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Tensions in air and rail integration based on a European longitudinal case study with stakeholders

Check for updates

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Integrating air&rail systems requires collaboration among transportation stakeholders. This study used Action Research to explore tensions during a 16-month real-life air&rail integration effort, structured around co-creation sessions. The single case study identified six system-level tensions: no control over airport slots, conflicting priorities in train stop allocation, misaligned scheduling, different business models, fragmented booking systems, and different passenger experiences. Additionally, three collaboration-level tensions emerged: limited mutual understanding, embedding systems thinking in organizational processes, and differences in organizational momentum. While these tensions primarily arose between air and rail operators, resolving them also requires infrastructure managers and government involvement. The identified tensions indicate that the actors tended to prioritize organizational interests over passenger needs. While co-creation fosters understanding, challenges extend beyond peer-level collaboration. Our findings suggest that involving an orchestrator and a European governing body could facilitate system-level decision-making. This may help overcome institutional and regulatory boundaries, for the benefit of air&rail integration.

Passengers rely on multiple transport systems to reach their destinations, particularly for longer distances¹. When these systems are integrated under one ticket into a seamless journey, this is referred to as multimodal transport^{2,3}. Multimodal integration has been widely discussed as a promising strategy for improving transport efficiency and reducing emissions^{4,5}. It has gained traction in urban settings, for instance, through emerging concepts such as Mobility-as-a-Service (MaaS)^{6–8}. At larger geographic scales, such as national or cross-border travel, one of the primary mode-integration options that receives attention is air&rail travel^{2,9,10}.

Air&rail integration is often compared to airline code sharing: two operators collaborate on a joint itinerary, but each maintains operational control over one leg of the trip^{9–12}. In the European context, societal attention has increased to promote air&rail as a sustainable travel alternative^{13,14}. The European Union has set clear ambitions in its Sustainable and Smart Mobility Strategy, aiming for a reduction of at least 55% in greenhouse gas emissions by 2030¹⁵. This strategy for 2030 also states that transport for distances under 500 km must achieve CO₂ neutrality.

While high-speed rail (HSR) infrastructure exists across much of Europe, as illustrated in the UIC High-Speed Rail Atlas¹⁶, and plans to optimize the HSR network are underway¹⁴, the service quality of the air&rail product in Europe remains low¹². This specifically pertains to digital services, including transaction, reservation, information, and planning

services^{17,18} (Toet et al., under review). A recent Eurobarometer survey on multimodality in Europe found that 36% of respondents have difficulties booking tickets that combine different modes of transport, such as train and air travel¹⁹.

Integrating air and rail systems into a single journey requires coordination across multiple actors—airlines, rail operators, infrastructure managers, and public administrators^{3,20,21}—each operating within distinct regulatory, financial, physical, and organizational frameworks^{12,22} (Toet et al., under review). In the European context, cooperation among these actors is complicated by public-private partnerships^{21,23}, different levels of governance^{21–23}, an unbalanced distribution of risks and financial obligations^{21,23}, and legal issues²⁰.

Much of the existing research on air&rail integration entails quantitative studies, literature reviews, or qualitative interviews. To our knowledge, no research has directly observed how air&rail integration efforts manifest in real life over an extended period. A qualitative study of this type could uncover how and why these phenomena occur in a specific manner^{24,25}. This aligns with existing research calling for an examination of the driving forces behind air&rail cooperation to effectively promote and integrate it in practice¹¹.

The study in this paper aims to address that gap by investigating how air&rail integration is experienced and enacted by stakeholders in

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a real-world setting. Service ecosystem theory^{26–28} points out how the development of a shared service proposition requires the integration of resources—such as knowledge and skills—by multiple actors within the service ecosystem, and how this is key to value creation for users²⁷. We therefore conceptualize air&rail integration as a dynamic, multi-actor process of co-creation across system boundaries. By adopting this perspective, we also address the need for research into collaboration tensions within service ecosystems^{29,30}.

Based on this approach, the paper investigates the following research question:

Which tensions emerge among key stakeholders during air&rail integration efforts in a European setting, and what does this reveal about the conditions required for successful air&rail collaboration?

We employed an Action Research (AR) methodology³¹ to study a single case of air&rail integration in Europe over a 16-month period. The case involved five key organizations: an airline, an (international) rail operator, an airport infrastructure manager, a public rail infrastructure manager, and a governmental body. These actors engaged in a structured series of co-creation sessions aimed at creating a shared understanding about air&rail integration in practice and exploring possible solutions. Building on prior work that positions co-creation as a methodological approach within AR³², these sessions were employed as both a practical intervention and a research method. They facilitated the advancement of air&rail integration while providing a context for observing and analyzing tensions within a real-world, cross-sector collaboration.

Literature review

Multimodal air&rail transport

Air&rail travel can be viewed as an application of multimodal transport. Definitions of multimodal passenger transport differ in the literature and are sometimes conflated with intermodal transport^{2,13,33}. In this study, we adopt the definition by Babić et al.² and Rodrigue³, who refer to multimodal transport as the use of two or more transport modes within a single passenger journey, under a unified ticket or booking system. This level of integration—both digital and organizational—is central to enabling seamless travel experiences.

Both multimodal and intermodal transport aim to combine the strengths of different transport systems—such as speed, coverage, and frequency—to enhance overall efficiency, connectivity, and sustainability^{4,5,34}. However, a key distinction lies in the degree of integration. If we follow the definitions of Babić et al.² and Rodrigue³, in intermodal passenger transport, users may need to navigate between loosely connected systems. In contrast, multimodal transport, as defined here, requires a higher level of coordination among service providers—such as integrated ticketing, synchronized schedules, and shared platforms—to support end-to-end journeys^{2,3}.

Although air&rail travel is practiced as a form of intermodal transport, with air transport complemented by rail travel bringing passengers from airports to the city center^{1,2,23}, air&rail as a multimodal form of travel is less common in practice².

A multimodal air&rail journey requires coordination among transport providers to connect services on TRIP aspects (transactions, reservations, information, and planning)¹⁷. Additionally, the provision of guarantees mitigates risks associated with missed connections¹². Efficient transfers at airports are essential for a smooth travel experience and can be achieved through infrastructure and service elements, including comfort, safety, accessibility, and clear passenger information^{1,35,36}.

Full alignment of services is rarely achieved in practice for air&rail transport operating on an intercity or international scale^{2,13,37} (Toet et al., submitted). In a study conducted by Li et al.¹¹, it was found that, in 2018, ticketing, reservation, planning, and cancellation assistance were only integrated on a few occasions within air&rail travel, all of which were located in Europe.

While air&rail transport can take many forms¹³, including regional airport access by rail, this study focuses on long-distance passenger travel. It examines the structural characteristics and institutional logics of each system to identify key obstacles and enablers of integration.

Characteristics of air and rail systems

Air transport enables direct connections between airports without being affected by natural barriers such as oceans, mountains or distance¹. However, air transport systems' boundaries are defined by mandatory airport procedures, requiring passenger security and passport checks before boarding^{1,38}. While aviation is the fastest option for long distances, its efficiency for shorter trips is reduced due to its reliance on mode changes before and after flights, since virtually no passengers have the airport as their final destination¹.

To maximize passenger volumes on long-distance flights, airlines transport travelers from surrounding areas to hub airports via short-distance flights, a model known as “hub-and-spoke”. This network connects smaller regional airports (spokes) to major hubs, optimizing capacity and operational efficiency^{38,39}. While this model reduces direct connections, it allows for greater overall reach within the aviation network³⁸. Airlines collaborate in this model through code-sharing¹⁰. As the hub-and-spoke model requires a transfer, efficient transfer times are necessary to facilitate efficient journeys for travelers³⁹. In contrast, the point-to-point network connects origin-destination pairs directly, eliminating layovers and making it preferred for short-distance routes^{38,39}.

European rail networks, in contrast, have primarily evolved for domestic travel, providing intercity transportation with frequent stops in city centers and typically without security or passport checks^{40,41}. HSR has enhanced cross-border connectivity but faces operational challenges due to variations in infrastructure, a legacy of independent national networks^{40–42}.

The aviation sector operates under a centralized, globally aligned framework, with international bodies like the IATA and ICAO harmonizing scheduling, communication protocols, and safety standards^{1,43}.

Governance in rail, on the other hand, depends on market structure; open-access markets allow multiple operators to bid for routes, while closed markets grant exclusivity via concessions⁴⁴. The infrastructure is publicly owned, and an infrastructure manager (often a governmental agency) establishes the timetable based on operators' preferences⁴⁴. Long-distance (international) rail governance is more fragmented, with different companies managing cross-border routes and national borders acting as regulatory and operational barriers⁴¹. Tracks in Europe are managed by various national or regional regulatory bodies overseeing safety requirements and determining (partly) railway timetables⁴⁴. This complexity makes cross-border high-speed travel more challenging than national HSR routes.

In aviation, an independent slot coordinator assigns and monitors airport access⁴⁵, while in European rail, timetabling is a nationally negotiated process shaped by political priorities and legacy arrangements⁴⁴. These governance differences lead to planning friction, scheduling incompatibilities, and unclear ownership over shared operations, posing barriers to air&rail integration²².

Air&rail integration can improve connectivity by linking airports to surrounding regions²⁰. HSR can complement aviation, particularly on routes ranging roughly from 300 to 800 km, where HSR has been found to be a strong competitor or even the dominant mode of transport^{1,12,46,47}. While HSR competes with short-distance flights, where HSR offers a similar or better travel experience^{10,48}, aviation retains a clear advantage in long-distance travel, of over 1000 km^{23,49}, especially in hub-and-spoke networks¹¹. This study focuses on air&rail as an integrated form of multimodal travel rather than on substituting air with rail.

Air&rail integration is proposed to lower CO₂ emissions by replacing short or medium-distance flights with train travel^{9,10}. However, literature

indicates that capacity freed by air-to-rail substitution in short legs may be redirected to long-haul flights, potentially increasing overall emissions^{41,50}. Additionally, air&rail integration could allow airlines to replace unprofitable short-distance flights while maintaining network connections and reducing airport congestion by shifting flights to rail^{9,10,23}.

Practical barriers to air&rail integration

Existing research demonstrated that the delivery of effective air&rail journeys is shaped by internal support processes and external factors (Toet et al., under review).

One such barrier is the lack of standardized IT systems, which impedes seamless data sharing and reinforces fragmentation between air and rail operators^{2,18,20,41}. Previous research indicates that organizations are often not authorized to share passenger data without consent, while operators resist sharing business information—such as schedules, operations, and financial data—with potential competitors^{2,20}.

Adapting physical infrastructure—such as stations and tracks—to support both systems is equally challenging due to high costs and long implementation timelines^{21,51–53}. Additionally, aligning national rail networks with global air travel schedules necessitates complex adjustments to train timetables to enable smooth connections^{1,2,12,40} (Toet et al., under review). Where HSR services connect directly to airports, operational challenges may arise, particularly regarding international security and border procedures³⁷.

Financially, the current small volume of air&rail travelers reduces the commercial incentives to address these issues^{2,12,52}. Furthermore, revenue-sharing issues between operators^{2,18}, as well as the differing strategies of air and rail operators concerning customer relationships and pricing policies, hinder collaboration¹².

Moreover, cross-border integration efforts often suffer from fragmented interorganizational collaboration, with each actor seeking to maintain control over its own domain⁵², compounded by a lack of clear ownership of the overall passenger journey^{2,22}.

Despite these challenges, some countries and projects have made progress. Lufthansa and Deutsche Bahn's 'Rail&Fly' program offers integrated ticketing and guaranteed air&rail connections on selected domestic routes. Air France and SNCF collaborate to provide reserved train compartments, and on a single route, baggage integration. KLM and Eurostar provide a joint service on one international route. In Switzerland, pilot studies have tested coordinated check-in and dynamic air&rail scheduling at hubs like Geneva and Zurich. These initiatives demonstrate technical feasibility; however, most remain bilateral and operator-specific in niche markets, with only a few achieving a high level of service^{11,12} (Toet et al., under review).

Similar developments are occurring in China under different circumstances and contexts. In China, air&rail integration is advancing through large-scale, state-led infrastructure projects^{54,55}, while Europe typically follows a more decentralized public-private partnership model^{56,57}. However, Europe is progressively moving toward an open rail market¹⁴, as highlighted by Regulation (EU) 2016/2338, which mandates the liberalization of domestic rail markets.

Stakeholder collaboration in multimodal integration

In air&rail integration, the role of airports is crucial yet often overlooked within stakeholder networks. They serve as physical interfaces between modes—through terminals, signage, and platform design^{36,58}—and coordinate operational processes like check-in and security, making them central to seamless passenger experiences³⁷. However, many airports operate as commercial entities with strategic priorities that may not align with public objectives for integrated, sustainable transport, underscoring the need to include airports in air&rail integration studies.

Benz and Stauffacher²² note that developing a multimodal rail transport hub requires decisions on technical, financial, and procedural constraints, areas in which not all stakeholders may have expertise. They

advocate for dividing the integration process into multiple co-creation sessions focused on these themes²².

However, these authors also describe that co-creation for multimodal integration is challenged by actors' limited resources and time²², as well as shifting political and internal dynamics^{22,59}, making it more of a collaborative process than a technical task requiring openness and coordination.

Method

This study adopted a qualitative AR approach, to explore air&rail integration within a single, longitudinal case study. Qualitative research provides an in-depth understanding of real-world phenomena by uncovering meaning in context^{24,60}. Focusing on a single case offered a rich context and the opportunity for a deep and longitudinal exploration of issues central to the research^{25,61,62}. The AR approach facilitated interaction between researchers and practitioners, generating scientific and practical insights while uncovering context-specific complexities^{31,32,63,64}.

Following AR principles, data generation, interpretation, and intervention occurred in an iterative research cycle, devised and facilitated by two AR researchers (the first two authors of this article). Co-creation sessions served as the main data-generating activities. The AR researchers acted as external helpers to the client system³¹, balancing active engagement with a reflective research stance. This dual role allowed them to guide the research process while analyzing tensions, ensuring findings were both practically relevant and scientifically rigorous.

Case selection

This study focused on a single case over 16 months, providing an opportunity for an in-depth investigation of air&rail integration in a real-world setting using an AR cycle⁶². The case was demarcated by the following properties²⁴:

- Context:
 - Air&rail integration at a major European airport hub.
 - The airport's proximity to the country's main borders often makes long-distance trains often de facto international and subject to cross-border coordination.
- Unit of analysis: the real-life process of air&rail integration, driven by practitioners from key transportation stakeholders.

The case was selected through purposive sampling^{24,25} to explore air&rail integration in a real-world setting, with convenience sampling²⁴ playing a secondary role due to the project's basis in an existing collaboration. The participating organizations had previously co-developed an initial action plan and shared a general understanding of air&rail travel and of each other's institutional roles and ambitions. While the collaboration between the organizations was already established, changes in staffing meant that several practitioners were new to the project and unfamiliar with each other. This created a mix of continuity and novelty: the organizational commitment provided structure and momentum, but some interpersonal relationships still had to develop.

Participating organizations and representatives

Two representatives from five organizations participated in the study, all involved in the ongoing air&rail integration effort: an airline, an (international) rail operator, an airport infrastructure manager, a public rail infrastructure manager, and a governmental body. The airline was the only private entity, with the state holding a majority share. The public rail infrastructure manager operates under the Ministry of Infrastructure, allowing direct government influence on its policies and strategies. This influence does not extend to the rail operator or the airport infrastructure manager, despite their ownership by the state and/or municipalities.

The representatives were purposefully chosen for their expertise by their organizations as information-rich practitioners²⁴ regarding air&rail travel. To ensure confidentiality, input from these practitioners and organizations, including observations and quotes, is kept anonymous. Whenever

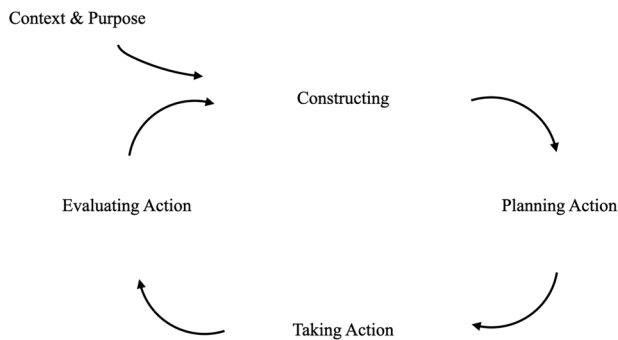


Fig. 1 | AR cycle phases⁶³. The AR cycle starts with the context & purpose phase, followed by constructing the research cycle, planning action, taking action and evaluating action. This evaluation can lead to the start of a new cycle, beginning again with constructing the research cycle.

possible, the organization or sector from which a quote originates is disclosed without revealing too much about a person or organization.

Research set-up

The AR cycle consists of four main phases: constructing, planning action, taking action, and evaluating action⁶³ (Fig. 1). This entire study, which encompasses multiple co-creation sessions, is considered as one AR cycle, with intermediate adjustments between sessions.

Before starting the AR cycle, AR researchers and practitioners together defined the context and purpose of the project in a pre-phase. Initially, they planned six co-creation sessions as part of the ‘taking action’ phase in the AR cycle. The sessions were facilitated by the AR researchers, and practitioners engaged in co-creation activities focused on specific themes.

In this study, we use a definition of co-creation based on design and innovation literature, which characterizes it as a creative process in which multiple actors collaboratively^{32,65,66} develop innovative ideas and solutions for a complex challenge^{22,67}, moving beyond a primary focus on consensus-based decision-making^{22,68}. Here, ‘creative process’ means that actors not only discuss and exchange knowledge but also jointly create something. Therefore, co-creation processes often feature activities found in design and innovation models^{69–71}, such as analysis, problem definition, synthesis, evaluation and decision making. For our sessions, co-creation was operationalized as the collaborative production of new, observable outputs—such as new insights, problem framing, designs and assessments—that integrate contributions from multiple stakeholders.

Methodologically, the co-creation activities were embedded in the AR cycle as the main intervention of the AR cycle³². Each session was designed and facilitated by the AR researchers and served a dual purpose: enabling real-time collaboration while simultaneously generating rich qualitative data. Importantly, the sessions were co-designed with practitioners, consistent with AR principles and the co-creation approach that emphasizes joint problem framing and iterative learning^{63,66}. This participatory format enabled researchers to remain close to the evolving dynamics of collaboration, while allowing practitioners to shape the focus and design of each session in response to real-world needs. Co-creation thus functioned both as a research method to surface tensions and as a practical mechanism to explore solutions.

Time was allocated after each session for evaluations among the AR researchers and by the practitioners⁶³. Based on these intermediate evaluations, adjustments were made to subsequent sessions as needed⁶³ (Fig. 2). For example, a discussion on key questions in session 4 took up so much time that there was no opportunity to link to the scenarios as originally planned. Consequently, an additional session was scheduled to focus entirely on connecting implementation plans with the scenarios. Near the end of the study, the primary AR researcher and practitioners reflected on the project’s results and process during interviews.

Data generation

Data was generated over 16 months throughout the AR cycle, supporting the research’s process-oriented perspective, which required extended data collection⁷². During the construction and planning phase, AR researchers and practitioners prepared reports and presentation slides to facilitate the co-creation sessions.

The six co-creation sessions focused on themes such as customer experience, infrastructure, network design, and regulatory conditions, using tools like scenario mapping^{73,73}, auto-ethnographic field studies^{74,75}, service blueprinting⁷⁶, and the development of implementation plans (Fig. 2). Each session was designed around specific objectives, but the process evolved iteratively. For example, the auto-ethnographic field studies in session 2 informed the blueprinting work in session 3. In session 6, the original plan to present conclusions shifted to negotiation and revision. This emergent structure, characteristic of AR, enabled deeper insights into stakeholder dynamics and system-level tensions. Detailed information about the structure and course of the sessions can be found in Supplementary Note 1.

Throughout the AR cycle, AR researchers took notes and maintained diaries based on the session discussions, reports, internal documents, and email exchanges. Interviews were conducted after two co-creation sessions (session 2 and session 6) to gain insights into practitioners’ perspectives on the content of the sessions and collaboration. These interviews were audio-recorded and transcribed. The notes and interviews allowed AR researchers to observe group dynamics and uncover underlying assumptions³¹.

Data analysis

The AR cycle resulted in the analysis of the pre-phase, six co-creation sessions, 15 interviews, and 14 journal notes. The AR researchers had access to a secondary data set of 146 mail-trails and group messages, which was used for the contextualization of findings from the primary data sources. Data analysis followed Braun and Clarke’s⁷³ six-phase approach to thematic analysis to interpret the underlying meaning in the data: 1) familiarization with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing potential themes, 5) defining and naming themes, and 6) writing the report.

Familiarization occurred through continuous engagement with the dataset, consisting of notes, diaries, interviews, documents, and presentation slides summarizing key insights from each session, during and after the project.

Coding took place in two rounds to ensure trustworthy results. In the first round, the first author inductively coded data from the first two sessions using Atlas.ti²⁴, followed by a review and refinement of the codes by all authors. The remaining data were coded in the second round, applying and also grouping the codes in the codebook²⁴. Codes were then deductively grouped into predefined support processes that form the backbone of multimodal air journeys, according to a preceding study (Toet et al., under review) (see Table 1).

Theme development was an iterative process. Preliminary themes were identified across categories and refined collaboratively through multiple review sessions. The final themes were translated into tensions as they represent, in line with service ecosystem theory, frictions arising when actors with varying goals and practices interact within shared institutional frameworks^{30,77}. The tensions were divided into system-level tensions and collaboration-level tensions. All authors contributed to the identification and refinement of the tensions, which were validated through member checking with the participating organizations to ensure “the accuracy of descriptions, explanations, and interpretations”²⁴ (p.58). The quotes have been translated into English and paraphrased where necessary to enhance readability.

The results were drafted by first describing the AR cycle and then analyzing the identified tensions. We followed guidelines stating that the AR story must be presented separately⁶³ and that a “thick description” of the phenomenon is essential for understanding the context and establishing

Fig. 2 | The execution of the AR cycle in this project. The context & purpose phase included two parts: one with AR researchers and one involving practitioners. This was followed by the execution of the AR cycle, where the taking action phase consisted of multiple co-creation sessions around a specific theme. The dotted line illustrates how the evaluation of each session influenced the next session within the AR cycle.

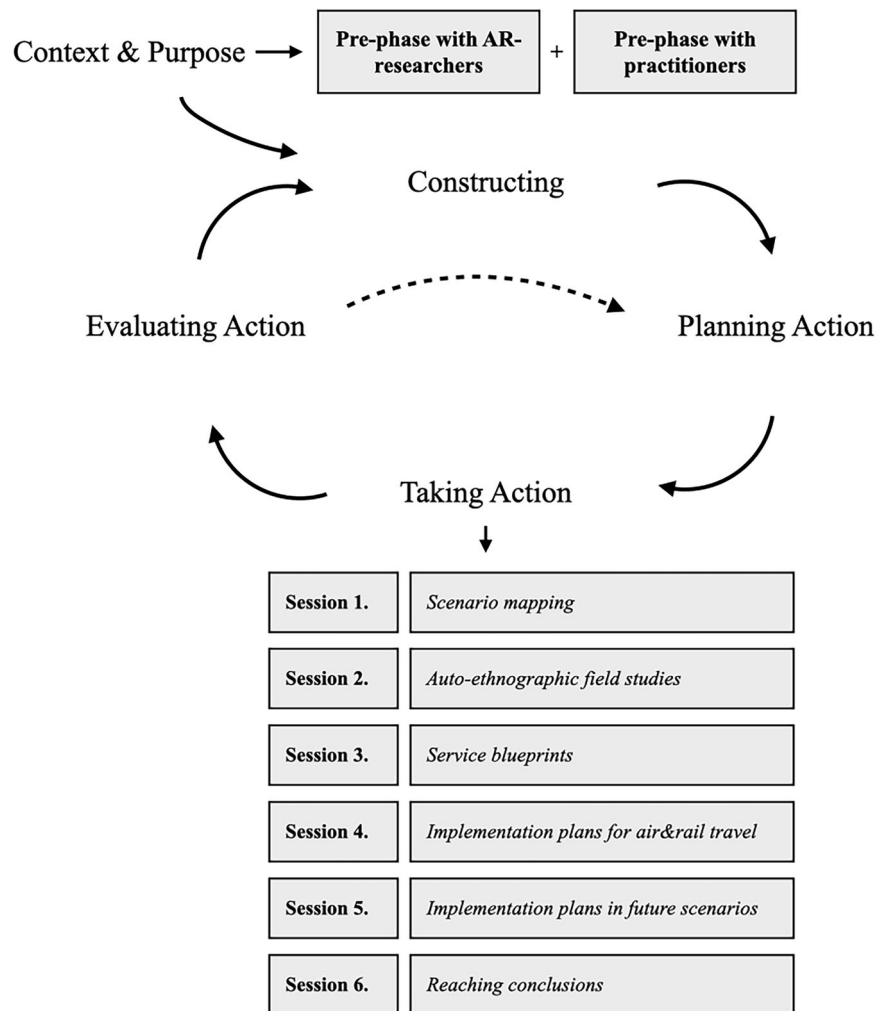


Table 1 | The emergence of system-level and collaboration-level tensions

Tension category	Tension	Code categories (support processes)	Code examples
System-level tension	T1. No control over airport slots	Strategy, market dynamics, and regulations	E.g., intra-airline slot competition, minimum connectivity requirements, and regulatory changes required
	T2. Conflicting priorities in train stop allocation	Physical infrastructure, scheduling, operations, (Inter) organizational	E.g., importance of transfer time, stopping train at the airport, security check for rail passengers, high costs
	T3. Misaligned scheduling between transport systems	Physical infrastructure, scheduling, operations, (inter) organizational, strategy, and regulations	E.g., transport capacity, rail meeting air connectivity standards, government steering of destinations
	T4. Different business models for air and rail travel	Scheduling, operations, commercial, (inter) organizational, strategy, market dynamics, regulations	E.g., Boarding pass check, dynamic pricing, air&rail as network strategy, airline not allowed to sell O&D train tickets
	T5. Fragmented booking systems	IT, operations, commercial, (inter) organizational, regulations	E.g., different train reservation systems, separate IT systems for rail and air, passenger information during disruptions, liability agreements required
	T6. Different passenger experiences between air and rail	Physical infrastructure, operations, commercial, and strategy	E.g., baggage issues in air-rail travel, many steps in the air travel process, O&D travel time different for transfer travelers, and explain passenger rights.
Collaboration-level tension	Sector differences affect mutual understanding	Participant involvement, co-creation dynamics, session methods, session process	E.g., subject-matter experts at the table, organizational openness, learning in action, substantive discussion needed for mutual understanding
	Embedding systems thinking in organizational processes	Market dynamics, participant involvement, session process, publication	E.g., absence of key stakeholders, internal feedback within each organization, uncertainty about external support for outcomes,
	Different organizational momentum	Market dynamics, participant involvement, the aim of sessions, and external influence	E.g., subject-matter experts at the table, creating a shared understanding, considering the current political context

research credibility, dependability and transferability^{78,79}. The report was reviewed by all authors to ensure a coherent and well-supported thematic synthesis.

Results

To answer the research question—which tensions emerge among key stakeholders during air&rail integration efforts in a European setting, and what does this reveal about the conditions required for successful air&rail collaboration?—we present two distinct but interrelated categories of tensions: system-level tensions and collaboration-level tensions. This distinction emerged inductively during the analysis of the co-creation sessions and helped structure the observed challenges. The study identified six system-level tensions arising from structural, technical, and commercial misalignments between air and rail systems. Additionally, three collaboration-level tensions were identified, relating to the dynamics that shape the integration process and the difficulties stakeholders faced in working together.

Tension 1. No control over airport slots

Practitioners involved in this case emphasized that for air&rail integration in Europe to yield sustainability benefits, airlines must reduce flight frequencies on certain routes and shift demand to rail.

However, air sector practitioners highlighted a barrier within the current regulatory framework: when an airline voluntarily relinquishes a slot, it risks losing access to that slot permanently. This is due to existing slot regulations, which mandate that unused slots be returned to a central pool for redistribution to competing carriers. While airlines may possess historic rights to specific slots, they do not have the authority to reduce the total slot capacity. They explained that slot allocation is governed by an independent regulatory authority, and all decisions concerning slot retention or redistribution are subject to standardized international rules. All practitioners recognized the difficulty of addressing this tension, as it would require new laws at the European or global level.

“This only works if you tighten these rules across all of Europe. It’s important to realize that.” (airport infrastructure manager)

This tension was explicitly addressed during the development of implementation plans (session 4) and reaching conclusions (session 6). During these sessions, differing views on slot allocation were expressed. Airline representatives recognized its link to sustainability but saw this as one of many operational and regulatory constraints, not a key driver for air&rail development. In contrast, rail operators viewed sustainability as a primary motivation for their involvement in air&rail initiatives, expecting integration efforts to support environmental goals. This led to a discussion about the goals of air&rail travel in this case. It did not yield short-term solutions or actions, as all practitioners recognized that resolving this tension requires a large-scale intervention.

Tension 2. Conflicting priorities in train stop allocation

Insights from the site visit (session 2) led practitioners to conclude that successful air&rail integration depends on trains stopping directly at the airport. They mentioned, based on this experience, that when rail and air infrastructures are not co-located, transfer times increase due to the need for additional transportation (e.g., shuttles or people movers). Airline representatives emphasized that direct rail access to terminals enhances travel efficiency, enables competition with air-to-air connections, and supports stakeholder collaboration.

“I think we have also established that if you do not stop at the airport, there is no air&rail integration.” (airport infrastructure manager)

Discussions during the co-creation sessions revealed a tension between air&rail passengers who need quick transfers and rail-only passengers who want to travel to the city center. This tension was particularly relevant in this case due to the presence of two international rail corridors leading to the

city’s main international rail hub. Each corridor served a different cluster of countries, but only one passed through the airport. As a result, trains on the other corridor would need to deviate from their optimal routes to stop at the airport, increasing travel time for rail-only passengers and reducing the attractiveness of rail-only travel. Rail operator representatives noted that since rail-only passengers constitute a larger market for rail operators than air&rail passengers, the rail sector cannot compromise too much for the benefit of air&rail travelers.

The airport practitioners emphasized that the government should decide where to implement air&rail services and which locations should be prioritized for stops. They also noted that large-scale integration of air&rail would require substantial modifications to the airport’s railway station infrastructure to accommodate a higher volume of passengers, representing a costly investment. Furthermore, the public rail infrastructure manager highlighted the financial burden of these upgrades and stressed the need for government involvement to make air&rail integration feasible.

Further exploration during the co-creation sessions, particularly session 3 on service blueprinting, suggested that an additional train stop before reaching the city center might be acceptable for rail-only passengers. A more optimal solution emerged with a proposed stop at the airport after halting at the central train station. This was discussed in the context of a planned new international rail hub on the outskirts of the city, which would be more strategically located in relation to the airport than the existing city-center hub. It was found that this solution could align with plans that had been and were being developed for new railway infrastructure, reducing the costs through synergistic advantages.

Tension 3. Misaligned scheduling between transport systems

During the co-creation sessions, efforts to coordinate air and rail schedules often stalled because of differing priorities between the two sectors. It was discussed that most international train operators in Europe have evolved as extensions of national train operators, which primarily generate revenue from domestic services and operate within national time frameworks. Consequently, practitioners mentioned that infrastructure, ticketing systems, and rolling stock vary between countries in Europe, complicating rail operators’ ability to provide transport across different routes. In contrast, global hub-and-spoke networks of airlines account for time zone differences and optimize code-sharing operations based on international circumstances. Common international schedules developed by rail operators often receive lower priority because both rail operators and infrastructure managers focus on national transportation within their respective countries.

“Our airline serves a large number of international travelers, whereas a rail operator is naturally much more focused on the national market. This makes direct comparisons challenging at times, but it is important not to lose sight of this distinction.” (airline)

During co-creation sessions, the need for alignment of train schedules with other countries’ rail networks and early and late airline flight times was discussed. However, running trains during off-peak hours was deemed commercially unviable for rail operators due to low demand from rail-only travelers. It was noted that without train connections to early and late flights, the airline would likely not adjust its network, leading to continued flight operations on these routes.

“It doesn’t matter if you run once an hour; it’s about having to operate a train at times that nobody wants. For example, having to run a train at 6 a.m., which is undesirable. Who will pay for that?” (rail sector)

Initially, rail operators stated that constrained capacity complicated adding new rail services without significant investment. However, co-creation in session 3 and session 4 revealed potential capacity for the near future, assuming planned infrastructure investments continue. Discussions highlighted that the bottleneck would be the economic viability for rail operators to exploit this capacity. Furthermore, with upcoming rail market

liberalization, governmental bodies would have limited control over schedules and routes, potentially leading to rail services not operating during less favorable times, important for air&rail travel.

“Initially, we had control through the concession, focusing on the main routes with the highest passenger demand. These were also the only routes where profitability was required. However, in the future, we may have more specific policy objectives in this area, but we will no longer have the ability to steer, as the concession will no longer exist.” (governmental body)

This tension related to *Tension 1 (airport slots)*, as any train services designed to connect with the flight network may prompt airlines to reassign the freed-up slots to other flights to avoid losing their slot rights. Consequently, we found that this made it unattractive for rail operators to adjust their rail schedule in this case.

Furthermore, the field study in session 2 allowed practitioners to experience firsthand—through an extended transfer—that frequent train service is as crucial as *Tension 2 (train stop allocation)*. Since air-to-air connections operate with efficient transfer times, the long transfer times associated with air&rail travel might hinder its competitive effectiveness. Importantly, these tensions were found to be mutually reinforcing in this case: if the train does not stop at the airport, the quality of the schedule becomes irrelevant. Conversely, even a well-located station may be ineffective without sufficient frequency. In this way, location and frequency are interdependent, with the tensions amplifying each other.

Tension 4. Different business models for air and rail travel

The findings show that different business models of air and rail operators discouraged both sectors from investing in joint solutions. The implementation plans (session 4) and their assessment in future scenarios (session 5) revealed this tension in depth.

The findings highlight the discrepancy between the demand-driven nature of airlines and the supply-driven transport system of national rail operators. Airline representatives explained that they adjust their networks to align with passenger demand and route profitability. Their hub-and-spoke model includes routes that may not be individually profitable but support overall network connectivity.

“We evaluate which flight is the most commercially viable and strategically important for the network.” (airline)

National rail operators in Europe work within a more rigid framework, following fixed hourly schedules set by public transport concessions. Rail sector representatives explained that their schedules do not change with demand shifts, and adjustments are limited to frequency changes that require long lead times. While international rail is somewhat demand-driven, it must integrate with national public transport, making it difficult to change destinations and frequencies.

“We create a timetable based on a base hourly schedule, and now we propose the same design approach in Europe. In rail, each hour ideally follows the same base pattern, or a variation thereof depending on market demand.” (rail sector)

It was discussed that the incremental costs of train services are higher and less easily distributed across international networks than those of hub airlines. Each route must be profitable on its own and is not effectively integrated into a larger network. Additionally, international hub airlines compete in an intercontinental market with many competitors, while rail operators face fewer competitors but encounter bureaucratic challenges within a smaller geographic scope.

This business model misalignment created ripple effects across multiple tensions. It reinforced *Tension 1 (airport slots)*, as the airline found it unattractive to give up slots without a financially viable rail

alternative. It is also related to *Tension 2 (train stop allocation)*, where rail operators deemed it unattractive to add airport stops that serve only a small group of air&rail passengers due to limited financial returns. In *Tension 3 (scheduling)*, the rigidity of rail scheduling seemed to clash with the demand-driven flexibility of airline schedules, affecting the economic feasibility of trains at unprofitable times. These dynamics suggest a coordination deadlock, with each sector waiting for the other to move first. Practitioners proposed that government intervention, through subsidies or shared risk mechanisms, could be a viable solution for issues that could not be resolved at the peer level.

“As long as it is not profitable or stakeholders see no benefit, they will not take action, perhaps except for sustainability reasons. [Air&rail] represents such a small share of their total passenger volume that it is unlikely to take off. You need to create a business model that works for both transport providers” (governmental body)

Tension 5. Fragmented booking systems

The lack of connectivity between airline and rail booking systems was found to limit the ability of passengers to book a seamless journey. This disconnect arose from differing collaboration experiences: the airline in this case operated within an air network for multi-leg flights, while it was noted that international rail operators often use separate digital platforms, especially across different countries, with limited integration.

During interviews, airline representatives explained that for air&rail journeys, they pre-book a set number of train seats and resell them in air&rail tickets. Consequently, we observed that the airline industry had a strong control over air&rail travel during the time of the study, which seemed to hinder a balanced collaboration between the sectors.

“Our airline has purchased a fixed number of seats through an IT solution from the rail operator. As a result, the airline can treat these train seats the same as airplane seats.” (airline)

During later co-creation sessions, friction emerged over managing disruptions caused by differences in booking systems between transport modes. It was discussed that airlines have more established procedures for assisting travelers during delays or cancellations, especially in transfers, and handle disruptions effectively. It was observed that in international rail, these processes are in general less mature, especially when delays occur around transfers between different operators. It was also discussed that airlines can manage disruptions effectively due to controlled boarding operations that provide precise passenger information. In contrast, train passengers have greater freedom before boarding, resulting in operators having less information about who is on board.

“In general, you don’t know exactly who is on board the train. You only know who bought tickets, and that’s it. There’s no record of where or when someone disembarked. Then I thought, that’s interesting because it also means you can’t rebook passengers, you simply don’t have that information.” (airport infrastructure manager)

This discrepancy indicates a lack of standardized liability for air&rail journeys compared to air journeys. Airline practitioners noted they provide disruption services to air&rail travelers because the airline sells the air&rail tickets. They cautioned against expecting rail operators to sell air&rail journeys, as this would make rail operators responsible for passenger compensation during disruptions. In air&rail journeys, the financial burden primarily falls on the airline, as a long-distance flight ticket is usually much more expensive than a train ticket. Practitioners explained that this disparity makes it more logical for airlines to cover compensation for disrupted train journeys rather than for train operators to compensate for disrupted flights. The drawback is that airlines will continue to bear the financial costs. An

actor managing an independent booking system was mentioned as a possible solution during session 3.

Moreover, one practitioner explained after session 6 that aligning booking systems would require data conversion between airline and rail IT systems, making the process labor-intensive and costly. Neither sector expressed a willingness to incur these costs; rail operators argued that the benefits did not justify the expense, while airlines stated their existing systems were already optimized for air&rail cooperation through collaboration with other airlines.

This tension was closely related to Tension 3 (scheduling): when booking systems are not integrated, it becomes challenging to dynamically align timetables or respond to real-time changes across different modes of transportation. Additionally, this issue was found to be connected to Tension 4 (business models). Since airlines sell air&rail tickets and assume the financial risk, they maintain control over the integrated product. As a result, we noted that they were designing their offerings to align with their own business models, making full integration of booking systems less urgent from their perspective.

Tension 6. Different passenger experiences between air and rail travel

The study found that passenger experiences - and therefore practitioner perspectives and priorities - differ considerably between air and rail transport. This was particularly salient through the field trip in session 2 and service blueprinting in session 3. Each sector viewed the modalities through its own lens, shaped by operational priorities and service standards.

We observed that airline practitioners often considered rail services inferior due to differences in onboard offerings, such as catering. They noted that passengers booking air&rail tickets expect a seamless transfer, like air-to-air connections. They also believed rail services lacked amenities like dedicated baggage handling and continuous passenger updates.

In contrast, rail operators did not see the need to adopt airline-style services; they viewed air travel as more cumbersome compared to their open-access processes, convenience, and seating comfort.

At an operational level, this tension was linked to Tension 4 (business models): diverging commercial logics lead the air and rail sectors to prioritize different aspects of service. For example, it was discussed that the maximum travel time for air&rail transfer passengers is shorter than that for international rail passengers on the same route. If the rail leg is too long, practitioners indicated that passengers may view it as an inferior alternative to air travel rather than an integrated part of their trip, as explained by an airline representative.

“4 h [of travel time] is correct for point-to-point travel, but not for transfers. The maximum for transfers is 2.5 h train travel times.”
(airline)

This tension was also connected to Tension 5 (booking system), as we found that fragmented systems may contribute to inconsistent service standards, making it unlikely that passengers will experience the journey as a single, seamless trip.

Tension 7. Sector differences affect mutual understanding

Data revealed that fundamental differences between the air and rail sectors complicated co-creation, particularly at the project's onset, as practitioners struggled to fully understand each other's sectors and perspectives. Industry standards were deeply embedded, with all practitioners being experts in their respective fields.

This tension was most pronounced among operators, while infrastructure managers exhibited similar tendencies, though it should be noted that the airport infrastructure practitioners demonstrated a solid understanding of the rail sector. In the governmental body, this

tension was not noted, as its representatives were two experts, one for each respective sector.

The field trip in session 2 was noted by practitioners as a valuable first step toward understanding each other's sectors, passenger experiences, and organizational priorities.

This tension was found to be linked to Tension 4 (business models): a fundamental lack of insight into each other's economic logic—demand-driven versus supply-driven—made it difficult to develop joint investment strategies or share risks. It was also related to Tension 5 (booking systems), where a limited understanding of technical and operational processes reduced trust and hindered integration, such as sharing passenger data or disruption responsibilities. Furthermore, it connected to Tension 6 (passenger experience), as differing service standards and assumptions about quality further deepened cross-sector misunderstandings.

“I find it remarkable that we can communicate so easily without truly understanding each other. All that time, I simply didn't grasp it fully. What perspective do they have?” (rail operator)

Tension 8. Embedding systems thinking in organizational processes

The co-creation sessions were designed by practitioners and AR researchers to understand the integration of air&rail travel from a systems perspective. However, reflecting on these sessions raised the question of whether the setup was overly complex.

“I sometimes wonder if we've made it too complicated with all those layers. [...] I'm not sure what the alternative is, but I do worry that it has become too complex. And then the question is, will we manage to translate this properly into a report?” (governmental body)

We observed that practitioners struggled to embed the generated knowledge, for example, gained through scenario mapping in session 1, into their organizations and to gain buy-in. Some practitioners began discussing project results and issues internally, which led to new input for and discussions in the project. A complication arose as the knowledge of the practitioners differed from that in their organizations. While practitioners may have acquired new knowledge through the co-creation sessions, their organizations had not, and ultimately, it is the organizations that must accept and implement changes.

“If you want to make decisions together and set priorities, you do need that boss as well and be able to rely on them.” (governmental body)

We found that the systems-level complexity of air&rail created challenges in documenting the findings of the co-creation sessions in a report. While making bandwidth estimates for passenger volumes and investments helped ground the discussion - particularly regarding the impact of the measures - the nuances necessary to fully capture the dynamics at play posed difficulties. This tension became particularly evident after session 5, where practitioners, for the first time, openly disagreed on certain topics as they were written down. With the end of the project nearing in session 6, the focus had shifted to considering the consequences of external communication of the project. The dialogue took on a more political dimension as various stakeholders articulated differing perspectives and aspirations. Extensive and repetitive discussions took place, which were not included in the initial project plan, but proved to be necessary to align perspectives and agree on what could be formally published.

“In general, I think these writing conclusions will still take a lot of time. I find it unlikely that we will finalize them today in a way that everyone agrees on. If that's the case, if it's not ready yet, then we simply need to keep working on it for longer.” (rail sector)

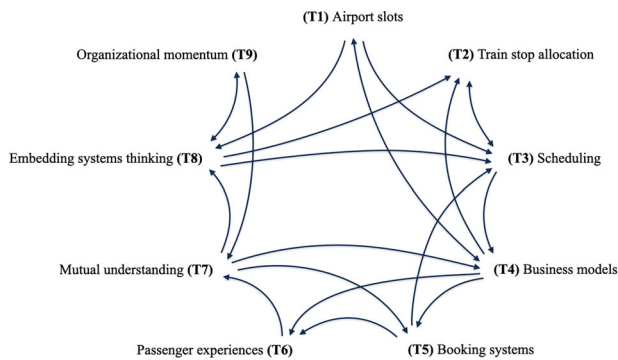


Fig. 3 | Interrelations between tensions. The figure shows the relations between the tensions identified in this study, highlighting their interdependence in the context of air & rail integration.

This tension was found to be connected to Tension 1 (airport slots), as during discussions, all practitioners continued to think from their own perspectives and struggled to identify solutions at the systems level. This tension was also related to Tension 2 (train stop allocation) and Tension 3 (scheduling). In those tensions, all practitioners agreed on the importance of airport stops and schedule alignment, but no decisions could be made because no actor was authorized to prioritize system-wide value over the interests of the individual organizations. Additionally, this tension was connected to Tension 7 (mutual understanding), as the lack of a shared language made it difficult for stakeholders to articulate system-level trade-offs and reach alignment.

Tension 9. Different organizational momentum

Difficulties with air&rail integration were found to stem partly from differing objectives among the involved organizations.

One organization joined later in the process because initially there were other, higher priorities within their organizational strategy. They became involved after the key project objectives had been defined during the *pre-phase*. This may have contributed to the difficulty in reaching an agreement on the project’s conclusions.

Moreover, while most of the practitioners expressed a need for developing a common longer-term strategy, which was also ingrained in the original project setup, there were organizations or practitioners who expressed a desire for a more action-focused, shorter-term approach.

Additionally, other parties that were not involved in the project, such as other international transport providers, were considered by the practitioners as crucial for future full-scale air&rail integration given the project’s international scope. Practitioners discussed that market liberalization might stimulate the entry of new players into the market, further complicating the landscape.

A contextual issue that seems to have influenced the priorities of some participating organizations and the momentum for the air&rail project was the change in national government during the project. The new government set different priorities, and simultaneously, a change occurred in how some organizations positioned themselves, also regarding the sustainability goals in the project.

“On the one hand, it’s very difficult to take action because not all interests are aligned. And it becomes even harder since there’s no clear direction from the government on where we want to go” (Airport infrastructure manager)

This tension was linked to Tension 7 (mutual understanding) because some organizations joined the process later or pursued different strategic goals, leading to misunderstandings among stakeholders. Additionally, it connected to Tension 8 (systems thinking), as diverging organizational dynamics hindered the development of shared momentum. While some

stakeholders were prepared to act, others needed to cultivate internal support, which slowed the collective ability to engage in system-level decision-making.

Interrelations between tensions

While each of the nine tensions emerged as a distinct challenge during the co-creation process, the tensions described in this chapter indicate that they are part of a larger systemic web of interdependencies. To clarify these dynamics, Fig. 3 visually illustrates the relationships between the tensions discussed in this chapter. These connections were informed by inferred causal relationships²⁴ put forth by practitioners during the co-creation sessions and the authors’ cross-analysis of the resulting data. By mapping these dependencies, we aim to promote more integrated thinking about the tensions related to air&rail integration. The figure indicates how the connections between the tensions are shaped, and whether they are unidirectional or bidirectional according to this study’s data. Supplementary Note 2 gives a description of the connections.

The figure shows that tensions 3, 4, and 7 have the most connections. This suggests that addressing the tensions in scheduling and business models, as well as fostering mutual understanding among stakeholders, could significantly impact on air&rail integration.

Discussion

This study enhances the literature on air&rail integration by providing a deeper understanding of the tensions that arose during an air&rail integration project in a European context. Our findings outline the dynamic process of co-creation among operators, infrastructure managers, and governmental bodies. The most critical tensions arose at the interface between air and rail operators, yet all actors were necessary to address the tensions effectively. Therefore, this research positions air&rail integration in Europe within the service ecosystem literature^{27,29,80}, revealing that no single actor can create value independently.

Many tensions identified in this study are specific to integrated *multimodal* air&rail transport^{2,3}. Had the integration focused instead on *intermodal* air&rail coordination^{2,3}—where each operator maintains separate ticketing and scheduling systems—tensions such as conflicting schedules, different business models, fragmented booking platforms, and collaboration-level tensions would likely have been less prominent. However, this would also limit the potential benefits of seamless passenger experiences.

The interconnectedness of the tensions suggests deeper systemic themes in air&rail integration. We argue that these tensions should not only be viewed as individual challenges but, perhaps more importantly, as reinforcing frictions. Understanding how these tensions interact provides a more nuanced explanation for why air&rail integration is challenging to achieve in practice in Europe and how this can be improved. In what follows, we connect the results to existing literature by grouping the tensions into three underlying themes (Table 2): 1) financial incentives, 2) regulatory frameworks, and 3) historical legacies.

Based on our analysis, financial incentives appear to underlie most system-level tensions—except for tension 6 (passenger experiences)—and collaboration-level tension 9 (different organizational momentum).

Airlines, as private entities, must remain profitable, and it was observed that they were generally unwilling to relinquish airport slots unless compensated (tension 1). Similarly, resolving tensions related to train stop allocation (tension 2), schedule alignment (tension 3), and booking system integration (tension 5) requires financial investments or compromises that operators were hesitant to make. This reluctance arose partly from the substantial infrastructure upgrades needed^{21,51-53}. Next, while research underscores the importance of synchronizing air and rail schedules^{2,12}, our findings indicate that differing scopes of airlines, which operate under an international framework¹, and rail operators, constrained by national transport^{40,41,44}, may cause schedule alignment issues that lead to trains operating at less advantageous times for rail operators. Additionally, connecting different booking systems was found to necessitate investment, and

Table 2 | Grouping of air & rail integration tensions into broader themes

Theme	Description	Related tensions
Financial incentives	Tensions are influenced by the need to create commercially attractive offers and avoid financial losses.	T1: No control over airport slots T2: Conflicting priorities in train stop allocation T3: Misaligned scheduling between transport systems T4: Different business models for air and rail travel T5: Fragmented booking systems T9: Different organizational momentum
Regulatory frameworks	Regulatory frameworks determine what is allowed and what is not, making coordination and integration legally and institutionally complex.	T1: No control over airport slots T2: Conflicting priorities in train stop allocation T3: Misaligned scheduling between transport systems
Historical legacies	Air and rail sectors are shaped by decades-old systems, leading to institutional inertia.	T1: No control over airport slots T2: Conflicting priorities in train stop allocation T3: Misaligned scheduling between transport systems T4: Different business models for air and rail travel T5: Fragmented booking systems T6: Different passenger experiences between air and rail travel T7: Sector differences affect mutual understanding T8: Embedding systems thinking in organizational processes

neither air nor rail operators have demonstrated a willingness to undertake this in our study.

A deeper issue lies in the fundamental differences between the business models of airlines and rail operators (tension 4), as both seek financial stability but pursue it through different strategies.

Our study aligns with existing research^{10,13} by demonstrating that rail operators need to be profitable on individual routes, whereas airlines may incur losses on certain segments and compensate through the hub-and-spoke model. This structural mismatch suggests difficulties for cooperation.

Revenue-sharing was noted as a barrier in previous studies^{2,18}, but it was not a key tension in our case. This may be due to the airline bearing the financial burden of air&rail journeys and being the primary seller of integrated tickets. This arrangement reinforces the airlines’ dominant role in air&rail products, with rail operators not expected to offer such services independently. The European Commission’s Sustainable and Smart Mobility Strategy¹⁵ aligns with this by urging airlines to sell multimodal tickets, resulting in inequitable air&rail integration among stakeholders.

As noted in previous research, we found that at the time of the study, the small volume of air&rail travelers reduces commercial incentives to invest in air&rail integration^{2,12,52}. Consequently, we cautiously suggest that individual organizations may not be expected to make such investments or choices without financial incentives. This highlights the potential role of an orchestration entity that can facilitate collaboration and make decisions that individual stakeholders may avoid, especially when those decisions benefit some organizations while disadvantaging others.

This aligns with the notion from service ecosystem theory that value co-creation by different organizations requires collaborative resource integration among multiple actors^{28,29,81}. While Vargo and Lusch²⁸ do not explicitly refer to an “orchestrator,” their emphasis on coordination mechanisms implies the necessity of such a role. Frow et al.⁸² state that actors with diverging opinions and goals within a service ecosystem can be brought together through orchestration. Similarly, Friend and Malshe⁸³ describe that orchestrating activities with stakeholders and facilitating orchestration among other stakeholders is vital for ensuring coherence, alignment, and effectiveness within multi-actor systems. Building on this, Caridà et al.⁸¹ argue that the role of the orchestrator remains underdeveloped in ecosystem research and call for more empirical investigation into how this role is enacted in transport systems.

In the context of multimodal transport, orchestration is beginning to receive attention. The Bonvoyage project has demonstrated how digital routing platforms can integrate services from multiple providers⁸⁴, while the

ORCHESTRA project⁸⁵ has introduced a traffic orchestrator within a polycentric governance architecture to align rail, road, air, and water systems. Additionally, the EU’s TEN-T framework provides a macro-level structure for transnational infrastructure planning. However, these initiatives mainly focus on technical or data-level coordination.

During our 16-month AR study, the absence of an actor with overall decision-making authority appears to have led to a lack of alignment on next steps, preventing any action for the system as a whole. This lack of progress was likely hindered by constraints that no single actor could resolve alone.

Furthermore, regulatory frameworks played a significant role during the co-creation sessions, and they can be expected to influence the integration of air&rail transport in wider Europe.

Existing regulations hindered progress toward air&rail integration in our case study, particularly in Tension 1 (airport slots). Airport slot allocation is managed by independent entities⁴⁵, and this, along with capacity constraints, limits the potential for air&rail integration to reduce CO2 emissions^{41,50}. Tension 2 (train stop allocation) and Tension 3 (scheduling) highlighted similar issues, as rail networks are predetermined at the national governance level⁴⁴, making them difficult to change.

Discussions also focused on how some legislation may change. For example, due to the upcoming European rail market liberalization, the government might partially lose control over operators regarding train stops (Tension 2) and train schedules (Tension 3). Consequently, it was discussed that steering integrated air&rail development may become more challenging if operators apply for routes they deem promising, instead of governance organizations assigning routes for auctions⁴⁴.

The effects of the current and forthcoming legislation identified in this case study strengthen the suggestion for a governing body that can stimulate air&rail integration in Europe. This is supported by existing literature on multimodal transport^{11,20,21,23}. We believe that such a body is important for effectively utilizing policy and regulation as adaptable levers to the benefit of air&rail development, in line with existing research⁵. In the air sector, an example of a governing body is IATA, which makes decisions on topics where governments cannot reach consensus⁴³.

Based on our findings, we believe that air&rail travel requires new responsibilities for such an entity or possibly an entirely new actor, as it necessitates intervention that spans the transportation system. In Europe’s historically nationalized and now increasingly liberalized transport sectors, top-down coordination from a single public authority is unlikely. Therefore, adding a governing/orchestration entity or function to the European-level ecosystem emerges as a more feasible and context-sensitive alternative.

Finally, we found that many of the tensions stem from the legacy of existing systems, which have shaped how stakeholders operate. As a result, practitioners tended to approach challenges within the confines of their own systems, aligning with existing research that describes how actors seek to maintain control over their domains⁵². While this may seem obvious or abstract, overcoming siloed thinking is crucial for air&rail integration, as its absence—evident in most tensions—perpetuates the fragmentations of current systems.

We found that this siloed thinking was influenced by legacy networks^{1,40–42}, as well as long-standing partnerships in the air sector¹ and divergent infrastructure between air and rail^{40–42} that is difficult to change^{21,51,53}. These systemic structures and historical responsibilities illustrate the inertia described by Dooms et al.⁵⁹ in the context of complex port infrastructure development.

The tensions indicate that when attempting to change long-standing practices, resistance can arise from some involved organizations, as they perceive any changes as a threat to the success of their systems. This was evident in tensions related to airport slots, train stop allocation, scheduling, business models, booking systems, and passenger experiences. Especially passenger experiences, highlighted in existing literature with various strategies for customer relationships¹², further emphasize the reluctance of operators to move away from their established systems. Consequently, we found that operators, primarily airlines, strive to replicate the travel experience they provide within their air systems, suggesting a lack of real resource integration. This supports previous research that identifies air travel as the focal point of air&rail travel² (Toet et al., under review).

On collaboration levels, we found that the legacy of systems influenced a lack of mutual understanding (tension 7) among actors. This aligns with existing research on the competitive attitudes that air and rail operators have toward each other^{10,48}, which inhibits the sharing of business information^{5,20}. However, we also observed that during co-creation, a considerable amount of the required information was already available among individual practitioners and their organizations. By convening them in co-creation sessions, they were able to collaboratively synthesize this knowledge on a system-level.

Reflecting on the potential of air&rail transport (section 2.2)—airport connectivity²⁰, lowering CO2 emissions^{9,10} and network expansion^{9,10,23}—we advocate that achieving successful air&rail integration benefits from organizations to adopt an innovative, whole-system mindset during co-creation sessions. Existing frameworks, processes, standards, and policies were identified as key leverage points in the transportation system⁸⁶, and our findings suggest that these should be viewed as variables that can be designed rather than fixed preconditions.

This study aimed to inform both practice and research on transport integration, though its insights on air&rail integration in Europe may have limited transferability to other contexts^{24,78}.

The study was conducted in a country where the major hub airport is near national borders, making long-distance trains effectively international. This geographical and institutional setting required cross-border collaboration, which may differ from cases involving only national operators.

Additionally, as a single case study, the findings were influenced by specific political, organizational, and contextual factors⁶². The applicability of our findings to other contexts, especially outside Europe, may be limited. Although the study does not seek to produce universal knowledge, we encourage readers to reflect on where similar dynamics might apply²⁴. To help the assessment of the transferability of the results²⁴, a description of the co-creation sessions is provided in the Supplementary Information.

Moreover, the study was based on a purposively selected case²⁴ embedded in an existing collaboration between key stakeholders. While this facilitated trust-based access and open dialogue, pre-existing institutional relationships and familiarity among practitioners may have shaped both collaboration dynamics and research outcomes. Replicating such processes in other regions with different governance models or market conditions may

be challenging. Beyond these directly involved organizations, other important stakeholders, such as transport operators from other countries, are crucial for air&rail integration.

Furthermore, the co-creation sessions were designed to address some known tensions previously identified by AR researchers, practitioners, and the literature, while also exploring potential future directions. This approach may have pre-emptively resolved some tensions. For example, the field study encouraged practitioners to understand each other's end-users and perspectives from the outset, helping to identify Tensions 6 and 7 early and allowing for early resolution.

Finally, several potential solutions, such as adding a train stop or building a new international rail hub, emerged during the co-creation process. These proposals reflect stakeholder input but were not developed by the authors. While practitioners acknowledged the complexity of these solutions in terms of cost, environmental impact, and operational practices, these factors were not systematically analyzed. Therefore, the proposals should be viewed as exploratory and indicative of relevant interventions.

Building on the limitations noted above, future research could enhance the understanding and practical application of air&rail integration through several avenues.

Future studies should replicate this research with a broader range of participants, organizations, and regions. Including more diverse transport stakeholders and exploring additional hubs, such as multimodal rail stations, could test the relevance of the identified tensions. Investigating settings without prior collaboration could also illuminate how trust and alignment develop from scratch.

Next, future research should explore strategies for managing the tensions identified in this study, particularly concerning orchestrators and governing bodies. This could clarify how such entities facilitate integration processes, especially in fragmented governance contexts. Further investigation into the interrelations between the tensions can reveal effective intervention points.

While some integration barriers discussed in the literature review (e.g., data-sharing and revenue-sharing issues) were not dominant in the empirical data, they remain critical for air&rail integration and should not be overlooked in future research.

Furthermore, the impact of co-creation session design on the identification of tensions warrants further exploration. Specifically, it would be valuable to study how methods such as scenario planning and field studies at the project's outset influence the type and timing of tensions uncovered.

Finally, future research could also examine how session content is embedded within participating organizations over time and how that affects organizational buy-in and sustained commitment. Understanding how co-creation processes navigate differing strategies and organizational momentum would enhance knowledge about what supports or inhibits collaborative progress in air&rail integration.

Conclusion

This study identified nine interrelated tensions that emerged among transport stakeholders during co-creation for air&rail integration in a European context. By adopting a service ecosystem perspective, this study provides a more holistic understanding of the integration tensions related to air&rail travel in Europe. The findings underscore that while the air and rail sectors share a common goal of facilitating seamless air&rail journeys, their differences in IT, infrastructure, operations, scheduling, commercial practices, and (inter)organizational practices create tensions that hinder successful integration. Additionally, market dynamics and regulations complicate the integration process but also offer opportunities for air&rail travel when approached differently.

Six system-level tensions were identified regarding air&rail integration: no control over airport slots, conflicting priorities in train stop allocation, misaligned scheduling between transport systems, different business models for air and rail travel, fragmented booking systems, and different passenger experiences between air and rail travel. The analysis

also revealed three collaboration-level tensions related to air&rail integration: sector differences affect mutual understanding, embedding systems thinking in organizational processes, and different organizational momentum.

The tensions highlighted in this study indicate that when it comes to critical decisions, air&rail integration is primarily approached from the perspectives and interests of the involved organizations. To achieve sustainable and successful air&rail integration, we emphasize the need to move beyond this siloed approach. This case study demonstrates that co-creation can support a smoother development process by fostering mutual understanding between organizations.

However, certain challenges extend beyond the decision-making power of peer-level collaboration. Our findings suggest that introducing an orchestration/coordination entity into the organizational ecosystem could facilitate cooperation and decision-making. Supporting this with legislation at the European level may provide a promising way forward. There are multiple ways to operationalize such a function, for example, through an expanded transport authority, a regulated cooperation agreement, or even monopolization under a single coordinating actor. The necessity and implementation of such a function will depend on the institutional, legal, and political context of each country or region. These insights emphasize that successful air&rail integration requires innovative thinking that transcends existing regulatory and institutional frameworks.

Data availability

The datasets generated and analyzed during the current study are not publicly available due to confidentiality concerns, as they contain information that may be traceable to the participating practitioners and organizations. However, the data are available from the corresponding author upon reasonable request.

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Author contributions

A.T. conceptualized the study, collected and analyzed the data, and prepared and finalized the manuscript. J.K. also conceptualized the study, collected and analyzed the data, and contributed to the review and editing of the manuscript. K.B. contributed to data analysis and reviewed and edited the manuscript. S.S. also reviewed and edited the manuscript. All authors read and approved the final version.

Competing interests

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Additional information

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