018) and the ODOT *Bicycling and Pedestrian Plan* (2016). In other words, the plans have largely delivered in what they intended on doing in relation to commercial data collection. In contrast to the approach taken by the Oregon Department of Transportation (ODOT), Transport for London (TfL) research is considerably more dependent upon the bespoke analysis of Strava Metro data for policy appraisal. Whilst this review does not detail all uses of Strava Metro data at both Transport for London (TfL) and the Oregon Department of Transportation (ODOT), it does outline and emphasise how Strava Metro data are being used directly to support strategic priorities for cycling outlined within cycling plans. In short, I argue that out of the two regional government departments, it is arguable that TfL have become more dependent upon Strava Metro data to sustain their reporting for the Healthy Street scorecards. In the next section, I outline some of the risks of this dependency in the next section on *Raising Data Efficacy Concerns.*

6.3. Raising data efficacy concerns

In this next section, I explore the reported issues and obstacles that transportation professionals experienced whilst using Strava Metro data. Following an extended discussion of technical challenges of using Strava Metro data to support transportation models, I discuss contractual and data transparency concerns of Strava Metro data. Within this section I therefore focus on the politics of "big data" and reflect upon how concerns related to privacy, access, and ownership impact the delivery of cycling policies at the regional government scale. Before arriving at this discussion, I return the focus back to the technical issues related to Strava Metro data at Transport for London (TfL) and the Oregon Department of Transportation (ODOT).

As discussed within the previous section of this chapter, part of the challenge for researchers at the Oregon Department of Transportation (ODOT) related to the issue of spatial "accuracy". Whilst a critical review of Strava Metro data was seen to reduce statistical error, such as direct demand modelling of trying to predict where cycling journeys start and end, Strava Metro data could not be leveraged within highly detailed crash prediction models. Part of this challenge derives from the spatial matching of geographical positioning system (GPS) data with an underlying transportation or road network. In other words, the specific locations of cyclists are not "exact". Indeed, as discussed within Chapter 2, all GPS data are estimated locations via triangulation of a device using three satellites. Thus, the specific routing information of GPS traces may have a margin of error, metres away from the exact location of a GPS recording. To make sense of GPS traces, these data are then "matched" to an underlying map or road network to visualise how GPS traces correspond to an existing road network. For Strava Metro data products, this process is performed by the commercial software company before it is shared with regional governments. Thus, Strava Metro data are 'pre-processed' by the company Strava. Part of this pre-processing includes aggregating all data included for the Strava Metro project[9] within selected geographic boundaries, such as the State of Oregon or city of London. As a result of this, Strava Metro samples are only estimates of cycling activity, and these estimates are mapped by Strava before reaching the regional governments. Reflecting the challenges faced by researchers at the Oregon Department of Transportation (ODOT), data scientists at Transport for London (TfL) noted how the pre-processing of data resulted in technicalities:

> *"It fundamentally doesn't work for us because of the network we give to Strava. We provide them with a custom network that we use, we get it from Ordnance Survey and it's very detailed. At each junction, there would be like thirty nodes and it's trying to figure out the wait time for any of them is a bit tricky."* **(Transport for London, Data Scientist)**

The issue discussed by the TfL Data Scientist relates to one specific data product called Strava Metro "nodes", or data related to junctions. Nodes refer to intersections of "edges" (or "roads"), and Strava Metro supply these data to assess aggregated and estimated waiting times of cyclists. These data, according to Strava Metro, may provide insight into the average wait time cyclists are "stationary" (not cycling) at junctions. As the TfL Data

[9] Note that Strava app users are invited to participate into Strava Metro by volunteering their data, and some may not choose to 'opt-in' to the data collection effort. Not all Strava users will be included within Strava Metro datasets.

Scientist notes, however, these data were not useful from an analytical perspective as the network within London is too complex to derive wait times for specific nodes (where edges, or streets, meet). This was further complicated by Transport for London's (TfL) requirement that Strava Metro data should be matched to a network supplied by the UK Ordnance Survey, which is not open-source or freely accessible for public use. This is a departure from Strava Metro's standard approach of matching aggregated Strava journeys to an open-source platform called Open Street Maps (OSM), which can be edited and updated online by public users. Whilst TfL may not have been able to address this issue by accessing the "raw" Strava data (that has not been processed), this example does offer insight to the dependency upon Strava to supply data that meets the needs of the regional government partner.

To overcome the technical issues of Strava Metro data, Data Scientists at Transport for London (TfL) instead utilised edge data (related to spatial data such as streets or paths) to develop the transportation model to review cycling flows by calculating estimated cycling speeds. By assessing average cycling speeds, the lead Data Scientist at TfL responsible for the traffic signalling model to estimate time savings (and thus progress toward the revised Healthy Streets policy) found an unexpected and dramatic change in Strava Metro data. Referencing changes made to Strava Metro data following the implementation of the EU General Data Protection Regulation (GDPR) in the United Kingdom (which Strava Metro continued to use for all processing globally), the Data Scientist noted that:

> *"In April 2018 Strava changed their algorithm which does the GPS matching up the edges and ever since then the journey time data we've got has been way too fast."* **(Transport for London, Data Scientist)**

As the Data Scientist at TfL discusses, above, since a change in the processing of Strava Metro data, estimated calculations of cycling speeds notably increased compared to estimated cycling speeds observed from Strava samples pre-GDPR. In justification of these changes, in an interview with a representative for Strava Metro, a spokesperson emphasised that changes to how Strava samples are created is a direct response to privacy legislation and to enhance data privacy for app users:

> *"When we do our onboarding and privacy comes up as a conversation, we do obviously follow GDPR guidelines. So, the data is fully aggregated, there must be a minimum of 3 individual users that have done that street, or been down that trail, but we role the counts into multiples of 5, so you'll never be able to identify one single user."* **(Strava Metro, Partnerships)**

This approach reflects common ethical and government requirements for the use of secondary quantitative data sources, such as the approach taken by the Office for National Statistics (ONS) within the UK, whereby sources are aggregated to ensure that individuals are not identifiable, especially by nature of geography. In other words, sources of data should not reveal personal characteristics of people with their personal information such as their home and work postcode. In this example at Transport for London (TfL), whilst the Data Scientist responsible for this analysis expected data to arrive in a different format to pre-GDPR data (that had previously not been aggregated into counts to the nearest 5 for streets and lanes), the surprise for TfL related to a lack of communication (or miscommunication) regarding the measures taken by Strava to create Strava Metro samples:

> *"This is journey time data and how it jumps in 2018 this is like for the same edge. In 2017, 'oh look it's 8mph' and [then] suddenly it's a lot more noisy and less reliable as a data source but also bigger. And then in October this year there was another jump, which we didn't know about because they didn't tell us they were changing anything. I just had to discover it when I started calculating all the cycle benefits and they all came out negative."* **(Transport for London, Data Scientist)**

As the Data Scientist at Transport for London (TfL) emphasises, above, the estimated cycling speeds for Strava Metro data samples along one location in north London increased considerably following a processing change made by Strava. This change is illustrated in Figure 7 created by the TfL Data Scientist to emphasise the differences of calculated cycling speeds between pre- and post-GDPR Strava Metro data related one location in London. As Figure 3 demonstrates, average speeds fluctuated from 2018 following a processing change. In response to this, the Data Scientist at Transport for London (TfL) noted communication issues with Strava, combined with a limited understanding of precisely how Strava Metro samples are generated:

> *"I have been meaning for a while to set up a phone call with them [Strava Metro] so they can explain to me in detail how their algorithm works."* **(Transport for London, Data Scientist)**

As the Data Scientist at Transport for London (TfL) illuminates, above, the commercial company Strava do not provide specific details regarding how Strava Metro samples are generated. Whilst a descriptive account of Strava Metro samples is shared with organisations such as Transport for London (TfL), public administrations are dependent upon the commercial partners 'word' regarding sample generation. In other words, regional government departments do not have access to the raw data, nor the specific details (or "algorithm") used to create Strava Metro samples. Consequently, organisations such as TfL and ODOT are entirely dependent upon the private sector to perform what would have traditionally been public-sector functions (Haynes, 2015). As the regional government departments are removed from the data collection process, the organisations cannot review sources of data such as Strava Metro based on the business model set up by Strava. Central to the processing of raw Strava data to create Strava Metro data concerns relate to wider political tensions related to data privacy and adhering to legislation, such as GDPR and the California Consumer Privacy Act.

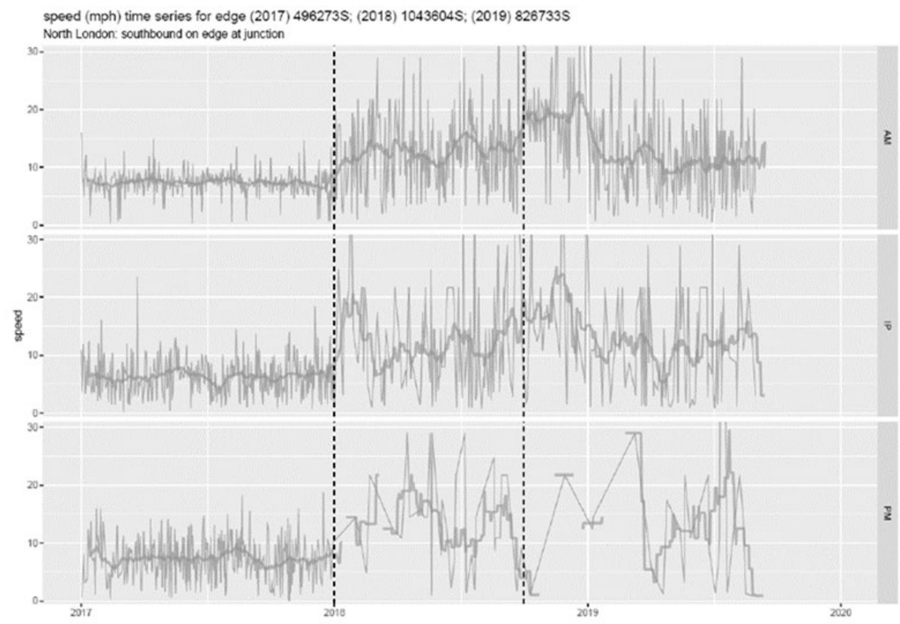

Figure 3: Strava Metro speed and time series graph at a location in London to illustrate differences in speeds before and after 2018 following an algorithm change by Strava (Source: Grayson / Transport for London, 2018)

6.4. Comparing best practice

In this next section, I draw upon the Strava Metro data uses and lessons that Transportation of London (TfL) could learn from the Oregon Department of Transportation (ODOT) and vice versa. It is important first to emphasise that transportation professionals at both Transport for London (TfL) and the Oregon Department of Transportation (ODOT) demonstrate a very thorough technical understanding of the potential uses of Strava Metro data for data analyses. Under no circumstances are commercial sources such as Strava Metro data seen to “speak for themselves”, and there appears to be very limited risk of Strava Metro data “replacing” the traditional sources of data related to cycling, such as manual and automated cycle counts. This provides assurance to critical data scholars concerns that regarding “big data” being privileged over “small data” sources (Dalton & Thatcher, 2014). Rather, “big data” sources are viewed as complementary to other forms of data related to cycling, and thus critical appraisals have been conducted to understand the characteristics of Strava Metro data samples to assess how these compare with the more traditional approaches of quantifying, understanding, and evaluating cycling.

The relative advantages of Strava Metro data use at the respective regional government departments relates back to policies outline by regional government cycling plans. At the Oregon Department of Transportation (ODOT), the potential of Strava Metro data reflected specific policies related to issues such as safety. Indeed, as the *Oregon Bicycle and Pedestrian Plan* (2016) demanded, more data related to cycling safety was required to support cycling, in addition to the potential uses of commercial data sources to support efforts to understand cycling. However, commercial data sources are not the only requirement outlined by the ODOT *Oregon Bicycle and Pedestrian Plan* (2016), which placed particular emphasis on the need to harness overlooked and under-utilised data sources collected by other government departments within the State of Oregon. Whilst these uses at the Oregon Department of Transportation (ODOT) largely follow the guidance set out by plans and policy, there is one issue: the analysis of data sources related to cycling may not lead to any changes toward realising the ODOT vision of supporting journeys made by cycle by the year 2040. Yes, the vision seeks to move toward a society whereby "everyone" is welcomed to participate, but the absence of an actual target makes this goal very difficult to evaluate.

This contrasts with the uses of Strava Metro data at Transport for London (TfL). Though the TfL *Cycling Action Plan* (2018) also emphasises the opportunity to utilise commercial data sources, it places far greater emphasis upon data innovation. Again, this lives up to the expectations set out by the respective TfL *Action Cycling Plan* (2018), as the creative intuition of data scientists at TfL demonstrated using Strava Metro data to calculate time saving benefits for all cyclists at certain junctions along the Transport for London Road Network (TLRN). Using Strava Metro data, TfL created a dedicated metric to assess benefits of traffic signal engineering, and thus the monitoring of policy toward achieving the *Mayor's Transport Strategy* (2018) of 80% of journeys made by cycle, foot, or public transport. Whilst this does appear to be successful use of Strava Metro data, there are clear risks of dependency upon a data source to monitor a metric that was never anticipated by cycling plans or policies. Though the TfL *Cycling Action Plan* (2018) does have set targets to support future cycling, it is increasingly being based on sources of commercial data that are not clearly stated by policy. I suggest the comparative concerns here relate to the Oregon Department of Transportation's (ODOT) lack of statistical measures to support cycling as noted within the *Oregon Bicycle and Pedestrian Plan* (2016), and Transport for London's (TfL) openness (albeit highly critical) to utilise commercial data to support policy without clearly articulating or matching this to anticipated objectives within cycling plans. I do not suggest here that observed differences in Strava Metro uses are unequivocally linked to the anticipated uses expressed by regional government cycling plans, however I am suggesting that Transportation for London's (TfL) *Cycling Action Plan* (2018) does offer licence to explore data rather than dictate, and this is seen through reported uses at the regional government department.

So far, this chapter has focused on answering how Strava Metro data are used by regional transportation authorities, across different national contexts. I have shown that whilst there are commonalities between Strava Metro data uses by TfL and ODOT, including appraising the samples to understanding the characteristics of commercial sources and to compare these with other more "traditional sources" of data related to cycling, differences are present. These differences derive from different research agendas, which I suggest are principally driven by respective cycling plans at Transport for London (TfL) and the Oregon Department of Transportation (ODOT). Furthermore, I have emphasised the risks associated through contracting with commercial data sources such as Strava, including data dependency and transparency. In the next section, I return to the discussion of prevailing values in cycling, that risks futures being based on a form of technocratic mobility justice.

6.5. Reluctantly embracing technocracy

In this next section for this chapter, I critically discuss how present uses of Strava Metro favour and promote a technocratic form of mobility justice. By doing so, I answer the third research question of this thesis, which asks: *how does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?* Whilst "big data" sources such as Strava Metro may help to "illuminate" certain practices of cycling, I suggest that there remain concerns that these data uses may reinforce and exacerbate existing injustices observed within contemporary society. To emphasise this point, I begin with a review of how Strava Metro data use is justified by transportation professionals at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), and by the commercial vendor, Strava. Following this, I then introduce perspectives of transportation professionals that are sceptical of app data uses for the governance of cycling. To open this critique, I next focus on how sample bias is accepted by transportation professionals at regional governments.

Data scientists, transportation researchers and planners at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) acknowledge the limitations of Strava Metro data. Without question, samples that are shared with the regional governments are firmly understood as containing data bias, and that

Strava users are unlikely to share similar cycling behaviours to non-Strava users. Despite this recognition that Strava Metro samples are highly unlikely to be representative of all cycling within society, the appears to be some resignation that this unrepresentativeness of sample characteristics are justified on the grounds that bias data is still statistically representative of cycling. When discussing the decision to include all Strava users (non-commute and commute) data within the Transport for London (TfL) model to predict cycling across London, the lead Data Scientist added:

> *"It would be interesting to maybe break this model down into commuters and non-commuters but then at the end of the day the cyclist is a cyclist and when you're comparing it to the manual counts, they're just counting everyone."* **(Transport for London, Data Scientist)**

There are assumptions made here regarding what cycling data represents. In the above statement from the Data Scientist at Transport for London (TfL), irrespective of the motivation for cycling, all cyclists are cyclists. By adopting this stance, cyclists are viewed as a homogeneous collective that share common ground in that they count as cyclists. In the example above, the TfL Data Scientist pondered whether filtering data to remove "non-commute" Strava Metro data would lead to any observable differences between cycle journeys that are tagged as "commutes" by app users. Strava users are encouraged to tag cycle journeys to work, as these can be filtered to support transportation professionals understand the commuting behaviours of Strava users. However, in this example at TfL, commute and non-commute journeys are combined to assess how all Strava Metro data compare with other sources of data, such as cycle counters within London. In other words, smaller data sources like cycle counters do not discriminate by who cycles or for what purpose, thus "big data" sources such as Strava Metro should not need to discriminate either. Thus, the central questions that is placed upon Strava Metro samples regard how "representative" the commercial app sources are when compared to existing and observable cycling practices. As discussed above, this is also reflected by the Oregon Department of Transportation's (ODOT) critical assessments of Strava samples, that initially sought to ascertain how Strava Metro data compared with cycle count data within the city of Portland. By performing these analyses, the initial questions asked of Strava by regional governments thus seek to answer the question: does Strava cycling reflect existing cycling? If the answer is yes, whilst acknowledging that biases are present within commercial sources, then commercial sources seemingly pass a quality assurance test for further analyses, such as time saving calculations at TfL. Indeed, this reflects the assumptions held by the commercial data vendor Strava:

> *"We're not promising that it's going to cover every single cyclist, but you can use it as a correlation for existing data."*

> "*With the Strava data, alongside the other existing kind of counter data, you could start to build a correlation and almost attribute an R squared number. So, we regularly see .8, .9 as a relative value for Strava cyclists.*" **(Strava Metro, Partnerships)**

The key word in the statement from the Strava representative, who is responsible for establishing partnerships with external partners such as regional transportation departments, is "correlation". As discussed above, Strava draw upon examples of academic research (such as those outlined in Chapter 2) to emphasise the case that Strava Metro data *is* "representative" of cycling. Whilst deficiencies exist within Strava Metro data, these are overcome by statistical significance of commercial sources and comparisons with observed cycling counts. Thus, although Strava Metro data samples are not representative of all cycling journeys, it is representative of cycling journeys that are observable and visible. The problem here relates to the assumption that however bias data are, these data remain representative of data related to cycling. This reflects the concerns of equality and social justice related cycling that brought into question when an unrepresentative mode of mobility is evaluated using an unrepresentative data source, such as Strava Metro.

Consequently, as the examples of reported uses at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) suggest, Strava Metro data uses at the two regional governments did not seek to address issues of marginalisation or exclusion of users in cycling as there is no policy in place to explicitly address this issue using Strava Metro data sources. There is an assumption therefore that by improving conditions for cycling, such as promoting safety and efficiency, this will serve to benefit all existing and potential future cyclists. This supports a utilitarian and distributive vision of justice, one that assumes by enhancing provision for cycling will be experienced equally across society. However, as discussed in Chapter 3, cyclists are not a homogenous collective whose needs are somehow equal. Indeed, cycling plans, at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) are also very mindful that cycling needs are very heterogenous, and thus set out to address this complex policy issue (see Chapter 5). Despite this recognition, when it boils down to understanding cycling mobility needs using "big data", there is a very strong focus on quantitative data that treats all cyclists as the same (see Sheller, 2018). As such, the unevenly weighted, policy "problems" discussed in the previous chapter are brought into sharp focus. As shown, the fixation of supporting the individual needs such as efficient travel to work, does not work in tandem with complementary work to support to diversification of cycling. To emphasise this concern, I next draw critical perspectives of transportation professionals that are sceptical of the uses of Strava Metro data due to the concern for social justice.

6.8. Challenging technocratic approaches of justice

In this section, I return the focus back to the discussion of justice. Specifically, I use this next section to critically discuss how existing data uses at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) risk accelerating and exacerbating existing injustices of cycling by "scripting" cyclists as predominantly commuters. I argue that whilst existing uses of Strava Metro data may help to support certain approaches of justice, I assert that the technocratic approaches taken by Transport for London (TfL) and the Oregon Department of Transportation (ODOT) falls short of a more comprehensive approach toward mobility and data justice. The central concern relates to the uses of data such as Strava Metro without a more holistic approach toward mobility justice that is considerate of differing and heterogeneous cycling needs. To emphasise these mobility justice concerns, I introduce additional perspectives of transportation professionals based in the UK and USA that express concern regarding the Strava Metro data uses at regional government departments. Before I start this critique, I next outline a summary recap of the interwoven approaches toward mobility and data justice which guide the analysis of Strava Metro data uses.

Whilst spatial infrastructures that support cycling are brought toward the centre stage of planning and governance of mobilities by Transport for London (TfL) and the Oregon Department of Transportation (ODOT), the approaches of data ambitions and uses struggles to keep pace with the interwoven concerns from the demands raised by an emerging mobility and data justice. In Chapter 3, I outlined Sheller's (2018) call to develop a mobile ontology for justice, which goes beyond the transportation justice and spatial justice theories. The issue for Sheller (2018) related to the existing theories of justice being a-mobile, or "spatially-contained", which falls short for a more comprehensive understanding of how mobilities at different scales are interrelated and how mobilities are "brought into being". These scales include bodily scales, systems of transportation scales, and city scales. To complement Sheller's (2018) emerging theory toward mobility justice, I introduced additional literature from data justice to emphasise the need to critique how "big data" uses impact and govern mobilities, emphasising concerns related to data privacy. Following Sheller (2018), I do not argue that there is one single definition of justice, as this would undermine the complexity of issues that contemporary societies face today, which may be very different to the issues that face future societies. Rather, by evaluating Strava Metro data uses at Transport for London (TfL) and the Oregon Department of Transportation (ODOT) using a broader understanding of mobility justice, it is possible to demonstrate that a narrow utilitarian and distributive sense of justice emerges, which I will emphasise next.

The issue I observe with existing "big data" practices at TfL and ODOT relates to treating cycling in isolation as an infrastructural challenge, offering limited consideration to how decisions affect people differently. I am not arguing that approaches to Strava Metro data uses are inherently unjust, but rather the regional government departments overlook complexity of how decisions (or ambitions) made "stages" (Jensen, 2013) the governance of mobilities. To emphasise concerns, I next introduce critical perspectives from transportation professionals that have not utilised Strava Metro data, starting with perspectives from Sustrans. Sustrans is a transportation charity based in the United Kingdom (UK) that manage and own sections of a "national cycle network" (NCN). In addition to the management of recreational routes across the UK, Sustrans also work closely with local, regional, and national governments in the UK to support projects related to walking and cycling. As a recognised stakeholder for transportation schemes in London, Sustrans London were invited to a presentation regarding Transport for London's (TfL) uses of Strava Metro data, but following this meeting expressed concerns publicly regarding commercial data uses. In an interview with Sustrans for this project, the representative at Sustrans noted:

> "*women move differently to men through space, if you keep on recording cyclists who commute and try to get their commute as fast as possible, they're not going to stop at the shops, they're [Strava users] just going to bomb down the main road to get to work as quickly as possible and you think that's how all the world wants to move, which is so far away from reality, it's just going to reinforce an aggressive, competitive environment where you provide radial routes in and out of workplaces where men work, and it's just never going to broaden mix of people cycling.*" (**Sustrans, Head of Built Environment**)

As the Sustrans spokesperson stresses, there is a concern that through the uses of Strava Metro data, predominantly datafied voices are privileged. This brings the discussion back to an earlier concern of how statistically "representative" Strava users are of other data sources, Strava Metro data therefore privileges people that may cycle out of choice, and not necessity (Golub et al., 2016; Spinney, 2021). The rationale for individual users of Strava are not explored in this study, yet there is an established and observed consensus that Strava app users are motivated by fitness and speed (Barrett, 2016; Smith & Treem, 2017) and not necessarily by multi-purpose trips. Sheller (2018) brings attention to how planning for transport historically ignores complexity, including trips related to unpaid labour such as childcare and voluntary care. Yes, the availability of "big data" related to cycling may position the mode further along a transportation agenda, but utilisation of seemingly bias data sources does not address fundamental issues that have been created by existing and highly gendered mobility regimes, that have privileged mobility of commuter needs. In relation to age, the Sustrans representative adds:

> *"Collect all the data you want from phones, if the child doesn't have a phone, they're no-one, and how does that, you know, how can you justify that? There's not going to be a single journey to school on commuter Strava… If you cycle to school that is like the main thing that correlates with your cycling as an adult, you're missing all of that."* (**Sustrans, Head of Built Environment**)

As the Head of Built Environment at Sustrans discusses, sources such as Strava are seen to contain significant data biases, especially regarding trip-purpose such as journeys to school. Indeed, though the limited availability of data related to cycling has shaped what forms of analysis are possible at TfL and ODOT, there remains a very narrow conceptualisation of who is recognised and understood as a cyclist (Spinney, 2021). Additionally, this brings us back to the issue of what topics are legitimised as topics for deliberation. Indeed, the uses of data are not discussed with people that may be affected by changes to the built environment. Furthermore, non-productive journeys, such as slow cycling mobility (Popan, 2019), dwelling, and play spaces do not feature in the analysis of Strava Metro data. Consequently, children's mobility, for example, does not feature in the modelling efforts, and thus any infrastructures that may arise (however subtle) from the analysis and utilisation of Strava Metro data ignores "non-standard" and "offline" actors (Spinney, 2021). Rather, it is the visibility of cycling, in spaces and times of highest conflict with other modes of transport that are driving the analysis of Strava Metro at the regional government departments at TfL and ODOT. Informal care work, multiple-purpose journeys, fears, and anxieties of cycling are assumed to be supported by the hyper-rationalisation cycling as a measurable science.

6.7. Discussion: how socially just cycling futures are possible

In this discussion section, I address the final research question of this thesis: *how can Strava Metro data use by transportation professionals be rethought to deliver more equitable and just velomobile futures?* As a recap of how we've arrived at this question, it is first important to re-emphasise the core concern raised by this thesis. The dominant policy framing of cycling's "problems" within policy plans such as the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016) offer consideration to the need to diversify cycling yet continue to prioritise capitalist accumulation and individual freedoms. Due to an unequal weighting of these policy "problems", I argued that data collection and appraisal mechanisms risked further separating these problems further, potentially contributing to socially unjust framings of cycling. Through interviews with transportation professionals at Transport for London (TfL) and the Oregon Department of Transport (ODOT), I argue that these risks have materialised. Thus, the "datafication" of cycling, is accelerating the tensions between these two important, but unequally weighted "problems". That is not to suggest that privatised sources such as Strava Metro should be omitted from analysis, rather, there is an ethical and urgent imperative to afford genuine and equal weighting to questions of diversity. To do this, policy plans must recognise the potential harms by understanding that there the needs of mobility users of heterogenous, without relying upon transportation professionals to make these decisions (i.e., Transport for London's decision not to use of Strava Metro within their comprehensive CYNEMON model). Equally, transportation administrations must work with communities, through collaborative planning and engagement with communities, especially when data are used to underpin decisions.

Indeed, seeking to ascertain the representativeness of data such as Strava Metro data is insufficient, even when socio-economic and deprivation data are considered. Thus, cases of Strava Metro data use fall considerably short of a comprehensive approach to mobility justice, that offers meaningful consideration which moves beyond the distribution of cycle specific provision, people's capacity to make use of cycling will be narrowed to the existing beneficiaries who value faster, more efficient journeys to workplaces. In other words, the greatest agency will continue to be afforded to those that (A) already cycle, and (B) are highly visible to transportation data collection efforts. Consequently, the "baseline" of cycling is being validated by data understood as an unrepresentative mode. There is certainly a lack of consideration of how analysis of cycling through modelling actively constructs imaginary cyclists (Cox, 2020; Spinney, 2021). Echoing concerns raised by Dalton et al. (2016: 5-6) "big data" sources such as Strava Metro are empowering transportation authorities to "remake the world through their algorithms, less interpreting than 'actively framing and producing'" of who counts as a cyclist. Of greater concern relates to the assumptions of what is valuable for cycling and in turn perpetuating these values through data models.

For example, as discussed above, the technocratically driven approaches observed Transport for London (TfL) focus upon peak demand hours also privileges cycling during daytime hours. Whilst morning and afternoon peaks during winter months mean that cycling will not be conducted during day light hours, the focus on peak times ignores the evening and night-time cycling. If the time saving benefits are limited to daytime hours, the needs of cyclists outside of these hours are also at risk of being overlooked due to less demand. These may include people that do not have regular working patterns. The needs of the most "visible" cyclists are thus emphasised by the availability of Strava Metro at Transport for London (TfL). Indeed, the speeding up and efficiency of cycling also fails to consider social connections. As discussed by Gartner (2016), highway infrastructures to cities have been assumed to support the needs of rural women, yet issues such as access to social infrastructures and communities by Gartner's (2016) participants were valued considerably above faster access to employment centres. As Gartner (2016) states, the failure to consult with rural women consequently led to highway infrastructures that did not support frequently made journeys (Gartner, 2016). The same risks apply and are visible at both Transport for London (TfL) and the Oregon Department of Transport (ODOT). The concern here is simple: irrespective of how much data is available related to cycling, a failure to address the fundamental barriers that stops marginalised and excluded people from participating in cycling, therefore, is unlikely to result in a future mobility system that addresses these mobility injustices. The same applies to generational issues related to cycling, echoing the critique raised by Spinney's (2021) issue with the internationally praised Dutch CROW (2007) *Design Manual for Bicycle Traffic*. Spinney (2021: 65) observed how children are viewed as "deficient adults" by the CROW Manual, who are anticipated to adapt to "normal" cycling behaviours as they age. The CROW (2007) design guidance seeks to accommodate cyclists, whilst simultaneously holding the assumption that children will adapt to "adult" cycling.

At the Oregon Department of Transportation (ODOT) there is also scope for critique from a social justice perspective. Indeed, as the successful utilisation of demand modelling suggests, predictions of cycling remain based upon an existing cohort of cyclists. However, this also applies to attempts to leverage Strava Metro data for transportation safety and crash prediction models. Although Strava Metro data could not be successfully assigned to an underlying road network to Oregon's road network, the ambition to predict (and thus prevent) accidents through data perpetuates another assumption regarding safe cycling. As Whitelegg (2020) discusses, data related to accidents are helpful in one sense, but not in another. If there are few reported or estimated crashes, this does not mean that an environment is perceived as safe or desirable to cycle in. Moreover, it is evident that through the utilisation of Strava Metro data, journeys made by children (largely) unaccounted for. As discussed within Chapter 2, Strava Metro is a social media platform aimed at an adult population, and therefore Strava Metro samples are unlikely include any trips made by children. Establishing a baseline of cycling around existing cyclists therefore thus prioritises journeys for adults. Equally, older cyclists are also largely unrepresented by Strava Metro samples. Research by Jones et al. (2016) has emphasised that cycling at speed has a negative impact for older cyclists that increasingly struggle to perform "taken-for-granted" cycle manoeuvres, such as turning necks to observe surroundings. To continue cycling into older age, cyclists must 'adapt' (Jones et al., 2016) to the environment through cycle technology. With an absence of clear guidance regarding establishing and utilising a baseline of cycling using sources such as Strava Metro, I therefore suggest that future cyclists will be expected to "adapt" to velomobility systems that favour higher speeds.

Existing policies at TfL and ODOT explicitly call for more cycling, but do not consider at "what cost" for society. Undoubtedly cycling is good for people to participate in. The benefits for the individual, the state, and the environment are numerous. However, the evidencing of more cycling using sources such as Strava Metro data cannot be relied upon to draw conclusions of successes in cycling without fuller consideration to how cycling may unwittingly have a damaging impact for people in societies. The "idealised script" (Cox, 2017; Spinney 2021; Fallon, 2008; Yaneva, 2009) of cycling planning and data practices has been written to consider all people. Indeed, policies at TfL and ODOT articulate this need. There are, however, no guarantees that all hoped-for future cyclists will understand, have capacity, or wish, to act upon this "idealised script" of cycling if the needs of cycling continue to privilege and favour a selected (increasingly datafied) few. As such, existing data practices at TfL and ODOT, using sources such as Strava Metro, seek to "(re)create" cyclists that will take advantage of cycle systems within a rigid political and ideological framing (Cox, 2017).

Thus, there appears to be little consideration to the spheres of "production" (from data to cycle-specific infrastructures) to "consumption" (who in the future will cycle) (Fallon, 2008). Policies reviewed within this analysis seek to reflect and pragmatically replicate the successes of northern European cycling successes, drawing upon the guidance such as the CROW Manual (Spinney, 2021) where cycling mode share ranges from 10-26% (Parkin, 2018). Despite this, there are also failures and opportunities for "high-cycling" (Aldred, 2016) countries to improve conditions of cycling to also create a more inclusive network. More cycling does not mean more diversity in cycling (Aldred et al., 2016). Equally, more cycling is not inherently good for all of society, particularly in the US where cycling has been critiqued for its privileging of those that are already highly mobile (Stehlin, 2014; 2019; Golub et al., 2016). Thus, I suggest, along with several other authors (see Popan, 2019; Spinney, 2021 for example), that there is an imperative need to re-imagine and re-conceptualise cycling policies. As this thesis shows, the "datafication" of cycling has generated new opportunities to monitor and evaluate cycling, and thus legitimise the mode from a policy perspective, yet this must be done with greater sensitivity to diversify cycling. Failure to do so will result in further tensions between supporting an increase of cycling mode share, whilst continuing to undermine efforts to foster inclusive, socially just cycling futures.

This brings us to a discussion of what socially just cycling futures look like, and how they can be worked toward. It is important to emphasise the relative merits of existing uses of Strava Metro data by the two regional government administrations reviewed for this thesis. With respect to the Strava app users, their data are aggregated and anonymised before these are shared with government administrations. Furthermore, as discussed within chapter 2, Strava app users are required to opt-in to the metro data collection project, and thus resulting data sets shared with public administrations adhere to existing data protection legislation, such as GDPR. However, as this analysis has shown, existing data practices at organisations such as Transport for London (TfL) and the Oregon Department of Transportation (ODOT) fall short of an interwoven approach to mobility and data justice which goes beyond data privacy. Indeed, the central concerns raised by this analysis relate to the lack of deliberation and engagement with the wider public on critical data exploration, thus does that stand up to a more comprehensive demands of social justice that go beyond utilitarian and distributive justice considerations. As such socially just cycling futures must start with user diverse user needs and capabilities, which can only be achieved by working directly in collaboration with communities, including those who are not presently captured by the "datafication" of cycling.

6.8. Conclusion

In this chapter, I addressed three research questions. The chapter first explored Research Question 2: *how Strava Metro data is used by transportation authorities at regional scale of government, and across different national contexts?* I analysed uses of Strava Metro data at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), paying particular attention to the role of cycling plans and policies in guiding the analysis of Strava Metro data. I argued that whilst both TfL and ODOT had critically explored Strava Metro samples, innovation is taken further at TfL. Following this, I addressed Research Question 3: *how does Strava Metro data use by transportation professionals perpetuate mobility injustices in different national contexts?* By introducing additional critical perspectives of transportation professionals, I argued that both Transport for London (TfL) and the Oregon Department of Transportation (ODOT) offer consideration to injustices, but when doing so focus heavily upon utilitarian and distributive justice considerations. I argued that by promoting these issues, TfL and ODOT risk supporting the needs of a narrow section of society, that may value qualities such as speed and efficiency. The problem concerns an absence of deliberative justice regarding Strava Metro data uses, despite efforts to diversify cycling across the State of Oregon and the city of London. The results of Research Questions 3 do not suggest that sources of data use such as Strava Metro are inherently unjust or should not be utilised, but that the approaches such as the creation of metrics through innovation certainly support variants of cycling that privilege speed and efficiency, such as cycling commuting during peak traffic hours, which offers little to support the diversify cycling. As such, tensions between attempting to increase the convenience of cycling offers little to foster greater inclusivity are evidenced.

Following this, I outlined a discussion for the fourth and final research question of this thesis: how can Strava Metro data use by transportation professionals be rethought to deliver more equitable and just velomobility futures? In short, I have argued that there must be a rebalancing for the policy “problems” outlined within policy plans such as the TfL *Cycling Action Plan* (2018) and the ODOT *Oregon Bicycle and Pedestrian Plan* (2016). The tensions between seeking to (1) increase cycling mode share, and (2) to diversify cycling are left unaddressed by technocratic analysis of new data sources such as Strava Metro. The privileging of cycling that is made “visible” through data sources does so based on an existing cohort of cyclists, that may have very different needs to future cyclists. By basing cycling futures on commercial data that is evidently unrepresentative of society, there is a clear risk that cycling futures will fail to unlock the benefits of cycling equally across society for all people. Unless policy "problems” are reconceptualised to afford equal weight to the imperative need to diversify, the “datafication” of cycling will contribute to socially inequitable and unjust cycling futures.

Chapter 7: Conclusion

7.1. Introduction

This thesis has critically shown how the "datafication" of cycling is accelerating mobility and data injustices associated with the privileging on efficiency and individual freedom over diversity. In this final chapter, I provide a summary account of this thesis to stress the urgency for further critique and research related to this theme, and the policy opportunities which are available to support more socially inclusive cycling futures. To conclude this doctoral research, I re-emphasise the unique academic contribution of this work, and outline future directions for further critical research related to the "datafication" of cycling and debates concerning an interwoven approaches to support mobility and data just societies.

7.2. Summary of research

Throughout this thesis I have examined the relationship between the "datafication" of cycling and theories of justice, related to mobilities and data. Across seven chapters, I have built upon the central concern of social inequalities and injustices related to the dominant policy framing of cycling within specific "lower-cycling" contexts. Although I stress the need for cycling within these "lower-cycling" contexts, I critically ask questions regarding who benefits from the "datafication" of cycling – and more crucially, who does not. Following a review of literatures related to "datafication" processes, I outlined how the need to assess how the mass availability of "big data" has impacted cycling specific policies. Prior to conducting fieldwork for this thesis, I stressed how unrepresentative privatised data, such as Strava Metro, may unfairly privilege cyclists who are already highly mobile within society, who may cycle out of choice, and not necessity. To underscore the urgency to review how these data are utilised to support cycling related policies, I detailed theories of mobility and data justice to critically appraise "big data" uses by public administrations, such as Transport for London (TfL) and the Oregon Department of Transportation (ODOT). Through a critical policy analysis of cycling policy plans published by TfL and ODOT, coupled with semi-structured interviews with transportation professionals that have analysed Strava Metro data, I argue that significant tensions between policy ambitions emerged. Despite policy aspirations to (1) increase the total number of cyclists, and (2) diversify cycling, I argue that these goals do not work in tandem.

Irrespective of whether these reflect different funding priorities, I maintain that tensions between these goals are accelerated by the "datafication" processes, which struggles to achieve these ambitions simultaneously. Specifically, this is due to the prioritisation of "big data" analysis which focuses on highly individualised values, such as cycling speeds and efficiency, over the need to diversify. The issue is compounded as firstly cycling is an unrepresentative form of mobility due to its dominant policy framing, and secondly it is evaluated through unrepresentative forms of app data, such as Strava Metro. I thus argue that policy ambitions to support more inclusive cycling are thus positioned as secondary ambitions to increasing total numbers of cyclists. To move towards more egalitarian and mobility just futures, this thesis demonstrates that cycling policies must address both problems by moving away from measures to increase cycling mode share as their core priority and questioning the use of data. Rather, cycling policy plans should start with an ethical imperative to diversify participation in cycling, which is fundamental to sustainability. Without a re-evaluation of cycling policies and plans, uses of commercial data such as Strava Metro will benefit and unfairly privilege those who are already highly mobile, and who may cycle out of choice, not necessity. As I emphasis throughout, the benefits of more cycling across society are numerous, yet there is no guarantee these will materialise without transformative policy that aligns inclusive cycling provision with data practices that focus on mobility needs and affordances, rather than observable data and estimated demand.

Through this study, I have also uniquely contributed to contemporary debates related to "datafication" and an emerging mobility and data justice. Indeed, as discussed within Chapter 2 whilst significant attention has been afforded to the theorisation of "datafication", there are considerably fewer empirical contributions that have critically appraised these processes within their specific contexts (Flensburg & Lomborg, 2021). Furthermore, applied to cycling policy, there was a significant absence of literatures related to assessing the "datafication" of cycling, which this thesis has sought to mitigate. By assessing "big data" uses at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), this thesis has evidenced how cycling policy ambitions are supported. As discussed within Chapter 2, this thesis focused exclusively on the Strava Metro data, which, for some working definitions, does not qualify as "big data" – this research thus problematises debates regarding "datafication" and as such further work is required to conceptualise the blurred boundaries between understandings of "small" and "big" data. Indeed, despite not adhering to some academic definitions, Strava Metro data's impact echoes the debates of "datafication" related to concerns and debates including data privacy, digital exclusions, and private public partnerships. Furthermore, this research has equally contributed to emerging debates of mobility and data justice and has evidenced that further research is required to work directly with communities that may experience mobility injustices through the privileging of "big data", which I discuss next.

7.3. Future directions

This research has opened significant debate regarding the "datafication" of cycling within a specific policy context of London, and across Oregon. Whilst the policy ramifications are stated, above, there is urgency for researchers to critically engage with the "datafication" of cycling, and how mobility injustices are experienced by people who are directly affected by its impact, however subtle. Indeed, this research focused on assessing the "datafication" of cycling, and how these processes "stage" mobilities from "above", by policy and professional practitioners. As such, further research is therefore required to work with people and communities, to explore how the public may engage with decisions that are related to "datafication", including deliberative practices and procedural engagement – core tenets of an emerging approach toward mobility justice – which has profound policy implications beyond the cycling. It is my hope that this research serves as a critical springboard to generate further critical debate regarding the "datafication" of wider mobilities beyond this thesis' strategic focus on "lower cycling" contexts.

As a noted within Chapter 4, this doctoral study focused upon selected organisational uses of Strava Metro within the Transport for London (TfL) and the Oregon Department of Transportation (ODOT), this study is not representative of all regional government uses of Strava Metro data in the governance of cycling. The study originated and developed from reported uses within the cities of London (UK) and Portland (Oregon, USA), two cities within "lower-cycling" national contexts that have already received significant academic attention from cycling researchers (Broach et al., 2012; Aldred et al., 2015). Thus, this thesis relates to western cities that are already highly researched. Furthermore, this thesis focused on two English-speaking, western contexts, and studied selected regional level of governments of Transport for London (TfL) and the Oregon Department of Transportation (ODOT). In response to this, there are opportunities to expand the scope of this thesis beyond western cities such as London and Portland. This would respond to Zuev et al.'s (2021: 4) to explore the "broader diversity of successful and innovative examples of cycling innovation and governance and learn from failed initiatives and projects elsewhere".

Finally, there are also opportunities to explore the impact of "datafication" at the local level of government. Indeed, this thesis focused exclusively upon uses of Strava Metro data at the regional governments department level of TfL and ODOT as the two organisations were amongst the first to acquire Strava Metro data. Since the start of this thesis, there have been significant changes toward attitudes toward cycling, including increases in public revenue in cycling specific funding to support mobilities throughout the SARs COVID-19 pandemic which emerged during 2019. Since that time, not only have budgets for cycling changed, but also of changes to Strava Metro's business model to support a cycling agenda.

Reflecting upon the examples of Strava Metro data use at Transport for London (TfL) and the Oregon Department of Transportation (ODOT), it is evident that transportation professionals at the regional government departments are highly skilled and critical researchers. In scenarios, where Strava Metro data could not be utilised for certain analyses, these data were not used. These included data not being used by ODOT for crash risk modelling, despite circumstances where the commercial data reduced margin of error of cycling demand. At Transport for London (TfL), Strava Metro data did not provide detailed information regarding routing, once again highly skilled analysts did not use the commercial data sources directly to support modelling for the CYNEMON model. Furthermore, when issues arise regarding Strava Metro samples, transportation professionals are openly vocal and critical of samples and how they are generated. Transport for London's (TfL) open critique of samples and processing is one very encouraging example of this. Taking these observations together, it was possible to conclude that uses of Strava Metro data are not, under any circumstances, assumed to "speak for themselves". As an example of "big data" (for the purposes of this thesis), Strava Metro are also not seen as a "replacement" of "small data" such as manual or automated cycle counts for regional governments. However, the same assumption cannot be held for local government departments that may not have the technical or financial capacity to critically assess Strava Metro samples. There is a significant and urgent need to assess how local government departments use Strava Metro samples for future research efforts.

Appendices

Appendix A: Policy documents analysed

Policy Title	Date of Publication	Organisation
Mayor's Transport Strategy	March 2018	Mayor of London
Guide to the Healthy Streets Indicators	November 2017	Transport for London
Healthy Streets for London: Prioritising walking, cycling and public transport to create a healthy city	February 2017	Transport for London
Vision Zero action plan: Taking forward the Mayor's Transport Strategy	July 2018	Transport for London
Freight and servicing action plan: Making London's streets safter, cleaner and more efficient	March 2019	Transport for London
Cycling action plan: Making London the world's best big city for cycling	December 2018	Transport for London
London Cycling Design Standards	2014	Transport for London
Cycling and Walking Investment Strategy	2017	Department for Transport
Gear Change: A bold vision for cycling and walking	2020	Department for Transport
Oregon Transportation Plan	September 2006	Oregon Department of Transportation
Oregon Bicycle and Pedestrian Plan	May 2016	Oregon Department of Transportation
Oregon Transportation Safety Action Plan	2016	Oregon Department of Transportation
Oregon Public Transportation Plan	September 2018	Oregon Department of Transportation
Oregon Highway Plan	Amended May 2015	Oregon Department of Transportation

Appendix B: Semi-structured interview guide

Semi-structured interview guidance: Core topics (1 hour interview)
Overview to thesis and introductory questions **Provide participant with a participant information sheet and consent form.** Ask participant about their role: *Are you able to provide a background to your work?*
1. Policy needs for Strava Metro data Ask participant about the need to Strava Metro data: *Does Strava Metro data support the delivery of policy?* *Why is Strava Metro data required?*
2. Uses of Strava Metro data Ask participant regarding uses of Strava Metro: *How are Strava Metro data used at the organisation?* *Has the analysis of Strava Metro data led to any infrastructural changes?*
3. Perspectives of Strava Metro data Ask participant regarding any challenges or concerns regarding Strava Metro data use: *Have you experienced any challenges using Strava Metro data?* *Are you able to comment on working with Strava?*

Appendix C: Participant information sheet

University of Brighton

Participation Information Sheet: Pilot Interview

The Datafication of Cycling: Effects and Opportunities at the Intersection of Industry and Policy.

You are invited to take part in this research study aimed at understanding the role of partnerships and data sharing in the delivery of cycling provision.

What is the purpose of the main study?

The main project seeks to research and understand how crowdsourced app data, such as Strava Metro, are understood and used by transportation authorities, policy makers, and industry in the delivery of cycling provision through qualitative interviewing.

Why have I been invited to participate?

You have been asked to participate as you have professional experience in working as a transportation officer, with experience working in partnership with external organisations to improve cycling provision.

Pilot interviews will be used to identify key questions and themes for discussion for the main phase of data collection.

Do I have to take part?

The participation is voluntary, and participants are free to withdraw at any time without giving a reason.

Will I be paid for taking part?

You will not be paid to take part, but you will be offered refreshments for participating.

Will my taking part in the study be kept confidential?

All data will be anonymised and securely be held for a period of up to three years after the completion of PhD research. Personal information that may identify you will be changed (anonymised) in any reports, articles, or presentations.

Transcription will be fully anonymised and will be transcribed by the lead researcher only.

You will be invited to review a full transcript of the interview, and to check the accuracy of any quotations used as part of the study. It will be retained and used in the analysis phase. Digital audio recordings will be destroyed once they are transcribed.

Please note, although anonymity is provided, other participants (e.g. colleagues) may be able identify you through the nature of your responses.

What will happen if I don't want to carry on with the study?

You may withdraw at any time without giving a reason.

What will happen to the results of the project?

The results will be published as part of the PhD dissertation, and may be made available through academic reports, publications, or presentations.

Who is organising and funding the research?

This research is funded the ESRC South Coast Doctoral Training Partnership (UK Industrial Strategy steer).

What if there is a problem?

Any concerns or complaints will be addressed. Please refer to: Dr. M. Darking, Chair of the School of Applied Social Science Research Ethics Panel, University of Brighton.

Researcher contact details:

Shaun Williams, PhD Researcher, School of Applied Social Science, University of Brighton.

Supervision contact details:

Dr. F. Behrendt, Lecturer in Media Studies, University of Brighton.

Who has reviewed the study?

This study has been reviewed and approved by the Research Ethics Committee of the University of Brighton School of Applied Social Science.

Appendix D – Participant consent form

Participant Consent Form

The datafication of cycling: effects and opportunities at the intersection of industry and policy

Please state:

Company and Position:

Age: 20s, 30s, 40s, 50s, 60s+

Gender: Female / Male / Other, please specify:

Researcher only - Participant Identification Number:

CONSENT FORM

Name of Researcher: Shaun Williams

Please tick:

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that I am free to withdraw, without giving any reason.

3. I understand that interview data collected, interview recordings and photographs, from me may be used in future reports, articles or presentations by the researcher.

4. I understand that my name or any personal information which may identify me will not appear in any reports, articles, or presentations.

5. I agree to be part on this study.

6. Do you give consent for future contact or follow-up interview?

____

Name of Participant Date Signature

____

Researcher Date Signature

Appendix E – Reflections on pilot interviewing

Following the collection and review of a Strava Metro sample for the UK city of Manchester, qualitative interview questions were developed and conducted with transportation planners with an interest in supporting walking or cycling transportation initiatives. To increase the scope of data collection for the pilot research, interviews were open to any actor aware of Strava Metro. Pilot interviewees required no experience working with Strava Metro products. Furthermore, pilot interviewees did not need to be a stakeholder with a vested interest in Strava Metro products. Therefore, no rigid inclusion guidelines were applied to pilot interview recruitment. This allowed the interviewer to collect pilot data with transportation planning consultancies and software workers who were not the focus of the research. Pilot interview participants followed the same research ethical approval guidelines and were informed about the research project through the Participant Information Sheet (PIS) and offered the opportunity to review and amend the Participant Consent Form (PCF) if appropriate. For example, participants could reject aspects, such as permission to allow the researcher to record the interview. All participants were reminded that they were participating in the pilot study of the project, though their responses to questions may or may not be used as part of the final data collection. The qualitative interview pilot data collection phase ran from February 2019 to March 2019 and included discussions with transportation and software professionals from the cities of Cardiff (UK), Dublin (Ireland), London (UK), and Nottingham (UK).

A reflective diary was used to record the process of pilot interviewing. The main learning outcome of piloting demonstrated that interviewing with experts is a time-restrictive process, given that participants are employed representatives of an organisation. Most interviews lasted less than one hour and were scheduled to last for a maximum of one hour using an email appointment scheduling software. Four interviews followed a semi-structured interview guide, that allowed participants to expand about questions of interest, and to allow the researcher to ask for clarification. One pilot interview was intentionally left 'unstructured'; although this approach covered key discussions, the approach was dismissed due to time constraints working with professional participants. Two pilots experienced minor technological issues with Skype software relating to connectivity and signal issues. Audio-files were recorded using a manual voice recorder and were transcribed using no specialist transcription software. The main practical learning outcomes that emerged from pilot interviewing are outlined in Table 3 and are accompanied with solutions which were operationalised during the main collection phase.

Practical Learning outcome	Solution
Anticipated participants during the data collection phase are unlikely to be able to offer more than 1 hour of their time to this project.	Ensure participants are fully aware of project before interview via email and phone communication.
Scheduling appointments with email software was used by all participants and therefore would likely be used during main data collection phase.	Continue to use appointment scheduling software.
Semi-structured interviews provided clarity to the interview process.	Keep fieldnotes of discussions throughout the research process and use email and phone communication to tailor research questions, if necessary.
The use of unstructured interviewing was dismissed from the study due to anticipated time restrictions of transportation professionals.	Semi-structured interviews are preferred for interviewing. Structured interviews may be used if requested by the participant (i.e., if participant requested set of interview questions in advance of interview).
Remove Skype and telephone interviews as an option for main data collection phase participants to avoid potential technological issues.	Skype or telephone interviews may be offered only if requested by participant, or due to logistical reasons (physical distance to interview).
Specialist transcription software required for transcription.	School of Applied Social Science, University of Brighton have a licence for f4transcripk software.

Table 4: Lessons from Pilot Interviewing

Pilot interview data were transcribed into Microsoft Word and saved into *Rich Text Format*. These files were then uploaded to qualitative analysis software NVivo. NVivo was selected to assist with the organisation and exploration of data (Woolf and Silverman, 2018). A pilot deductive approach to coding interviews was developed by the researcher, prior to collecting pilot interview data, based primarily upon a review of literature. Thematic analysis was selected as the primary mode of analysis for qualitative data. Contrasting to other modes of qualitative data analysis, such as discourse analysis, thematic analysis "is not wedded to any theoretical framework" (Braun and Clarke, 2006: 81); as an interdisciplinary project that engages with several research fields, this is important due to the flexibility of the approach.

Coding is the process of collating and grouping key text and words together. This initially emerged as the "DEAPS" codebook proposed by the researcher to guide the coding process of interviews within NVivo. The

“DEAPS” acronym informed the coding of text under the following themes relating to Data, Evidence, Action, Partnership, and Skills. For example, pilot participant responses related to discussion of “data” were coded within the “data parent node”, which included sub-themes (child nodes) of specific examples (such as ‘big data’ and ‘data analysis’). The decision to design and test a deductive framework emerged from the researcher’s decision to adopt a thematic analysis (Braun and Clarke, 2006). Participant interview responses were treated at the latent level, whereby language is assumed to have a direct relationship with the research questions. Treating responses at the latent level contrasts to an inductive approach to participant responses, where themes may “emerge” from the data. Braun and Clarke (2006: 83) add that themes which may emerge during the analytical process have little or no relation to the research questions. Upon coding of the pilot interviews, the “DEAPS” framework was eventually rejected by the researcher as being too prescriptive and researcher led. Furthermore, the initial codebook did not support analysis from a justice lens. Consequently, the “DEAPS” framework was abandoned in favour of an abductive approach to coding interview transcripts which is elaborated within the main data collection phase and analysis. In the next section, I change the focus toward the researcher positionality, and reflect upon how experiences throughout the thesis also impacted upon the analytical decisions taken.

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