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Experimenting with automated driving for technology or for the city? A matter of governance cultures

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Urban experiments have been promoted as means to enable innovation for sustainability, particularly in urban mobility. Yet, they have been criticized for struggling to stimulate broader transformations, as they often are detached from public-value principles, lack embeddedness in the cities' everyday realities and are industry-oriented. How cultural changes on different governance levels intersect to produce urban experiments with transformative potential has received little attention. This paper focuses on how urban experiments are co-created with broader governance cultures in multiple governance levels, and what the implications of this co-creation are for urban transformation. We provide a theoretical background on the interrelations between governance cultures and urban experimentation, and the debate on urban experimentation within Science and Technology Studies, transition/innovation studies and urban studies to identify the main barriers for urban transformation. We, then, present our methodology consisting of the case study selection of the multi-level governance nexus State-Region-City in Stuttgart and Karlsruhe, our data collection with interviews and documents, and the analytical tool of storylines to capture the co-production of governance cultures and urban experiments. We continue with the analysis of the case study of automated driving experimentation with the concept of storylines. Our findings show that urban experiments are more likely to lead to urban transformation when the local public sector has a strong role in governance processes, and when experiments emerge through deliberation on daily urban problems and policy agendas. When governance processes are mainly led by state and industry actors who prioritize testing technologies as universal and scalable byproducts, it is less likely for urban experiments to lead to urban transformation. Finally, we discuss when urban experimentation advances technology *per se* and when it adds public value and advances sustainability, arguing for a co-existence of different kinds of urban experiments. We conclude with future research and policy implications.

KEYWORDS

urban experiments, automated driving, multi-level governance, sustainable mobility, storylines, governance cultures

Introduction

Urban experimentation, including pilots and trials of new mobility technologies, is central to discussions about smart, green, resilient, and liveable cities, as practices of bringing about sustainable urban transformation (Hajer and Versteeg, 2018; While et al., 2021). Building on a wider "experimental turn" in social sciences, urban experimentation is positioned as a means for dealing with the uncertainty associated with introducing novel technologies to the city, to tackle "wicked" problems such as climate change, traffic congestion, or enable wider transformations (Gross et al., 2005; Overdevest et al., 2010). It is still debatable whether this experimental turn represents an actual opportunity for urban transformations or an industrial playground for testing new technologies with cities and regions as mere facilitators (Evans et al., 2021). In any case, there is consensus among practitioners and academics that urban experiments have been struggling to fulfill their promise of stimulating broader transformation, and they are often detached from local policies, and everyday contexts and realities of cities (Haughton and McManus, 2012; Grandin et al., 2018; Marres, 2020; Torrens and von Wirth, 2021).

Urban experiments are, by design, temporary and organized with specific goals and learning objectives in mind that need to be achieved and delivered before project funding runs out (Evans et al., 2016; Engels et al., 2019). As such, urban experiments are often viewed as limited but scalable niche projects that aspire to induce large-scale change. However, the tendency to foreground scalability as the main pathway for systemic change, assumes that change happens through one-size-fits-all solutions that can be applied in any context (Pfotenhauer et al., 2021). This impedes continuation and integration of learning in urban sustainability policies and downplays the urban experiments' potential to produce context-dependent knowledge on how urban transformation can and should be achieved. Eventually, it obscures how urban experiments are actually produced through governance, as they do not occur in a vacuum (Evans et al., 2016; Voß and Schroth, 2018; Sengers et al., 2019; Torrens and von Wirth, 2021). Furthermore, urban experiments reflect a "politics of niches," as selective political practices produce niches not only in terms of technology, but also in terms of societal norms and policies in a bottom up way (Raven et al., 2019; Savini and Bertolini, 2019).

The present debate largely ignores how urban experiments are produced within their broader urban contexts and specific governance cultures and vice versa, despite the emphasis on learning (Evans et al., 2021). This leads to mischaracterization of urban experiments' contribution to the governance of sustainable urban transformation. This paper aspires to redress this issue by asking *how urban experiments are shaped by governance cultures (and vice versa) and what are the implications for urban transformation?* To address this question, we view urban experiments as governance practices arising and embedded in broader multi-level governance cultures, whose potential for urban transformation and public value is contingent on those governance cultures. We provide a comprehensive account of how changes on different levels of governance intersect to eventually produce urban experiments, and how governance is (re)produced by them. We do so by analyzing the cultural shift in the governance of automated driving in the State of Baden-Württemberg (State of BW) and the City-Region of Stuttgart (nexus City-Region-State). Using automated driving as an empirical case of urban experimentation, we show how two types of experiments are co-created in relation to two specific governance cultures. Ultimately, this paper contributes to the wider debate of whether urban experimentations are about corporate interests for technology and business development or about cities trying things out to achieve public value and sustainability.

The remainder of this paper is divided into five sections. In Section Theoretical Background, we first present our theoretical background consisting of governance cultures and experimentation literature, focusing on automated driving and the main factors impeding urban transformation, drawing from transition studies, urban studies, innovation studies, and Science and Technology Studies (STS). Our theoretical background has a (northern) European focus, thus it is not representative of the dynamics between urban experimentation and urban transformation at a global scale. In Section Methodology, we present our methodology comprising the multi-level governance case study of automated driving, our data collection methods comprising document analysis and interviews, and storylines as an analytical tool for investigating the co-creation of urban experimentation and governance cultures. Section Findings: The storylines of co-shaping of governance cultures and urban experiments presents the empirical findings of our two storylines, namely "experimenting for technology" and "experimenting for the city" reflecting two distinct governance cultures of dealing with automated driving; "car governance culture" and "mobility governance culture," respectively. The two storylines reflect how two different governance cultures shape two different kinds of urban experimentation of automated driving in the State-Region-City nexus. In Section Discussion, we abstract and discuss considering the implications of our findings to the prospects of urban transformations. We conclude with recommendations for future research and policy implications in Section Conclusion.

Theoretical background

Governance cultures

The term governance culture underlines cultural meanings and values in relation to acceptable purposes and appropriate mechanisms of governance practices (Rogge and Reichardt, 2016; Paulsson et al., 2017; Olin and Mladenović, 2022). Therefore, it allows for an account of the broader cultural

context (e.g., operational assumptions, modes of thought, related practices, and organizational mechanisms) in which these actors and institutions are embedded (Mladenović et al., 2020). Studies on governance of automated driving and urban mobility foreground how the latter are perceived, negotiated and justified (for example Stead, 2016; Cohen et al., 2018; Porter et al., 2018; Stilgoe, 2018; Curtis et al., 2019). There are also studies of mobility politics illustrating how "mobility cultures" that reflect distinct cultural contexts including norms, values, and related mobility practices of people, shape governance processes (Rau, 2008; Aldred and Jungnickel, 2014). Wentland (2017) points to different rearticulations of socio-technical imaginaries of the electrification of transportation in Germany, including certain meanings and visions around the car culture, and how these imaginaries shape governance through interactions in political initiatives and processes of actor coalitions. Mögele and Rau (2020) show how specific governance cultures reflect specific visions for the future of mobility that underpin particular governance practices. However, the aforementioned studies do not emphasize how existing governance cultures influence the experimentation with automated driving (or mobility in general). The latter is significant, because experiments come to shape how automated driving is ultimately interpreted, enacted, and eventually implemented in particular contexts.

This coincides with the general tendency in research on urban experimentation to not focus on how urban experiments are co-produced by and reflect broader governance cultures and shifts. Particular and dominant governance cultures can promote or inhibit urban experiments that envision different pathways for urban transformation. Yet, most of the literature on the governance of urban experiments deals with it as something that is up for grabs and *ad hoc* (Wentland, 2017; Engels et al., 2019), instead of an all-encompassing culture-laden framework that produces and (re)shapes urban experiments. This detaches urban experimentation from the importance of cultural norms in how experiments are set up and how they influence urban transformation. In this paper, we aspire to shed light to the role of governance cultures in shaping urban experiments (and vice versa). We do so by analyzing how different kinds of experiments of automated driving emerge through different governance cultures. The latter constitute the dynamic interaction of arguments, stakeholders, practices, and settings in a multi-level governance context. This analytical process is operationalized through the analytical concept of storylines (see Section Methodology).

Urban experiments and urban transformation

Crucially, urban experimentation is a crux which provides insights in the tensions and opportunities in the urban realm and constitutes an arena of observing how urban transformation and sustainability can occur through interventions and changes in governance (Bulkeley and Castán Broto, 2013). In light of global challenges and "wicked problems," such as, e.g., climate change, traffic congestion, accessibility, and energy consumption, urban experimentation has been embraced as an increasingly dominant practice in urban governance through testing new technologies, business models and solutions (Evans et al., 2016; Caprotti and Cowley, 2017). In this sense, urban experimentation has emerged as a means through which actors attempt to navigate, learn about, and make sense of the present complex realities of these challenges, whilst also making tangible visions of the future (Gross and Krohn, 2005; Wentland, 2017; Engels et al., 2019; Torrens and von Wirth, 2021).

One domain in which urban experimentation is particularly critical is automated driving. The Society of Automotive Engineers (SAE) defined five levels of vehicle automation. While levels 1 and 2 include some automated functions (driving support systems), it is level 3 that enables the driver to have hands-off the vehicle in certain traffic or environmental conditions. In the highest levels of automation, an automated system performs all dynamic tasks of driving in certain (e.g., in highways on level 4) or in all conditions (level 5) (Hopkins and Schwanen, 2021). There have been tests of all different levels of automated driving in different environments (e.g., urban roads, highways, parking lots, dedicated lanes) and different modes of transport (e.g. private cars, public transport buses) (Williams, 2021). In particular, testing automated driving represents a real-world experimental approach of introducing technology in society, as it often takes place on public roads and interacts with existing users and infrastructure (Jackson et al., 2014; Stilgoe, 2018, 2020; Marres, 2020).

Cities experiment with automated driving in various ways. Many cities compete with each other for public funding to develop scenarios and studies on automated driving or to facilitate demonstrations (POLIS, 2018; While et al., 2021), while others work with tests and pilots of automated driving as part of smart city projects (Joss et al., 2019; Marres, 2020). In several places, test beds for automated vehicles are flourishing, affecting rural roads, highways, and cities (Rupprecht et al., 2018; Stilgoe, 2018). On a larger scale, entire regions have been framed as test beds for regional redevelopment around certain technology clusters in an attempt to find recipes against economic and social decay also in similar regions (Späth et al., 2016; Engels et al., 2019). Crucially, these experiments introduce and enable the adoption of unfinished and potentially risky technologies precisely because certain design questions about risks and/or safety can only be resolved through empirical use. This is because automated driving is premised on machine learning algorithms, which require very large quantities of "real world" data to be trained (Stilgoe, 2018). Thus, its testing is for societal learning as much as for machine learning. This speculative introduction of not fully tested and dynamic technologies and

associated risks into society resonates with the idea of "society as a laboratory," which aims to capture the uncertainties of large-scale technologies (Beck, 1992; Sørensen, 2018).

Yet, urban experiments have been criticized for their limitations in practically inducing broad urban transformation (Evans et al., 2021). Literature provides a variety of explanations for that.

Competitive project funding is usually deployed to address urban sustainability challenges. Municipalities generally design projects to test new solutions, *ad hoc*, with little scope for integrating previous results from similar efforts or other places. These externally-funded projects are unreliable: they end abruptly once funding runs out. This leads to poor integration of pilots/trials with each other and in the urban contexts and policies (Hodson and Marvin, 2010; Cugurullo, 2020). When this project-logic is taken for granted, compounded with pressure from funding requirements and internal requirements of project based-organization, learning is fragmented and not effectively integrated into an urban-regional governance level, hindering transformation (Torrens and von Wirth, 2021).

How experiments are framed is also problematic. Urban experiments are often viewed as mere technology tests under real-world conditions or as a tentative, locally confined demonstration focusing on technical performance (Evans et al., 2021). Particularly in regard to automated mobility, experiments are often framed and set up as regulatory sandboxes for temporarily modifying regulations to allow technologies to unfold their uncertainties in a relatively controlled environment (Engels et al., 2019; Servou, 2020). Exceptions and rule adaptations are approved on an on-off basis to facilitate technology implementation (Freudendal-Pedersen et al., 2019). For example, implementing a test-field for automated driving might interfere with existing relationships between road users, insurers, local residents, traffic lights, street signs, and digital infrastructure. Crucially, as Engels et al. (2019) argue, such experiments both test and re-configure society around a new set of technologies and envisioned futures embedded in associated governance modes—often against considerable resistance from predominant governance modes. Thus, urban experiments could be strategically deployed to co-produce socially desirable governance frameworks in tandem with emerging technologies (Marres, 2020; Marres and Stark, 2020).

Furthermore, the expectations surrounding urban experiments overemphasize scalability rather than the transformation of organizations or urban contexts (Smith and Raven, 2012; Evans et al., 2021). Much of the Strategic Niche Management literature has become interested in the issue of scalability in the sense of aggregated learning. This strand of literature assumes that gathering experience in specific localities can lead to creating the learning that helps consolidate new non-situated socio-technical configurations that may bring about transitions of socio-technical systems (e.g., transport, energy) at a wider scale (Torrens et al., 2018). Yet, such non-situated configurations are suitable for aggregating learnings from similar or complementary experiments occurring in multiple localities, but not for integrating learnings from different types of experiments into local policy agendas, which might eventually compromise urban transformation. A place-based approach, which would contextualize innovation into local realities and needs, has received little attention in literature (Torrens et al., 2018). Recent analyses indicate that the expectation of scalability might be too optimistic and miss opportunities to deliberate and articulate the public benefits of urban experimentation (Jasanoff, 2004; Pfotenhauer and Jasanoff, 2017; Engels et al., 2019; Pfotenhauer et al., 2021).

However, there have been growing calls for moving beyond *ad hoc* experiments and the insistence on upscaling as primary transformation mechanism (Savini and Bertolini, 2019; Monstadt et al., 2022). These contributions argue for moving toward longer-term and diversified modes of urban experimentation that embrace multiplicity and co-creation (Evans et al., 2021; Torrens and von Wirth, 2021). For instance, transition studies have investigated the political processes involved in the deliberate development of niches that afford experimentation and learning for path-breaking innovations (Schot and Geels, 2008; Raven et al., 2012; Smith and Raven, 2012). Torrens et al. (2018) focused on bridging the research gap in transition studies between the design of niches and the national/international systemic changes that promote technologies, providing a place-based account of the co-evolution of governance and urban experimentation. For Evans et al. (2021), moving from a project-logic to changing business-as-usual relies on capturing and embedding experiential learning into organizations rather than on experiments' technical performance. Recent research has shown that capturing experiential learning requires a change in values, norms, assumptions, actor networks, and practices on different levels of governance (Servou, 2020). Nevertheless, despite the literature's progress in embracing co-creation, multiplicity and learning processes in urban experiments, it still tends to ignore how these processes emerge through changes in governance. Crucially, urban experiments are based on certain assumptions about desirable technological change and real-world use patterns, thus they are inevitably political and normative. Savini and Bertolini (2019) argue that experimental agency entails a set of political biases and normative assumptions that need to be problematized. In other words, urban experiments embody particular governance cultures, shaped by the interests and values of those involved.

Methodology

Case study selection

To investigate how urban experiments are context-and-location-bound and embedded in specific governance cultures, we deploy an embedded multi-level governance case study of

the emergence of urban experimentation of automated driving in the multi-level governance nexus of the State of BW, the Regions of Stuttgart and Karlsruhe, and the City of Stuttgart in Southern Germany. A case study is a detailed, empirical inquiry of a phenomenon and the context in which it emerges, allowing the researcher to bring together theoretical and empirical elements to generate knowledge about the phenomenon under investigation. Since urban experimentation in its governance cultures is an entangled, contingent, and context-dependent process, we identified the case study approach as the most fitting design for our research. Our aim with this case is not to produce generalizable conclusions but rather context-specific knowledge (Flyvbjerg, 2006). We structured this as a multi-level governance case study to provide a comprehensive account of how funding, argumentation and planning for urban experiments emerges through the interaction of different governance levels and industrial settings, and how eventually becomes relevant for the urban level. This type of governance has been also termed as "fuzzy governance" (Bache et al., 2015) and "decentered governance" (Bevir and Rhodes, 2006), and serves the purpose of dealing with the increasing complexity of society, something that one political-administrative level cannot cope with alone (Hajer and Wagenaar, 2003; Hajer and Versteeg, 2005; Wagenaar, 2011). This is particularly relevant for automated driving, where states, regions, and cities are all involved in its experimentation and governance, being dependent on each other, while at the same time engaging in deliberative processes with different industries [e.g., the automotive and Information and Communications Technologies (ICT)]. The multi-level governance nexus of the State-Region-City is relevant exactly because of this interdependence.

The State of Baden-Württemberg (BW) is one of Germany's 16 federal states and has some of the most economically strong regions in Europe, especially Stuttgart and Karlsruhe. Stuttgart is Europe's strongest exporting Region and supports its strength through the automotive and mechanical engineering sectors (TAF-BW, 2021). It is home to the automotive companies Daimler and Porsche and the largest automotive supplier Bosch. Stuttgart's identity is tied to this history, and it is often referred to as the "car-friendly city," "cradle of automobile," and "holy ground" of the Daimler-Porsche-Bosch triangle (Daude, 2019). Karlsruhe is one of the top ICT hubs in Europe with high concentration of companies and research institutions and strong IT security elements. It is often referred to as the "Karlsruhe Technology Region" with future energy systems, smart mobility, and industry 4.0 being the key aspects of academic and industrial research in Karlsruhe (Zimmermann, 2018).

The federal level is also significant: Germany has authorized testing of automated driving in real-life conditions since 2015, while in 2021 the German Government released an act amendment for allowing tests of level 4 automated driving on public streets. In this line, the State of BW has taken many initiatives funding projects and pilots on urban experimentation, especially automated driving, as it has its own test bed for automated and connected driving in Karlsruhe (TAF-BW, 2021). The Karlsruhe Region is the knowledge and R&D hub of the State of BW. Karlsruhe includes well-known research institutes in Europe, such as the Research Center of Informatics in Karlsruhe and the Karlsruhe Institute of Technology (KIT) (State Ministry Baden-Württemberg, 2018).

Meanwhile, the Stuttgart Region sits between the State of BW and the City of Stuttgart and has certain delegated political tasks. For instance, the inter-municipal Regional Development Association (Verband Region Stuttgart) can initiate and co-fund projects on public transport and economic development (Heinelt and Kübler, 2005). This establishes a strong link between mobility and economic competitiveness in the Region.

Overall, economic competitiveness is central for mobility governance in the multilevel governance nexus, because of the significance of big automotive and ICT players. Furthermore, since Stuttgart and Karlsruhe are major hubs for these industries, the three governance levels (State-Region-City) are inextricably related (Heeg, 2002; Fricke, 2020).

Thus, providing "thick descriptions" (Geertz, 1973) of the multi-level governance of experimentation of automated driving in the State-Region-City entails a deeper engagement with its intricate governance cultures and how they shape urban experiments. Ultimately, this paper examines these governance levels (settings) jointly through storylines (see Section Storylines as an analytical tool to studying urban experiments in their governance cultures) to highlight the contrasting governance cultures and provide context for the different kinds of urban experimentation of automated driving.

Data collection

For data collection, we sought to capture both argumentative and practical manifestations in the empirical material. We use a combination of document analysis (14 documents) and 13 semi-structured expert interviews that the first author conducted in 2018 and 2019 (see Table 1) (Witzel, 2000). The documents collected and analyzed for this paper include minutes of meetings, policy papers, gray literature and press releases from 2016 to 2021 (see Appendix)[1]. The interview material comprised three employees from the State Ministries of Transport and Economics, three employees from the Economic Development and Mobility Planning Departments of the City of Stuttgart, two local politicians from the City Council of Stuttgart, three employees from the automotive sector (Daimler/moovel and Bosch), and two administrative officials from the Region of Stuttgart (Economic Corporation of the Region of Stuttgart and Regional Development Association) (see Table 1). The interviews were conducted between 2018 and 2019. For our

1 Text material was translated from German into English by the authors.

TABLE 1 List of interviews used for analysis.

No. interview	Description	Date
Interview 1	Expert at Cluster Automotive Region Stuttgart at Economic Corporation of the Region of Stuttgart	December 12, 2018
Interview 2	Head of Bureau of Economic Development at City of Stuttgart	January 17, 2019
Interview 3	Expert at Ministry of Economics Baden-Württemberg Division of Automobile Production Industry	March 14, 2019
Interview 4	City Planner at Sustainable Mobility Department of the City of Stuttgart	March 15, 2019
Interview 5	Senior Director of Regional Development Association Division Economics Infrastructure	January 5 2018
Interview 6	Expert at Automotive Technology Bosch	November 2,9 2018
Interview 7	Expert of City Relations at Mobility Services Daimler	January 25, 2019
Interview 8	Expert at Ministry of Transport Baden-Württemberg Division of Public Transport	November 16, 2018
Interview 9	Local politician from the Left Party (SOES LINKE PLuS)	July 2, 2018
Interview 10	Senior Expert Future Mobility at Bosch	November 7, 2018
Interview 11	Expert at Ministry of Transport Baden-Württemberg Division Electric Mobility Vehicle Innovation	December 19, 2017
Interview 12	Project Manager at Sustainable Mobility Department of the City of Stuttgart	April 23, 2019
Interview 13	Local politician from Social Democratic Party (SPD)	July 14, 2018

sample, we carried out a criteria-based selection of relevant interviewees online based on the organization they represent, and a snowball technique to find more relevant interviewees. All interviewees had to be actively involved in the governance processes in the region of Stuttgart as well as actively deal with automated driving. Following that, we selected interviewees from different governmental levels (state and city), different institutions (ministries, planning department, companies, and associations) and different parties in order to provide a heterogeneous sample.

Data analysis revolves around a triangulation of different sources of data material and methods (Lamnek, 2005; Flick, 2011). We analyzed our diverse empirical material in a MAXQDA software following an open coding approach to identify groups of actors, settings, related practices, and arguments that form storylines, which in turn reflect specific governance cultures that shape different kinds of urban experiments.

Storylines as an analytical tool to studying urban experiments in their governance cultures

Governance cultures are crucial to how experiments are set up and implemented, as they are carriers of norms, values, and assumptions. As such, they are contingent on meaning-production (Hajer, 2006). Culturally-sensitive studies have been informed by discursive approaches for tracing, analyzing and interpreting meanings in governance processes (see Tschoerner-Budde, 2019; Mögele and Rau, 2020; Mögele, 2022). STS further argue that experiments are not only contingent on discourses and meanings, but also through practices and material settings that are preconfigured according to particular research interests and expectations (Voß and Schroth, 2018). Thus, understanding how urban experiments are shaped in governance cultures (and vice versa) requires a combined interpretive and practice-oriented research approach that allows for empirically tracing the negotiation of problem frames and ontological assumptions as well as the material configurations of experiments.

This paper deploys and modifies the concept of storylines to analyze how urban experimentation of automated driving is co-created in governance cultures. To do so, it draws inspiration from Argumentative Discourse Analysis (ADA; Hajer, 1995a, 2006), and STS studies (Law, 1999, 2009; Latour, 2004, 2005). The concept of storylines originates in ADA, which has been used for empirical investigations of implicit cultural meanings on governance studies, including mobility governance (e.g., Hajer, 1995b; Hajer and Kesselring, 1999; Servou, 2019, 2020; Tschoerner-Budde, 2019; Mögele, 2022). Storylines in ADA reflect a specific understanding of a given governance issue. They are short-cut phrases that summarize narratives that bring together different institutional rules, administrative routines, cultural norms, and values that are taken up by actors to reach an outcome, develop a specific strategy or certain policies (Hajer, 1995a, 2003). Yet, there has been critique that ADA's storylines overemphasize what is said and how it is said (discursive deliberation), and lack explicit attention to practical and material manifestation of governance (i.e., Müller, 2008; Mattissek and Wiertz, 2014). Even though ADA includes practices as a constituent of storylines, its conceptualization of practices as operational routines attached to specific discursive structures limits the analysis from capturing the dynamic changes within the uncertain, multi-actor and multi-level governance of today, which reflects more closely the governance of urban experiments. STS studies argue that practices of experimentation are characterized by temporality (Callon et al., 2009; Law, 2009), and material settings, such as physical, spatial and technological elements (Servou, 2019).

Therefore, this paper complements the ADA approach with an STS approach to methodologically enrich the concept of storylines with a more performative and co-creative conceptualization of practices and materialities. Our objective is to comprehensively account for how governance cultures shape urban experiments (and vice versa), unearthing the meanings found in arguments about the experiments' normative objectives and the performative practices that enact those meanings. We deploy storylines as an analytical tool to examine the dynamics and interactions contributing to the emergence of urban experiments, attending to the governance cultures, which they reflect. We conceptualize storylines as empirically-informed frames, including particular sayings and doings that reflect how specific governance cultures play out, interact and produce governance practices, including urban experiments. Hence, we shift the analytical focus toward a joint analysis of meanings and practices of governance cultures in urban experimentation.

The data collection and analysis of storylines was conducted by the first author of the paper as part of her doctoral thesis, tracing the developments of automated driving in a chronological order from 2016 to 2021, combining material from public documents, interviews, and online press releases. The storylines were structured chronologically around the interplay and integration of four elements: (1) a set of arguments, (2) a set of stakeholders, (3) a set of practices, and (4) a set of (administrative and material) settings that were studied in parallel and in relation to each other. The combination of different qualitative methods (i.e., interviews and documents) were complementary, served as triangulation and ensured the coherence of storylines. As a second step of meta-analysis, the storylines were double-checked, discussed, and edited by the other two authors of the paper to further ensure robustness of qualitative methods. Ultimately, the authors analyzed how storylines are produced and interact with each other to elaborate on how different governance cultures shape urban experiments in relation or in contrast to each other (Hajer, 1997; Keller, 2007).

Findings: The storylines of co-shaping governance cultures and urban experiments

Two storylines stood out in our analysis, of "experimenting for technology" and "experimenting for the city," which represent distinct governance cultures concerning automated driving and shape two different kinds of urban experimentation of automated driving. The "experimenting for technology" storyline shows how a car-centric governance culture shaped the implementation of a test-field for automated and connected driving in Stuttgart and Karlsruhe in a rather techno-centric way. The "experimenting for the city" storyline addresses an alternative mobility governance culture that shaped the emergence of an urban pilot for an on-demand shuttle service positioned as a precursor of automated driving, which became a regular service in Stuttgart's public transport.

The "experimenting for technology" storyline: Reflecting a car governance culture

Traditionally the State-Region-City nexus has been characterized by a dominant *car governance culture*, which developed after World War II. This car governance culture considers car production as essential for the economy and the wellbeing of the nexus and leads to a global orientation of both the governance culture and car production. The very essence of being a mobile and active citizen is associated with individual car ownership and automobility (Mögele and Rau, 2020): the car is still at the core of everyday mobility. This is reinforced by Stuttgart's geography, distributed in a very large Region consisting of many small and middle-sized cities. Traffic volumes are high with large numbers of commuters from smaller towns (Zimmermann, 2014). In the absence of a peripheral ring road, public-transport, and road users are forced to share a limited transport infrastructure, resulting in congestion on main arterial roads and deteriorating air quality (Interview 12, 2019). Karlsruhe has a well-developed public transport and car-sharing system, but it is still has a big share of car use. These factors have converged into shaping a car governance culture in the multi-level governance nexus.

Yet, during the last decade there has been a political discussion about the economic restructuring of the State of BW and the Stuttgart and Karlsruhe Regions through merging automotive and ICT (Interview 3, 2019), to face the international competition from the ICT sector (e.g., Google and Uber). Despite its globally dominant position in automotive manufacturing, BW is lagging behind from the United States and China in high-tech companies and software development. For mobility, this entails diversifying the car governance culture to include new ITC-based vehicle technologies such as electric mobility, ride-hailing fleets, and automated driving (Interview 7, 2019). As an interviewee from the Region of Stuttgart stated:

> *The discussion was about how we can deal with this gap between Silicon Valley and the classical car industry here in Stuttgart; combustion engine on the one side and fully electric vehicles on the other… assistance systems, automated cars at the end of the development maybe. This was the beginning of the discussion, so we can figure out what the gap between Silicon Valley and the Region of Stuttgart is (Interview 5, 2018, p. 5).*

In this context, automated driving was considered as instrumental for the economic transformation of BW, reproducing and protecting the car governance culture, instead of a concrete mobility solution. Thus, new alliances and networking groups positioned the ICT sector at the center of the economic restructuring of the State, highlighting the importance of establishing a symbiotic link between the production of automotive technology and the ICT sector, with automated driving as one of the innovations considered (Interview 6, 2018; Interview 10, 2018; Interview 11, 2017).

A key outcome of these discussions was a tender for a test-field for automated and connected driving in 2016. The Ministry of Finance and Economics of BW published a call for tenders in BW. The purpose was ensuring that BW keeps its attractiveness as an automobile location both globally and within Germany by testing the conditions for a convergence between the automotive industry and the ICT industry (Interview 3, 2019). As stated in the call:

> *The future of mobility requires new approaches in the technology fields of vehicle, energy, information and communication technologies and production (...) Various sources of information in and around the vehicle will be linked in the future even more to provide systems for efficient traffic flow control and driver assistance systems for improving road safety. (. . .) The transport infrastructure and the IT architecture in automobiles need to be expanded and harmonized to connect the information and automation of driving functions (Ministry of Finance and Economics Baden-Württemberg, 2016, p. 1–2).*

The parties eligible for application were non-profit universities, business-oriented research institutions, and municipalities in BW. Commercial enterprises were excluded, but cooperation with companies was permitted. Briefly after the call's publication, a representative from the local Christian Democratic Union (CDU) party submitted a proposal to the City Council of Stuttgart claiming that Stuttgart had to apply for this tender as the State Capital. This was the first time that the City of Stuttgart's council picked up officially the topic of automated driving. The CDU representative argued:

> *It is not just the two car manufacturers Daimler and Porsche that make the automotive industry particularly important for Stuttgart as a business location. To keep it that way, we need to help lay the foundations for forward-looking research and innovation (. . .) Such a test-field would be a clear commitment that we want to maintain technological leadership in the automotive industry (. . .) The car was invented here, then the revolution must also start from here, if a kind of reinvention of the car takes place (State Parliament Baden-Württemberg, 2016, p. 1).*

That argument follows a similar line to the Ministry of Economics of BW: an economic argument about preserving technological leadership. The proposal mobilized the City Council, then led by the Green party. Thus, the City of Stuttgart together with the City of Ludwigsburg and the Region of Stuttgart made a joint project application for the test-field (Interview 1, 2018). Apart from the left party, local politicians who argued for applying for the test-field were focusing on the car as the core element of testing. At that time, the City Council debates framed automated driving as a reinvention of the passenger private car, reproducing the car governance culture that has been dominating Stuttgart. The application phrased the test-field as a means of enabling the City of Stuttgart to position itself as a major automotive and high-tech location. While there was no debate and specific elaboration about how automated driving could help with the city's mobility problems before the application, the submission of the application triggered further discussions.

In particular, a representative from StadTISTEN[2] pointed out in a proposal to the City Council, that while the industry's developments were progressing rapidly, the uncertain impacts on the regional mobility system, public transport, public space, environment, and energy requirements were not even hinted at by the City. Responding to this proposal, the left party stressed that the test-field should not give the impression that the switch to a mobility governance culture "away from the car" and toward public transport is no longer necessary (City of Stuttgart, 2016, p. 2; Interview 9, 2018). The social democratic party (SPD) agreed that only a strong local public transport in Stuttgart could deal with the traffic challenges and claimed that the City Council should set the goal to develop Stuttgart as "the public transport capital" of Germany (Interview 13, 2018). Overall, the City Council supported the City's involvement arguing that the local level must adapt to the topic, learn and gain experience through testing.

Eventually, the State of BW handed over the grant decision for 5.5 million euros to set up, construct and operate the test-field to another applicant, Karlsruhe (including the cities of Heilbronn and Bruchsal; TAF-BW, 2021). The explanation was that Karlsruhe had a stronger cluster of R&D for automated driving, and less complex urban landscape to test automated driving (Interview 1, 2018; Interview 2, 2019; Interview 3, 2019).

As such, the test-field construction began in 2016, and it went into operation in May 2018, and has been running since. It has been framed as a "real-life laboratory" and a "regulatory sandbox" with everyday road traffic scenarios where applications of automated and connected driving can be tested (BMWi, 2019). The test-field covers all relevant public road types from

2 Political party in the City of Stuttgart founded shortly after the heyday of the protests against the highly controversial transport infrastructure megaproject concerning Stuttgart main station called "Stuttgart 21."

inner-street 30-speed zones to motorway sections in real-life conditions, and includes applications in public transport. The test-field's scope includes all levels of automated driving with vehicles for individual and public transport, and the new digital infrastructure. The test-field BW has been the first in Germany to include applications on public roads in all traffic situations; while it has (re)designed and equipped existing public space to conduct tests in an open environment. It has also modified regulations on public roads to allow technologies to unfold their uncertainties. The set-up of this "real-life laboratory," especially what concerns the algorithmic development, the sensors and the intelligent infrastructure for automated driving, is meant to be scaled up to other places.

Even though the test-field BW brought together public and private actors and was funded by the public sector (State of BW), it has not functioned as a public policy instrument with public value and sustainability as its main objectives. Three main reasons stand out: (1) Foregrounding the goal of scalability of the "real-life laboratory" ignored the urban mobility realities and the policy objectives for sustainable mobility. (2) There was no articulation of conflicting interests of the different kinds of testing (e.g., urban mobility vs. industrial policies). (3) The funding source of the test-field was the "Strategic Dialogue Automotive Industry BW" initiative led by the Baden-Württemberg State Ministry (FZI, 2021), something that indicates the orientation of the test-field toward the private car. As the Deputy Minister-President and Minister of the Interior, Digitalization and Migration stated at the opening of the test-field:

> *"Today, on the birthday of the automotive pioneer from Baden-Württemberg, Bertha Benz, we are launching the Test Area Autonomous Driving and bringing the mobility of the future in a real operation to our streets. We were pioneers in engine development, the core of an automobile. We want and will continue to be pioneers in the digital age. The automated automobile is the future of Baden-Württemberg" (KIT, 2018).*

Even though the test-field was supposed to test different kinds of mobility, the automobile remains at the core of the political aspirations. It rather functioned as a regulatory sandbox (Engels et al., 2019; Pel et al., 2020) to test various kinds of automated technologies and modes, yet without co-creation of new regulation that would connect automated driving to real-life mobility problems and generate public value. This is related to the fact that the main guiding principle was the digitalization of the automobile, instead of clearly defined principles and objectives on sustainability and public value.

Overall, the test-field was produced and shaped through the car-centric governance culture, and was set up mainly by economic actors from the State and the Region levels, the automotive and ICT industries and research institutes, while the urban level remains relatively passive. The main objective is the economic restructuring of the State-Region and reinforce its powerful position as an industrial hub by strengthening the automotive and ICT sector collaboration. That objective is tied to the development of widely scalable technological solutions. Meanwhile, sustainable urban mobility is deprioritized, as there is limited attention to testing automated driving to improve use cases at the urban level or help solving existing mobility issues. Implicitly, the assumption is that getting the technology right will resolve hindrances, and that the major obstacles for adoption of autonomous vehicles are related to vehicle-technology. Overall, the Karlsruhe test-field aimed to simulate road conditions realistically but remained detached from the urban everyday mobility realities. While the test-field is equipped for testing both individual passenger cars and collective transport, the political justification for it is centered on the reproduction of the entrenched car-centric governance culture of BW. The focus on developing different vehicle technologies, and the top-down funding came from the State Ministry and the automotive industry (i.e., Strategic Dialogue Automotive Industry). That test-field's scope neglected questions around regulation and governance, and did not seek to create, regulate or integrate new services into urban policies.

The "experimenting for the city" storyline: Reflecting a mobility governance culture

Despite failing, the application for the Stuttgart test-field triggered substantial discussions in the City Council regarding the need to consider, test and learn how automated driving can contribute to sustainable mobility in Stuttgart. Those debates highlight an alternative governance culture emerging in Stuttgart over the last decade, namely a mobility governance culture more tailored to city-regional mobility problems.

This mobility governance culture has been emerging since the municipal elections in 2012, when the green party assumed office. Ever since, there has been a gradual shift in priorities toward local mobility issues characterized by a strong dependency on local governance actors (Fricke, 2020). The mobility governance culture has been producing future visions of the "human-friendly city" with 2030 as a target year, including recovering space for active modes, intermodality, on-demand sharing services and sustainable logistics (Daude, 2019). It foregrounds a collective meaning of mobility; being mobile means, "being able to collectively move," not be limited to individual (auto)mobility. Practically, this encompasses not only the promotion of suitable passenger cars, such as electric cars, but also the production of vehicles for collective movement such as (automated) buses, shuttles, and mobility (shared) services (Mögele, 2022). As such, the daily use of public transport for commuting represents the dominant practical manifestation of being mobile in the mobility governance culture. Other practices

aim to restrict individual automobility through driving bans, the promotion of community buses in rural areas (Mögele and Rau, 2020).

Autonomous driving emerged in this debate concerning the application for hosting the test-field. Around that time (in 2016), the political scene was changing due to elections in Baden-Württemberg and a reform and task redistribution among the ministries. The incumbent Green/SPD coalition gave way to a Green/CDU coalition. At the state level, the responsibility over automated driving changed from the Ministry of Economics to the Green-party led Ministry of Transport (State Ministry of Baden-Württemberg, 2016). After the latter took over, the impacts of automated driving on urban mobility started being emphasized as well as the importance of protecting public transport (Interview 8, 2018). As the Minister of Transport stated: "*Automated vehicles should lead to more public transport, not less. Pedestrians and cyclists should feel safer and not get into the car more often for reasons of comfort*" (Ministry of Transport Baden-Württemberg, 2016).

This shift signaled the 100% funding of the MEGAFON study (Interview 8, 2018). This study, commissioned by the Ministry of Transport in BW, considered different scenarios to explore the synergies between automated driving and public transport to help ensure public transport would remain the main mobility provider in cities, instead of private providers (Friedrich and Hartl, 2016). The key conclusion of the study was that only automated ridesharing controlled by public transport would decrease traffic volumes, space occupancy and congestion in the city center, while rail public transport should be maintained and strengthened (Friedrich and Hartl, 2016). A laissez-faire scenario of prevailing technological development without regulation, replacing the privately-owned car was excluded from the beginning, as it was considered "*obviously negative*" (Friedrich and Hartl, 2016, p. 7).

After the MEGAFON study was presented in public hearings and conferences (in 2017), the City of Stuttgart included automated driving in its Local Transport Development Plan (NVEP), the first local policy document to do so. The NVEP made clear that automated driving should be implemented for on-demand mobility services, integral to public transport. This argument was backed up by key findings of the MEGAFON study: a shift from individual traffic to automated driving could increase traffic volumes up to 40% in Stuttgart. Since the urban road network cannot cope with this increase, public transport needs to be in control of automated driving (City of Stuttgart, 2018a, p. 12).

Accordingly, the NVEP provided a policy guideline regarding potential competition to public transport on-demand mobility offers. As stated by the Green Major during the final meeting of the City Council for approving the NVEP.

> *It is important to protect public transport investment as the backbone of urban transport and to further promote its acceptance. Demand-driven transport offers with automated vehicles from private companies are therefore to be interlinked in a suitable manner with public transport or a possible competition is to be counteracted by tariff specifications (City of Stuttgart, 2018b, p. 44).*

The NVEP was the first local policy document to signal that direction. The document mentioned that a level 3 on-demand mobility service with shuttles was already piloted and was meant to become a regular service operated by the public transport company of Stuttgart SSB in collaboration with moovel[3], Daimler's on-demand mobility service provider. This so-called "Flex Pilot" was tested by moovel as a temporarily cost-free service in Stuttgart for 6 months (December 2017–May 2018). The pilot allowed moovel to further develop on-demand algorithms for the platform and optimize the intermodal routing. This was a preparatory phase to test the technical part of the platform and its usability cost-free, before SSB took over the operation of the on-demand shuttle service, and integrated it as a public transport service. Two areas underserved by public transport and the city center's business area were served. Eventually, Flex Pilot proved to be a very attractive mobility option late at night when the buses, trains, and trams run less frequently; more than 20,000 passengers used the free service (Mercedes-Benz Group, 2018). Thus, moovel handed over the operation of the service to SSB in June 2018, and its name changed to SSB-flex, which then became a fully operational mobility service.

SSB-flex went through a second pilot phase until August 2019, before becoming a regular service. It launched as a pilot service with minibuses combining routes and bundling passengers' travel requests, aiming to learn to solve the "last mile" problem in areas underserved by public transport, increase the overall use of public transport, and eventually further develop the outskirts of Stuttgart. The local policymakers celebrated the SSB-flex pilot as an automated on-demand services precursor. They expected that as soon as automated shuttles became widely available, similar mobility services would experience a significant boost due to reduced operational costs (i.e., no need for drivers). The argument was that since the technology is not ready yet, the idea would be to test an on-demand service to gather data and information about how the service works in the city, if it covers the needs of citizens, and if it is economically viable. As such, it was framed as an add-on to public transport. As an interviewee from the Mobility Department of the City of Stuttgart explained:

> *I believe that SSB-flex is kind of, let's say, pre-testing. This can be, let's say, preparation for using automated cars in public transport later to try to find out about the market chances… There may be some fields where you can actually use this reasonably… For example, the last mile… this may*

3 Now moovel became REACH NOW due to the merging of mobility services between Daimler and BMW.

> *be a solution for the last mile; if you have the S-bahn[4] line and you need to have a transport offer for the last four-five kilometers (Interview 4, 2019, p. 2).*

During both pilot phases, the permission for testing the on-demand mobility service was given through the experimental clause of the German Passenger Transport Law (Personenbeförderungsgesetz—PBefG). This experimental permission normally lasts for a maximum of 5 years. Thus, a more permanent regulatory solution was needed for SSB Flex to become regular service (Interview 4, 2019). However, the Passenger Transport Law only recognizes two types of transport services; occasional services (rental car) and regular services (bus/rail transport); on-demand mobility services are neither, as it uses virtual stops. Therefore, SSB lobbied at the national level to include its on-demand mobility service under the Passenger Transportation Law, to allow control by public transport providers and secure its value for sustainability and urban mobility. The Regional Council of Stuttgart (Regierungspräsidium) granted approval based on the Passenger Transport Regulations, which normally concerns scheduled bus services. Thus, SSB Flex became the first on-demand regular service in Germany. The pilots were co-producing regulation together with technology.

Since 2019, SSB Flex is available in the entire city and during the night as a regular mobility service. SSB is responsible for the data center, ticketing and drivers; moovel manages the digital platform and user app interface. The fleet, supplied by Mercedes-Benz vehicles, is partially electrified. For moovel, working with SSB provided experience on how a mobility service works in a city, and what kind of policy and regulatory framework would be suitable for a future use case. The SSB used the learnings gathered through the two pilot phases to develop a high-value service for the city that corresponds to real needs and can actually induce urban transformation. SSB have claimed that these experiences have allowed them to learn across a multitude of aspects, such as legal, strategy, operations, planning, and the political aspects. Moreover, their collaboration with moovel prepared them for dealing with expected changes in technology, training and preparation of public transport toward on-demand automated mobility services (Barrett et al., 2019).

Overall, it was when the mobility governance culture gained traction that urban experimentation of automated driving was framed around city and sustainable mobility needs. The urban experiments co-produced through the mobility governance culture show a distinct and predominant involvement of the local actors, namely the City, SSB in collaboration with the automotive industry (i.e., moovel/Daimler). Most importantly, the local actors phrased SSB-flex as the precursor of automated driving without rushing into experimenting with automated driving in city traffic; instead, they adopted an incremental strategy of different testing phases of an on-demand service that corresponds to pressing mobility needs of citizens, with a broad learning agenda. In turn, the City sought to ensure that on-demand mobility services stay within the spectrum of public transport, and produced—along with the technical specifications—novel regulations and practices.

4 S-bahn refers to the urban-suburban rail systems serving metropolitan regions in Germany.

Discussion

There is consensus that urban experimentation can be configured in different ways, and often does not manage to induce urban transformation and ensure public value. We highlighted four related challenges: the project-logic, the technology-centricity, the assumption of scalability, and the expectation of finding one-size-fits-all technological solutions. Too often, the context in which experimentation is being shaped, and the decisions specify it are neglected (Voß and Schroth, 2018; Savini and Bertolini, 2019). Here, we reflect on the key learnings from our analysis and consider its potential and challenges.

First, how urban experiments can provide fertile ground for the mutual co-shaping of technology and governance. Both storylines showed that urban experimentation is deeply embedded in governance cultures and practices and can serve to reproduce it. The test-field was targeted primarily at vehicle technologies, facilitating the industry to accelerate its development, without creating new regulation for the implementation of automated driving in real-life conditions. The two pilot phases in Stuttgart, in turn, focused on responding directly to the city's needs and creating a viable complement to public transport. Furthermore, the on-demand mobility pilots in Stuttgart were part of a wider alternative parallel discussion about safeguarding the city from unintended consequences and ensuring public transport as the implementation field of automated driving. In this case, not only urban experimentation was produced through a set of governance practices, namely change of responsibility between ministries, funding of a study supporting public transport, and the inclusion of automated driving as a public transport service in the local transport plan, but also produced new regulation to convert the experiment into a regular and permanent urban mobility service. Thus, automated driving was produced within, but it also reconfigured an alternative mobility governance culture. This study also contributes to the governance of automated driving showing how experimentation of automated driving can happen due to a variety of policy objectives (e.g., economic restructuring), and not necessarily for directly implementing the technology *per se*. Our findings are in line with existing STS literature on the co-production of technology and governance in innovation processes and urban experiments (Pfotenhauer and Jasanoff, 2017; Marres and Stark, 2020). They further contribute to this

literature by showing how storylines can be used to interrogate the multi-level governance structures of co-production—which is missing from STS studies on urban experimentation. This forms the basis for an analysis encompassing both macro and micro argumentative interactions and practices, instead of dealing with either separately.

Second, how co-production of urban experiments and governance is characterized by multiplicity and heterogeneity. By tracing how specific framings and objectives are enacted, mobilized, and contested in multi-level and multi-actor governance, it becomes clear that urban experimentation is not deterministically framed by one single governance culture or a singular trajectory led by a single governance level. Instead, in line with Hodson et al. (2017), urban experiments are co-produced through a performative interplay between different governance levels, actors, arguments, practices, and different socio-technical systems (i.e., automotive, ICT, public transport). In particular, looking at the multi-level governance of the City-Region-State nexus through the concept of storylines reveals, as Engels et al. (2019) would put it, the parallel co-productionist relationships between the car governance culture and the mobility governance culture in shaping distinct urban experiments. In the test-field in Karlsruhe, there were tests on public transport, and discussions at the City Council on how to experiment for the city, while in the Flex-pilot and SSB-flex cases, there was collaboration between the automotive industry (moovel) and public transport. Therefore, the multi-level governance perspective underscores how the transformative potential of urban experimentation emerges through contestation, conflict, and performativity. In turn, it challenges the assumption that top-down approaches with prescribed guidelines lead to a single trajectory of urban experimentation (Hodson and Marvin, 2010). It also moves beyond long-lasting dichotomies, such as individual automobility vs. public transport and is sensitive to the ambivalence, complexity, and uncertainty of reality. This adds a contribution to the literature of how learning is captured and metabolized in urban experimentation (see Evans et al., 2016, 2021; Torrens et al., 2018), in the sense that urban experimentation can provide fertile ground for aggregated and aligned learning from multiple governance levels, thus becoming an innovation tool for fostering urban transformation.

Third, how urban experimentation comes to be configured is context-dependent. Our findings show that urban experimentation may lead to policy change and urban mobility innovation when it addresses a locally oriented vision and well-articulated needs. Grounding experimentation on a clear local agenda, and structuring experimentation to meet specific goals that are pertinent to the concerned stakeholders and users is essential. As a platform for multiple types of experiments, the test-field was meant to be implemented on a large scale, but remained detached from local realities and reinforced an individualistic and car-centric view of what autonomous vehicles are for. This is in line with previous work on scalability in test beds and how it is in tension with local innovation (see Pfotenhauer and Jasanoff, 2017; Engels et al., 2019; Pfotenhauer et al., 2021). Meanwhile, the on-demand mobility pilots in Stuttgart took place after a clear set of objectives were defined for the pilots through local deliberation and policies. The local public sector was in charge of staging the urban experimentation process, and concerned with producing public value, which highlights the importance of place-based concerns as the reference point of experimentation (Torrens et al., 2018; Evans et al., 2021). This insight also links to the debate on how projectified governance and top-down funding constrain the objectives of experimentation in terms of public value (Torrens and von Wirth, 2021). While the first proposal for a Stuttgart test-field was structured as a project dependent on state funding, and primarily aligned with economic/industrial objectives, the on-demand mobility pilots were grounded in the local accessibility and last mile problems and were not dependent on projectified funding, but on horizontal and incremental collaboration between public transport and the industry (moovel). This calls for future studies to investigate, map and conceptualize the processes through which experimentation can be shaped by other rationales, independently of scalability aspirations and projectified funding, e.g., through bottom-up forms of collaboration.

Fourth, complementing different kinds of experimentation to test both technological and social innovation is crucial. Storylines allowed for comparing different kinds of experimentation; a test-field that supported different kinds of experiments and an actual experiment in the city. While a test-field narrowly defines the parameters of what needs to be tested (in our case vehicle technologies under different road circumstances), it is still necessary for the early stages of technological development. Yet, assuming that testing technology in a test-field by itself can provide all solutions and lead to directly replicable experiences everywhere can limit the urban transformative outreach. In contrast, the on-demand mobility pilots in Stuttgart focused on testing and improving the social. In doing so, the mobility pilots attached a different meaning and purpose to innovation, centering it on developing a comprehensive response to tackle a social-oriented purpose (i.e., accessibility, last mile). This in turn led to adapting existing regulations and contributed to wider urban transformations. Testing both the technical and the social is thus crucial but often not thought-through in policies—which privilege the former and neglect the latter. Therefore, the idea that different forms of experimentation can and should co-exist, which is line with the notion of multiplicity advanced by Hodson et al. (2017), needs to be embraced by policymakers. Future research needs to be more discerning when addressing the aims of (public-led) innovations, whether urban experiments

achieve urban transformations, and what notions of public value are foregrounded.

Conclusion

In this paper, we set out to understand "*how urban experiments are shaped by governance cultures (and vice versa) and what are the implications for urban transformation?*" Using storylines, we sought to capture the influence of governance cultures, and provided a comprehensive, co-productive and culturally-sensitive account of the link between urban experimentation and governance cultures. Focusing on the multi-level governance of urban experimentation of automated driving in the nexus City-Region-State, we were able to contrast two key storylines and related governance cultures, concerning "experimenting for technology" and "experimenting for the city." The former is co-produced by a car governance culture and the latter by an emerging mobility governance culture that responds to (private) automobility's persistent problems.

We conclude that researchers and practitioners need to critically examine the storylines through which different kinds of experimentation come to be justified and legitimated, to advance urban experimentation as a means toward sustainability. We showed that storylines provide a powerful analytical tool for unpacking the interplay of the politically charged processes, cultures and materialities that shape experimentation. Future research would do well to embrace radical incrementalism and performativity, investigating how integrating urban experiments into concurrent governance dynamics and cultural contestations enables urban transformation. For this, comparative empirical studies are necessary, within and across governance nexuses, that capture contrasting and complementary paths for experimentation.

Our results also show that experimentation aligned with very specific policy objectives, supported by appropriate regulatory frameworks, and targeting concrete societal challenges can mobilize actors quickly and efficiently. Local governments can play a crucial role, both articulating these challenges and working across governance levels to set the scene for experimentation. This sits in contrast with efforts to set up test-beds offering generic experimentation support, which are informed by traditional rationales (e.g., competitiveness and economic restructuring). These test-beds' contributions are not as self-evident: they foster technological capabilities detached from sustainability objectives or urban transformations, which may counter other local efforts to foster sustainable mobilities. Hence, our recommendation is for policy actors and proponents of experimentation to prioritize the former, tying experimentation with societal outcomes from the onset, and building bespoke support and regulatory structures to match and accelerate urban transformations—in sustainability directions.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

ES conducted the field work, data curation, analysis, wrote the literature review, and contributed to the conceptualization of the paper. MM conceived the idea of the paper and contributed to the analysis and literature review. JT helped to ground the work on the debate between urban experimentation and urban transformation and to streamline the argument. All authors were involved in editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2022.956853/full#supplementary-material

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