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Beyond automobility? Lock-in of past failures in low-carbon urban mobility innovations

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ABSTRACT

Automobility, including the infrastructures, technologies and institutions that created high dependence on private car use, has led to significant environmental and climate problems and notably high carbon emissions. Now cities are attempting to move beyond this failed regime by experimenting with a range of different mobility innovations. In this paper, we examine whether emergent policy-led experiments and innovation processes in low-carbon mobility are learning from the past, or whether they are reproducing key elements of past policy failures. Through four case studies – Birmingham, Stavanger, Milton Keynes and Melbourne – we assess attempts to break out of high-carbon automobility through three key factors, namely diversification of travel options, a shift from individual to shared forms of mobility, and whether these aspects are implemented at scale. We find that while all cities show potential for diversification and sharing at scale, current modes of innovation exhibit features that may reproduce rather than reduce high-carbon automobility. Our analysis attributes this risk of continued failure to how policy-led experimentation and innovation are structured and themselves become locked in, thereby upholding the obdurate automobility regime.

1. Introduction

In studies of energy policy and low-carbon transitions in general, the primary focus of policy research has arguably been on best practices, promising initiatives and ambitious targets, and on the constraints of implementing these (Stead, 2016; Macário and Marques, 2008). Naturally, policymakers and analysts are keen to understand how and why some cities, municipal governments, or urban-level actors achieve successful policies, and what barriers such policies encounter. There is currently a paucity of research on policy failure (McConnell, 2015; Sokołowski and Heffron, 2022). Studying failure, however, can be as important as studying the fraught paths to success. Assessing failure may uncover some of the deeper-seated, obdurate processes that underpin systemic transformation, including skewed power relations, ideological bias and lack of institutional capacity (Edmondson et al., 2019; Howlett et al., 2015; Baker and McCann, 2020).

In this paper, we examine whether emergent policy-led experiments and innovation processes in low-carbon mobility are learning from past failures, or whether they are reproducing key elements of past policy failures. This is of concern as for emerging mobility innovations to make a substantial contribution to low-carbon transitions, they must achieve significant breaks from the failures of the existing paradigm of automobility. In line with Sokołowski and Heffron (2022), we adopt a broad understanding of policy failure which includes not only an inability to meet some narrowly defined objectives but failure to meet broader social goals including sustainability and justice.

In the post-World War II period, urban planners across the US, Europe and elsewhere started planning cities premised on private automobility. In terms of energy policy, as well as environmental, climatic and land use policy, this paradigm or regime of automobility has now come to be widely regarded as a failure (Barr, 2018; Marsden et al., 2019; Sheller and Urry, 2016). Among other problems, the facilitation of private automobility is associated with urban sprawl, which is in turn closely interrelated with high energy consumption and emissions

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(Newman and Kenworthy, 2015; VandeWeghe and Kennedy, 2007). In recent years, this resultant car-centric high-carbon model is assumed to have been replaced by a "sustainable mobility paradigm" (Banister, 2008), which has attempted to negate the errors of the previous paradigm. Today, low-carbon and sustainable mobility have become mainstream, at least rhetorically.

The key concern of the paper is whether this shift to low-carbon mobility has learnt from the failures of the previous paradigm, or if it reproduces some of the characteristics underlying this failure. We ask, *do ongoing forms of experimentation and innovation in mobility constitute a significant break with automobility?* We examine this question through four case studies – Birmingham, Stavanger, Milton Keynes and Melbourne – cities that cover a wide range of characteristics in overlapping yet distinct transport transitions and sectoral legacies. Our analytical framework emphasises learning from failure, and particularly the relationship between innovation and path dependency (cf. Mattioli et al., 2020). Empirically, we examine how cities experiment with new urban mobility solutions in implicit or explicit response to the failures of previous regimes.

Our contribution to knowledge is to show that a central failure of the past – a tendency towards monoculturing in mobility solutions – may be reproduced through current modes of innovation. The findings of the article temper some of the prevailing optimism surrounding mobility experiments and clarify what a transition out of the paradigm of automobility would entail. We argue that moving beyond automobility would require a stronger and more coherent project of inclusive decarbonisation through multi-modal integration alongside the introduction of alternative fuels and last-mile solutions.

The article proceeds as follows. In section 2 we provide an overview of relevant literature on policy failure, and outline our approach to what it means to break out of a failing paradigm. Section 3 outlines our empirical approach and the case cities, while section 4 presents the analysis, which centres on what we hold as three key factors to breaking with automobility – diversification, shift to shared mobility, and scalability. Section 5 presents the conclusions of the research and identifies policy implications.

2. Theoretical discussion

2.1. Understanding policy failure

Policy failures are rarely clear-cut, as policies have multiple goals, framed differently by political actors who may support the same policy for different and divergent reasons (Howlett et al., 2015). The goals of policies may also change over time, as the opinions and interests of citizens and politicians shift and new concerns come onto the agenda. Part of this shift can be explained by how some political actors and movements are able to seize the agenda and construct narratives suggesting that previous policies have failed. In other words, policy failure is bound up with politics and power (McConnell, 2015).

In the energy sector, especially in the specific area of low-carbon mobility that we focus on here, the key question is not so much whether a particular policy is widely agreed to have failed in relation to its own objectives. Policies often do fail in relation to their own objectives, of course. Yet studies of concrete policies and regulatory frameworks suggest that such failures are produced by cognitive, affective and legal barriers inherent to regulatory design or implementation processes (Sokołowski, 2020; Gössling and Cohen, 2014). More broadly, policy can be deemed to have failed when it is part of producing problematic climatic, environmental or socially unjust outcomes (cf Davidson, 2020). Sokołowski and Heffron (2022, p. 4) define energy policy failure as "any energy policy which does not meet local, national, and international energy and climate goals across the activities of the energy life-cycle and where just outcomes are not delivered." They propose to assess such justice failures along five dimensions: procedural, distributive, restorative, recognition and cosmopolitanism (see also Heffron et al., 2018). Failures along these dimensions are often visible only over longer periods. While a policy may have achieved its own objectives, such objectives may be rooted in a socio-technical regime with particular assumptions, models and epistemologies that, over time, reproduce problematic outcomes relative to the normative goal of just low-carbon transitions.

Therefore, we understand failure in the context of socio-technical regimes, with their own internal logics of policy objectives, actors, institutions and discourses, as well as within the larger frame of sustainability transitions. There is considerable literature on socio-technical transitions in general (see Köhler et al., 2019 for an overview), that we will not discuss in detail here. In studies of mobility, there is relatively broad agreement that what Urry referred to as the system, or regime, of "automobility" has failed. As he writes (Urry, 2004), the regime has "locked in" a highly unsustainable, high-carbon society in which built infrastructures, cultures and norms constrain the ability to transition to more sustainable forms of mobility.

In terms of energy use and climate change, the problem with car dependence is that it 'locks in' high rates of energy consumption, through particular land use patterns, technological dominance, and so on. Influential studies by Newman and Kenworthy (1999, 2015) demonstrate at the city level how strongly per capita transport-related energy consumption is associated with population density, taking the latter as a proxy indicator for automobile-dependent urban form. These studies document the impact of strong legacies of past car-oriented policy and planning. Such policies are accompanied by deeply entrenched preferences, attitudes and practices formed within wider ideologies of individual liberty, choice, efficiency and safety, all of which support car travel in ways that seem difficult to change (Barr, 2018; Urry, 2004).

As these dynamics play out in automobile-dependent urban contexts, they tend to reproduce lifestyles and attitudes towards travel, which become manifest in consistent residential and mobility choices over time (Kandt et al., 2015; Scheiner, 2018; Van Acker et al., 2014). This intimate and self-reinforcing relationship between automobile-dependent urban form and car travel has produced a degree of infrastructural lock-in, preventing alternative modes from operating efficiently and satisfying travel needs. Consequently, urban planners, urbanists in general, and scholars concerned with sustainability widely consider this regime of automobility a failure (Geels et al., 2011; Marsden et al., 2019).

2.2. Can new mobilities break with the failures of the automobility regime?

There is a current groundswell of innovation in low-carbon mobility. This is likely driven by digitalisation, renewable energy technologies, and the political stimulus for more sustainable ways to move people around in growing and densifying cities. The urgency to mitigate climate change is a policy driver that has led to ambitious targets at national, regional and urban scales, growing the demand for low-carbon solutions such as electric buses and bicycles while increasing pressure to phase out fossil fuel cars.

However, it remains uncertain whether and to what extent these new mobility forms disrupt automobile dependence. For example, shared and demand-responsive services, possibly coordinated in a Mobility as a Service (MaaS) framework, emphasise the more efficient and less costly allocation of travel (Becker et al., 2020; Kamargianni et al., 2016). Yet, shared mobility services may only marginally reduce energy consumption if they fail to alter patterns of travel demand (Marsden et al., 2019). Similarly, the increased uptake of autonomous services, including shared ones, may even be counter-productive, if unaccompanied by reductions in car use and ownership levels (Acheampong et al., 2021; Pangbourne et al., 2020). Micro-mobility advocates envision more active and less resource-intense travel, but such solutions largely remain within the individual choice paradigm and often tend to shift demand away from active travel and public transport rather than from car travel (Christoforou et al., 2021).

We contend that a key failure of the regime of automobility is that of *having established obdurate materialities, practices and ways of thinking that privilege a presumed monoculture in mobility*. We understand "monoculture" here to mean regimes and systems that centre on one or a few types of technology, while narrowing down possibilities for other types. In other words, we take a pluralistic view of innovation, understanding socio-technical transitions as something more than simply exchanging one technology with another. Innovation also entails shifting the underlying structures, norms, practices and forms of organisation that underpin technological usage (Barr, 2018; Geels et al., 2011; Rinkinen et al., 2021). Obduracy in mobility is a result of not only the durability of roads, buildings and cities, but also of the intangible ways of thinking and acting that have co-evolved with these material artefacts (Hommels, 2005; Shove et al., 2015), as well as of a particular regulatory environment that upholds individualized norms of transport provisioning (Gössling and Cohen, 2014).

Learning from the failures of the regime of automobility means not merely substituting fossil-based vehicles with low-carbon automobility, but also shifting locked-in structures and the political economic norms that constitute them (Mattioli et al., 2020; Hopkins, 2017). In other words, beyond characterising the regime of automobility as centered on the private vehicle (Sovacool and Axsen, 2018), we crucially also approach it as *the facilitation of monoculture in transport options, premised on the conception of mobility as an individualized practice and on the private ownership of the means of transport*.

The socio-technical transitions literature can be helpful in understanding how to break out of lock-ins of obdurate systems such as automobility. This literature, in similar fashion, understands systems as consisting of networks of actors and institutions, material artefacts and knowledge (Geels, 2004). Niche innovations are typically seen as driving regime change, but the nature of this change is subject to much debate. A mainstream view is that the front end of innovation is characterised by multiplicity, contingency and openness, yet as profit-oriented firms seek economies of scale in order to reduce unit cost, this diversity is streamlined and reduced through convergence and lock-in towards dominant design (Arthur, 1989). Here obdurate infrastructure and processes of lock-in serve to steer innovations towards the paths formed by existing regimes, reinforcing monocultures within technologies and practices. Transitions scholarship on innovation also highlights practices of experimentation that can induce deeper regime changes and more significant breaks with socio-technical regimes of the past. This literature increasingly recognizes the multiplicity of experimentation (Torrens et al., 2019; Ansell and Bartenberger, 2016), as well as grassroots innovation (Smith and Seyfang, 2013) and a plurality of forms of innovation (Coenen and Morgan, 2020).

One way to break from unsustainable transport regimes prevalent in cities is to seed multiple locally situated projects which focus on a diverse range of potential mobility solutions. This approach seems to be favoured in contemporary urban policy making circles. Some examples include bike sharing schemes, autonomous bus routes, e-scooters, car-free zones, and free public transport. However, pilot projects are often fragmented. In order to achieve a transition to more sustainable mobility regimes, knowledge has to be wrangled and aggregated from these via inter-local and trans-local phases and finally form the basis of cosmopolitan niches (Smith and Raven, 2012). Since the selection of potential innovations emerging from these processes is not blind but socially constructed, these innovations are framed and filtered by intermediaries and subject to power and politics (Kivimaa et al., 2019; Haarstad and Wathne, 2019).

In the following section, we use four case studies to examine policy-led innovations and attempts to overcome the failures of the regime of automobility, addressing the extent to which they learn from or reproduce the failures of the automobility regime. To structure the discussion, we look at three key elements of breaking out of automobility, namely diversification of travel options, a shift from individual to shared forms of mobility, and whether these aspects can be implemented at scale.

3. Analytical approach: A comparison of four car-centric cities

3.1. Case study selection and comparison

The four case cities – Birmingham, Stavanger, Milton Keynes and Melbourne – have been purposively selected for the study. The cities share several major characteristics that are of interest to this article. First, each city has defined ambitious carbon emission targets and aspires to be seen as a leader in transitions towards low-carbon mobility. Second, they are each faced with strong automobility legacies, which present major obstacles for such transitions. Third, to overcome these obstacles, each city has developed strong actor networks that attempt to stimulate innovation towards low-carbon forms of mobility through the pursuit of ambitious projects and agendas aimed at promoting sustainable forms of travel through experimentation with novel mobility solutions. These initiatives range from off and on-road experiments with autonomous vehicles, successive rollouts of shared mobility schemes, electrification of vehicle fleets and more general urban policy experiments, such as strategies, projects and networks around urban resilience, climate action and smart cities. So, the four cities face similar challenges of dealing with automobility and car-centric urban development – challenges that are shared with many cities in Westerns countries and to some extent beyond (Hall, 2014).

At the same time, the case cities have diverse and different demographic, topographic, cultural and political contexts in which these similarly motivated and structured initiatives take place. Table 1 provides an overview of the similarities and differences of the case studies along key dimensions relevant to the analysis. The analysis is not primarily concerned with distinguishing and comparing individual features of the case cities, but rather identifies common trends in how cities attempt to break with automobility and highlights the challenges of doing so.

Our empirical analysis is based on published policy documents, media content and promotional material, all of which are publicly accessible with sources referenced in the text. In addition, the authors have worked on the cases through several research projects over time. The analyses of Melbourne, Milton Keynes and Stavanger also draw on interviews with public officials with responsibility for policy development and implementation within transport and urban development. Interviews with officials presented an opportunity to look behind and beyond the rhetoric of transport and urban development policies, and to improve our understanding of the intentions of planners and decision-makers. Drawing on this body of empirical material, we critically review how current mobility innovations are thought to enable transitions towards low carbon mobility. We focus on policies that directly relate to modes of travelling; upstream interventions such as land use planning and urban design, which exist in all cities, are not included, to delimit the scope of the research and enable sufficient analytical depth in cross case comparisons.

Some limitations of our study should be noted. Our focus on transport-related innovations does not take on board concerns of land use planning, urban design and densification. Our selection of the most significant innovations, while informed by extensive experience and literature, is nonetheless necessarily subjective. Our case studies are automobile-dependent cities in Western countries, whereas the experience elsewhere may be marked by key differences that merit further investigation.

3.2. Automobility and low-carbon experimentation in each city

The specific policy contexts of each city exhibit both similar and divergent dynamics in addressing automobile dependence. We will now look at these in turn.

Table 1
Case comparison along key characteristics.

	Birmingham (WMCA region)	Stavanger	Melbourne	Milton Keynes
Population	2,900,000	144,000	5,159,211	230,000
Gross population density (pp/km^2)	3220	3000	520	2584
Emissions per capita (CO2 equivalents	3.9 (2019)	2.9	22	5.3 (2014)
Car share of modal split	60%	59% (in the region Nord-Jæren)	76%	65% (journey to work)
Climate policy targets	Net Zero by 2041	80% CO_2 cut by 2030; zero growth in car traffic	45–50%; 50% for all new car sales to be zero emissions vehicles by 2030	Carbon neutral by 2030 and carbon negative by 2050
Transport governance and coordination	Integrated, strategic authority, Transport for West Midlands (TfWM)	Regional authority responsible for transport provision,	Integrated, strategic regional authority, State of Victoria Department of Transport, Local Governments across metropolitan Melbourne	Milton Keynes council (not specific to transport)
Key low-carbon mobility policy/ programs (examples)	Walking and cycling infrastructure, Tram line extension, Hydrogen-powered Sprint Bus services, electrification of public, private and commercial vehicle fleets, Midlands Future Mobility Testbed	Smart city Lighthouse, electrification of buses, BusWay, Car Sharing	Metro tunnel, Melbourne Airport Rail, 20 min neighbourhoods	EV infrastructure development, dockless electric bike scheme, park + ride, premium bus route network, bus prioritization, micro-metro, “the go-to UK test-bed for on and off-street CAV [Connected and Autonomous Vehicle] testing”

Sources: Statistics Norway, West Midlands Combined Authority, Transport for West Midlands, Australian Bureau of Statistics, Victoria Climate Change Strategy, Milton Keynes Council.

The metropolitan region of Birmingham, known as West Midlands Combined Authority (WMCA), has historically been a strong centre of the transport industry and seeks to build on this legacy to successfully transition to an innovation-driven, post-industrial economy. The region aspires to become a global leader in transport innovation, specifically in the development of Connected Autonomous Vehicles (CAVs) and supporting infrastructure, battery technology and related areas of manufacturing, propulsion, simulation and testing (MFM, 2018). The region became the UK’s first Future Transport Zone, which is a funding initiative led by the UK Department for Transport (DfT) to enable experimentation and trialling of new mobility solutions (DfT, 2019). The region secured £31 million from government and the private sector to develop the Midlands Future Mobility Testbed, which is envisaged to be the UK’s largest road network equipped with 5G wireless networks and intelligent monitoring to enable the testing and operating of CAVs (MFM, 2018). Through these projects, the region positions itself as a testbed location for private transport and mobility businesses who wish to trial new solutions and services (TfWM, 2021). In parallel, extensions of the tram line and the development of rapid bus services are underway, and the region became the first in the UK to roll out a commercial Mobility-as-a-Service platform (TfWM, 2019a). Such initiatives are aimed at decarbonisation, inclusion and active travel.

Stavanger is currently rebranding itself, shifting emphasis away from Norway’s ‘oil city’ to an ‘energy city’. To diversify its economic base, and to improve the mobility situation around the large Forus Industrial Park outside the city centre in particular, the city has initiated various smart city initiatives. Several of these are centered on low-carbon mobility solutions. Stavanger is a European Union Smart City Lighthouse City, it hosts the largest smart city conference in the Nordic countries, and employs a smart city coordinator.

Among the key mobility solutions of the EU-funded Lighthouse project were the use of electric or hybrid technologies for transport vehicles owned by the municipality, electric buses, improvement of charging infrastructure, the use of open data to improve urban transport, among other projects to electrify transport technologies and make transport more effective (Haarstad and Wathne, 2019). Beyond the smart city initiative, the city is developing a Bus Rapid Transit solution, called Busway, but due to funding problems and political disagreement, the completion of this system is significantly behind schedule. Other initiatives underway include piloting autonomous buses in multiple locations, including a spatially sandboxed test arena in the Forus Industrial Park, and an emerging pilot project on drone-based aerial mobility, electric buses, and micro-mobility.

Similar to most Australian cities, Melbourne is characterized by a dominant and deep-seated path dependency on automobility where traditional narratives have framed the transport task as that of mobility and alleviating congestion with technical and road building solutions (Legacy et al., 2017). Dovey et al. (2017) conclude that “despite decades of compact city policy, there has been little change to the practice of ever-expanding suburban fringe development and freeway building that entrenches and exacerbates car-dependency”. This lock-in is partly explained by Melbourne’s metropolitan governance deficit: an absence of clear and effective institutional arrangements across its metropolitan territory for urban planning and development, and for the coordination of urban services and infrastructure (Steele and Gleeson, 2010). In view of this lock-in, there has been a suite of experiments initiated by local government(s) to test and trial whole-of-city approaches to intractable metropolitan planning challenges across transport, housing and energy, often framed to make Melbourne ‘future-proof’ in view of climate change and related socio-ecological imperatives (Davidson and Gleeson, 2018).

Notably, the Resilient Melbourne strategy, developed as part of Melbourne’s membership in the 100 Resilient Cities network orchestrated by the Rockefeller Foundation, touted cycling as an important priority area for growing resilience, in the face of climate change and Melbourne’s hypertrophic population growth and congestion problems. One of its flagship projects, the ‘Metropolitan Cycling Network’ aimed to coordinate a metropolitan proposal for establishing cycle paths and corridors. This experiment struggled however to gain clear visibility and generate legitimacy (compared to other Resilience Actions). Journeys to work involving cycling remain at levels between 1 and 2 percent. Despite a multitude of cycling plans, it is primarily seen as a recreational activity. Melbourne’s car dependency also spills over to its public transport infrastructure. Despite having the largest tram system in the world, it is at the same time considered to be one of the slowest in the world due to approximately 75 per cent of the network being shared with other traffic on Melbourne’s roads.

Milton Keynes is now one of the UK’s fastest growing urban areas, with its population expected to double by 2050. As a new town built in the 1960s, the city stands apart from many other UK towns and cities because it was informed by 20th century planning concepts and visions circulating in international networks. The resultant city form is constructed around an American style grid of fast roads designed to facilitate fluid vehicular transport unrestricted by low rise, green neighbourhoods. It is dominated by an infrastructure built for motorised vehicles to travel between areas assigned separate and distinct uses – housing, shopping, business – and thus transport by car is deeply rooted in the city.

Throughout its 50-year history local actors have systematically sought to position Milton Keynes as a 'test bed' for innovations in sustainable living: business and governmental actors can test new ideas in place in Milton Keynes, setting standards for future adoption of technologies around the UK (PRP Architects, 2010). Various innovations have been trialled and developed through these test bed arrangements. The urban fabric strongly frames the search for sustainability solutions and city governance actors are often preoccupied with transport based technological innovations, e.g. Electric Vehicles (EVs) and Connected and Autonomous Vehicles (CAVs). Such approaches are deeply embedded in Milton Keynes governance networks and reinforced by national institutions located in the city and UK Government funding schemes (related to the UK Industrial Strategy) which Milton Keynes has successfully accessed.

4. Analysis: opportunities and tensions in moving beyond automobility

In the following, we assess whether the most recent spate of mobility innovations in the case cities represent a substantial break with and demonstrate learning from the failure of their automobility regimes. We have defined this failure as locking in a monoculture in transport options, through the obduracy of both infrastructures and practices, thereby upholding a highly energy-intensive socio-technical regime. Do the new innovations and experiments in our case cities manifest as significant shifts away from this failed regime, to less energy-intensive mobility sector solutions?

To address this overarching concern, we now examine cases in light of three interrelated factors, expressed through three questions. First, *are new innovations opening up diverse choices in modes of mobility?* Only a wide range of mobility options can provide the conditions for reducing car use in favour of alternative, low-carbon modes. Second, *to what extent do mobility innovations enable shifts from ownership to shared travel?* Breaking with the paradigm of individual choice and ownership is a prerequisite to superseding resource-intensive mobility systems (Barr, 2018; Nikolaeva et al., 2019; Marsden et al., 2019). Third, *can the new mobility innovations be scaled up to a significant extent?* Innovations must be scalable to break with the established regime of automobility and have real-world impact.

4.1. Are new innovations opening up diverse choices in modes of mobility?

In all four cases, we identify tensions between the potential to open up diverse modal choices and the persistence of existing infrastructure and practices which inhibit such potential from being realised despite the existence of various innovations. Milton Keynes (MK) is a relatively young city, with a distinctive sense of place emanating from its obdurate grid road system. While MK has ambitions to significantly reduce carbon emissions, motorised transport innovations such as EVs and CAVs with potential to extend this sense of place tend to be prioritised and a logic of layering infrastructure atop an unsustainable substrate followed. Innovations that challenge motorised transport such as those associated with micro-mobility (e.g. scooters and e-bikes) while present in MK currently tend to fall outside its development trajectory and generate less traction in local governance networks.

Melbourne displays a similar tendency to prioritise traditional infrastructure in its major transport investments, which flow to road and partially rail development, entrenched in a debilitating hub-and-spoke model. While commercial car-sharing appears to be gaining momentum, shared biking mobility schemes have largely stalled and e-scooters are currently in their infancy. Experimentation explicitly targets active transport, notably improving road layouts to improve biking safety, but a scattered push for metro-rail, tram and bus modes with inadequate alignment is leading to urban splintering. Thus, rather than implementing the high-level planning target of a 20-minute city, experimentation hardly dents the intractable car-based mobility regime, especially in suburban Melbourne.

In Birmingham, strategic initiatives focussing on public transport and active travel hold potential for modal diversity. The tram extension on reactivated railway lines and the development of rapid bus services will put in place viable alternatives to automobility accessing the city centre. Public demand for such solution is evident in steady pre-pandemic increases of tram and train patronage (TfWM, 2017). This shift may be further supported by the digital integration of bus, rail, taxi and car-sharing services through Whim, the commercial MaaS platform the region rolled out in 2018 (TfWM, 2019b). Yet, the impact of MaaS in part depends on the participation of mobility companies, such as car sharing providers, and widespread uptake at a large scale is currently not evident (Pangbourne et al., 2020). In parallel, ride-hailing services have been permitted to operate early in the region and commercial car and bike sharing providers further complement the range of mobility options, although uptake has been slow to date (TfWM, 2019a). Overall, early experience in Birmingham suggests that investments into authority-owned public transport services have hitherto had more impact on diversifying mobility practices than new, commercially operated mobility solutions.

Similar ambiguity is evident in Stavanger, where bus fleet electrification may decrease emissions but does not expand the range of modal choices or increase levels of service provision, which are closely linked to demand. Other low-carbon modal experiments like shared biking and digital public taxis (requested for the price of a bus ticket in trial municipalities via a website called 'fetch me': https://hentmeg.no) remain marginal compared to car-centric mobility practices embedded in infrastructure that continues to attract significant finance. The home-job-home ticketing scheme that subsidises period transport passes for employees in the region and connects existing public transport modes helps businesses to facilitate non-car commuting and is supported by mobility hubs, which co-locate access to multiple modes, including car-sharing options. A push for 'video-for-all', which seeks to expand telecommuting through improved digital access, seeks to decrease car trips by public-sector employees. Yet, as in the other case cities, these emerging initiatives complement rather than confront the mainframe reliance on automobility in existing urban transport regimes.

4.2. To what extent do mobility innovations enable shifts from ownership to shared travel?

The case cities do feature mobility innovations aimed at shared travel. However, the extent to which they enable shifts away from ownership-based mobility regimes remains highly uncertain. Stavanger's home-job-home scheme incentivises a shift towards subscription-based multi-modal mobility (buses, suburban rail and city bikes) by enrolling workplaces and their employees, and BusWay strengthens public transport. But car-sharing and micro-mobility e-scooters remain outside its ambit. Providers of e-scooters are still hard to control for the municipality, as they each pursue their own platforms, but centralised regulatory platforms with incentives for spatial distribution are underway in Norwegian cities. E-scooters appear to be replacing walking rather than driving, and it is therefore questionable whether they advance shared and low-emission mobility. Car-sharing companies including *Bilkollektivet* [The Car Collective] and the main public operator's *Kolumbus Bildeling* [Car Sharing] are also pursuing individual platforms. Each of these solutions exclude various publics – home-job-home's workplace-orientation does not reach the selfemployed, nor extend to family members, and car-sharing remains hard to access in low-density suburbs. Mobility hubs address this density issue partially through park-and-ride options that lessen car use rather than displacing ownership.

In Milton Keynes there are several shared mobility innovations which mostly fall under the banner of micro mobility, including two shared bicycle schemes, one for the short-term leasing of e-cargo bikes and three e-scooter schemes. There are also plans for shared EV clubs based around community EV charging hubs. Although there is increasing interest in shared mobility in MK and a number of options are developing, these initiatives are currently somewhat marginal to the development of Milton Keynes which continues to emphasise the use of cars as the main form of personal mobility (albeit increasingly EVs) over other forms of transport. Thus the grid road system and sense of place emanating from it tend to exert a powerful framing effect on transport innovation in MK and modulate the generation of diverse transport options.

Car-sharing solutions in Melbourne are primarily commercial – GoGet and Hertz' Flexicar. Unlike in Stavanger they feature hardly any low-emission cars, but similar to Stavanger they are concentrated in central Melbourne and a suburban rarity. Policy has placed high hopes on autonomous vehicles, which has been criticized however for using a future technology focus as a smokescreen for lack of present action. Consequently, individual car ownership remains the popular default, with apparently little appetite for shared forms of mobility.

In Birmingham, some initiatives to diversify mobility options are also aimed at encouraging shared mobility and thus reduction of car ownership. Shared mobility options include an expanded provision of authority-run rail and bus services alongside market-led car sharing and ride-hailing services. While patronage of tram and rail transport services have increased prior to the pandemic, bus ridership has consistently declined in the past decade (TfWM, 2017). As some of this decline coincides with the introduction of ride-hailing services (Kandt and Leak, 2019), integration and coordination of commercial shared mobility solutions seems necessary to promote ride sharing in the region. The MaaS platform offers potential to do this, but its impact depends on its design and operation. While there is little data on uptake, commercial participation remains modest compared to highly visible company participation in Helsinki, where Birmingham imported the scheme from (https://whimapp.com/uk/). As a result, commercially run services are currently little integrated, and citizens seem hesitant to take up ride-sharing in a region marked by persistent socio-economic inequalities (TfWM, 2019a). Overall, a shift to shared mobility seems challenging without developing strong policy levers to encourage sharing.

4.3. Can the new mobility innovations be scaled up to a significant extent?

In both Stavanger and Melbourne, it is evident that despite a good deal of experimentation, it fails to break with the regime of automobility in terms of providing a diverse range of options and shared mobility models that are scalable. The experiments that appear to hold promise have not achieved buy-in for rapid expansion into full-scale alternatives. Prospects for autonomous vehicles appear to be framed within the extension of private automobility. Even though experimentation is underway and some of it highlights potentials for shared and low-carbon mobility, it is unclear how policy frameworks will encourage new forms of ownership and shared usage alongside the introduction of new technology. There appears to be a gap between the celebration of technological potentials for shared and diverse mobility on the one hand, and the willingness of policymakers and other decisionmakers to realize these shifts in practice, on the other.

Testbed innovation projects in Milton Keynes are presented as solutions with transferability to other urban contexts; yet many such projects fade away when public finance is withdrawn. Their impact even within Milton Keynes is marginal despite being well-aligned with the city's policy goals. Arguably, Milton Keynes' mobility governance has been inflected by a managerial approach characteristic of industrial enterprises geared to competition, short-term efficiency and solutionism. The 'projectification' of innovation to secure public funding renders testbed projects an end in themselves, losing sight of longer-term public-minded planning goals that require 'care' by enrolled actors.

Similarly to Stavanger and Melbourne, insufficient care erodes the ability of Milton Keynes to undertake the structural changes necessary for innovation projects to achieve long-term goals like decarbonisation, risking that Milton Keynes may become a city of perpetual 'fast experiments' and real-life testbed from which actors routinely extract and abstract technologies and ways of working to other contexts. Proliferating in city governance networks, the imaginary helps to direct serial investments to 'quick fixes' in incremental layers steered by incumbents, limiting investments to transformative socio-technical innovation and practices that consequently fail to challenge the automobility regime.

Birmingham, by virtue of having an integrated transport authority spanning all modes, enjoys a strong institutional basis for upscaling. With this capacity, the region continues to significantly improve public transport through rail-based investment and operation. A strong emphasis is also placed on a more efficient, region-wide bus network (TfWM, 2016), although the deregulated nature of bus services in the UK outside London has hitherto restricted scope for strong coordination. The Midlands Future Mobility Testbed for CAVs is specifically aimed at assessing the feasibility of upscaling. In so doing, the region's transport authority emphasises a vision of CAVs as last-mile shared services to fill gaps in public transport provision (MFM, 2018; TfWM, 2019a). On the other hand, the political rhetoric highlights innovation and economic development in the region since the supporting co-funding scheme includes significant private investment from the local automotive industry (WMCA, 2018). Accordingly, current CAV trials emphasise technical aspects such as safety, traffic flow and energy savings rather than the strategic design of integrated transport systems. Scalability is also constrained by time-limited financial support by the UK government, after which continuation is reliant on local sources including from the private sector.

4.4. Case synthesis

We argue that a shift away from automobile dependence can only be achieved through strategies that diversify mobility options and enable sharing at scale. Adopting the lens of diversification aimed at reducing car use and sharing aimed at reducing car ownership, we assess the probable impact of innovations on moving beyond automobile dependence (Table 2).

In all cities, we find that many policy-led innovations primarily aim to diversify mobility options within the confines of a car-centric transport system. For instance, cycling and walking infrastructure initiatives in Milton Keynes did not often aim to displace automobility, but complement it and enable leisure activities. Emerging innovations also seem to be constrained by overt policy reliance on a 'market competition' logic that blocks the possibility for alternative modes to scale rapidly, leading to a preference for innovation to 'fit-and-conform' rather than 'stretch-and-transform' (Smith and Raven, 2012). Indeed, early experience suggests that rather than shifting demand away from private cars, emerging modes, such as e-scooters or ride hailing services, also compete with other, greener modes, such as cycling, walking and public transport.

Diversification alone is therefore unlikely to transform the prevalent automobility regime. Most innovations aimed at sharing focus on asset sharing rather than trip sharing. While asset sharing offers potential to reduce car ownership, services such as car, bike sharing or minicabs continue to sustain an individualized approach to mobility. Digital MaaS platforms may provide greater access to asset-sharing modes, but these may again attract demand away from public transport and active travel. Extension and improvement of public transport are the only services that

Table 2
Selected, major mobility innovations emphasised in the cities' vision of mobility transitions.

Innovation	Cities	Type	Diversification	Sharing	Scalability	Impact on low carbon mobility
Bikesharing	BH, MK, MB	Commercial initiative	Yes	Partly (asset sharing)	No	Limited geographical coverage, specific target group
Commercial car sharing	All	Commercial initiative	No	Partly (asset sharing)	No	Limited geographical reach, specific target group
Connected Autonomous Vehicles	BH, MK	Trial	Uncertain	Uncertain	Yes	Public-private technology testing aimed at testing scalability; may increase or decrease car use and ownership
Demand-responsive bus	MK, ST	Capital investment	Yes	Yes (asset and trip sharing)	No	Fill service gaps of public transport to reduce car use and ownership; limited geographical coverage
Expansion of public transport	BH, MB	Capital investment	Yes	Yes (asset and trip sharing)	Yes	Increased coverage of trip sharing modes to reduce car use and car ownership
Alternative fuels for bus fleets	BH, ST	Capital investment	No	No	Yes	City-wide 'greening' of fleet; not aimed at diversification/ sharing
Micro-mobility, e.g. shared e-scooters	MK, ST, MB	Commercial initiative	Yes	Partly (asset sharing)	No	New mode for short-distance travel, may reduce car use but also compete with other low carbon modes
Mobility as a Service	BH	Commercial initiative	Yes	Yes (asset and trip sharing)	Uncertain	Digital mobility platform, impact contingent on participation and design, may reduce car use and ownership
Mobility hubs	ST	Capital investment	Yes	Depends, partly (asset sharing)	No	Access to alternative modes in one place to reduce last-mile car use
Provision of charge points	BH, MB, ST	Capital investment	No	No	Uncertain	Enable electric mobility at scale – but these can be limited by scarcity of raw materials
Ride hailing	All	Commercial initiative	Yes	Partly (asset-sharing)	No	Asset-based sharing; may reduce car use
Walkability and cyclability	BH, MB, MK	Capital investment	Yes	No	No	Promote active travel to reduce or supplement car use.

contribute to diversification and greater levels of shared mobility in both senses. With or without MaaS, current experience suggests that uptake of asset and ride-sharing services does not occur at a pace that would promise transformative change in any of the case cities.

Although upscaling is an objective in current on- and off-road CAV trialling, its impact on diversification and sharing will depend on whether or not CAVs are adopted as privately owned vehicles. While transport authorities view CAVs as potential low-cost last-mile services that may improve social inclusion, commercial interests would favour private ownership and the establishment of an adequate road infrastructure to support this. Limits to upscaling of operated bike and car sharing schemes arise from their commercial nature; they tend to be concentrated in more profitable inner-city areas that are already well connected, while pricing schemes may prevent certain groups from accessing these services.

5. Conclusion and policy implications

In this paper, we have adopted a broad perspective on policy failure, seeing it as failure to meet a broad set of social goals including sustainability and justice (Sokołowski and Heffron, 2022). Based on these case studies, we hold that a key failure of the past – narrowing down transport options to the private car – is being reproduced through many current modes of innovation. All four case cities exhibit a great deal of experimentation with new mobility technologies, to a significant degree driven by the ambition to decarbonize mobility. We examined these through three factors we consider key to transcend the automobility – diversification of mobility options, a shift from individualized to shared mobility, and prospects for upscaling. Through this lens, we find that ongoing forms of experimentation and innovation do not yet constitute a significant break with the culture of automobility as an obdurate form of mobility. To use the terminology of Smith and Raven (2012), these forms of innovation in mobility tend to fit-and-conform rather than stretch-and-transform.

Our analysis suggests that many innovations cater to unquestioned levels of individual mobility and are thus unlikely to be more than downstream fixes of more deeply entrenched, unsustainable practices. They are also locked into the infrastructure of the automobility regime (such as the existing road network), and in some instances, justify further investments in that infrastructure. Initiatives for shared mobility remain fragmented and lack adequate integration and coherence to enable shifts away from automobility. They risk becoming peripheral elements of automobility regimes that lessen car use while perpetuating reliance on the present model of car ownership. The alternatives that are given room to flourish lack credible strategies for upscaling through coherent policy support and enrolment pathways for private investment and users. As a result, there is a risk of perpetuating the failures of automobility in smart, digitalised form as incremental layering atop existing infrastructures that prioritise automobility regimes.

Cities and national governments must identify and root out car-centric regulations, such as mandates on car parking and road size. Yet moving beyond automobility regimes requires commitment to a stronger and more coherent project of inclusive decarbonisation through multi-modal integration, alongside the introduction of alternative fuels and targeted last-mile solutions. Public transport possibly combined with demand-responsive shared transport are the only services that have successfully been scaled up in the past, as evident in many cities with well-developed public transport and ride-hailing systems. The very purpose of public transport is population-wide coverage, albeit full coverage heavily depends on public funds in automobile-dependent urban form. Nevertheless, expanded and improved provision of public transport, possibly through new last-mile demand-responsive services, is the only option that meets all three criteria: it would increase diversification, is based on sharing, and is scalable to entire regions.

Breaking with the failures of the past will likely require more radical – and thus potentially riskier – policy actions in the area of scalable solutions that integrate mobility services within a strong vision of shared mobility – rather than simply proceeding up the existing automobility curve as electric cars do. In such a vision, public transport systems would be recognized as the key component around which other innovations can be built to serve last-mile travel, possibly joined up through a MaaS platform (Merkert et al., 2020; Enoch et al., 2020). Without a clearer system-wide vision and stronger regulation, the innovations alone are likely to reproduce the sub-optimal resource use monoculture entails, e.g. road space and resources allocated to large vehicle fleets that serve individual needs through service provision underpinned by commercial value and economic growth rather than by systems of provision responsive to collective needs. As a result, the current mix of innovations is likely to reproduce the individualistic approach to mobility that entails, and even encourages, greater demand for movement and linked energy use.

CRediT authorship contribution statement

Håvard Haarstad: Conceptualization, Investigation, Formal analysis, Writing – original draft. **Siddharth Sareen:** Conceptualization, Investigation, Formal analysis, Writing – original draft. **Jens Kandt:** Conceptualization, Investigation, Formal analysis, Writing – review & editing. **Lars Coenen:** Conceptualization, Investigation, Formal analysis, Writing – review & editing. **Matthew Cook:** Conceptualization, Investigation, Formal analysis, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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