REVIEW   **Open Access**

Representations of urban cycling in sustainability transitions research: a review

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Abstract

Background Increased cycling is generally recognized as a highly important project in decarbonizing urban transport. Despite well-researched and broadly accepted benefits of cycling, bicycle mobility plays only a marginal role in the modal share for most cities.

Purpose To make sense of this paradox, this review article investigates how cycling research engages with the governance of cycling. The review focuses on how cycling mobility is envisioned, approached and described within the change-oriented field of sustainability transitions research.

Findings Through a systematic reading of 25 peer reviewed scientific journal articles, we find that the articles mainly focus on technological objects of change (e-bikes and bikesharing systems); incumbent actors; and established planning and policy measures applied to new contexts. Most studies are evaluative, lacking the forward-looking and change oriented ambition transitions research set out to address. To contribute to increased cycling mobility in urban contexts, we conclude that future cycling research might benefit from adopting more diverse and clear notions of governance objects, actors and measures.

Keywords Urban cycling, Cycling practices, Cycling technologies, Sustainability transitions, Transport governance

1 Introduction

Increased cycling is generally recognized as an important project for decarbonizing urban transport and personal mobility [23]. Despite the benefits of cycling being well-researched and broadly accepted, bicycle mobility plays only a marginal role in the modal share for most countries [10, 41, 42]. The reasons for this discrepancy are multifarious and context dependent [14]. However, we suggest that a potential part of the answer to this paradox lies in how cycling is represented as an object of governance, and the way changes in cycling are envisioned, approached and described in research.

In this article, we review cycling research approached through lenses of sustainability transitions research, a field of study that in recent years has received increasing attention due to its orientation towards understanding and guiding fundamental change processes, including within transport and mobility [38].

Transitions and transformation are two terms often used interchangeably [34]. In this article, we acknowledge their original conceptual difference and delineate our review to transition studies. Transitions research tends to focus on societal sub-systems, suited to our investigation of urban cycling. While transformations research, typically centers on socio-ecological relations on different societal levels, cutting across different (urban) domains (ibid.). Transition studies are concerned with the modalities of change, the relation between facilitating and blocking mechanisms, essential, we claim, for investigations of cycling governance. Despite our focus on transitions, dominant transitions frameworks don't exclude transformations, but conceptualize them as one

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of several pathways in transitions (see [27, 34]. Inspired by sustainability transition research, we conceptualize cycling as a socio-material system co-constituted by both material (e.g., built infrastructure, topography, transport modes) and social elements (e.g., people, institutions, norms and regulation) [26, 38]. We are particularly interested in how transitions research represents the material (hard) and social (soft) elements of cycling, as well as how and by whom the socio-material system ought to change to advance cycling.

Numerous literature reviews on cycling have previously been undertaken. Earlier reviews have collated knowledge on the utility aspects of cycling, where for example commuting practices have been a dominating focus [20, 30]. Various programs, policies and instruments to support cycling have been analyzed [3, 32]. Additional reviews have investigated cyclists' safety in sharing road space with motorized vehicles [46] and means of making cycling more accessible through bicycle infrastructure, such as bikeway networks [11], or bicycle parking [31]. Previous reviews have furthermore shown an increased interested in 'smart' cycling innovations, such as bike-share systems (BSS) [24], e-bikes [1] and data-driven approaches to inform transport planning and design [29].

While there are known measures positively correlating with increased cycling, few reviews explore how increased cycling could be initiated and managed beyond individual projects or technologies [32, 48, 74]. While existing reviews indirectly touch upon different dimensions of cycling governance, none focus solely on cycling governance in urban contexts. This is despite wide academic consensus that it is particularly in urban environments, where cycling can play out its advantages over motorized individual transport [49]. Ryghaug et al. [52] recently argued for the benefits of accentuating Social Science and Humanities perspectives in transport and mobility research to support policy and planning. We see our study responding to their call for realizing quicker and more just transitions towards environmentally benign, low-carbon transport and mobility. In reviewing scholarly research outputs, we acknowledge the importance of knowledge production in representing and envisioning (future) mobility systems. Our focus on urban cycling contributes to discourses challenging "dominant mobility regimes and car dependency" [52], p.761). Heuristically, our focus on the governance of cycling, foregrounds the necessity of better understanding and adapting governance constellations and the processes they engender or inhibit. It is our ambition to analyze dominant representations of the socio-material system constituting cycling in urban spaces, and to identify gaps and blind spots that need further inquiry. With this article we seek to stimulate critical reflection on how

sustainability transitions research might expand the scientific visions of cycling in future transport systems, and contribute to a more transformative cycling governance in urban spaces.

In the following section we present the methodology, introducing the analytical framework and methods for this review. This is followed by a presentation of our results where we unpack the 'what', 'who' and 'how' of cycling in transitions research. In the final conclusion and discussion we reflect on the implications of our findings in relation to sustainability transitions research and for cycling governance more generally.

2 Methodology
2.1 Analytical framework
Transitions research commonly portrays transport systems as constellations of tangible and intangible elements that form complex interactions. Examples include the connections between people, transport modes, built infrastructure, topographical and geographical landscape features, rules and regulation, values and norms [5, 26]. These co-constituting effects are largely referred to as, 'socio-technical', 'technological innovation' or 'socio-material' systems. For example, in their review on transport research and climate change mitigation Schwanen et al., ([55] p. 994) suggest that common elements in transport systems include: "transport technologies, the price or commodity value of carbon, the 'hard' infrastructure, the 'soft' psyche and behaviour of users, and the institutions governing transport systems".

Apart from identifying the hard and soft elements of the system that transition scholars focus on when researching cycling mobility, transition scholars typically portray transitions as processes involving several actors, relating to each other in a myriad of ways, and affect or are affected by actions or events in different ways [2]. However, transitions literature has been critiqued for (over)emphasizing the role of incumbent actor groups [38], which risks reproducing existing actor categories as well as underlying power relations [2]. Against this background, it is important to critically interrogate the individual and collective actors included in cycling research, as it shapes how cycling governance is envisioned and enacted. Attending to actors helps approximate who is seen and not seen as affecting, or designing change in the realm of urban cycling (such as, transport engineers, planners, policymakers, and decision-makers more broadly), and who is affected by this change as a potential user of a cycling innovation (the broad public) [50].

Taking this critique of transition studies into account, and for illuminating how cycling is made an object of governance, materially and socially, we took inspiration from the analytical framework developed by [69–71].

Developed and applied to disentangle how structure and agency are represented in the context of back casting scenarios, the analytical frameworks focus on and helps distinguish between objects of change (what will change?), agents of change (who will make change happen?) and measures of change (how will change be brought about?). These analytical questions have guided our review, and helped capture dominant representations of cycling and cycling governance in transitions research.

2.2 Material & methods

The literature review follows the process steps of screening, scoping and assessment [7]. The steps aim at being overt and consistent, collectively adhering to systematic literature review approaches [7]. Three aspects informed the search syntax we applied to the databases,'cycle', 'urban' and 'transition'. We used both Scopus and Web of Science databases to search for peer-reviewed scientific publications in English [9, 31]. We tested synonyms for the three themes, as well as Boolean operators and truncations to increase the amount of obtainable results. We started from a baseline search string — *(cycl* OR bicycl* OR bik*) AND (urban OR city OR town) AND (transition).* Related terms and synonyms were subsequently introduced to the two thematic groups *'cycle'* and *'urban'*. While the terms 'transition' and 'transformation' are often used interchangeably, they invoke different system conceptualizations, they also tend to have different analytical foci, and are frequently affiliated with different strands of research [34]. While this omission limits the scope of our review, we achieved higher precision in our search, leading to more comparable search results. The sequenced search process allowed us to evaluate the impact of individual search terms on the number of obtainable results and furthermore enabled a more transparent and reproducible screening process. Including and testing new search terms provided the final search string:

(cycl* OR bicycl* OR bik* OR "active commut*" OR velo* OR e-bi* OR e-cycl* OR "elect* cycl*" OR "elect* bicycl*" OR "active transport*" OR "active mobilit*" OR "sustainable mobilit*" OR "sustainable transport*" OR "sustainable commut*") AND (urban OR city OR cities OR town OR metropoli* OR municipal* OR borough* OR neighborhood OR conurbation OR suburb* OR downtown OR exurb OR midtown) AND (transitio).

The search process began in autumn, 2018 and continued until summer, 2022. We obtained a total of 3133 publications that we assessed in two stages (see Fig. 1). We oriented our analytical approach and its depiction at the PRISMA 2020 guidelines [43], which provides "a standard for the reporting of systematic reviews and meta-analyses in the published journal literature […]." [7], p.311). During a first screening round, the lead author

read titles and abstracts of the search results. No strict exclusion criteria regarding sources, document or study type where applied in this process step so that no potentially relevant articles were excluded for citation screening or as background material for this study. We included articles that showed a potential sustainability transitions framing, referred to cycling or related innovations, and position the study in an urban context. The first assessment stage resulted in 110 peer-reviewed original articles that explicitly introduce the field of sustainability transitions in the introductory, or background section, relate to transitions approaches as heuristic frameworks, and discuss results in a context of sustainability transitions. Of these 110 articles, 17 studies fit all inclusion criteria. We furthermore traced the references of the 17 studies and set up search alerts in Scopus and Web of Science, which resulted in 8 additional studies eligible for inclusion. Subsequently, 25 articles met all inclusion criteria and remained for synthesis and analysis.

The articles selected were coded manually and thematically by the lead author using the analytical questions as a framework [7], i.e. what will change? Who will make change happen? How will change be brought about? Since the analyzed articles included descriptions of diverse factors, measures and actors impacting cycling in given cases, we present the dominant themes foregrounded in each article. These dominant themes were deduced by close reading of abstracts, research questions, aims and/or objectives, results and conclusions of each article. As an illustration, objects of change (what) comprise various cycling technologies, such as e-bikes or bikeshare technologies. These cycling objects introduce, or facilitate, particular cycling practices. Compared to cycling objects -which relate to a particular cycling activity- measures (how) appear more broadly formulated, and not directly tied to specific objects nor cycling practices. The actors (who) refer to both general groups relevant to cycling or cycling developments (e.g., NGOs, public authorities, marginalized groups) and groups explicitly identified as being significant to individual case studies. Describing cycling activities and measures to enhance cycling invariably implies mentioning the cyclist, or who is involved in development, implementation and management of cycling measures, for this reason we have integrated the question of 'who' in the presentation of objects and measures.

3 Unpacking the 'what', 'who' and 'how' of cycling in transitions research

3.1 Overview – theories and empirical contexts

Our analysis shows how application of transitions theories have differed and developed over time. Prior to 2015 we see a phase of testing transitions approaches
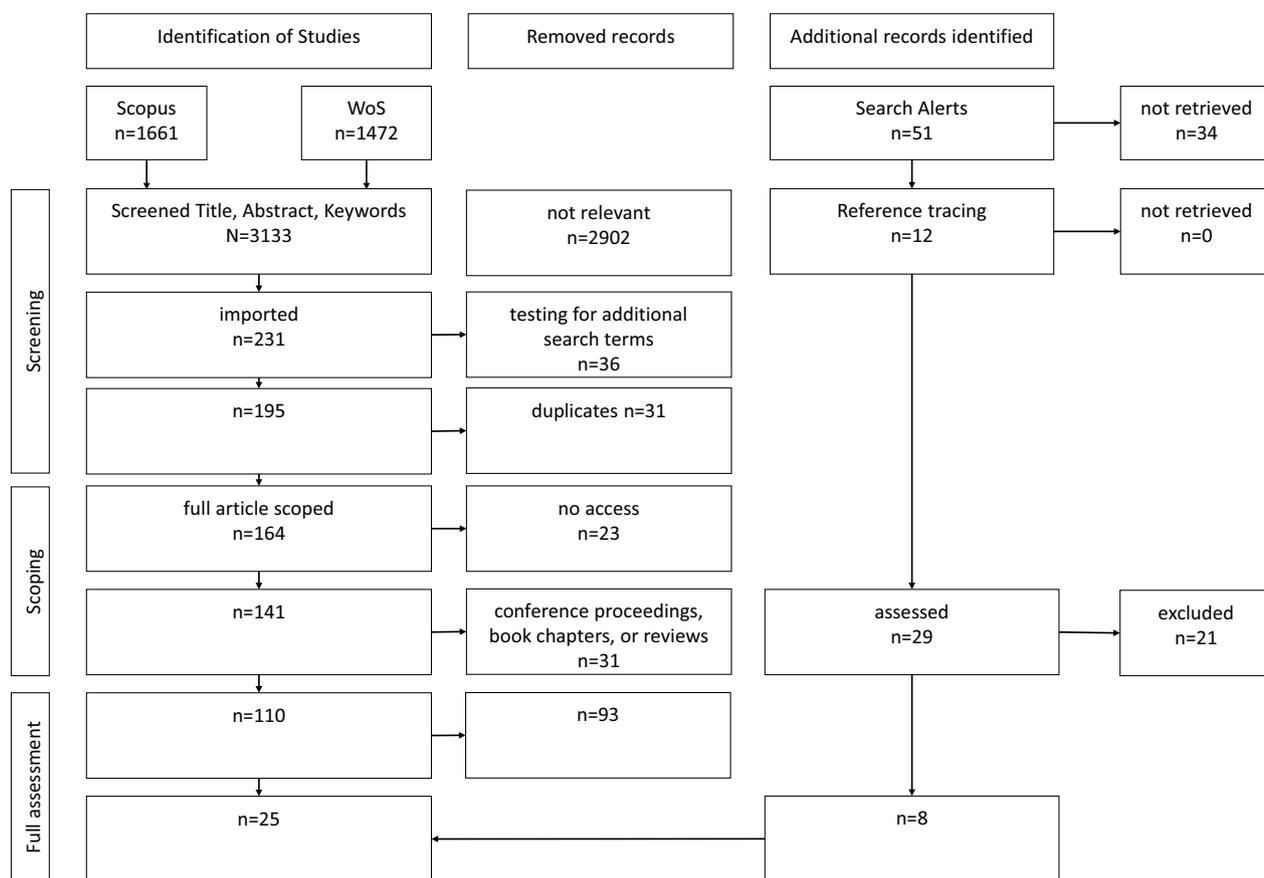
Identification of Studies	Removed records	Additional records identified

Screening

Scopus n=1661 | WoS n=1472

Screened Title, Abstract, Keywords N=3133 → not relevant n=2902

Search Alerts n=51 → not retrieved n=34

Reference tracing n=12 → not retrieved n=0

imported n=231 → testing for additional search terms n=36

n=195 → duplicates n=31

Scoping

full article scoped n=164 → no access n=23

n=141 → conference proceedings, book chapters, or reviews n=31

assessed n=29 → excluded n=21

Full assessment

n=110 → n=93

n=25 ← n=8

Fig. 1 Review process flow chart

on cycling and transport in general. Several authors explicitly test the applicability of transitions theories on transport and mobility as objectives of their studies [4, 73]. The multi-level perspective (MLP) [25, 51] appears synonymous with transition frameworks, with many of the authors referencing the MLP early on in their study, or using it to explain transitions. The MLP is the most prominent heuristic applied either explicitly [16], Ó[66] or in an adapted form [13, 39, 40]. The MLP is frequently modified by incorporating other heuristics, concepts, frameworks, or theories,including notions of justice [44] or spatial scales [73]. Apart from the MLP, adaptations to Strategic Niche Management (SNM) [8], the Technological Innovation System (TIS), and Social Practice Theory [12] can be observed in the literature. The studies furthermore commonly draw on theoretical and conceptual notions that informed the development of transitions theories, such as Science and Technology Studies (STS), Innovation Studies and Evolutionary Economics [38]. Vreugdenhil & Williams [68] provide the earliest example of the reviewed studies using not an explicit theory, but a broader socio-technical notion. Despite the spread of

different theoretical tenets, all the reviewed studies share an understanding that cycling is embedded in a system consisting of material elements and non-material relations, and that cycling is in a struggle against persistent transport system elements of motorized personal transport.

So, in what contexts is transitions research on cycling located? Given this study's focus on urban cycling, the boundaries of the functional system of transport largely coincide with the administrative boundaries of the urban areas. However, several studies incorporate notions of vertical governance relations drawing connections to superordinate regional or national administrative levels [4, 39, 40, 56]. Culture, topography, climate, administrative systems, urban layout and infrastructure, all affect the status of cycling and its prospective role in urban mobility systems. While the studies presented in our review reflect this diversity, there is a trend towards case city selections centered on Europe, with a strong focus on Copenhagen and Amsterdam. This is followed by studies from China [39, 40, 73, 73], South and South-East Asia [4, 56, 57, 61] and a single study from Istanbul. In most cases

the best practice examples of Amsterdam and Copenhagen are mentioned and often explicitly used as benchmarks for comparison, or as providing learning potential for cities with a low cycling mode share (e.g., [16, 28].

In the following subsections, we present key findings according to the analytical framework. Table 1 presents the characteristics of the 25 included studies, categorized by the empirical cycling object that is foregrounded in the respective studies and the measures for change.

3.2 The 'what' of cycling

Throughout the reviewed articles, cycling objects are the points of interventions for cycling-promoting measures, providing a material anchor to which alternative cycling activities are enabled in urban transport systems. Moreover, given the origins of sustainability transitions in Innovation Studies and STS, it comes as no surprise that the articles reviewed tend to emphasize technological innovations. Two particular cycling objects are dominant, namely electric bikes (e-bikes) and bike-sharing systems (BSS).

E-bikes are generally portrayed as an important technological innovation to enhance cycling levels. The earliest studies into e-bikes explore their emergence in Chinese cities. Lin, Wells and Sovacool [39, 40], examining Beijing, Tianjin, Shanghai and Nanjing to understand the status of the e-bike in Chinese mobility systems, as well as its future prospects as part of China's urban mobility systems. Lin et al., [39, 40] use survey data to investigate and estimate e-bike adoption and mode choice, where non-users, potential users and users of e-bikes are considered the most central groups to influence the uptake and use of e-bikes. In contrast, Wells and Lin [73] take a more exploratory approach, uncovering processes that lead to the rapid growth of e-biking in Chinese cities. The authors emphasize the 'spontaneous emergence' of e-bikes in the absence of governmental support, leaving local authorities scrambling to post-regulate e-bike technology to mitigate unsafe and disruptive cycling practices. There are clear connections between Wells and Lin [73] and the BSS cases introduced below, where market actors were crucial in driving the introduction of a cycling-technology in a comparably short time. The Chinese case studies conclude that e-bikes are unlikely to become a permanent addition to the urban mobility mix, or have any considerable impact on transitions towards sustainable urban transport due to the continued high demand and planning for automobility [39, 40, 73]. In a Canadian context, Edge and colleagues [19] present a role for e-bikes different to the Chinese cases. In investigating stakeholders' perception of e-bikes and their potential in transitioning Toronto's urban mobility system, the authors reveal the potential for e-bikes to replace cars and become integrated in a low-carbon system of mobility together with public transit. This transition is seen as being reliant on enhanced policy coordination, support, and regulation of e-bike use [19].

BSS is another technological innovation in the transitions' literature reviewed that serves as a point of interventions. Bikesharing is, however, not a new phenomenon. Since its introduction in the Netherlands in the 1960s [17, 24], new actors, technologies, and business models have diversified the provision of shared cycling. In general, articles focus on BSS from a *technological, innovation* or *public–private partnership* perspective, which direct attention towards different groups of actors and measures. As a technology, BSS is commonly differentiated according to the infrastructure requirements of the systems, technologies, and the flexibility they provide for pick-up and drop-off. For example, station-based systems require docking stations distributed across the city, where bikes can be collected and returned. In the earliest studies on BSS in this review, Ó Tuama [66] provides a positive example of bikesharing technologies using station-based sharing system in Dublin as a case. By applying the MLP heuristic Ó Tuama shows how the introduction of dublinbikes led to knock-on effects that changed Dublin's wider socio-technical transport system. As with earlier station-based sharing applications in the Netherlands [67], public actors sought to tailor the project to the local context that led Dubliners, many with limited experience of cycling in the city, to embrace the service. Dublinbikes introduced traditionally non-cycling groups to experience the city from the saddle, inspiring reflection on the inadequate cycling infrastructure, which in turn is argued to have further strengthened cycling advocacy efforts. Ó Tuama [66] exemplifies how the introduction of an innovative cycling technology can lead to users and advocacies seeking to advance cycling more generally.

ICT and the ubiquitous use of smartphones, has enabled free-floating, or dockless systems to become more prevalent. For example, in the low-cycling context of Santiago, Saud and Thomopoulos [53] argue for novel data analysis and visualization tools for sharing providers to expand and optimize their sharing schemes. But bikesharing technologies are not unproblematic. Tan and Du [63] exemplify the effects of rapid implementation of dockless sharing systems in Guangzhu, China, where private sharing providers, backed by extensive capital, flooded the urban mobility systems with their dockless service that were not considered in governmental land-use regulation.

In recent years, there has been an increased interest in bikesharing systems as innovations within motorized transport systems. In the low-cycling share global South

Table 1 Overview of reviewed studies

Authors and publication year	Study title	Aims	Objectives	Emphasized actors (Who)
Cycling Objects (What)				
E-bikes				
[19]	Shifting gears on sustainable transport transitions: Stakeholder perspectives on e-bikes in Toronto, Canada	Explore how governance actors in the transport system perceive e-bikes	- Explore how governance stakeholders see the role of e-bikes in sustainability transitions - Explore their role in uptake or rejection of the technology	Transportation governance actors ("strategic policy development, regulation, enforcement and infrastructure management in the City of Toronto, Canada") pp.199–200
[39]	Benign mobility? Electric bicycles, sustainable transport consumption behaviour and socio-technical transitions in Nanjing, China	Analyze the role of e-bike use in the urban transport system of Nanjing	Analyse "attitudes and characteristics" (p.224) of residents towards e-bike use	(Potential) users and other mode users directly addressed through survey
[40]	The death of a transport regime? The future of electric bicycles and transportation pathways for sustainable mobility in China	- Describe the future development of e-bikes in China - Apply the MLP to transport systems	- Identify factors that will influence the further adoption of e-bikes - Analyse how e-bikes compare to other modes of transport - Predict whether e-bikes will consolidate their role in the transport system, or not	(Potential) users and other mode users directly addressed through survey
[73]	Spontaneous emergence versus technology management in sustainable mobility transitions: Electric bicycles in China	Explore reasons and mechanisms behind the rise of e-bikes in China	- Analyze why e-bike emerged in absence of active policy support in China - Multi-scalar MLP application to explain change processes in the e-bike market	Market and policy-actors
Bikeshare systems (BSS)				
[53]	Towards inclusive transport landscapes: Re-visualizing a Bicycle Sharing Scheme in Santiago Metropolitan Region	- Analyze the implications of introducing a BSS in its social and institutional dimensions - Introduce a new tool for managing BSS in a Global South context	Combining the MLP with alluvial diagrams and circular dendrograms to inform planning and operation of BSS	- Focus on local authorities (comunas), but also public and private transport planners and policy-makers - Undifferentiated users that provide data for improving services (BSS-users compared to other public space users)
[63]	The Governance Challenge within Socio-Technical Transition Processes: Public Bicycles and Smartphone-Based Bicycles in Guangzhou, China	Analyse how technological transport innovations affect modes of urban governance	Explore the effects of change from public bikes to technology- enhanced sharing systems had on mobility governance in Guangzhu, China	o
[60]	Bicycle Policy in Mexico City: Urban Experiments and Differentiated Citizenship	Examine how bicycle policy (sustainable transport innovation) affects urban citizenship unequally in different parts of Mexico City	Apply a "Cities and Low carbon Transitions framework" [21] to evaluate and conceptualize transport as a socio-technical system - Introduce urban citizenship concepts to emphasize how cycling infrastructure affects inequality [33]	Policy-actors: BSS-firms, urban administrators, NGOs and advocates

Table 1 (continued)

Authors and publication year	Study title	Aims	Objectives	Emphasized actors (Who)
[61]	Social enterprise as catalyst of transformation in the micro-mobility sector	- Introduce social entrepreneurship to sustainability transitions research - How social enterprises as innovations interact with the existing socio-technical transport regime	Describe how a local University bikeshare scheme grew to become the first established bikeshare operator in Manila	Social entrepreneurs, volunteer community around it and advocacies
[57]	Policy, users and discourses: Examples from bikeshare programs in (Kolkata) India and (Manila) Philippines	Examine how cycling transitions play out in Manila and Kalkota with a focus on bikeshare schemes (PEDL, Kolkata & UPBS, Manila)	Investigate the dynamics in changing administrative regulations and the role of bikeshare users through a novel transitions framework focusing on administrative and socio-institutional practices mediated by user roles and discourses (political, cultural and smart)	Based on (Schot et al., 2016) users are: - producer of new practices, legitimators of visions and aspirations - intermediaries shaping and (re-)aligning systems' elements - citizens becoming active in challenging existing regimes, while nurturing and protecting the niche, and - consumers who purchase the cycling service
[18]	The Dynamics of Public Participation in New Technology Transitions: The Case of Dockless Bicycle Hire in Manchester	Examine how and why an innovation (local BSS) failed in Manchester	Understand the political and public implications of a niche innovation	Local public authorities, bikeshare provider, the public as end-users, particularly young people
[45]	Dockless bikeshare in Amsterdam: a mobility justice perspective on niche framing struggles	Analyse bikeshare actors attempts towards legitimization	Integration of mobility justice and socio-technical transitions concepts	Bikeshare providers, researchers supporting sharing economy (niche) city government, conventional BSS providers, NGOs, researchers wary of the sharing economy, organized residents
[66]	Ripples through the city: Understanding the processes set in motion through embedding a public bike sharing scheme in a city	Explore the effects of introducing a public bikeshare scheme (dublinbikes) to an urban system	Apply a MLP to map the existing socio-technical transport system and the disruptive and reconfiguring effects of the bikeshare scheme after break-through	Cycling advocacies, users
[67]	Business model innovation and socio-technical transitions. A new prospective framework with an application to bike sharing	Develop a prospective transition framework	Investigate potential for various bikeshare providers' business models to grow (scale) based on increasing returns, industry structure around the innovation and the institutional context	bikeshare providers, industry and public institutions

Measures addressing cycling (How)

Infrastructural interventions

[22]	Encountering bikelash: Experiences and lessons from New Zealand communities	To investigate organized, community-level, opposition to bike lanes (bikelash)	- What are the motivations for bikelash? - What are the experiences of supporters (e.g, local council and transport agency planners) and opponents (e.g, conservative community members and local retailers)? - What are the responses to bikelash?	Supporters and opponents of bicycle infrastructure

Table 1 (continued)

Authors and publication year	Study title	Aims	Objectives	Emphasized actors (Who)
[68]	White line fever: a sociotechnical perspective on the contested implementation of an urban bike lane network	Develop a ST-systems perspective to capture dynamics of social and technical elements	- Investigate how the bike networked developed after implementation - Explore how bike lane implementation affected the urban transport system	o
Policy and planning (innovation)				
[8]	The challenge of the bicycle street: Applying collaborative governance processes while protecting user centred innovations	Explore how collaborative governance affects SNMP exemplified through the bicycle street as a policy innovation	- Describe how bicycle streets originated and developed in Germany, Belgium and the Netherlands to protect cycling practices - describe challenges of collaborative governance and protecting practices through a case of a bicycle street in Eindhoven	o
[44]	The legal street: a scarcity approach to urban open space in mobility transitions	Identify and compare spatial allocation and appropriation by bicycles and cars and how they affect sustainable mobility transitions	- Identify regulations for space allocations - Identify practices for appropriating space - Explore the implications on mobility transitions	o
[36]	Reinventing the bicycle: how calculative practices shape urban environmental governance	Explore how novel knowledge-producing practices affect how cycling is known, made visible and governed	Analyse how calculative devices (a form of epistemic practice, such as accident statistics, or cost–benefit analysis) were used to understand and act upon cycling in Copenhagen since the 1900s	Urban planners as main users of calculative devices
[28]	Urban transport transitions: Copenhagen, City of Cyclists	Derive insights from Copenhagen's bicycle strategy by assessing in which aspects it has worked (success), where it didn't work (limitations), and the reproducibility of the strategy	Investigate the role of market-based, soft policy and command-and-control measures since the 2000s to advance cycling in Copenhagen	o
Comprehensive systems perspective				
[58]	Policy learning and sustainable urban transitions: Mobilising Berlin's cycling renaissance	Explore a proposed learning relationship on cycling policy	- Multi-actor analysis to understand the role of policy in Berlin's cycling increase - Analysis of Manchester's policies and interviews with planning and policy actors to understand the adoption of Berlin's model	o
[4]	Hot or not? The role of cycling in ASEAN megacities: Case studies of Bangkok and Manila	Apply TIS-approach to cycling	- Describe cycling in Bangkok and Manila (status-quo and advances) - Describe necessary steps to develop cycling's role in the transport systems - test TIS-framework on sustainable transport	Policy-makers (as this is the take-away of the TIS-framework

Table 1 (continued)

Authors and publication year	Study title	Aims	Objectives	Emphasized actors (Who)
[13]	A socio-technical transition framework for introducing cycling in developing megacities: The case of Istanbul	Introduce a framework to facilitate transitions towards cycling in developing Megacities where cycling is marginalized	- Apply the MLP to Istanbul's ST-transport system around cycling - Suggest pathways for cycling transitions in Istanbul	(potential) cyclists and "experts" (urban or transport planners, engineers and public administrators
[56]	Cycling the city, re-imagining the city: Envisioning urban sustainability transitions in Thailand	Demonstrating the relevance of urban imaginaries' envisioned by change agents' to prefigure the context of urban sustainability transitions	Describe how urban imaginaries emerge, gain substance, are communicated and mobilized	Cycling campaigners
[16]	Getting Londoners on two wheels: A comparative approach analysing London's potential pathways to cycling transitions	Identify pathways and barriers to upscaling of London's cycling niche	Compare historical cycling transitions in Amsterdam with the current status of cycling in London	Policy-makers, advocacies and cyclists
[12]	Bicycle commuting in an automobile-dominated city: how individuals become and remain bike commuters in Charlotte, North Carolina	To better understand how bike commuting is adopted and maintained	Elicit bike commuting practices in Charlotte based on commuters' first-hand accounts	Experienced and novice cyclists, officials, planners and employers

contexts of Asia and the Americas [53, 60, 61, 63], BSS are commonly framed as niches within transport systems dominated by motorized individual transport. This contrasts with the situation in cities with high cycling levels, such as Amsterdam, where sharing systems compete with individual 'traditional' cycling. Where different sharing systems are available, BSS compete with each other in its own niche of transport. Another take on innovation is provided by van Waes and colleagues [67]. In their study on sharing providers, the authors position bike sharing business models, rather than the bike sharing technology, as the innovative element. Departing from Dutch city contexts, the authors assess various sharing business models and suggest that their potential to scale up hinges on the models as such, but also the industry structure of sharing providers, the alignment or friction with formal and informal institutions, and the potential for increasing returns on investment [67]. Another type of studies approaching bikesharing models as innovation address the effect of non-profit organization entering the mobility market from outside. Sunio et al. [61] show how social entrepreneurs, in Manila, succeeded in addressing local mobility needs by creating their own niche through developing a sharing scheme at a University. The study argues for the alignment of narratives and collaboration with advocacy organization to benefit from established sustainability-oriented advocacy efforts. The case adds weight to the roles of grassroots initiatives and social enterprises for furthering cycling services in the maturing cycling context of the global South. Bikesharing business models have also been addressed from discursive perspectives. In their analysis of mobility niches in Amsterdam, Petzer, Wieczorek and Verbong [45] emphasize the discursive struggles between bikesharing advocates and their opponents. Opponents want to protect the existing cycling culture, while sharing advocates try to break out of the cycling mobility niche. The authors find that cycling proponents struggle against motorized modes of transport traditionally supported by planning systems. It is particularly difficult to negotiate which kind of bikesharing should be prioritized, and to demonstrate how different sharing models cater to different user groups.

An additional type of study concentrates on the relationships between public and private actors in BSS. In the Netherlands station-based cycling for commuters is favored, having become institutionally embedded through long-standing collaborations between transport providers and local public actors. Sosa López in Mexico City [60], Sharmeen et al. in Kolkata and Manila [57] and Dudley et al. in Manchester [18] emphasize the role of BSS users and public authorities in mobility transitions. Though in different contexts, the three cases underline the importance of attuning BSS to local circumstances and involving the public at an early stage in order to adapt the BSS according to local contexts and needs to avoid marginalizing actors. For example, in a case study of Mexico City's bicycle policy, Sosa Lopéz [60] shows how the Ecobici bicycle sharing system exacerbated mobility injustices. The close collaboration between city authorities and profit-oriented bikesharing providers meant that the sharing system failed to address local mobility needs. City authorities prioritized quick roll-out of the sharing scheme, rather than adhering to a collaborative process in the project's planning and implementation, which meant that Ecobici was located in affluent parts of the city, excluding those most dependent on bicycle mobility.

In summary, we found that E-bikes and BSS are the most common cycling-technologies presented as cycling objects. Both technologies that diversify cycling practices and provide potentially new demographics access to cycling. E-bikes extend cycling ranges and promise less effort in cycling to also increase cycling for transport and logistics. BSS are mostly positioned as part of short, multi-modal trips for commuters and visitors. For e-bikes and bike sharing, the reviewed studies commonly describe a struggle of embedding the technologies in urban transport systems. In addition to 'normal' cycling's challenges in auto-dominated urban systems, particularly regulatory barriers constrain their entry and spread. E-bikes do not fit into existing transport regulation and their potential to replace carbon-intensive travel modes is uncertain. The successful implementation of sharing systems relies on early and close collaboration of sharing-providers with public authorities to avoid land-use conflicts over limited urban space. Even when successfully launched, operation and maintenance pose further challenges, such as profitability, rebalancing bicycle fleets, vandalism and wild parking. Particularly sharing systems feed into smart city scenarios, where they generate valuable data and make use of smart technology for comfortable and convenient use.

3.3 Measures addressing cycling—The 'how' of enhanced cycling mobility

In this section, we elaborate on the measures represented as enabling or hampering cycling levels in urban contexts. In our review, we identify three types of measures recurring in the literature, namely: *physical infrastructural interventions*; *public policy and planning (innovation)*; and, what we refer to as a *comprehensive systems perspective*. The latter theme refers to articles broadly interested in mapping out and understanding cycling's status and/or potential in urban systems.

We identified two articles highlighting the effects of introducing *physical infrastructural interventions* to

support cycling in the low-cycling contexts of New Zealand [22] and Australia [68]. The provision of cycling infrastructure separating cycling from motorized transport is commonly seen as a crucial cycling-supporting element. Jointly, the two articles exemplify that even minor interventions, such as painted bike lanes, can lead to adverse community responses that need to be anticipated and accounted for. Both articles point towards the importance of strong political leadership and adjusting established planning and governance processes to implement cycling measures challenging the status-quo of embedded and accepted car-oriented systems. Vreugdenhil and Williams [68] provide the first conceptualization of cycling as a sociotechnical system in our analysis. The authors develop the argument that the material introduction of bike lanes can lead to far-reaching local opposition. In a similar vein, but utilizing an actor-oriented approach, Field and colleagues [22] investigate the motivations for "bikelash" (backlash against bike lanes) and identify that coalition-building around community concerns beyond the minimum planning requirements of information and participation are essential to reconstructing bike lane opponents' perceptions of cycling-supporting interventions.

Another set of measures include *public policy and planning innovation*. Petzer, Wieczorek and Verbong [44] introduce an innovative heuristic, 'legal streets framework', to reconceive urban open space through formal allocation processes, scripted through urban transport policies and informal appropriation practices. By applying the legal streets framework on Amsterdam, the authors show how restricting spaces for parking and driving cars freed up spaced for cycling and walking. In aspiring cycling context (e.g., Brussels, Birmingham), the authors suggest that the "legal streets framework" can assist local authorities to pursue and actively reduce automobile space even when regional, national and supranational governance marginalize pro-cycling policies. With the ambition to rethink public mobility policy and behavior, Jensen, Cashmore and Elle [36] direct attention to the role of knowledge-producing practices in how cycling is conceptualized. Using Copenhagen as a case, the authors demonstrate how the use of cycle accident statistics, regular assessment of the city's cycling status and cycling-support measures and quantifying the monetary benefits of cycling, created argumentative support and accountability in public cycling policy. Combined, these interventions contributed to the city's current status as a leading cycling city. Petzer and colleagues [44] provide an innovative way of using existing policy frameworks, while Jensen et al. [36] present new policy measures. In contrast, Gössling [28] comprehensively evaluates Copenhagen's existing transport policies to derive which policy mix has led to the city's high cycling rates. Success in cycling promotion since the early 2000s, is argued to be grounded in a mix of market-based, soft-policy and command-and-control measures that led to Copenhagen's unique cycling status. Other studies note that the importance of consultation and consensus-oriented collaborative processes can be overemphasized, and that collaborative processes alone cannot replace enforceable regulation on motorized traffic [8].

In contrast to measures targeting *physical infrastructure, public policy and planning innovation,* the articles categorized as *comprehensive systems perspective* are typically exploratory in scope. Instead of departing from predefined actor groups, scales, and policy boundaries these articles investigate how existing transport systems' elements and configurations, pose barriers, or present opportunities for cycling practices to develop. An exception are Caldwell and Boyer [12], who are specific about the cyclist group and cycling practice they investigate in that they seek to understand how cycling commuters adopt and maintain cycling to work. In comparison, an example for a more open, exploratory approach is provided by Bakker and colleagues [4], who present a study of Bangkok's and Manila's current cycling status in the transport system, where they identify and assess the potential of different system components (e.g., actors, networks, institutions) as a means to increase cycling levels. The authors identify a diversity of actors relevant to cycling governance, including utility and recreational cyclists, local and national policy makers, advocacy organizations, media outlets, local bike shops, cycling industry, police, etc. In an analysis of cycling's role in Istanbul's transport system, Canitez [13] suggest that cycling issues need to be vertically supported from national down to city levels, and horizontally integrated into policy areas beyond transport, such as environmental and land-use policy. Canitez [13] argues that urban and transport planners, engineers and public administrators need to move beyond the technological focus on built infrastructure for cycling, and engage with the social aspects of cycling. In particular the narrow understanding of cycling as a recreational activity for men, which is subordinated to automobility [13]. In a similar vein, de Boer and Caprotti [16] argue that the social representation of cyclists and cycling in London must become wider. Inspired by Amsterdam's historic success in advancing cycling, de Boer and Caprotti [16] investigate the potential of a similar transition taking place in London. Apart from identifying regime actors, such as public authorities, policy-makers, transport engineers and advocacies as the main drivers of radical transformations, the authors note how cycling in London was dominated by a homogenous group of dedicated young, male

cyclists. As well as suggesting "carrot and stick" policies to restrict car accessibility and parking (e.g., through congestion charges), and designated cycling infrastructure to make cycling more attractive and competitive with other transport modes, De Boer and Caprotti ([16], p.624) argue that cycling needs a broader representation to become more inclusive and widely recognized as a "practical transport mode".

In addition to expanding social representations of possible cyclists, Sengers [56] draws attention to the agency of particular groups of actors in cycling transitions. Using Thailand as a case, Sengers [56] explores the role of cycling advocates and the visions for cycling they convey through their work. The author describes cycling campaigners as "change agents", crucial for imagining and proliferating alternative cycling futures for the country. Lastly, Sheldrick, Evans and Schliwa [58] describe how cycling transitions are highly contextual and cannot easily be copied. Manchester, to secure funding for urban transport projects, entered a cooperation with Berlin to learn from their recent success in advancing cycling. The authors suggest that Manchester simplified and reframed complex socio-technical processes that led to increased cycling in Berlin. Instead, Manchester presented Berlin's pro-cycling success as strategic and policy driven. In contrast, the authors argue, the main impetus for increased cycling levels in Berlin derived from inhabitants' recognition that the urban setting, predominantly broad roads and dense service provision in neighbourhoods provides physical preconditions conducive to cycling.

Our review shows that the 'how' of cycling is concerned with the modalities of increasing cycling practices. Not necessarily new ideas, but seen in new ways as part of intervening in the social and material fabric of the city, cycling measures uncover new problems and opportunities for increased cycling. Old topics such as context sensitivity are revamped, with 'novelty' or 'innovation' depending on where certain interventions take place. Practical examples of completely new ways of constructing cycling and related issues reimagine the construction of cycling policies, programs and instruments. Under the theme 'comprehensive systems perspective', the benefits of transitions frameworks come to the fore in that they provide analytical heuristics to explore cycling conditions systemically.

4 Concluding discussion
In this review, we have aimed to unpack dominant representations of urban cycling in transition studies regarding cycling activities, the main actors, and the measures focused on in the literature. In the following, we summarize key findings, gaps and blind spots, and discuss the results in relation to the wider transitions literature to identify avenues for future cycling research.

4.1 Actors' roles in transitions towards increased cycling
In performing the practice of cycling, cyclists are probably the most important actors in cycling governance [8]. Although this review reflects a growing engagement with urban cycling in transitions research, and a great diversity regarding useful frameworks, as well as geographical, temporal and empirical foci, the actor groups highlighted in most studies are remarkably consistent. For example, independent of geographic context, actors involved in cycling transitions appear to be e.g. local public authorities, policy-makers and planners together with technology providers. The distinction between actor categories is often blurred, with different actors collaborating in different ways to implement and manage, for instance, e-bikes or BSS. As the two Oceania bike lane cases reveal [22, 68], best practice in one context does not imply direct transferability into other contexts. Local communities play an important role in accepting cycling infrastructure and adopting cycling practices. It is plausible to assume that important actors may be overlooked if the identifications of actors and their roles in cycling transitions are based on predefined categories, or if their roles and relations are unspecified. Another blind spot is the interactions of actors, which may hold an important role in shaping cycling. Generally, it remains rather unclear what roles (potential) cycling practitioners and diverse cycling practices might play in transforming urban mobility systems. Against this background, sustainability transitions research on cycling would benefit from more clarity on what it is that should be governed (vélomobility and/or people who cycle), who is and who could or should govern (public authorities, advocacy organizations, public institutions/or practitioners, citizens), through which measures and towards what end.

4.2 Reflections on applications of transitions frameworks to urban cycling
The reviewed articles might not push the theoretical vanguard, but they do provide important contributions in testing and applying transitions frameworks to cycling. In addition, through reliance on qualitative methods transitions research softens the divide between traditionally positivistic transport studies and mobilities research. Transitions literature confronts us with the obduracy of urban systems. With few exceptions, the built environment manifests in car-centered transport systems that are difficult to change. The studies we analyzed in this review, challenge car-oriented planning, requiring planners and policy makers to broaden the vision for alternative transport and mobility futures. The academic community is

well equipped to make important theoretical, empirical and policy-relevant contributions for advancing cycling, such as new ways of seeing and knowing urban space and cycling's role in it (e.g., [36, 44]).

Our results demonstrate that cycling research in transition studies has an empirical focus on two dominant objects: e-bikes and bikesharing systems. While innovative cycling technologies are in focus, less attention is paid to more traditional mundane cycling activities, which still have an important transformative role to play, particularly in low-cycling contexts [49, 72]. The large share of research on technological and economic aspects of cycling reflects a reproduction of ecomodernist ideas, with technological substitution essential for transitions. The representations of actors and measures are largely structured in line with e-bikes and BSS, by which public actors and private businesses can boost cycling levels. This framing furthermore suggests that people cycling, or the unspecified broader public, can become 'users' or 'consumers' and cycling a 'product'. Few studies exemplify non-standard cycling-supporting measures (e.g., social entrepreneurship) [57, 61], or that new cycling technology and cycling practices can be implemented in absence of policy support [39, 40, 63, 73].

The expanding engagement with urban cycling in transition studies appears to follow the general trajectory of transitions theories and frameworks, typically including retrospective analyses and status-quo assessments of urban systems in the early stages of application [38]. This is often in combination with investigations of technological or policy innovations (at times combined with conceptual foci on justice and equity) [45]. Similar to this general trajectory, the majority of research we reviewed takes an analytical or evaluative position where the research focus suggests to test or advance transitions theories through extrinsic case studies rather than aiming for fundamental changes of urban mobility, and enhanced cycling levels. Transitions research provides useful lenses to assess the status quo and to guide cycling interventions in urban systems. Yet, cycling issues, let alone their governance, currently form a niche within sustainability transitions research.

In conclusion, our analysis suggests that to date, urban cycling transitions scholarships lacks normative and change-oriented ambitions. Indeed, as with other fields of sustainability-related studies, it might not be researchers' task to *only* provide policy-relevant research, but also to challenge and provide alternative visions for current governance systems of transport and mobility. We consequently recommend scholars to provide an impetus to reframe taken-for-granted assumptions and knowledge about cycling, and explore methods that can help bring sometimes incidental or experimental notions of seeing and knowing cycling to the fore.

4.3 Suggestions for future research

Our results underline a dominant techno-economic focus in transport and mobility research argued to limit transitions towards just and low-carbon mobility systems [52], p.757). We recommend further research to overcome epistemological and ideological lock-ins in both research and practice. Future studies might help eliciting processes of vision-creation and provide practice-relevant tools (e.g. [47]). Imaginaries have previously proven constructive in this regard and might provide inspirations (e.g. [35, 64], see also [56]. To re-imagine alternative mobility and transport futures with cycling as a key means of movement, future research might further seek inspiration from de-and postgrowth scholarship for alternative representations of cycling in relation to well-being and bodily experience (e.g.[15], [62],). This because cycling (together with walking) can provide a low-tech and low-emission archetype of movement that goes against the "techno-economic paradigm" and "neo-classical perspectives of cost minimization dominant in transport research" [52], 757). To strengthen policy relevant knowledge for cycling, we need to consider how cycling is measured and valuated. More research on and for alternative sustainable mobility indicators is needed. Particularly to assess the co-benefits of cycling in relation to motorized individual transport among others based on space use, emissions, mental health (e.g. [6, 59]. Social practice theory has been applied to transport and mobility issues (see [37]) and in dialogue with transitions studies [54, 72]. Practice theory has proven useful in providing policy-applicable recommendations to advance sustainable mobility that warrant future research to further explore it in conjunction with cycling. Finally, given the omission of "transformations" in our study and particularly the urban transitions and transformations research communities having moved closer together in recent years [34, 65], future literature reviews could broaden the scope by including "transformations", potentially in combination with the thematic foci mentioned above.

Author contributions
DV developed the research design, conducted the analysis and synthesis and wrote the paper. JW contributed to developing the introduction, methodology and provided comments and revisions on draft versions of the paper. SH contributed to developing the introduction, presentation of results, discussion and provided comments and revisions on draft versions of the paper.

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References

1. Arsenio, E., Dias, J. V., Lopes, S. A., & Pereira, H. I. (2018). Assessing the market potential of electric bicycles and ICT for low carbon school travel: A case study in the Smart City of ÁGUEDA. *European Transport Research Review, 10*(13), 1–9. https://doi.org/10.1007/s12544-017-0279-z
2. Avelino, F., & Wittmayer, J. M. (2015). Shifting power relations in sustainability transitions: A multi-actor perspective. *Journal of Environmental Policy & Planning, 18*(5), 628–649. https://doi.org/10.1080/1523908x.2015.1112259
3. Anaya-Boig, E. (2021). Cycling Policies. In R. Vickerman (Ed.), *International Encyclopedia of Transportation* (pp. 241–245). Elsevier.
4. Bakker, S., Guillen, M. D., Nanthachatchavankul, P., Zuidgeest, M., Pardo, C., & Van Maarseveen, M. (2018). Hot or not?: The role of cycling in ASEAN megacities: Case studies of Bangkok and Manila. *International journal of sustainable transportation, 12*(6), 416–431. https://doi.org/10.1080/15568318.2017.1384522
5. Banister, D., Anderton, K., Bonilla, D., Givoni, M., & Schwanen, T. (2011). Transportation and the environment. *Annual review of environment and resources, 36*(1), 247–270. https://doi.org/10.1146/annurev-environ-032310-112100
6. Blondiau, T., Van Zeebroeck, B., & Haubold, H. (2016). Economic benefits of increased cycling. *Transportation Research Procedia, 14*, 2306–2313.
7. Booth, A., Sutton, A., & Papaioannou, D. (2016). *Systematic approaches to a successful literature review* (2nd ed.). Sage.
8. Bruno, M. (2020). The challenge of the bicycle street: Applying collaborative governance processes while protecting user centered innovations. *Transportation research interdisciplinary perspectives, 7*, 100209. https://doi.org/10.1016/j.trip.2020.100209
9. Bryman, A. (2016). *Social Research Methods* (5th ed.). Oxford University Press.
10. Pucher, J. R., & Buehler, R. (2021). Cycling to Sustainability. In J. Pucher & R. Buehler (Eds.), *Cycling for Sustainable Cities* (pp. 1–10). MIT Press.
11. Buehler, R., & Dill, J. (2016). Bikeway Networks: A Review of Effects on Cycling. *Transport Reviews, 36*(1), 9–27. https://doi.org/10.1080/01441647.2015.1069908
12. Caldwell, K. B., & Boyer, R. H. W. (2019). Bicycle commuting in an automobile-dominated city: How individuals become and remain bike commuters in Charlotte. *North Carolina. Transportation (Dordrecht), 46*(5), 1785–1806. https://doi.org/10.1007/s11116-018-9883-6
13. Canitez, F. (2019). A socio-technical transition framework for introducing cycling in developing megacities: The case of Istanbul. *Cities, 94*, 172–185. https://doi.org/10.1016/j.cities.2019.06.006
14. Chen, W., Carstensen, T. A., Wang, R., Derrible, S., Rueda, D. R., Nieuwenhuijsen, M. J., & Liu, G. (2022). Historical patterns and sustainability implications of worldwide bicycle ownership and use. *Communications Earth & Environment.* https://doi.org/10.1038/s43247-022-00497-4
15. Cox, P. (2022). Vélomobility is to degrowth as automobility is to growth: prefigurative cycling imaginaries. *Applied Mobilities.* https://doi.org/10.1080/23800127.2022.2087134
16. de Boer, M., & Caprotti, F. (2017). Getting Londoners on two wheels: A comparative approach analysing London's potential pathways to a cycling transition. *Sustainable Cities and Society, 32*, 613–626. https://doi.org/10.1016/j.scs.2017.04.019
17. de Wildt, A. (2015, May 5). *Witte fietsplan.* Hart. https://hart.amsterdam/nl/page/49069/witte-fietsenplan. Accessed 01 Jan 2023.
18. Dudley, G., Banister, D., & Schwanen, T. (2019). The dynamics of public participation in new technology transitions: The case of dockless bicycle hire in Manchester. *Built Environment., 45*(1), 93–111. https://doi.org/10.2148/benv.45.1.93
19. Edge, S., Goodfield, J., & Dean, J. (2020). Shifting gears on sustainable transport transitions: Stakeholder perspectives on e-bikes in Toronto, Canada. *Environmental Innovation and Societal Transitions, 36*, 197–208. https://doi.org/10.1016/j.eist.2020.07.003
20. Ek, K., Wårell, L., & Andersson, L. (2021). Motives for walking and cycling when commuting – differences in local contexts and attitudes. *European Transport Research Review, 13*(1), 1–12. https://doi.org/10.1186/s12544-021-00502-5
21. Evans, J., & Karvonen, A. (2014). "Give me a laboratory and i will lower your carbon footprint!" - urban laboratories and the governance of low-carbon futures. *International Journal of urban and Regional Research, 38*(2), 413–430. https://doi.org/10.1111/1468-2427.12077
22. Field, A., Wild, K., Woodward, A., Macmillan, A., & Mackie, H. (2018). Encountering bikelash: Experiences and lessons from New Zealand communities. *Journal of transport & health, 11*, 130–140. https://doi.org/10.1016/j.jth.2018.10.003
23. Fishman, E. (2016). Cycling as transport. *Transport Reviews, 36*(1), 1–8. https://doi.org/10.1080/01441647.2015.1114271
24. Fishman, E. (2016). Bikeshare: A Review of Recent Literature. *Transport Reviews, 36*(1), 92–113. https://doi.org/10.1080/01441647.2015.1033036
25. Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems. *Research Policy, 33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015
26. Geels, F. W. (2012). A socio-technical analysis of low-carbon transitions: Introducing the multi-level perspective into transport studies. *Journal of Transport Geography, 24*, 471–482. https://doi.org/10.1016/j.jtrangeo.2012.01.021
27. Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy, 36*(3), 399–417
28. Gössling, S. (2013). Urban transport transitions: Copenhagen, City of Cyclists. *Journal of Transport Geography, 33*, 196–206.
29. Hardinghaus, M., & Nieland, S. (2021). Assessing cyclists' routing preferences by analyzing extensive user setting data from a bike-routing engine. *European Transport Research Review, 13*(1), 1–19. https://doi.org/10.1186/s12544-021-00499-x
30. Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: An overview of the literature. *Transport Reviews, 30*(1), 59–96. https://doi.org/10.1080/01441640903187001
31. Heinen, E., & Buehler, R. (2019). Bicycle parking: A systematic review of scientific literature on parking behaviour, parking preferences, and their influence on cycling and travel behaviour. *Transport Reviews, 39*(5), 630–656. https://doi.org/10.1080/01441647.2019.1590477
32. Heinen, E., & Handy, S. (2021). Programs and Policies for Promoting Cycling. In R. Buehler & J. Pucher (Eds.), *Cycling for Sustainable Cities* (pp. 119–136). MIT Press.
33. Holston, J. (2009). *Insurgent citizenship: Disjunctions of democracy and modernity in Brazil.* Princeton University Press.
34. Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). Transition versus transformation: What's the difference? *Environmental Innovation and Societal Transitions, 27*, 1–3. https://doi.org/10.1016/j.eist.2017.10.007
35. Jasanoff, S. (2015). Future Imperfect: Science, Technology, and the Imaginations of Modernity. In S. Jasanoff & S.-H. Kim (Eds.), *Dreamscapes of modernity* (pp. 1–33). The University of Chicago press.
36. Jensen, J. S., Cashmore, M., & Elle, M. (2017). Reinventing the bicycle: how calculative practices shape urban environmental governance. *Environmental Politics, 26*(3), 459–479.
37. Kent, J. L. (2022). The use of practice theory in transport research. *Transport Reviews, 42*(2), 222–244
38. Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., ... Wells, P. (2019). An agenda for sustainability transitions

research: State of the art and future directions. *Environmental Innovation and Societal Transitions, 31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

39. Lin, X., Wells, P., & Sovacool, B. K. (2017). Benign mobility? Electric bicycles, sustainable transport consumption behaviour and socio-technical transitions in Nanjing, China [Article]. *Transportation Research Part a-Policy and Practice, 103*, 223–234. https://doi.org/10.1016/j.tra.2017.06.014

40. Lin, X., Wells, P., & Sovacool, B. K. (2018). The death of a transport regime? The future of electric bicycles and transportation pathways for sustainable mobility in China. *Technological Forecasting and Social Change, 132*, 255–267. https://doi.org/10.1016/j.techfore.2018.02.008

41. Macmillan, A., Connor, J., Witten, K., Kearns, R., Rees, D., & Woodward, A. (2014). The societal costs and benefits of commuter bicycling: Simulating the effects of specific policies using system dynamics modeling. *Environmental health perspectives, 122*(4), 335–344. https://doi.org/10.1289/ehp.1307250

42. Oja, P., Titze, S., Bauman, A., de Geus, B., Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: A systematic review. *Scandinavian journal of medicine & science in sports, 21*(4), 496–509. https://doi.org/10.1111/j.1600-0838.2011.01299

43. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, 71. https://doi.org/10.1136/bmj.n71

44. Petzer, B. J. M., Wieczorek, A. J., & Verbong, G. P. J. (2021). The legal street: A scarcity approach to urban open space in mobility transitions. *Urban Transformations, 3*(1), 1–24. https://doi.org/10.1186/s42854-021-00018-0

45. Petzer, B. J. M., Wieczorek, A. J., & Verbong, G. P. J. (2020). Dockless bikeshare in Amsterdam: A mobility justice perspective on niche framing struggles. *Applied mobilities, 5*(3), 232–250. https://doi.org/10.1080/23800127.2020.1794305

46. Poudel, N., & Singleton, P. A. (2021). Bicycle safety at roundabouts: A systematic literature review. *Transport reviews, 41*(5), 617–642. https://doi.org/10.1080/01441647.2021.1877207

47. Psarikidou, K., Zuev, D., & Popan, C. (2020). Sustainable cycling futures: can cycling be the future? *Applied Mobilities, 5*(3), 225–231. https://doi.org/10.1080/23800127.2020.1845073

48. Pucher, J., & Buehler, R. (2008). Making Cycling Irresistible: Lessons from the Netherlands. *Denmark and Germany. Transport Reviews, 28*(4), 495–528. https://doi.org/10.1080/01441640701806612

49. Pucher, J., & Buehler, R. (2017). Cycling towards a more sustainable transport future. *Transport Reviews, 37*(6), 689–694. https://doi.org/10.1080/01441647.2017.1340234

50. Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H., & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management, 90*(5), 1933–1949. https://doi.org/10.1016/j.jenvman.2009.01.001

51. Rip, A., & Kemp, R. (1998). Technological change. In S. Rayner & E. L. Malone (Eds.), *Human Choice and Climate Change 2* (pp. 327–399). Battelle Press.

52. Ryghaug, M., Subotiˇcki, I., Smeds, E., von Wirth, T., Scherrer, A., Foulds, C., Robison, R., Bertolini, L., Beyazit İnce, E., Brand, R., Cohen-Blankshtain, G., Dijk, M., Pedersen, M. F., Gössling, S., Guzik, R., Kivimaa, P., Klöckner, C., Nikolova, H. L., Lis, A., Marquet, O., Milakis, D., Mladenović, M., Mom, G., Mullen, C., Ortar, N., Paola, P., Sales Olivera, C., Schwanen, T., Tuvikene, T. & Wentland, A. (2023). A Social Sciences and Humanities research agenda for transport and mobility in Europe: Key themes and 100 research questions. *Transport Reviews, 43*(4), 755–779. https://doi.org/10.1080/01441647.2023.2167887

53. Saud, V., & Thomopoulos, N. (2021). Towards inclusive transport landscapes: Re-visualising a bicycle sharing scheme in Santiago Metropolitan region. *Journal of Transport Geography.* https://doi.org/10.1016/j.jtrangeo.2021.103004

54. Shove. (2012). The shadowy side of innovation: Unmaking and sustainability. *Technology Analysis & Strategic Management, 24*(4), 363–375. https://doi.org/10.1080/09537325.2012.663961

55. Schwanen, T., Banister, D., & Anable, J. (2011). Scientific research about climate change mitigation in transport: A critical review. *Transportation Research Part A: Policy and Practice, 45*(10), 993–1006. https://doi.org/10.1016/j.tra.2011.09.005

56. Sengers, F. (2017). Cycling the city, re-imagining the city: Envisioning urban sustainability transitions in Thailand. *Urban Studies, 54*(12), 2763–2779. https://doi.org/10.1177/0042098016652565

57. Sharmeen, F., Ghosh, B., & Mateo-Babiano, I. (2021). Policy, users and discourses: Examples from bikeshare programs in (Kolkata) India and (Manila) Philippines. *Journal of Transport Geography, 90*, 102898. https://doi.org/10.1016/j.jtrangeo.2020.102898

58. Sheldrick, A., Evans, J., & Schliwa, G. (2017). Policy learning and sustainable urban transitions: Mobilising Berlin's cycling renaissance. *Urban Studies., 54*(12), 2739–2762.

59. Smits, J.-P., & Veraart, F. (2020). Toward a Long-term measurement system of sustainable mobility. In M. Emanuel, F. Schipper, & R. Oldenziel (Eds.), *A U-turn to the Future: Sustainable Urban Mobility since 1850.* Berghahn Books.

60. Sosa López, O. (2021). Bicycle policy in Mexico City: Urban experiments and differentiated citizenship. *International Journal of Urban and Regional Research, 45*(3), 477–497. https://doi.org/10.1111/1468-2427.12992

61. Sunio, V., Laperal, M., & Mateo-Babiano, I. (2020). Social enterprise as catalyst of transformation in the micro-mobility sector. *Transportation Research Part A: Policy and Practice, 138*, 145–157. https://doi.org/10.1016/j.tra.2020.05.027

62. te Brömmelstroet, M., Nikolaeva, A., Glaser, M., Nicolaisen, M. S., & Chan, C. (2017). Travelling together alone and alone together: Mobility and potential exposure to diversity. *Applied Mobilities, 2*(1), 1–15. https://doi.org/10.1080/23800127.2017.1283122

63. Tan, H., & Du, S. (2021). The governance challenge within socio-technical transition processes: Public bicycles and smartphone-based bicycles in Guangzhou China. *Sustainability.* https://doi.org/10.3390/su13169447

64. Taylor, C. (2004). Modern Social Imaginaries. *Duke University Press.* https://doi.org/10.2307/j.ctv11hpgvt

65. Torrens Westman, L., Wolfram, M., Broto, V. C., Barnes, J., Egermann, M., Ehnert, F., Frantzeskaki, N., Fratini, C. F., Håkansson, I., Hölscher, K., Huang, P., Raven, R., Sattlegger, A., Schmidt-Thomé, K., Smeds, E., Vogel, N., Wangel, J., & von Wirth, T. (2021). Advancing urban transitions and transformations research. *Environmental Innovation and Societal Transitions, 41*, 102–105. https://doi.org/10.1016/j.eist.2021.10.026

66. Tuama, D. O. (2015). Ripples through the city: Understanding the processes set in motion through embedding a public bike sharing scheme in a city. *Research in transportation business & management, 15*, 15–27. https://doi.org/10.1016/j.rtbm.2015.03.002

67. van Waes, A., Farla, J., Frenken, K., de Jong, J. P. J., & Raven, R. (2018). Business model innovation and socio-technical transitions. A new prospective framework with an application to bike sharing. *Journal of Cleaner Production, 195*, 1300–1312. https://doi.org/10.1016/j.jclepro.2018.05.223

68. Vreugdenhil, R., & Williams, S. (2013). White line fever: A sociotechnical perspective on the contested implementation of an urban bike lane network. *Area, 45*(3), 283–291. https://doi.org/10.1111/area.12029

69. Wangel, J. (2011). Exploring social structures and agency in backcasting studies for sustainable development. *Technological Forecasting and Social Change, 78*(5), 872–882. https://doi.org/10.1016/j.techfore.2011.03.007

70. Wangel, J., Gustafsson, S., & Svane, Ö. (2013). Goal-based socio-technical scenarios: Greening the mobility practices in the Stockholm City District of Bromma, Sweden. *Futures, 47*, 79–92. https://doi.org/10.1016/j.futures.2013.01.005

71. Wangel, J. & Gustafsson, S. (2011) *Scenario Content, Outcome and Process – Developing and testing methodologies for goal-based socio-technical scenarios* (Report No. TRITA-INFRA-FMS 2011:3). Royal Institute of Technology, Stockholm. https://www.diva-portal.org/smash/get/diva2:418213/FULLTEXT01.pdf

72. Watson, M. (2012). How theories of practice can inform transition to a decarbonised transport system. *Journal of Transport Geography, 24*, 488–496. https://doi.org/10.1016/j.jtrangeo.2012.04.002

73. Wells, P., & Lin, X. (2015). Spontaneous emergence versus technology management in sustainable mobility transitions: Electric bicycles in China. *Transportation Research Part A: Policy and Practice, 78*, 371–383. https://doi.org/10.1016/j.tra.2015.05.022

74. Winters, M., Buehler, R., & Götschi, T. (2017). Policies to promote active travel: Evidence from reviews of the literature. *Current Environmental Health Reports, 4*(3), 278–285. https://doi.org/10.1007/s40572-017-0148-x

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