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On different lanes: A cross-case analysis of urban experimentation for autonomous driving☆

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ABSTRACT

Autonomous vehicles (AVs) are considered a promising element in the sustainable transformation of urban mobility systems. Yet, their potential impact and benefit is highly dependent on how they are integrated into existing infrastructures. This paper explores urban experimentation shaping the development and governance of AVs by analyzing two empirical cases in Germany: Hamburg and Karlsruhe. We highlight the role and interplay of visions and expectations in guiding experimentation and governance processes of socio-technical transitions. Based on expert interviews, (urban) mobility strategies, and project insights, we examine how stakeholder expectations and overarching visions mutually influence experimental designs, outcomes, and learning processes. The comparative analysis uncovers two distinct approaches: In Hamburg, experimentation is embedded in a strong vision-related configuration anchored in its Digital Mobility Strategy, aiming for long-term scalability and predefined public-transport goals; Karlsruhe adopts a more expectation-centered approach focused on research-driven and incremental socio-technological advances conceived more generally. By examining how such different future orientations are linked in each case and how they shape experimentation, the paper extends existing perspectives on governing transition pathways. We emphasize the role of temporal dynamics of future orientations as they are enacted, adjusted, and stabilized through experimental practices, alongside institutional arrangements and policy instruments.

1. Introduction

Autonomous vehicles (AVs) have the potential to have a major impact on the future design of mobility systems. In urban areas, in particular, expectations range from more sustainable, accessible and efficient public transport services to concerns that automation may further reinforce car dependence, land consumption and urban sprawl (Kolarova et al., 2019; Legêne et al., 2020; Lyons, 2022). Whether AVs contribute to more sustainable mobility pathways or exacerbate existing problems depends less on technological capabilities alone than on how they are governed, integrated and embedded into existing infrastructures and mobility systems. Given the strong path dependencies of urban transport systems, such as the paradigm of the car-friendly city illustrated, early choices and institutional arrangements can have long-lasting effects on future development trajectories (Schippl et al., 2022).

As transition research has repeatedly shown, innovation trajectories are shaped by a co-evolutionary interplay of technical and non-technical factors. In this context, experimentation has become a central governance strategy for dealing with uncertainty around autonomous mobility. Across many cities, AVs are being tested through pilot projects, living labs, test fields or demonstrators, which are often framed as opportunities for learning under real-world conditions (Dowling and McGuirk, 2022; Engels et al., 2019; Evans et al., 2021; Savini and Bertolini, 2019; Stilgoe and O'Donovan, 2023). Among the countries actively shaping the future of mobility through policy, for instance, Germany has taken significant steps in recent years to establish the legal foundations necessary for a breakthrough in autonomous vehicle deployment (BMDV-Bundesministerium für Digitales und Verkehr, 2021; BMDV-Bundesministerium für Digitales und Verkehr, 2024). These regulatory advances aim to establish a framework that enables

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experimentation and scaling of innovations. Importantly, such experiments do not only test technologies. They also embed and communicate assumptions about desirable futures, acceptable risks and plausible development pathways for urban mobility. These assumptions are articulated through expectations regarding feasibility, performance and societal benefits, and are often linked to broader visions of socio-technical change, such as climate neutrality, shared mobility or digital innovation (Haugland and Skjølsvold, 2020).

Despite a growing body of literature on urban experimentation and autonomous mobility, research has paid limited attention to how experiments are influenced by or even governed through future orientations and their dynamics (e.g., Haugland, 2023). While studies frequently refer to visions or expectations, these concepts are often used interchangeably or treated as loosely defined background conditions. In addition, there is limited research on how experiments are embedded in or disconnected from long-term transition pathways, neglecting overarching discourses and intertwining with local governance. As a result, we know comparatively little about how different configurations of visions and expectations shape the design and integration of experiments – and how experimental outcomes, in turn, feed back into future orientations, governance practices and potentially relate to societal benefits (Marres, 2024; McAslan et al., 2021; Servou et al., 2022; Stilgoe and O'Donovan, 2023). Moreover, empirical case reporting on experiments in the context of AV remains scarce compared to the numerous projects, and existing publications are only weakly linked to transition literature (Fraske et al., 2025).

In this paper, we argue that (1) analytically distinguishing visions and expectations, while explicitly emphasizing their interdependence, offers an important lens for understanding the governance of experimentation. We conceptualize visions as relatively stable, collective and normative future orientations that provide directionality, legitimacy and alignment, while expectations function as more provisional, revisable assumptions about feasibility, learning and coordination under uncertainty. This allows us to show (2) how different configurations of these orientations shape experimentation. Crucially, visions and expectations are interrelated. We highlight that (3) experimentation is shaped by existing visions and expectations, while experimental outcomes primarily recalibrate expectations and only indirectly stabilize or challenge visions.

Against this background, the paper addresses the following research question:

How do visions and expectations shape the governance of experimentation for autonomous driving, and how do experimental practices feed back into these future orientations?

Empirically, we explore this question through a comparative case study of urban experimentation with autonomous driving in the two German cities of Hamburg and Karlsruhe. Both cities are actively engaged in testing AVs, yet they differ markedly in how experimentation is framed, embedded and governed. Against this backdrop, the next section outlines the theoretical background, drawing on transition research, scholarship on visions and expectations, and urban experimentation studies. We then introduce the two case studies and describe our methodological approach based on expert interviews and strategy documents. The analysis examines how experimentation with autonomous driving is shaped by different future orientations, focusing on starting points, actors, experimental designs and learning processes. The paper concludes by discussing the implications of these findings for the governance of (urban) mobility innovation.

2. Theoretical background

Our theoretical approach draws on transition studies to analyze the governance of experimentation with autonomous driving. First, we situate our work within the literature on governing socio-technical transitions, which highlights the long-term, systemic dynamics through which innovations interact with institutions and actor constellations (Section 2.1). Second, we build on literature on visions and expectations as future orientations that coordinate action under uncertainty (Section 2.2). Third, we engage with research on experimentation, emphasizing its role as a place-based and iterative governance practice (Section 2.3).

2.1. Governing socio-technical transitions: A brief contextual overview

The introduction of autonomous vehicles entails changes in both technical systems (e.g., infrastructure, operation centers) and social systems (e.g., regulation, public perceptions), and must be aligned with existing or emerging mobility patterns and service models. As such, autonomous driving can be understood as part of a socio-technical transition, involving long-term changes in technologies, institutions and actor constellations (Fraedrich et al., 2015; Geels, 2002; Köhler et al., 2019). These transitions unfold neither linearly nor purely technological, but emerge through dynamic interactions between actors, power relations and contextual conditions (Geels, 2020).

Within this literature, experimentation is widely recognized as a key governance mechanism for navigating uncertainty in transition processes. As transitions are "complex and unstructured processes of change" and "therefore require technological, organizational, place-explicit, and governance experimentations" (Loorbach et al., 2017, p. 614), experiments play a central role in exploring alternative configurations under real-world conditions (Ceschin, 2014; Sengers et al., 2019). They involve collective processes of searching and learning among diverse stakeholders that enable iterative adjustments to strategies, policies and technological designs (Hoogma et al., 2002; Van den Bosch, 2010; von Wirth et al., 2018) and can mobilize support and legitimacy for change (Brown et al., 2003; Voß et al., 2009). In this sense, experiments are "[not merely] a space for testing and demonstrating technological solutions, but also […] a vital component in a socio-technical system" (Fraske et al., 2025, p. 2), with the potential to challenge lock-in and path dependencies and to stimulate transitions towards specific societal goals (Van den Bosch and Rotmans, 2008; Van Poeck et al., 2020).

2.2. Visions and expectations as constitutive elements of transition processes

As complex and unstructured processes involving multiple actors and institutional layers, transitions are fundamentally shaped by how actors orient themselves towards the future. Transition scholars have emphasized that visions and expectations play a crucial role in providing such orientation, guiding strategic choices, structuring actor coalitions and coordinating action under uncertainty (Borup et al., 2006; Grin et al., 2010; Hajer and Pelzer, 2018; van Lente, 1993). While visions and expectations are closely related and often used interchangeably in the literature (Eames et al., 2006; Schot and Geels, 2008; Julsrud and Aasen, 2024; Sovacool et al., 2019; van Oers et al., 2020), we argue that analytically distinguishing them, while explicitly acknowledging their interdependence, enhances our understanding of experimentation and transition processes.

Instead of representing fundamentally distinct types, visions and expectations constitute different configurations of future orientations that operate at different levels and with different effects, "highlight[ing] different dimensions of how we relate to the future" (Rohracher and Konrad, 2024, p. 2). Within the transition literature, visions are widely regarded as a key device for enabling and steering socio-technical change. They are understood as collectively shared, normative orientations that articulate desirable futures and contribute to the directionality of transition processes (Grin et al., 2010; Kok et al., 2022). By providing such reference frames for future orientation, visions can empower actors and networks to strategically explore alternative development pathways, legitimize change and formulate shared goals and agendas (Kemp et al., 1998; Loorbach et al., 2017; Pel et al., 2020;

Purchase et al., 2024).

Rather than specifying concrete steps or assessing feasibility, visions are relatively stable and operate predominantly at collective levels, such as cities or broader societal contexts. They align heterogeneous actors, mobilize resources and provide continuity over time by bundling diverse interests, knowledge and values into coherent narrative orientations (Sovacool et al., 2019; Wiek and Iwaniec, 2014). In this way, visions may keep implementation open while still stabilizing directionality over time, supporting the emergence of particular pathways through legitimacy and coherence rather than detailed prescriptions (Berkhout, 2006).

From the perspective of the sociology of expectations, visions can be understood as a particular configuration of expectations that operate at different levels of the same future-oriented process, with visions representing a more collective, normative and stabilized form (Truffer et al., 2008; van Lente, 2012). Expectations themselves circulate among actors as present-oriented anticipations of future developments and play a central role in guiding action under conditions of uncertainty (Borup et al., 2006; Konrad et al., 2016). As future-oriented statements, expectations provide provisional and revisable assumptions about feasibility, performance and potential benefits of emerging technologies. Rather than establishing fixed narratives or promises, they support coordination and motivation by enabling collaboration among actors with different interests while remaining open to adjustment as new knowledge is generated (van Lente and Rip, 1998). In this sense, expectations are inherently dynamic and typically oriented towards short- to medium-term horizons (Truffer et al., 2008). Only when expectations become narratively bundled, normatively charged and temporally extended do they take the form of visions that provide longer-term directionality and collective orientation (van Lente, 1993).

2.3. Experimentation: Between local trials and scalable pathways

Building on this understanding of visions and expectations as future-oriented elements, experimentation can be approached as a key site in which these orientations are materially enacted and negotiated in practice. In transition research, experiments respond to the need for "technological, organizational, place-explicit, and governance experimentations" (Loorbach et al., 2017, p. 614) under conditions of uncertainty and have therefore become a central governance strategy (Ceschin, 2014).

Several attempts have been made to differentiate experimental approaches, for instance by distinguishing them based on actors, focus and the areas they aim to improve such as market positioning or transformations towards shared mobility (Dowling and McGuirk, 2022; Sengers et al., 2019). Transformation-oriented experimentation or roll-outs are often closely tied to the idea of scaling, as they seek to move beyond isolated trials and embed experimental practices into broader systems. In transition studies, such scaling processes are typically seen as potentially crucial pathways through which niche innovations can contribute to regime change (Engels et al., 2019). Yet, a singular focus on scaling risks neglecting the specific political, institutional and spatial contexts in which experimentation takes place.

In urban settings in particular, experiments are embedded in local governance arrangements and serve as place-based practices through which strategic ambitions and future orientations are translated into real-world interventions (Bulkeley et al., 2016; Evans, 2016; Evans et al., 2021; Servou et al., 2022). As such, experiments can function as governance mechanisms that connect broader visions and agendas with situated forms of implementation and learning (Fraske et al., 2025). Through experimentation, actors gain empirical insights into the feasibility, performance and societal implications of emerging technologies. The diversity of experimental settings points to the fact that experimentation is not a uniform practice but is organized around different assumptions about purpose, temporality, and desirable outcomes. These assumptions are closely tied to how visions and expectations of socio-technical change are articulated and enacted in practice. Against this background, experiments constitute arenas in which future orientations are articulated, contested and aligned, thereby influencing the directionality of transitions and potentially stabilizing or challenging existing socio-technical configurations.

Crucially, experimental outcomes primarily feed back into expectations by confirming, revising or challenging assumptions, while overarching visions are typically affected more indirectly and over longer time horizons. In this sense, experimentation constitutes a key site of learning and adjustment through which future orientations are negotiated and transition pathways are shaped over time (Ryghaug et al., 2022; Schot and Geels, 2008). Taken together, this highlights that the relationship between visions, expectations and experimentation is hierarchically related but variably coupled in practice, shaping how future orientations are stabilized or revised over time. For example, experiments can also serve as sites of prospective market shaping, as future-oriented discourses around possible services and markets help align ecosystem actors, value propositions, and investment priorities under uncertainty (Purchase et al., 2024). Similarly, work on visioning in network strategizing highlights how higher-order orientations are repeatedly developed, mobilized and revised through cycles of visioning, networking and reflecting (Abrahamsen et al., 2023), processes that experimentation can both support and destabilize. This conceptualization provides a useful lens for analyzing experimentation with autonomous driving, where high levels of uncertainty, strong future imaginaries and place-specific governance arrangements intersect. Autonomous vehicle experiments thus offer a particularly revealing empirical context to examine how visions and expectations are enacted through experimentation and how such practices shape emerging transition pathways in urban mobility systems.

3. Context and methodological approach

Our empirical investigation combines contextual analysis with qualitative methods to examine how visions and expectations are enacted, negotiated and revised through experimentation with autonomous driving in Germany. We focus on two regional case studies – Hamburg and Karlsruhe – that exemplify contrasting strategies and governance approaches in the implementation of autonomous driving. This contextualization allows us to trace how future orientations shape experimentation processes and mobility strategies in specific urban settings (Section 3.1). We then outline our qualitative methodological design based on expert interviews and document analysis, detailing data collection, coding and interpretation procedures (Section 3.2).

3.1. Towards autonomous driving in Germany: The cases of Hamburg and Karlsruhe

Germany has set itself the goal of becoming a global leader in autonomous driving technology and regulation in 2021. An important tool for the implementation are the so-called test fields, which started in 2015 with testing of automated driving in a protected space, and expanded through the 2021 amendment for tests of level 4 automated driving on public streets (BMDV-Bundesministerium für Digitales und Verkehr, 2021). The test fields on public roads are an essential part of the national strategy to promote research and innovation (BMDV-Bundesministerium für Digitales und Verkehr, 2024). As a result of the test fields and the act amendment for level 4, several cities and regions in Germany have started projects to test autonomous driving under real-world conditions.

Against this background, our study adopts a qualitative research design, where we focus on two of such regions in Germany as case studies that are implementing autonomous driving in different contexts. Such contexts are shaped by regional characteristics and the diverse priorities and programs related to automated driving. The selection of two technologically advanced regions allows for an analysis of

contrasting development approaches in the field of autonomous driving and illustrates different governance and experimental settings (Table 1). One of the case studies is Hamburg, a city in the northern part of Germany with around 2 million inhabitants, making it the second largest city in Germany (FHH-Freie und Hansestadt Hamburg, 2024a). As a city-state (one of Germany's 16 federal states), Hamburg combines municipal and state-level responsibilities. The other case study region is Karlsruhe, which is the third largest city in the federal state of Baden-Württemberg in South-West Germany with around 310,000 inhabitants (Stadt Karlsruhe, 2024).

Hamburg. The mobility strategy, which was adopted in 2016, is an important strategic pillar for Hamburg and contains a large number of measures that should help to achieve the mobility goals, in particular the climate goals (FHH-Freie und Hansestadt Hamburg, 2016, p. 4). In the same year, a strategy for intelligent transportation systems and services was introduced, with autonomous driving being briefly mentioned. This also formed part of the lead-up to hosting the ITS World Congress (Intelligent Transport Systems) in 2021, where prototypes of autonomous vehicles were showcased to an international audience. Therefore, between 2016 and 2021, several projects for innovative mobility solutions were implemented. The 2016 strategy was updated in 2022 to the Digital Mobility Strategy, which aims to address the opportunities presented by digitalization and automation to a greater extent. The strategy represents a central basis for the implementation of the mobility transition, which in turn represents a separate strategy (FHH-Freie und Hansestadt Hamburg, 2024b, p. 8). Other strategies such as the Hamburg Takt, which aims to ensure that by 2030, every Hamburg resident can access a public mobility option within five minutes, were also incorporated (FHH-Freie und Hansestadt Hamburg, 2024b, p. 2). The Digital Mobility Strategy links expanding public transport, promoting cycling and walking as well as the digitization and electrification of transport with key urban development issues, e.g. in the city center and along the main roads (FHH-Freie und Hansestadt Hamburg, 2024b, p. 8). This development is actively promoted by the city and by political actions—a popular statement which is attributed to the head of the transport company Hochbahn based on an agreement between the Federal Ministry of Transport and Hamburg emphasizes the aim of reaching 'up to 10,000 autonomous vehicles by 2030' (BMDV-Bundesministerium für Digitales und Verkehr, 2022). The governance is strongly driven by sustainability visions such as fewer private cars and increased shared mobility. It promotes advanced technologies to become a model region for innovative mobility. The establishment of a new state-owned company for digital mobility transition in 2022, New Mobility Solutions Hamburg, is part of the strategic portfolio management (Hamburger Hochbahn AG, 2022). Technology partners such as Moia, specializing in ridepooling, and Holon, a vehicle manufacturer aiming to reimagine mobility, diversify the innovation landscape in Hamburg (Benteler International AG, 2023).

Table 1
Overview and comparison of the case regions.

	Hamburg	Karlsruhe
Starting point for AV engagement	2016: Strategy for the ITS World Congress, climate plan	2016: Proposal for the test field autonomous driving Baden-Württemberg under the leadership of Karlsruhe
Central actors and consortia	Formal integration (project and use case based) Combining local and state authorities Strong integration of industrial partners	Platform integration (centered on the test field) Almost exclusively local and regional actors as part of the test field (KVV, FZI, KIT, HKA, Fraunhofer)
Milestones	2018: Start of the test field automated and connected driving 2019: MOIA service starts 2022: Founding of New Mobility Solutions 2025: Autonomous ridepooling in the inner city	2018: Opening of the test field 2021: Final build-up of the test field infrastructure
Guiding principles	'Up to 10,000 autonomous vehicles by 2030' Becoming leading model region in Germany	Enabling a regional test and innovation environment for AVs; research-driven, with a focus on technical maturity
Experiments	7+ shuttle pilots on different scales since 2019 Public-private partnerships Focus on scaling in different phases	Two shuttle pilots in 2020 and 2023 Primarily tech-focused (private) tests
Implications for future mobility	Focus on shared mobility and ridepooling to improve (sustainable) mobility Fulfillment of Hamburg Takt	'Market creation' for AV solutions Public transport as one cornerstone

Karlsruhe. With universities such as the Karlsruhe Institute of Technology (KIT), several research institutes and companies, Karlsruhe is a center of technology and innovation. Karlsruhe has been known in Germany for a comprehensive region-wide approach fostering public transport and cycling structures and the so-called "Karlsruhe model", which is connecting smaller towns and villages in the rural hinterland with the city center (Zimmermann, 2018). Since 2021, Karlsruhe has also operated an underground metro system. More broadly, its public transport network encompasses more than a dozen tram lines (KVV-Karlsruher Verkehrsverbund, 2023). The high use of sharing offers, e.g. car and bicycle, is another notable aspect. In Karlsruhe, the topic of autonomous driving can be dated back to the proposal of the test field in 2016, which ultimately started in 2018. With this, Karlsruhe has a stronger focus on technology testing and emphasizes the test field for novelty creation in general with conducting some cases testing technical components of autonomous vehicles and two projects for a real-world demonstration of autonomous shuttles provided by the FZI Research Center for Information Technology (TAF-BW, 2021). Besides players such as the FZI and Fraunhofer IOSB for Optronics, System Technologies and Image Exploitation, KIT is also involved in the test field, contributing autonomous driving research projects that have so far focused primarily on feasibility and accompanying studies. Another participating university is Karlsruhe University of Applied Sciences (HKA). The operator of the test field is the Karlsruhe Transport Authority (KVV) who primarily acts as a consultant for usage and booking options for the test field. The test field is supported by the federal state of Baden-Württemberg. In addition, the network Technology Region Karlsruhe (TRK) brings together stakeholders from cities, districts, a regional association, several companies and scientific institutions in the region around the city of Karlsruhe, with mobility being a core area (TRK, 2025). In this context, Karlsruhe primarily collaborates with local stakeholders through the test field.

3.2. Data collection

Between May 2024 and November 2024 qualitative semi-structured interviews with 13 experts were conducted in both cities to investigate guiding objectives in the design and implementation of mobility experiments for autonomous driving. The interviewees were directly involved in autonomous driving projects and planning, representing a range of institutional contexts, including government (state and city), technology firms, research institutions, and transport operators. The interview partners were selected based on criteria related to the organization, plans, and projects they are or were involved in, ensuring a broad spectrum of perspectives was covered (Table 2).

The expert interviews focused on strategy development for the (urban) mobility system and the role of autonomous driving within it, with particular interest to how these strategic goals are realized in practice in both cities and how they influence approaches for urban mobility in the long term. Therefore, central topics were the organizational role in the mobility sector, strategy development, projects and experiments, relevant stakeholders, gained insights and learning

Table 2
List of interviews used for analysis.

#	Context	Role	Competencies
1	Hamburg Local	Ministry Public	Transport planning and traffic development, strategy for city's mobility goals
2	Hamburg Local	Business developer Public-private	Project management, funding, digital mobility, public transport
3	Hamburg Local	Transportation company Public	Project management, autonomous driving, intelligent transport systems
4	Hamburg Local	Transportation company Public	Stakeholder management, strategic planning, mobility policy
5	Local-related to Hamburg	Mobility platform provider Private	Mobility consulting, partnerships with cities and public transport companies
6	Hamburg Local	Vehicle manufacturer Private	Product management and development, user experience
7	Hamburg Local	Business developer Public-private	Project management, interface between strategy and implementation of innovative mobility solutions
8	Karlsruhe Local	Association of transport networks Public	Project management, transport planning and development of the local public transport
9	Local-related to Karlsruhe	Ministry Public	Transport planning, automated and connected driving, cooperative traffic systems, vehicle technology, vehicle registration and vehicle safety, strategy for the federal state of Baden-Württemberg
10	Karlsruhe Local	Research center and vehicle manufacturer Private	Project management, procurement, commissioning and approvals of shuttles
11	Local-related to Karlsruhe	Software provider for traffic simulations Private	Product management, traffic simulation including testing, planning and optimization, including automated driving functions
12	Karlsruhe Local	Research Institution Public	Research automatization and vehicles systems engineering
13	Karlsruhe Local	Research Institution Public	Research transportation studies, accompanying research of various projects in Germany including both Hamburg and Karlsruhe

processes.

The interviews were audio-recorded, transcribed and analyzed following the principles of qualitative content analysis, using MAXQDA for coding (Mayring, 2014). The coding scheme combined deductive and inductive elements. Core categories were informed by the theoretical distinction between visions and expectations and by concepts from the literature on socio-technical experimentation, which served as sensitizing concepts. These deductive categories were complemented by inductively developed sub-codes that captured context-specific interpretations, uncertainties and governance dynamics emerging from the empirical material. By combining actor-related (e.g., "referring to political actors") and thematic codes (e.g., "institutional motivation to engage with the topic," "strategic relevance," "goal of experiment"), we were able to trace how visions and expectations are articulated differently across institutional positions and how these differences shape experimentation practices within each city. The interviews were conducted by individual members of the research team, both face-to-face and digitally, in each of the two cities. They lasted an average of 54 min, with the shortest interview being 37 min and the longest being approximately 74 min.

Alongside the interviews, strategy documents were used for the analysis. For the case of Hamburg, this includes the Digital Mobility Strategy (FHH-Freie und Hansestadt Hamburg, 2024b), feasibility studies for accelerating innovations on autonomous mobility (Metropolregion Hamburg, 2022), and the ITS strategy (FHH-Freie und Hansestadt Hamburg, 2016). With regard to Karlsruhe, this primarily entails the strategy for automated and connected mobility (Ministry of Transport Baden-Württemberg, 2020). This complemented the interview data by overarching perspectives that reveal long-term development directions and institutional priorities of existing efforts to introduce autonomous mobility. Moreover, they illustrate how various stakeholders—from public administration to industry and research—coordinate their goals, and more importantly, how they communicate these to the public.

In addition, members of the research team have been involved in accompanying research on autonomous mobility projects, particularly in Karlsruhe. This involvement provided contextual insights into real-world implementation processes and governance dynamics. To mitigate potential bias, these insights were used as background knowledge to inform interpretation rather than as primary empirical material. Taken together, the combination of expert interviews, document analysis, and contextual background information enables a comparative analysis of how visions and expectations are mobilized in the governance of autonomous driving experiments in Hamburg and Karlsruhe.

4. Results

In the following, we provide an overview of the case study results, structured around three overarching aspects for each respective case: (1) visions and expectations, anchoring in long-term urban agendas, and ties to respective local challenges, (2) the experimentation for autonomous driving, which illustrates how the urban experiments to date have been designed and implemented, and (3) the interplay between visions, expectations and urban experimentation.

4.1. Hamburg

4.1.1. Future orientations and strategic anchoring

Hamburg operates on a ***collective, city-wide level*** of future orientation, which is reflected in the Digital Mobility Strategy as one of the strategic anchors and the statement to deploy up to 10,000 autonomous shuttles by 2030. Before the Digital Mobility Strategy was formulated and eventually published in 2022, initial concepts for the preparation of the ITS World Congress were developed, allowing the first autonomous driving projects in Hamburg to be traced back to 2016. The idea was to respond to this *"trending topic"* (Interview 2) and to position Hamburg as a city committed to implementing and utilizing innovative technologies. The design and implementation of experiments for autonomous driving are closely tied to this overarching agenda and aligned with the city's broader vision for a sustainable mobility transition. While the strategic direction is clearly defined, the experiments are still expected to respond to the evolving needs of the city. As the strategy states: *"It is in Hamburg's interest to maintain and continuously develop an efficient, sustainable and affordable mobility offering for all modes of transportation. At the same time, Hamburg faces the challenge of countering the effects on the climate, health and quality of life associated with a constantly increasing demand for mobility"* (FHH-Freie und Hansestadt Hamburg, 2024b, p. 6). Autonomous driving plays a central role within this strategy with the main goal to shift traffic from private cars to shared and more efficient modes of transport, in alignment with overarching strategies such as the Hamburg Takt.

The ITS World Congress, held in Hamburg in 2021, was repeatedly cited by different actors as a significant milestone (Interviews 1, 2, 3). In this sense, Hamburg strategically mobilized expectations to construct an image of itself as an innovation hub, while on the other hand, accelerating the development of projects and prompting their completion in time for public presentation *"to get them on the road"* (Interview 2). The decision to host the UITP Global Public Transport Summit in Hamburg in both 2025 and 2027 reinforces this trajectory and signals the city's continued commitment to bring together and attract resources and build

networks (FHH-Freie und Hansestadt Hamburg, 2024b, p. 2). In line with research on socio-technical transitions, events prompting shifts in strategies, experimentation practices, or governance arrangements, support shaping directionality (e.g., Schot and Geels, 2008). In general, political leadership plays a proactive role, setting ambitious targets that both enable and pressure local implementation (Interviews 1, 2, 3, 7). Particularly, the role of figures such as Anjes Tjarks, Senator for Transport and Mobility Transition, is seen as instrumental by the interviewees. His presence at (inter)national events and active promotion of Hamburg's progress has played a critical role in projecting the city's ambitions on a larger stage. This ensures ***high levels of public circulation***, turning autonomous driving experiments into narrative devices signaling progress (Evans et al., 2016; Raven, 2005; Schot and Geels, 2008; Sengers et al., 2019).

4.1.2. Development and design of experiments for autonomous driving

Numerous projects have been launched in Hamburg in recent years that explore the requirements and potential uses of autonomous mobility in public transportation. The city's roadmap for the transition towards autonomous driving outlines a ***three-tiered approach to scaling experiments*** (Interviews 1, 2). The structured trajectory of autonomous vehicle (AV) experiments progressed from pilot projects (HEAT, eMoin, TaBuLa), which primarily serve research and development purposes and involve testing the technology on designated routes without the intention of immediate scalability, to demonstrators (ahoi, ALIKE), which aim to develop an integrated system for operating and booking AVs within public transport, and towards roll-outs (future scale-up of demonstrators), which represent the envisioned large-scale deployment of up to 10,000 shuttles by 2030, fully integrated into Hamburg's public transportation network. In this way, they articulate a ***rationale to urban experimentation,*** which is also reflected in the mobility strategy.

Another central point mentioned by the interviewees (1, 2, 4, 13) was the Real-World Laboratory for Digital Mobility (RealLabHH) which aimed to accelerate experimentation with emerging digital mobility solutions in the city (Metropolregion Hamburg, 2022). For instance, these included the development of a provider-independent mobility platform and solutions tailored to particularly vulnerable road users (FHH-Freie und Hansestadt Hamburg, 2024b, p. 14). The RealLabHH enabled pilot projects, which deliberately focused on technological feasibility and user experience, while excluding scalability in order to generate initial learning as mentioned by political actors and business developers (Interviews 1, 7). Building on these pilots, Hamburg subsequently moved towards demonstrators, which aim to integrate larger fleets of autonomous shuttles into the public transport system through app-based ridepooling. Taken together, these settings illustrate how experiments in Hamburg have gradually shifted from technological testing to system-level learning about integration, actor roles, and the preconditions for scaling.

At the same time, a tension emerges between Hamburg's ambitious scaling vision and the limited capacity of current experiments. Interviewees emphasized that small test fleets are unlikely to affect the modal split, while the lack of production-ready vehicles constrains real-world testing and public visibility (Interviews 4, 7, 13). However, the target functions as a visible marker of Hamburg's broader ambitions. As exemplified by a representative of a local transport company: *"We have to let as many people as possible drive these vehicles relatively quickly [...]. You can talk to them as much as you want and give them as many indicators as you want and say it's safer, back and forth, if people don't sit down and experience it for themselves, just as a car drives at 50 km/h in normal city traffic, I don't think many people have enough imagination for that if they haven't experienced it in real life"* (Interview 4). In line with the literature, this highlights that experiments are less about immediate systemic effects and more about shaping expectations (Borup et al., 2006; Evans et al., 2016). In this sense, they generate symbolic visibility and foster cooperation—even when their immediate practical impact remains limited (e.g., because of small test fleets) (Evans et al., 2016; Sengers et al., 2019).

Experiments in Hamburg also revealed that early fare structures led autonomous shuttles to be used mainly for leisure trips rather than everyday mobility. Such patterns highlight a broader risk discussed in the literature: experiments may fail to generate the desired ***socio-cultural impact*** if they remain confined to symbolic uses, thereby falling short of expectations for integration into everyday life (Hopkins and Schwanen, 2018; Stilgoe and O'Donovan, 2023). To address these shortcomings, Hamburg emphasizes, on the one hand, the previously neglected but increasingly important role that citizens should play in the future in the experiments. On the other hand, it complements real-world testing with traffic simulations to ensure that the services offered correspond to real mobility needs, rather than, for example, remain *"fun rides of 300 meters"* (Interview 5). These simulations support policymakers in anticipating behavioral and cost implications and in justifying measures deemed necessary to achieve modal shift goals.

4.1.3. Visions, expectations, and experimental dynamics

In this sense, both simulations and real-world experiments can be seen as governance practices that translate visions of sustainable mobility into concrete institutional arrangements (Savini and Bertolini, 2019; Servou et al., 2022). The establishment of New Mobility Solutions Hamburg which acts on behalf of the city to ensure a coordinated view of digital innovations in the mobility sector illustrates how the city has begun to ***institutionalize experimentation*** beyond single projects, embedding them into long-term governance structures. The interviews highlight that expectations associated with experimentation have shifted from exploratory learning in the earlier years towards questions of system integration and scalability. Hamburg's guiding vision of deploying up to 10,000 autonomous shuttles by 2030 exemplifies the role of experiments as political ***signals*** that project ambition and illustrates how expectations are mobilized and institutionalized. As mentioned, completed and ongoing projects are regularly evaluated with scalability in mind as well as climate targets (Interviews 4, 7, 13), which highlights an adjustment of expectations within the vision. Interviewees emphasize that the governance structures behind the strategy—including formats such as steering committees, working groups, project portfolios, and joint funding mechanisms—were strongly shaped by lessons learned during the ITS World Congress (Interviews 1, 2; FHH-Freie und Hansestadt Hamburg, 2024b, p. 15). These arrangements indicate that experiments not only generate technical knowledge but also ***stabilize governance routines that embed expectations into organizational practice*** (Schot and Geels, 2008). In Hamburg, political momentum around autonomous driving translated the city's vision into new governance arrangements that institutionalized experimentation as a core steering mechanism of mobility transformation.

Moreover, interviewees highlight the role of key actors and public figures who reinforce the guiding vision (Interviews 2, 4, 5, 13). The strong city-level vision aligns industrial and municipal expectations around a common narrative (Savini and Bertolini, 2019). As stated by a representative of the state agency of transport: *"The goal of 10,000 shuttles is a very ambitious one. It is a political goal that emerged in the context of a press conference held together with the Federal Ministry of Transport, where it was announced that Hamburg is to become a model region for digital mobility [...] This is perhaps more to be understood as a signal. I keep hearing from industry representatives that they support such an ambitious approach—while fully aware that it will be difficult to achieve"* (Interview 1). Thus, the signaling effect shapes the interplay between politics and industry and is welcomed by business developers: *"It is very good that politicians are setting a certain course"* and *"politicians refer to the industry because they have to supply the technology and the vehicles"* (Interview 2). This includes aligning with the interests of industrial partners, who seek to accelerate scalable service models such as ridepooling (Interview 2). Within this context, a fading of initial euphoria after the early phase of "hype" is reflected: the absence of production-ready vehicles and viable business models, as commonly cited as a

challenge, can prompt actors to reassess their strategies and view collaborations as valuable opportunities to explore applications, helping to move beyond autonomous mobility remaining a demonstration effort (van Lente et al., 2013). Especially industry actors attribute this, among other things, to the uncertainty around viable business models—particularly in scaling from pilots to long-term integrated services. The role of city actors is clearly seen in creating opportunities for industry and providing spaces for experimentation, treating industry not just as a supplier of vehicles, but as a partner for joint experimentation. This underscores ***the role of cities as active translators of expectations*** which use innovation partnerships and shared narratives to sustain momentum and align diverse actors around long-term goals. The ALIKE project, which was mentioned as a pioneer within the city, because *"we have all key players on board"* (Interview 7) further exemplifies this alignment. The integration of two *"impactful"* vehicle manufacturers (Holon and Moia) is cited several times by different actors as a success factor for the ALIKE project, being particularly promising and gives the project a unique profile (Interviews 1, 2, 3, 7). A *"complex chain of actors is needed"* (Interview 2) that includes cooperation and also keeping an eye on international developments and players instead of emphasizing competition. Such ***coalitions*** illustrate how experiments can function as ***sites of collaboration***, balancing interests and mobilizing diverse actors. This also resonates with work on prospective market shaping, which shows how future-oriented narratives and possible markets help coordinate ecosystem actors and stabilize value propositions in emerging fields such as autonomous mobility (Purchase et al., 2024).

4.2. Karlsruhe

4.2.1. Future orientations and strategic anchoring

In Karlsruhe, expectations are articulated mainly at the project level, centered on the test field as a research platform rather than on the city as a collective actor. Different interviewees described projects for autonomous mobility as less visible in the city—both in public discourse and in the urban space—often limited to ***smaller pilot initiatives without clear scaling trajectories***. The mayor's role in securing funding for the test field is widely acknowledged (Interview 8), who emphasized that the research location *"is crucial for the future of our cities and regions"* (KIT, 2021), highlighting place-based independent mobility solutions. Broader goals for autonomous mobility are primarily defined by Baden-Württemberg's state strategy, which focuses on strengthening research and innovation capacity and supporting regional value creation (Ministry of Transport Baden-Württemberg, 2020, p. 2). Within this context, Karlsruhe is seen as one potential location suitable for integrating autonomous vehicles into public transport and testing new mobility scenarios. As one state-level representative further explained: *"We want to move away from individual project funding. So, we no longer aim to support isolated projects […]. Instead, we are now considering launching an innovative procurement procedure—referred to as an innovation partnership. […] Once the first vehicles become available, the rollout won't happen in small, fragmented steps. Instead, there will be a focus on specific priority areas. And of course, partners who already have access to the topic will likely be among the frontrunners in this rollout process"* (Interview 9). This indicates a gradual shift from research pilots towards more coordinated roll-out strategies. Yet, compared to Hamburg, climate goals played only a minor role, reflecting both the lack of an overarching city strategy and the different structural conditions of a medium-sized city (Krombach et al., 2024, p. 105).

As mentioned, the test field was already shaped by technological considerations during the application phase, placing the focus on creating an environment for technological excellence rather than linking the activities to a comprehensive future vision of mobility in the city or region. The developments in Karlsruhe are guided by expectations on technical and regulatory progress that needs to be enabled and accelerated in order to make AVs work in general and to consider uncertainties regarding their future development. Expectations are therefore articulated in a more distributed and actor-specific manner (e.g., R&D, public authorities, state-level actors) and translated into priorities, even when specific operating permissions are pending, mobility-demand rationales are weak, service-oriented approaches (such as Mobility-as-a-Service) lose traction, or industry engagement becomes more cautious (Interviews 9, 10, 11). This stabilizes experimentation as technical and regulatory learning, while postponing questions of service integration and scaling.

4.2.2. Development and design of experiments for autonomous driving

Given the dominance of project-level expectations, experimentation in Karlsruhe is configured as a ***flexible research platform*** and translates expectations on technical reliability. Autonomous driving initiatives in Karlsruhe trace back to 2016, when the proposal for a regional test field was submitted, paralleling Hamburg's engagement. The test field officially began operations in 2018 and has since become a central reference point for AV developments in the region. According to different interviewees (Interviews 8, 9, 12), the test field functions as a platform that enables targeted research on driving functions and supports continuous technological advancement. Centered on the test field, Karlsruhe's AV experimentation has evolved primarily within a research-driven ecosystem. Projects such as EVA (2020) and SHOW (2023) were conceived as ***technical pilots***, focusing on vehicle sensing, teleoperation, and feasibility studies ***rather than a stepwise pathway towards urban integration***. In both the interviews and the test field's public self-description (website and outreach materials), the Karlsruhe approach is framed as a "real-world lab"—understood as a *"neutral ground"* (Interview 8), where technological innovations can be trialed under real-world conditions. In 2020, autonomous Easymile minibuses were deployed on the test field as part of the EVA project. In 2023, the SHOW project built upon this foundation, deploying autonomous shuttles once again in the test field. This time, the focus expanded from highly automated operation in controlled environments to more complex scenarios involving mixed traffic. One of the central aspects of this phase was the exploration of tele-supervision, further reflecting Karlsruhe's commitment to ***iterative learning and technological refinement*** through real-world experiments. In subsequent phases, attention shifted from sensor technology and vehicle perception, with the goal of improving the system's ability to interpret its environment to passenger transport and user experience, supported by surveys designed to gather insights into public perception and acceptance.

4.2.3. Visions, expectations, and experimental dynamics

Actors highlight the value of projects such as EVA, where citizens could join shuttle rides and repeatedly stress that technical trust can be achieved faster than improvements in mobility services (Interviews 5, 11). Public transport is seen less as a starting point for autonomous mobility solutions and more as a potential field of application that could be exploited at a later stage. The future of autonomous mobility is framed as ***contingent, uncertain and to be explored through iterative experimentation***. As one interview noted *"the expectation about when we would be able to see safe autonomous driving was wrong,"* so experimentation rather aims to *"further develop the decision-making process, the entire technology strand, in order to be able to present something like this in public space in a reliable manner"* (Interview 11). Research-driven actors stress that the primary focus is on further advancing technology itself rather than testing a mobility concept, with collectively defined urban objectives remaining in the background (Interviews 8, 10, 12). Although improvements for the public transportation were cited several times as an advantage (Interviews 8, 9, 10, 11), it was mentioned that the focus is not necessarily on integration into the already *"well-developed public transport system"* (Interview 12). Instead, developments within the test field are used to present the city as a technological pioneer as further highlighted by a researcher: *"Karlsruhe has a great public transport system […]. It's not primarily about solving traffic problems, but about being the market leader in certain areas. This is very much driven by the research*

institutes" (Interview 13). Projects focus on ***advancing technology*** instead of systematically embedding AVs into the mobility transition. However, different interviewees agree that *"something bigger is needed, but it costs an incredible amount of resources"* (Interview 10). State-level actors increasingly seek to move away from the previous *"Gießkannen-Prinzip"* (Interview 9) funding model ("water-can principle": German expression for fragmented funding policies across many locations with only limited resources) towards innovation partnerships with selected frontrunner cities and Karlsruhe is a potential area of application. This indicates a gradual ***re-coordination of expectations*** while acknowledging that such processes require significant administrative and financial resources, along with stronger ties to the federal government (Interviews 7, 9, 12).

Pilot projects or demonstrators are still valued for their performative role: even without scaling or a mobility scenario and lower speed, they can already be considered as a success. They provide first experiences for the citizens by not *"just throwing it in"* (Interview 9). One actor concludes: "*When you then come to the next stage, where they drive faster, people might remember it again and say, 'well, it was slow back then, but I actually felt quite good in it'"* (Interview 13). In this sense, Karlsruhe's experiments contribute to expectation-building through experiential learning, albeit within a research-led governance culture that prioritizes technology over mobility transformation. Nevertheless, experiments have also generated knowledge transfer about possible application areas—such as replacing large buses with smaller shuttles, or enabling barrier-free connections between city and periphery—issues that resonate with sustainability challenges (Interviews 10, 12).

5. Connecting the lanes: Synthesis and discussion of both cases

Building on a comparison of both cases, this section discusses the findings by abstracting from the empirical cases and focusing on the governing role of visions and expectations in experimentation for autonomous driving. It shows how different configurations of future orientation shape experimental design, scaling logics and the interpretation of outcomes, and emphasizes the implications of such findings for future research, particularly with regard to how experiments are influenced by, but also enact, stabilize, or recalibrate future orientations.

5.1. Steering: how future orientations govern experimentation

A first insight from the case comparison is that, consistent with our theoretical framing, visions and expectations govern experimentation in different but complementary ways. In Hamburg, experimentation is embedded within a strong vision-related configuration characterized by normative orientation (e.g., climate-neutral mobility and urban pioneering), directionality and alignment (integration into city-wide mobility strategies and articulated scaling trajectories), narrative coherence (a pronounced signaling function), and political legitimation. In this configuration, experiments are positioned as steps along an imagined long-term transition pathway. Expectations about and lessons generated through experimentation are interpreted primarily in relation to the overarching vision, serving to adjust implementation strategies and stabilize the overall direction.

In Karlsruhe, experimentation follows a more expectation-driven configuration shaped predominantly by technological refinement, feasibility assessment and incremental learning within a research-led environment. Expectations function as provisional and operational assumptions that organize technical development and enable coordination among heterogeneous actors without requiring agreement on overarching collective goals. As a result, experimentation remains deliberately open-ended, privileging adaptability and learning under uncertainty over strategic directionality.

In addition, both case regions highlight innovation partnerships as important governance arrangements, playing a critical role in translating expectations into more durable visions and institutional commitments. Rather than treating such arrangements merely as coordination tools, future research could examine how they mediate between exploratory experimentation and strategic anchoring within urban transformation agendas and create a coherent experimentation environment (Fraske et al., 2025, p. 11; Torrens and von Wirth, 2021).

5.2. Merging points: Scaling, interactions and the governance of future pathways

The comparison further shows that scaling is not necessarily an inherent feature of experimentation, but a future-oriented framing which is governed differently across cases. In Hamburg, scaling is anticipated narratively as part of a broader vision for transforming urban mobility before it becomes technically or institutionally realistic. Experiments are framed as early steps on an imagined pathway towards large-scale integration into public transport, even if their immediate empirical scope remains limited. Scaling thus functions primarily as a symbolic and strategic device that mobilizes actors and aligns expectations.

In Karlsruhe, experiments are framed as valuable without an explicit scaling logic, remaining open to future adaptations. At the same time, actors increasingly recognize that more coordinated and scalable approaches will be needed to embed autonomous driving in institutional responsibilities and public service provision. This points to an emerging search for stronger anchored future orientations to complement the currently expectation-driven experimentation in Karlsruhe.

For future research, longitudinal studies would help to better understand the development of expectations and visions over time, especially across experimental phases, and to record their effect on sociotechnical systems more precisely as well as investigate events and milestones that influence their governance. Recent developments in both cases after our data collection period illustrate this dynamic. In Hamburg, political actors have begun to temper the highly visible target of "10,000 autonomous shuttles," adjusting expectations regarding pace and scale, while maintaining the overarching vision of autonomous mobility as a cornerstone of a sustainable urban transport system and Hamburg's role as a pioneer (Ramsel, 2025). This development highlights the role of ambitious quantitative targets as performative expectations (Borup et al., 2006; van Lente and Rip, 1998). Such targets function less as realistic forecasts: as the interviews show, both public and private actors were aware from the outset that the target was unlikely to be met literally. Its primary function lay in forming directionality and giving vehicle providers security. This pattern resonates with research showing that visions often persist by absorbing critique through incremental adjustment rather than through abrupt abandonment (Hajer and Pelzer, 2018; Sovacool et al., 2019). In Karlsruhe, on the other hand, recent reflections by actors involved in the test field document a shift of expectations. Here, reassessments concern the sequencing of experimentation, suggesting that the early move towards publicly visible demonstrations preceded sufficient technological maturity and should have been preceded by more controlled research phases (Müller, 2026).

5.3. Intersections ahead: Implications for transition governance and urban experimentation

Abstracting from the individual cases and situating these findings within broader debates, our findings have several implications for research on transition governance and urban experimentation. First, distinguishing configurations of visions and expectations offers a more precise account of how experimentation can either stabilize a trajectory or remain deliberately open and adaptive.

Second, our analysis suggests that experiments should be understood not only as sites of learning or innovation, but as mechanisms that embed future orientations into situated practices (Evans et al., 2021; Haugland, 2023; Rohracher and Konrad, 2024; Ryghaug et al., 2022;

Savini and Bertolini, 2019). Governance therefore requires attention to the types of futures that experiments enact and reproduce as well. Our cross-case comparison specifies how this occurs in practice, for example, through sequencing and evaluation devices, organizational routines, or public events, the link between direction-setting and experimentation becomes tighter in Hamburg and looser and more iterative in Karlsruhe.

Third, the comparison refines how we think about the transfer of urban AV experiments across places. Transfer is often treated as a matter of replicating a technical set-up or testing prototypes in a new context. Our findings suggest that this frequently proves difficult because experiments also carry future orientations. When experimental practices are moved, these orientations are not simply reproduced; they are interpreted, contested, and reassembled in relation to local priorities, institutional conditions, and actor constellations. Future research could therefore trace such interpretive translations, for example, across policy documents, funding programs, conferences, and partnerships, and examine how they redefine what counts as feasible, legitimate, or successful in subsequent experiments. This aligns with Schippl (2024), who points out that a clear understanding of the normative orientation of experiments and developments is crucial for the long-term governance of AVs and mobility, yet this dimension generally receives far less attention than technical progress and its implications.

Finally, while both cases acknowledge the importance of citizen experience and trust-building, systematic citizen participation remains limited. This underscores a critical gap in current experimentation practices. Designing experiments not only for technical performance, but as arenas of social learning and co-shaping, remains an underdeveloped yet crucial dimension of experimentation as a potential trigger for socio-technical transitions (Bertolini, 2020; Haugland, 2023). Real-world labs offer a promising setting to operationalize more participatory approaches, but their role in mediating between different future orientations and public engagement warrants further investigation (Joost et al., 2025).

6. Conclusion

This study set out to examine how visions and expectations shape the governance of urban experimentation with autonomous driving, and how experiments in turn feed back into these future orientations. Bringing together transition research, scholarship on visions/expectations, and urban experimentation studies, we conceptualize experiments as sites of governing where future orientations become actionable: experiments translate particular understandings of desirable, feasible, and legitimate futures into situated practices, organizational arrangements, and evaluative criteria. In doing so, they contribute to research on how transition pathways are imagined and governed (Evans et al., 2021; Haugland, 2023; Savini and Bertolini, 2019).

The comparative analysis of autonomous driving experimentation in Hamburg and Karlsruhe shows that visions and expectations are not interchangeable registers of future orientations, but shape experimentation in different ways. In Hamburg, a more vision-driven configuration provided a collective frame for directionality and legitimation of the experiments and made scaling an explicit part of an imagined pathway. In Karlsruhe, a more expectation-driven configuration mainly organized feasibility and learning in the near term, keeping future directions more open-ended and less publicly stabilized. Rather than proposing a fixed typology of cities or experimental formats, we use these cases to highlight experimentation as a configurable and relational process, shaped by how elements of future orientations are combined, institutionalized and made consequential in practice. Conceptually and empirically, experiments do not only enact future orientations, they also generate feedback, for example, in reinforcing each other. This helps to explain under which configuration experimentation tends to stabilize directions, remain open to adjustment or constrain certain futures. This also shifts the attention to dynamics in experimentation, for example, by analyzing how particular events and evaluations may become turning points in building and coupling of visions, expectations and experimentation.

At the same time, this points to the limitations of our study. Since our analysis relies on retrospective expert interviews and documentary material from two German cases, it cannot fully trace shifts in future orientations or determine how prevalent these configurations are across other contexts. Moreover, we treat visions and expectations as one empirically entry point into a wider repertoire of future-making practices. Complementary work could draw on additional registers of future-making. For example, sociotechnical imaginaries foreground collectively stabilized and politically charged narratives, especially national or sectoral (Jasanoff and Kim, 2015); anticipatory governance highlights how institutions organize and steer uncertainty (Guston, 2014); and policy assemblage perspectives trace how experimental models, policy ideas and devices travel, are reassembled across contexts, and become institutionalized in place (McCann and Ward, 2012).

Despite these limitations, the paper suggests a transferable analytical lens that systematically connects visions and expectations to experimentation governance: examining how future orientations shape experimental processes, and how experimental feedback are reshaping them—recalibrating what is treated as feasible, legitimate, and worth pursuing over time.

CRediT authorship contribution statement

Veronika Stein: Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Tim Fraske:** Writing – review & editing, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jens Schippl:** Writing – review & editing, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used OpenAI to enhance the readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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Data availability

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