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Towards Passenger Oriented Multimodal Transport at Airports

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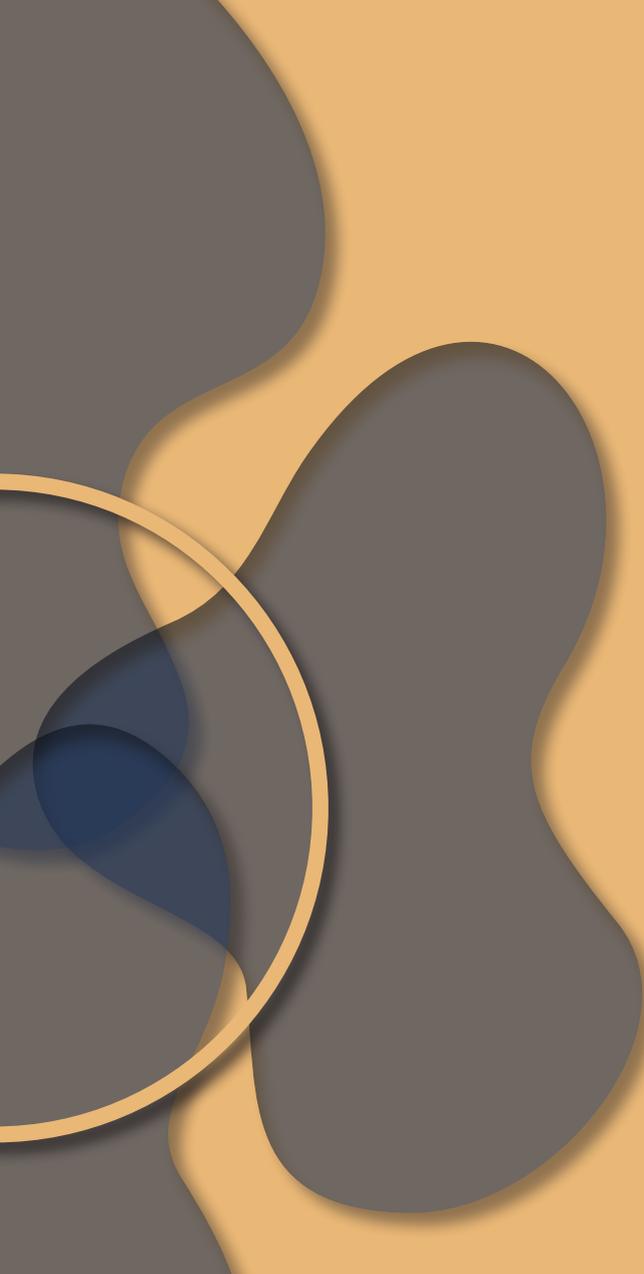Please check the document version above.

Aniek Toet

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Towards Passenger Oriented Multimodal Transport at Airports

Where it Connects

Towards Passenger-Oriented Multimodal Transport at Airports

Dissertation

for the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, Prof.dr.ir. T.H.J.J. van der Hagen,
chair of the Board of Doctorates
to be defended publicly on
Wednesday 10 December 2025 15:00 o'clock

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Book cover design, layout & graphics by Aniek Toet

Printed by Ridderprint

An electronic version of this dissertation is available at https://repository.tudelft.nl

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PROLOGUE

A title is the briefest possible summary of a story. Finding one for this dissertation compelled me to reconsider the story I wanted to tell.

What began as research into transforming airports into multimodal transport hubs, gradually evolved over the four-year PhD process into something broader and more nuanced than I initially anticipated. At the start, the airport was the focal point of my research and the lens through which I first explored multimodality. As the research progressed, that perspective shifted. The airport (as an organization) revealed itself not as the main character in this story but as one actor among many: a facilitator, occasionally a catalyst, but rarely the lead.

And so, a different perspective came into focus, one that no longer centered on a single place or organization but on the ecosystem as a whole. I investigated the systems that interact, the people who operate within them, the processes that shape one another, and the contextual dynamics that either build bridges or create barriers. Multimodal transport, I realized, encompasses all connections between travel modes.

In those connections, one recurring theme kept resurfacing: boundaries. Boundaries between systems, such as aviation and rail, each with their own logic, structures, values, and goals. Boundaries between organizations, often long-established and deeply rooted in existing routines and procedures. And boundaries between countries, sometimes demarcated by people and gates, as during passport control at the airport, and sometimes physically felt through changes in infrastructure, such as differing power lines, signals, and timetables in rail transport.

Boundaries can protect, structure, and provide clarity. As such, they are crucial in a PhD journey: without boundaries, expectations can grow indefinitely, leaving the PhD candidate vulnerable to an overwhelming workload. However, boundaries can also divide and impede innovation. The phenomenon of multimodal travel, central to this dissertation, seeks to blur those very boundaries to offer travelers a more connected and seamless experience.

In this thesis, I explored how systems, organizations, people, and transport can be brought closer together. I aimed to understand the differences among these systems by identifying friction points and intervening where possible.

The title of this dissertation reflects that realization. It invites readers to explore how design can serve as a tool for integration in a world defined by boundaries, ultimately guiding us to *where it connects.*

WHERE IT CONNECTS

It begins with a question[i],

born in moments of reflection.

What drives multimodality today?

What contexts and purposes lead our way?

By stepping into their stride[ii],

we leave assumptions at the side.

Each journey blurs the lines we drew,

and moving through, we create them too.

Beneath the doing lies the why[iii],

designed by those who stand nearby.

Through open words and searching eyes,

layers fall and systems rise.

We create what none could do alone[iv],

from viewpoints far beyond their own.

By dropping all that thought protects,

we find new meaning where it connects.

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GLOSSARY

Abbreviation	In Full
AR	Action Research
EU	European Union
HSR	High-speed Rail
H&S	Hub-and-spoke model
ICT	Information and Communication Technologies
MaaS	Mobility-as-a-Service
MJIAT	Multimodal journey involving air transport
MTH	Multimodal Transport Hub
PT	Public Transport
SET	Service Ecosystems Theory
TEN-T	Trans-European Transport Network

SUMMARY

With the rise of digitization and the increasing emphasis on sustainability, future mobility systems are expected to rely more on multimodal journeys, where various transport modes are combined into a seamless travel experience. This approach shifts the focus from individual transport modes to the overall passenger experience. In the air transport sector, air&rail integration exemplifies such multimodal journeys, providing opportunities to reduce congestion at airport hubs, enhance airports' competitive position, and promote more sustainable mobility. However, achieving seamless multimodal travel at airports is a challenge due to the integration of separate transport systems into a cohesive network.

Research goal

This dissertation investigated the integration of transport modes at airport hubs to improve passenger-oriented multimodal air journeys and offers insights for practitioners in the mobility sector, designers, and researchers, to design connections between transport modes. The following research questions guided the study:

1. *What are the properties of a passenger-oriented multimodal air journey?*

2. *What influences the effective delivery of a passenger-oriented multimodal air journey?*

3. *What tensions arise when stakeholders engage in the (co-)creation of integrated multimodal air journeys, and how can these be mitigated?*

Methodology

A qualitative Action Research approach was employed, beginning with a preliminary exploration of the context and purpose, followed by three iterative and reflective research cycles. This method facilitated an in-depth understanding of how passenger-oriented multimodal air journeys are developed and delivered in practice, as well as the identification of opportunities for improvement. In each research cycle, the primary researcher engaged at different levels: starting with reflections on personal experiences and assumptions through first-person practice, moving to interviews with field experts via second-person practice, and finally examining dynamics within the system related to the researched air&rail case from a third-person practice. The research focused on the integration of passenger-oriented multimodal air travel, using air&rail as the primary case, with each research cycle conducted in a comparable European context

involving different participants and data sources.

Context & purpose

The Action Research began with a literature review and an embedded field study within an airport organization to understand real-world practices. This exploration led to three guiding principles: prioritizing the passenger experience, adopting a systems perspective to address the complexity of multimodal integration, and providing actionable recommendations for practice. These principles proved to be essential in both the literature and practice for understanding and improving multimodal air travel and shaped the remainder of the study.

Research cycle 1

The first research cycle aimed to better understand the travel phases involved in multimodal air journeys, the factors influencing the passenger experience, and the role of airports in facilitating these journeys. Through autoethnography, the research cycle reflected on the travel experiences of both researchers and practitioners. The study identified eight key integration factors: journey explanation and preparation, personalized and proactive assistance, wayfinding, proximity of modalities and facilities, multimodal transfer services, balanced transfer time, waiting environments, and in-travel comfort. The findings show that multimodal air journeys cannot be treated as separate segments but must be designed as a seamless whole. From the passenger's perspective, each transfer between modes represents a system boundary crossing, setting multimodal travel apart from single-mode journeys. This highlights the need for close collaboration between transport systems to place the passenger experience at the center of multimodal air travel.

Research cycle 2

The second research cycle aimed to enhance the understanding of delivering passenger-oriented multimodal air journeys by interviewing transport and airport hub operators. This research cycle employed service blueprinting to analyze the processes that support the delivery of these journeys. The research identified five key factors influencing passenger experience: integrated booking systems, whole journey guidance, transfer time and ease, baggage management, and disruption management. An important insight was that the passenger experience already starts before departure, making pre-journey factors such as booking systems and journey preparation essential. To ensure that these factors are perceived in a positive way by travelers, processes –

such as IT, infrastructure, scheduling, operations, commercial activities, interorganizational activities, and strategic efforts – and external conditions – like market dynamics and regulations – should be aligned. The study further indicate that airlines often lead in shaping multimodal air journeys, through the *"baseline modality"* concept, which tends to implicitly set standards and shaping passenger expectations. Progress towards multimodal air journeys is hindered by delivery mechanisms that fragment responsibilities and goals among operators, and perpetuate competition in the market. Successful multimodal air transport delivery relies on collaboration within and across systems and regulations that promote integration.

Research cycle 3

In the third research cycle, interviews and co-creation activities were used to explore how stakeholders experience and shape the integration of air&rail transport in practice. The research identified six system-level tensions that emerged during co-creation: 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 were observed: limited mutual understanding, challenges in applying systems thinking within organizations, and differences in organizational momentum. These tensions extend beyond collaboration among individual partners and demonstrate the need for an orchestrator in decision-making, as well as for a European governing body to establish a supportive regulatory framework.

Conclusions

This research demonstrated that integrating transport modes with aviation necessitates a fundamental redefinition of the airport as a multimodal transport hub, where the airport is not seen merely as a physical junction but as a strategic actor in multimodality. At these hubs, various boundaries converge: between modalities, organizations, countries, and regulations, as well as within the transport systems themselves. These multiple boundaries explain why multimodal ecosystems are likely to stagnate. Furthermore, the research found that the baseline modality concept often steers passenger expectations toward a dominant modality (often the flight segment). As long as passengers base their experience on one (the dominant) modality, fragmentation in passenger experiences is likely to persist. The baseline modality also emerges in the delivery and development of multimodal air journeys. Airlines play a dominant role in this process, exerting significant influence on the design of the multimodal journey. This gives rise to a paradox:

insufficient coordination between transport systems can undermine the performance of the overall multimodal system, while passengers may simultaneously benefit from certain services provided by the air transport system throughout the entire journey.

Successful multimodal integration requires collaboration among various transport systems, joint decision-making with diverse stakeholders, and regulatory frameworks that are both flexible and supportive, all facilitated by effective orchestration. The transition to multimodal air transport largely depends on reconfiguring existing structures. This process is driven by collaboration, design practices, and experiential learning, where knowledge and practices are reshaped through open and shared innovation processes.

Future research and recommendations

The thesis outlined future research opportunities, such as exploring other contexts, diversifying participant groups, further developing key concepts, applying design interventions in transport, and studying the impact of digitalization on mobility. It concludes with action-oriented recommendations.

Operators should focus on ensuring clear communication, coordinated information, trained staff, consistent service quality, direct airport connections, aligned timetables, interoperable systems, simplified baggage handling, and brand-integrated partnerships.

Airports and other hubs can support multimodal air journeys by training staff, providing clear signage, ensuring efficient transfer infrastructure, streamlining processes, and offering comfortable waiting areas for each mode of transport.

Governments can enhance multimodal air travel by supporting reliable rail systems, offering financial incentives to stakeholders, facilitating negotiations, and ensuring viable business models for operator alliances.

Finally, the thesis emphasizes that successful multimodal air integration requires collaboration among stakeholders built on experiential learning (such as going on field studies), long-term internal anchoring of insights, and continuity in participation to ensure understanding and trust.

SAMENVATTING

Met de opkomst van digitalisering en de toenemende aandacht voor duurzaamheid zullen in toekomstige mobiliteitssystemen steeds vaker multimodale reizen voorkomen, waarbij verschillende vervoersmiddelen worden gecombineerd tot één naadloze reiservaring. In deze benadering verschuift de focus van vervoersmiddelen naar de totale reisbeleving van de passagier. Binnen de luchtvaartsector vormt de integratie van lucht- en treinvervoer (air&rail) een goed voorbeeld van dergelijke multimodale reizen. Gecombineerde air&rail-reizen bieden mogelijkheden om de drukte op luchthavenknooppunten te verminderen, de concurrentiepositie van luchthavens te versterken en duurzamere mobiliteitsoplossingen te stimuleren. Toch blijkt het in de praktijk een uitdaging te zijn om naadloze multimodale reizen via luchthavens te realiseren, vooral omdat het samenvoegen van afzonderlijke vervoerssystemen tot één samenhangend netwerk ingewikkeld is.

Onderzoeksdoel

Dit onderzoek richtte zich op de integratie van vervoersmiddelen op luchthavenknooppunten, met als doel reizigersgerichte multimodale luchtreizen te ontwerpen. Het onderzoek levert waardevolle inzichten op voor mobiliteitsprofessionals, ontwerpers en onderzoekers die zich inzetten voor het verbeteren van de verbindingen tussen vervoersmiddelen. Daarbij stonden drie centrale onderzoeksvragen centraal:

1. *Wat zijn de kenmerken van een reizigersgerichte multimodale luchtreis?*

2. *Welke factoren beïnvloeden de succesvolle uitvoering van een reizigersgerichte multimodale reis?*

3. *Welke spanningen ontstaan er wanneer verschillende belanghebbenden samenwerken aan de ontwikkeling van geïntegreerde multimodale luchtreizen, en hoe kunnen deze spanningen worden verminderd?*

Methode

Het onderzoek maakte gebruik van een kwalitatieve actie-onderzoekmethode, waarbij een verkennende fase werd gevolgd door drie iteratieve en reflectieve onderzoekscycli. Deze aanpak maakte het mogelijk om diepgaand inzicht te krijgen in hoe reizigersgerichte multimodale luchtreizen in de praktijk tot stand komen en waar verbeteringen mogelijk zijn. Tijdens elke onderzoekscyclus was de hoofdonderzoeker op verschillende niveaus actief: van reflecties op persoonlijke ervaringen en aannames (first-person

practice), via interviews met experts uit het werkveld (second-person practice), tot het bestuderen van de systeemdynamieken die samenhangen met de onderzochte air&rail-casus (third-person practice). De centrale focus van het onderzoek lag op de integratie van lucht- en treinvervoer, waarbij elke onderzoekscyclus werd uitgevoerd in een vergelijkbare Europese context, maar telkens met verschillende deelnemers en gegevensbronnen.

Context en doelstelling

Het onderzoek begon met een literatuurstudie en een praktijkstudie binnen een luchthavenorganisatie om inzicht te krijgen in de dagelijkse werkelijkheid van multimodale integratie. Deze verkenning leidde tot drie leidende uitgangspunten: de reizigerservaring moet centraal staan, het is noodzakelijk om een systembenadering toe te passen vanwege de complexiteit van multimodale integratie, en het onderzoek moet aanbevelingen opleveren die toepasbaar zijn in de praktijk. Deze uitgangspunten bleken in zowel literatuur als praktijk essentieel voor het begrijpen en verbeteren van multimodale luchtreizen en vormden de basis voor de rest van het onderzoek.

Cyclus 1

De eerste onderzoekscyclus had als doel een beter inzicht te krijgen in de verschillende reisfasen van multimodale vliegreizen, de factoren die de passagierservaring beïnvloeden en de rol van luchthavens bij het faciliteren van deze reizen. Door middel van auto-etnografie werden de reiservaringen van zowel onderzoekers als professionals geanalyseerd.

Uit het onderzoek kwamen acht belangrijke integratiefactoren naar voren: duidelijke uitleg en voorbereiding van de reis, persoonlijke en proactieve hulp, bewegwijzering, nabijheid van vervoersmiddelen en voorzieningen, overstapdiensten, een goed afgestemde overstaptijd, prettige wachtruimtes en comfort tijdens de reis.

De resultaten laten zien dat multimodale vliegreizen niet kunnen worden benaderd als losse onderdelen, maar ontworpen moeten worden als een naadloos geheel. Voor de reiziger betekent elke overstap tussen vervoersmiddelen een grensovergang tussen systemen, wat multimodaal reizen wezenlijk anders maakt dan reizen met één vervoersmiddel. Dit onderstreept de noodzaak van nauwe samenwerking tussen vervoerssystemen, zodat de passagierservaring centraal komt te staan.

Cyclus 2

De tweede onderzoekscyclus richtte zich op een beter begrip van hoe passagiersgerichte, multimodale vliegreizen kunnen worden

aangeboden. Hiervoor zijn gesprekken gevoerd met vervoersbedrijven en luchthavenbeheerders. Met behulp van service blueprinting zijn de belevingsfactoren en achterliggende processen in kaart gebracht die deze reizen mogelijk maken. Uit het onderzoek kwamen vijf factoren naar voren die de beleving van de reiziger sterk beïnvloeden: geïntegreerde boekingssystemen, begeleiding tijdens de hele reis, de tijd en het gemak van overstappen, bagageafhandeling en het omgaan met verstoringen.

Een belangrijke conclusie is dat de reiservaring al begint vóór vertrek. Daarom spelen zaken als boekingssystemen en voorbereiding een belangrijke rol. Om ervoor te zorgen dat reizigers deze aspecten positief ervaren, moeten processen zoals IT, infrastructuur, planning, operatie, commerciële activiteiten en samenwerking tussen organisaties goed op elkaar aansluiten. Ook externe factoren, zoals marktontwikkelingen en regelgeving, zijn hierbij van belang.

Daarnaast blijkt dat luchtvaartmaatschappijen vaak de toon zetten bij multimodale vliegreizen. Het zogenaamde *"baseline modality"*-concept bepaalt impliciet de normen en verwachtingen van reizigers. Vooruitgang op dit gebied wordt vaak tegengewerkt doordat verantwoordelijkheden en doelstellingen verdeeld zijn over verschillende partijen en doordat er concurrentie tussen operators bestaat. Succesvolle multimodale vliegreizen vereisen dan ook nauwe samenwerking en regelgeving die integratie ondersteunt.

Cyclus 3

In de derde onderzoekscyclus werd met behulp van interviews en co-creatieactiviteiten onderzocht hoe belanghebbenden de integratie van lucht- en treinvervoer in de praktijk ervaren en vormgeven. Het onderzoek bracht hierbij zes inhoudelijke spanningen aan het licht die zich voordoen bij samenwerking: gebrek aan controle over luchthavenslots, conflicterende belangen bij treinstoplocaties, uiteenlopende dienstregelingen, verschillen in verdienmodellen, gefragmenteerde boekingssystemen en afwijkende belevingen voor de reiziger. Daarnaast werden drie procesmatige spanningen geconstateerd: beperkt wederzijds begrip tussen partijen, moeite om systeemdenken binnen organisaties toe te passen en verschillende werktempo's tussen organisaties. Deze spanningen reiken verder dan de samenwerking tussen individuele partners en benadrukken de noodzaak van een regisseur die het besluitvormingsproces coördineert. Bovendien is er behoefte aan een Europese instantie die een ondersteunend regelgevend kader biedt voor multimodale integratie.

Conclusie

Dit onderzoek laat zien dat de integratie van vervoersmodaliteiten met de luchtvaart vraagt om een fundamentele herdefiniëring van de luchthaven als multimodaal vervoersknooppunt. De luchthaven moet daarbij niet enkel worden gezien als een fysieke overstaplocatie, maar als een strategische actor binnen de multimodaliteit. Op deze knooppunten komen uiteenlopende grenzen samen: tussen modaliteiten, organisaties, landen en regelgeving, maar ook binnen de afzonderlijke modaliteitssystemen zelf. Juist deze veelheid aan grenzen verklaart waarom multimodale ecosystemen vaak de neiging hebben te stagneren.

Daarnaast introduceerde het onderzoek het baseline-modalityconcept, dat laat zien dat passagiers hun verwachtingen vaak baseren op één dominante modaliteit, meestal de vlucht. Zolang passagiers hun ervaring baseren op één (dominante) modaliteit, blijft fragmentatie in de beleving waarschijnlijk bestaan. Dit mechanisme speelt ook een rol in de ontwikkeling en uitvoering van multimodale luchtreizen: luchtvaartmaatschappijen vervullen daarbij doorgaans een dominante rol, die sterk bepalend is voor het ontwerp van de multimodale reis. Dit zorgt voor een paradox: een gebrek aan afstemming tussen vervoerssystemen kan het functioneren van het totale multimodale systeem ondermijnen, terwijl passagiers tegelijkertijd wel profiteren van bepaalde diensten die vanuit het luchtvaartsysteem worden aangeboden.

Succesvolle multimodale integratie vereist samenwerking tussen verschillende vervoerssystemen, gezamenlijke besluitvorming met diverse partijen onder leiding van een regisseur en flexibele, ondersteunende regelgeving. De overgang naar multimodaal luchtvervoer hangt daarbij vooral af van het herinrichten van bestaande structuren. Dit gebeurt via samenwerking, ontwerpprocessen en leren door ervaring, waarbij kennis en werkwijzen opnieuw worden vormgegeven in open en gezamenlijke innovatieprocessen.

Toekomstig onderzoek en aanbevelingen

Het proefschrift schetst mogelijkheden voor vervolgonderzoek, zoals het verkennen van andere contexten, het betrekken van meer diverse deelnemergroepen, het verder uitwerken van kernconcepten, het toepassen van ontwerpinterventies in vervoer en het bestuderen van de invloed van digitalisering op mobiliteit. Het werk sluit af met actiegerichte aanbevelingen.

Voor vervoersoperators ligt de nadruk op heldere communicatie, afgestemde reisinformatie, goed getraind personeel, consistente servicekwaliteit, directe luchthavenverbindingen, op elkaar aansluitende dienstregelingen,

interoperabele systemen, vereenvoudigde bagageafhandeling en partnerschappen waarin merken en diensten zijn geïntegreerd.

Luchthavens en andere knooppunten kunnen multimodale luchtreizen ondersteunen door te investeren in goed opgeleid personeel, duidelijke bewegwijzering, efficiënte transferinfrastructuur, gestroomlijnde processen en comfortabele wachtruimtes voor alle vervoersmiddelen.

Overheden kunnen multimodaal luchtvervoer versterken door te zorgen voor betrouwbare spoorverbindingen, financiële prikkels te bieden aan betrokken partijen, onderhandelingen te faciliteren en levensvatbare businessmodellen voor samenwerkingen tussen operators te ondersteunen.

Tot slot benadrukt het proefschrift dat succesvolle multimodale luchtvaartintegratie samenwerking tussen partijen vereist, gebaseerd op ervaringsleren (zoals veldstudies), het duurzaam verankeren van inzichten binnen organisaties en continuïteit in deelname, zodat begrip en vertrouwen kunnen groeien.

1

CHAPTER 1. INTRODUCTION

1

It is November 6, just after three in the afternoon, when my delayed train finally rolls into the airport's station. "Please take all your luggage with you, and have a pleasant day or flight," the conductor announces as the train prepares to continue on to the city center. With my suitcase in hand, I hurry towards the airport's main hall. For a moment I check the wrong screens – arrivals instead of departures – but soon I know which gate to head for. At security, however, I find myself stuck in a long queue, despite holding an airline priority pass. As the minutes pass, I can't help but wonder: what happens if I miss my flight? After all, I booked this trip as one combined rail-and-air ticket with the airline. In the end, I just make it: after sprinting through the terminal I reach the gate, where the airline's staff smile and tell me I am the last passenger to board.

1.1   BACKGROUND

Journeys like these, in which rail and air travel segments are offered as a single product, are known as *air&rail travel.* This type of journey is part of the so-called hub-and-spoke (H&S) model (Jiang et al., 2017; Li et al., 2018; Román & Martín, 2014). In the original H&S model, airlines connect short- and long-haul flights through transfers at hub airports (Givoni & Banister, 2006; Wang et al., 2024). Through code-sharing, airlines in the H&S model cooperate by offering one leg of a two-leg trip (Li et al., 2018; Román & Martín, 2014) and provide passengers with rights in case disruptions occur (Chiambaretto & Decker, 2012; Rodrigue, 2024). A growing body of research emphasizes the potential for rail to replace short-haul flights in this model, especially for distances ranging from 300 to 800 km (Román & Martín, 2014; Rothengatter, 2010; Schmitt & Gollnick, 2016; Wan et al., 2016).

Air&rail travel at airports

Airlines and airports are pursuing combined air&rail travel for several reasons. First, incorporating rail into the H&S model can enhance the competitive position of major European airports (Janic, 2011; Román & Martín, 2014). Rail services, which cover varying distances, can expand the catchment area for airlines (Chiambaretto & Decker, 2012; Givoni & Banister, 2006; Li et al., 2018). The more transport connections and the higher the frequency of services, the stronger an airport's network position becomes (Givoni & Banister, 2006; Janic, 2011; Jiang et al., 2017; Román & Martín, 2014).

Second, many airport hubs are facing capacity constraints (Faber & van Wijngaarden, 2020; Jiang et al., 2017). Combining air with rail travel into a single journey can reduce dependence on short-haul flights and ease flight

congestion at hubs (Janic, 2011).

Third, aviation is under increasing pressure due to its environmental impact. Studies show that air travel is a major contributor to global CO_2 emissions (Baumeister, 2019; Gössling & Humpe, 2020; International Energy Agency (IEA), 2017). In response, the European Commission has set ambitious targets for 2050, including a shift toward low-carbon fuels and greater use of rail for passenger transport where possible (European Commission, 2021). In regions such as Europe, alternatives to short-distance flights are available, with rail emerging as a lower-emission option compared to flights (Baumeister, 2019; Eurocities, 2024; European Union Agency for Railways, 2024). Raising flight taxes alone is unlikely to achieve the desired shift to sustainable travel, as the wealthiest individuals – who represent only 10% of the population – are responsible for nearly half of global aviation-related emissions (Gössling & Humpe, 2020). Making rail journeys an attractive alternative to short-haul flights (air-rail substitution) and linking air travel with more sustainable modes (air&rail integration) is therefore increasingly explored as a strategy for reducing aviation's footprint.

Air&rail travel is the main focus of this thesis, but it is not the only way to respond to the three drivers for multimodal travel (competitive position, capacity constraints, and sustainability pressure). Bus services can substitute for short-distance flights, and new modes of transport are likely to emerge in the future. Innovations – such as alternative fuels, autonomous driving technologies, demand-responsive transport, and shared and integrated mobility services – are reshaping the wider mobility landscape (Butler et al., 2020; Docherty et al., 2018; Nikitas et al., 2020; Sprei, 2018). In this changing context, air&rail, as well as air&bus, represent a concrete application of multimodality centered around transfers at airport hubs. I refer to this type of travel as *multimodal air travel.*

Moving towards multimodality

Within Europe, there is an ambition to integrate various modes of travel, including air transport, into multimodal transport systems on both national and international scales (Bagamanova et al., 2022; European Commission, 2011, 2021). While travelers have always stitched together different modes in their journeys (Schmitt & Gollnick, 2016), multimodal integration differs as it refers to journeys that combine multiple transport modes under a single

ticket or contract[i] (Babić et al., 2022; Rodrigue, 2024).

Multimodal travel shifts the focus from individual segments of a trip to an integrated journey (Allard & Moura, 2016; Babić et al., 2022; Bagamanova et al., 2022; Huang & Mu, 2018; Rodrigue, 2024; Schmitt & Gollnick, 2016). This shift represents more than an infrastructural challenge: it reflects a broader transformation in how mobility is perceived; not merely as movement from A to B, but as a personalized experience (Canale et al., 2019; Kamargianni et al., 2016). Originally rooted in freight logistics (Babić et al., 2022; Rodrigue, 2024), multimodal integration has since been adapted to passenger travel.

The rise of multimodality is fueled by digitalization, enabled by advances in Information and Communication Technologies (ICT). Digital innovations enhance efficiency, affordability, and overall quality of mobility services (Ceder, 2021; Docherty et al., 2018). ICT-enabled systems provide real-time information and allow users to select from multiple routes and modes (Docherty et al., 2018; Lenz & Heinrichs, 2017; Noussan & Tagliapietra, 2020). Smartphones and other personal devices have become central to this development, enabling passengers to plan, pay for, and manage their journeys through a single interface (Butler et al., 2020; Canale et al., 2019; Rodrigue, 2024). These developments have made it increasingly important to design journeys tailored to the preferences of passengers (Babić et al., 2022; Ceder, 2021).

Furthermore, operators benefit when passengers are satisfied with their experiences, as satisfied travelers are more likely to remain loyal (Lai & Chen, 2011; Schmitt & Gollnick, 2016; Van Lierop & El-Geneidy, 2016; Wang et al., 2017). However, as the anecdote at the beginning of this chapter illustrates, multimodal air journeys are not yet flawless. Integrating other travel modes into the H&S network, where flights typically connect seamlessly (Givoni & Banister, 2006; Román & Martín, 2014), presents challenges, raises questions, and requires close collaboration among the stakeholders involved (Babić et al., 2024; Docherty et al., 2018; Guidon et al., 2020; Rodrigue, 2024). Ultimately, the promise of multimodality depends not only on the quality of individual modes but also on the effectiveness of their interconnections.

Connecting transport systems

Today's transportation network consists of separate subsystems, each based on specific transport modes (Aleta et al., 2017; Geurs et al., 2016).

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i   This thesis distinguishes between multimodal and intermodal transport, following Babić (2022) and Rodrigue (2024), who note that while both involve multiple modes, multimodal transport entails closer collaboration between providers to deliver a seamless end-to-end experience.

Strengthening multimodal transportation requires rethinking the transportation system as an integrated whole.

On a local and regional level, and most often in urban environments, multimodality is expressed through the concept of Mobility-as-a-Service (MaaS). MaaS integrates planning, booking, and payment across modes into a single digital interface that offers personalized and on-demand services, often via a subscription (Canale et al., 2019; Jittrapirom et al., 2017; Kamargianni et al., 2016). By connecting transport systems through digital platforms, MaaS demonstrates how multimodal integration can work in practice. It can be considered part of the shared mobility paradigm (Guyader et al., 2021) and is regarded as a potential way to encourage a shift from private cars to public transport (PT) (Alyavina et al., 2022; Guyader et al., 2021; Jittrapirom et al., 2017). Nevertheless, challenges remain, including cooperation among providers, clarification of stakeholder responsibilities (Eckhardt et al., 2018; Guyader et al., 2021), technical complexities in data sharing, and regulatory barriers regarding collaboration (Jittrapirom et al., 2017).

Although MaaS has so far been considered mainly for urban contexts (Canale et al., 2019; Guidon et al., 2020; Hensher, 2017), it has inspired thinking about multimodality at larger scales. Research suggests that MaaS principles could expand beyond city boundaries to include long-distance buses, trains, flights, and ferries (Alyavina et al., 2022; Eckhardt et al., 2018; Jittrapirom et al., 2017).

Yet, applying MaaS to long-distance travel introduces fundamentally different characteristics, such as higher ticket costs (Rodrigue, 2024), longer travel times, lower service frequencies, fewer alternatives, and (thus) the need for advance booking. These differences highlight that though the MaaS concept could offer valuable insights for understanding the creation of multimodality at airports, we must consider the distinct context that MaaS addresses compared to multimodal air travel.

Multimodal air travel

Multimodal air travel refers to long-distance journeys that combine an air leg with PT modes such as rail or bus, both at national and international scales (Schmitt & Gollnick, 2016).

Although cars are a common way to access airports (Babić et al., 2022), they are classified as private transport and thus excluded from multimodal air travel in this thesis, since such modes are not integrated under a single ticket or contract (Rodrigue, 2024).

Unlike private cars, PT services are publicly accessible and operate on fixed

schedules, routes, and infrastructures (Midor et al., 2020; Rodrigue, 2024; Veeneman et al., 2020). Although these characteristics make PT attractive, they also introduce complexity when different modes – each governed by distinct operators and regulators – need to be coordinated. It is this complexity of coordination which makes multimodal air travel with two legs consisting of PT modalities a worthwhile phenomenon to study.

The complexity becomes especially salient at the points where transport systems intersect and passengers switch modes, particularly in transit hubs such as airports (Li & Xu, 2019). Passenger satisfaction of the overall journey is closely linked to the transfer experience (Babić et al., 2022; Chauhan et al., 2021; Durand & Romijn, 2023), a critical phase of travel that is vulnerable to disruptions or cancellations, which may result in passengers being stranded (Monzón et al., 2016). Against this background, this thesis focuses on multimodal air journeys from departure to arrival nodes, with transfers occurring at airports. Airports are central to this study because they serve both as natural gateways for air travel and as convergence points for rail, bus, and other PT services (Rodrigue, 2024).

1.2 RESEARCH SCOPE

The research scope of this thesis is long-distance multimodal air travel, consisting of one air leg and one PT leg within a single ticketed journey (Figure 1). The analysis covers the journey from departure at a station or airport, through a transfer at an airport hub, to arrival at a station or airport, while explicitly excluding first- and last-mile transport.
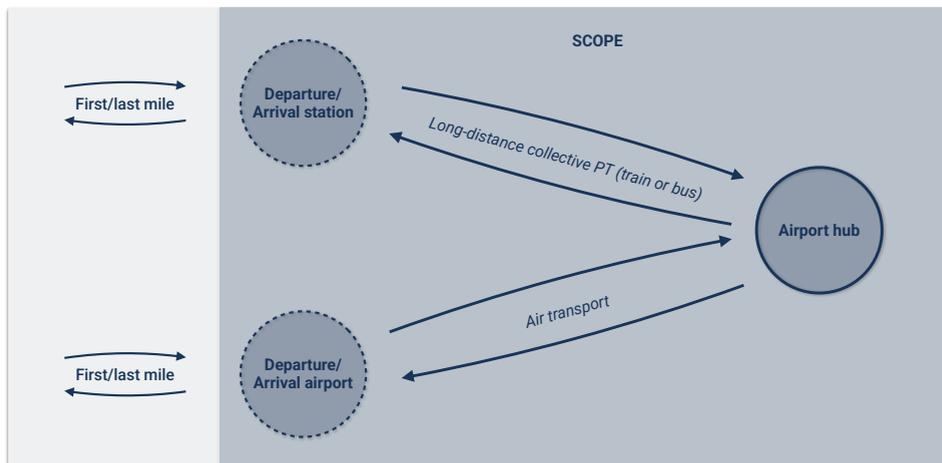
Figure 1. The scope of the thesis focuses on the multimodal air journey.

This thesis explores the design and improvement of multimodal air journeys through three dimensions: the passenger experience, journey delivery, and development (Figure 2).

First, understanding the passenger experience is important, as digitalization has increased the demand for a coherent journey rather than a fragmented travel chain (Camacho et al., 2016; Canale et al., 2019; Docherty et al., 2018). The multimodal air journey discussed in this thesis replaces combined flights within the H&S model, wherein passengers desire seamless connections and provide passengers with rights in case disruptions occur (Chiambaretto & Decker, 2012; Rodrigue, 2024). Consequently, it is imperative to uphold a comparable – or higher – experience level to retain passenger loyalty (Babić et al., 2022; Lai & Chen, 2011; Van Lierop et al., 2018; Van Lierop & El-Geneidy, 2016).

Second, while understanding passenger needs is important, the delivery of these journeys from the perspective of stakeholders helps us understand what influences their design.

Third, the development of these journeys necessitates coordination among multiple stakeholders. While challenges are well documented at local and regional levels in the context of MaaS, the coordination of multimodal air journeys involves a different context with different challenges at the (inter) national scale.

Passenger experience of multimodal air journeys

Delivery of multimodal air journeys

Development of multimodal air journeys
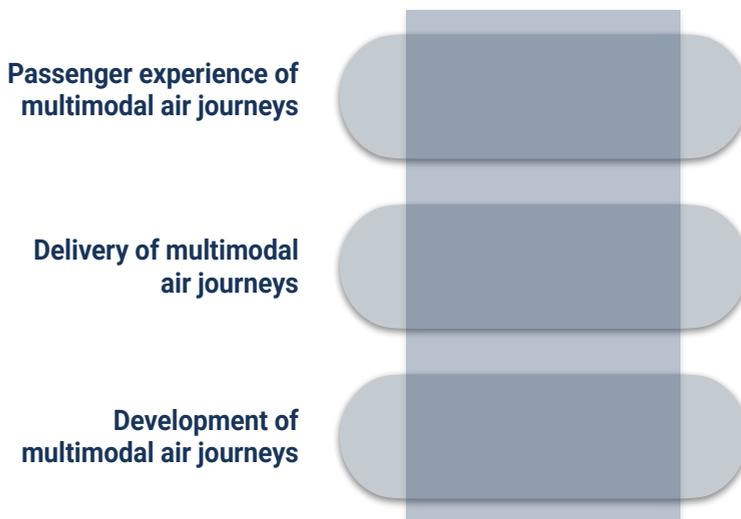
Figure 2. Overview of the three phenomena studied in this thesis.

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To this end, the empirical analysis in Chapters 4–6 concentrates on existing practices (primarily air&rail travel) to derive lessons for future multimodal air integration.

Initially, the research focused on the role of airport hubs in facilitating multimodal air travel (Chapter 3). As the study progressed, however, it broadened to encompass the entire multimodal air journey (Chapters 4–6), recognizing that successful integration at airport hubs depends on understanding how transport modes connect across the journey (see Section 3.3).

1.3   RESEARCH AIM

The aim of this thesis is to contribute to the integration of transport modalities convening at airport hubs into passenger-oriented multimodal air journeys, and to provide insights and recommendations for practitioners and researchers involved in this area. It is built on the premise that examining the complex environment of an airport can provide valuable insights applicable to regional airports and other transfer points.

The thesis adopts a paper-based structure, with each paper addressing specific research questions. For clarity, an overview of the three research questions is provided below.

1. *What are the properties of a passenger-oriented multimodal air journey? (Chapter 4 & 5)*

2. *What influences the effective delivery of a passenger-oriented multimodal air journey? (Chapter 5 & 6)*

3. *What tensions arise when stakeholders engage in the (co-)creation of integrated multimodal air journeys, and how can these be mitigated? (Chapter 6)*

Grounded in the design discipline – which is inherently interdisciplinary as it intersects with engineering, business, art, and science (see (Bremner & Rodgers, 2013)) – this thesis naturally contributes to multiple domains simultaneously.

Its primary contribution lies in the field of transportation, both in theory and practice, reflecting ongoing efforts to improve connections between transport systems.

Second, the thesis aims to contribute to service ecosystem theory (SET) and open innovation. Parallels were identified as SET includes multiplicity of

actors (Flaig et al., 2025; Vargo & Lusch, 2016) and multimodal transport involves the integration of service offerings by various transport actors (Babić et al., 2022; Rodrigue, 2024). The case of multimodal air transport can contribute to SET by understanding the practices involved in developing a multimodal service ecosystem in practice. Additionally, open innovation, which emphasizes the use of external ideas and knowledge (Chesbrough, 2003, 2006), provides a valuable perspective on resource integration with multiple stakeholders (Koskela-Huotari et al., 2016), such as in multimodal transport, and can also be enriched with insights from practice.

1.4 ACTION RESEARCH METHODOLOGY

This study adopts a qualitative approach as it is well suited for exploring complex, real-world phenomena in context (Malterud, 2001; Miles et al., 2014). Qualitative research offers the flexibility to uncover meaning in dynamic settings with multiple stakeholders, as in this study, and helps researchers *"understand how and why things happen as they do"* (Miles et al., 2014, p.11).

The specific research methodology employed is action research (AR), which enables the study of complex, context-bound processes such as multimodal transport while supporting practical improvement efforts (Coghlan, 2019; Reason & Torbert, 2001).

AR, with its longitudinal and immersive character, proved especially well-suited to my PhD project, developed in collaboration with TU Delft and an airport organization. Multimodal air travel relies on collaboration between transport organizations, something that often has long lead times before new developments emerge (Chwiłkowska-Kubala & Huderek-Glapska, 2020; Yatskiv & Budilovich, 2017). Therefore, it was essential for this thesis to collect data over an extended period from various perspectives.

While embedded in the airport's organization, AR's context-bound nature allowed me to engage directly with practitioners, facilitating learning and generating actionable knowledge (Coghlan, 2019; Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). AR investigates and addresses real-life problems through iterative and reflexive cycles to maximize value output (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007; Reason & Bradbury, 2008). This iterative nature emphasizes action and research through a participatory approach, involving professionals who need to enact the change (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007; Jones, 2018). Unique to AR is the researcher's role as an active participant in the inquiry process to facilitate change (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). Reflection

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is crucial, enabling researchers (and professionals) to understand ongoing activities, organizational dynamics, and personal assumptions (Coughlan & Coghlan, 2002; Dick, 2002).

Furthermore, the central AR principle that *"the best way to understand something is to try to change it"* (Kurt Lewin, as cited in Greenwood & Levin, 2007, p. 79) resonates with my background as a strategic designer. This background equipped me with both analytical and synthesis skills, the latter directly supporting the 'taking action' aspect of AR.

Other qualitative research methodologies, such as case study research and ethnography, share some of the properties of AR but lack the 'action' component (Miles et al., 2014). AR has rarely been applied in studies of multimodal (air) transport, presenting an opportunity to contribute both methodologically and empirically.

Over the course of four years, I immersed myself within the airport hub and related project groups. My dual role as researcher and participant enabled me to capture the dynamics of collaboration and to derive insights that are both theoretically grounded and practically relevant. In contrast to methods such as case study or ethnography, AR not only allowed me to observe and analyze these dynamics but also to actively intervene in them. This enabled the creation of knowledge that is simultaneously descriptive, explanatory, and transformative.

1.5   FOCUS ON AIR&RAIL TRAVEL IN EUROPE

Air&rail travel

The primary focus was on integrated air&rail travel, as this presented the most practical examples of multimodal air transport. In research cycles 1 (Chapter 4) and 2 (Chapter 5), an air&bus case was also included, providing a fresh perspective on the challenges and opportunities in linking non-aligned transport systems.

The emphasis on air&rail integration stemmed from both practical and research-driven considerations. First, air&rail journeys were already in place to some degree in various regions worldwide at the time of the study, offering a foundation in existing literature as well as opportunities to study these journeys and their development. Since I conducted AR, I aimed to study this integration process in real-world practice, with existing transport modes, through the lens of what Chesbrough (2003, 2017, 2020) refers to as *"harnessing and absorbing"* (to be further discussed in Section 2.3). The

airport where I was embedded as an AR-researcher features a train station with international rail services – a key enabler for air&rail travel (Li et al., 2018) – making it also a practical choice for studying the integration of air&rail.

Second, as the introduction described, achieving sustainability ambitions while maintaining a competitive airport hub position requires the integration of alternative, more sustainable modes into the H&S model. Rail has been identified as particularly well-suited modality for this purpose (Jiang et al., 2017; Li et al., 2018; Román & Martín, 2014).

The relevance of air&rail as a case is further strengthened by the fact that integrating rail into the air travel system poses distinct research challenges, primarily due to its reliance on extensive physical infrastructure, which incurs high costs and demands long development and implementation timelines (Campos & De Rus, 2009; Doomernik, 2015; RLI, 2020; Rattanakijsuntorn et al., 2024; Rodrigue, 2024).

Europe

Although air&rail initiatives also exist in other parts of the world, I have purposefully sampled (Miles et al., 2014; Patton, 2015; Silverman, 2009) from the European context, as it presents features that are relevant to the further development of air&rail integration.

First, Europe has a high-speed rail (HSR) network with further expansion plans (European Commission, 2011; UIC, 2024). The presence of a unified framework under the European Union (EU) supports coordinated development through instruments such as Trans-European Transport Network (TEN-T) (European Union Agency for Railways, 2024; Regulation (EU) 2024/1679).

Second, at the onset of this PhD research, some collaborations between air and rail operators were already in place across Europe (Li et al., 2018). With the ongoing liberalization of the European rail market, new partnerships were anticipated (Broman & Eliasson, 2019), potentially leading to an increase in air&rail initiatives. In Europe these partnerships often take the form of public-private collaborations (Nash, 2010; Zhou et al., 2018).

Additionally, the EU pursues ambitious climate goals, including a shift from air to rail travel to reduce carbon emissions (Chiambaretto & Decker, 2012; European Commission, 2011, 2021).

Furthermore, Europe's relatively short distances between cities, along with several European airports already connected to long-distance or HSR stations, make rail travel an attractive alternative to short-haul flights

(Schmitt & Gollnick, 2016).

Lastly, the thesis focused on Europe because, at the beginning of the research, strict COVID-19 restrictions made travel beyond the EU difficult. This made it challenging to physically visit other air&rail or multimodal air cases.

It is important to note that the European context differs from that of other regions worldwide. For instance, HSR is minimally present in North America (UIC, 2024), with limited investment in HSR due to the federal governance system (Veeneman, 2023, p. 20). In contrast, several Asian countries have developed extensive HSR networks (UIC, 2024) and forms of air&rail integration. However, there are differences in the ownership and management of transport planning compared to Europe (Nash, 2010; Veeneman, 2023; Zhou et al., 2018).

1.6 THESIS OUTLINE

This section outlines the structure of the thesis (Figure 3). The research design is presented in Chapter 2.

Following this, Chapter 3 features two papers, as this chapter articulates both the research purpose and the context for the study. It begins by defining the research purpose through a review of existing literature (Section 3.2) on the transformation of airport hubs into future-proof Multimodal Transport Hubs (MTHs). This section identifies knowledge gaps and establishes the study's direction. Section 3.3 builds on this foundation by exploring the context in practice. Drawing on an embedded research position at an airport hub, it investigates the necessity for change.

Next, we reach the core of the research: three empirical papers, each described in a separate chapter. Chapter 4 presents an autoethnographic case study focusing on the passenger experience of multimodal air travel. Chapter 5, through interviews with multimodal air travel stakeholders, examines how transport and hub operators define a high-quality multimodal passenger experience and how such a service can be delivered. Chapter 6 describes an AR intervention study in which key stakeholders from the air&rail ecosystem engage in co-creation sessions aimed at designing more integrated and passenger-oriented journeys.

Chapter 7 includes reflections on the study, along with implications and recommendations for future research. Chapter 8 presents the overarching conclusions of the thesis.

Finally, Chapter 9 concludes with a personal note in the form of a travel diary, encapsulating the researcher's journey and the insights gained throughout

the project.

Each chapter contains its own list of references. In addition, a complete reference list combining all sources cited throughout the dissertation is provided at the end.
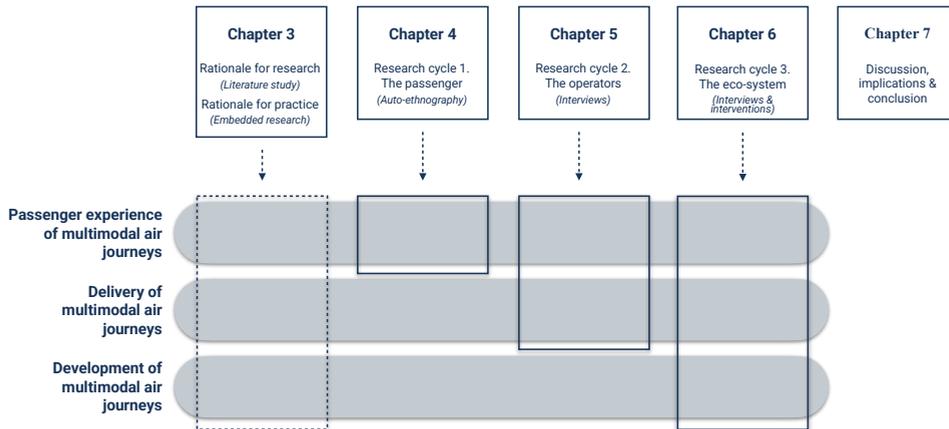
Figure 3. Overview of the thesis

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This chapter explains the design of the PhD research, outlining the overall strategy for conducting the project. Understanding this design helps to interpret the findings within the broader narrative. The chapter begins by detailing my philosophical stance as a researcher and my position within the research context. Next, it discusses the core characteristics of the AR approach, including the three central practices of AR.

CHAPTER 2. RESEARCH DESIGN

2.1   RESEARCHER POSITIONING

In qualitative research, the researcher's background influences the content, approach, and interpretation of the study (Greenwood & Levin, 2007; Malterud, 2001b; Patton, 2015). Therefore, as an AR-researcher engaged in close collaboration with organizations, it is important to maintain transparency regarding my philosophy and prior knowledge (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007; Malterud, 2001b; Shenton, 2004).

2.1.1 RESEARCHER PHILOSOPHY

My ontological stance is constructivist, assuming that meaning is co-created through interaction (Patton, 2015). Philosophically, the thesis is grounded in pragmatism, holding that theory and practice are deeply interconnected (Cornish & Gillespie, 2009; Greenwood & Levin, 2007; Morgan, 2007). As a philosophical tradition, pragmatism proposes that there is a single objective world, but our perception of it is inherently subjective (Cornish & Gillespie, 2009; Morgan, 2007). AR embraces this view by focusing on specific, context-bound issues, co-creating knowledge with a diverse set of practitioners while believing that it enriches the research and change (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). AR aims not only to describe or understand the world but also to change it, embodying the pragmatic belief that knowledge should lead to action (Reason & Torbert, 2001).

2.1.2 POSITIONING WITHIN THE STUDY CONTEXT

Trained as a strategic designer, I conducted my PhD within a faculty focused on two key areas: innovation and design processes, and the interaction between people and complex systems.

During the PhD, I was embedded as an AR-researcher in the organization of a major European airport hub. At the outset of the study, my familiarity with this airport was limited to that of a traveler, as it frequently served as the starting or ending point of my flights. However, my understanding of the organization's inner workings was limited. Furthermore, I had not yet undertaken a multimodal air travel experience, which is the focus of this thesis. A personal motivation for starting this research was to contribute to making the transport system more sustainable.

During the PhD research, my role as a researcher gradually shifted from that of an outsider to a partial insider (Greenwood & Levin, 2007). Initially, I joined the airport's innovation team as a PhD candidate; later, I took on an interim role within the innovation team focused on multimodality. This

experience deepened my sense of belonging and enriched my understanding of both the internal airport environment and the broader multimodal air transportation system. After 16 months, when the innovation team shifted its focus away from multimodal air travel, I transitioned to the airport's masterplanning team to continue working on the integration of air&rail travel. During the last research cycle (Chapter 6), I transitioned to a multi-organizational air&rail group, consisting of five different stakeholders: an airline, an international rail operator, an airport infrastructure manager, a public rail infrastructure manager, and a governmental body. In this role, I facilitated co-creation sessions among the five organizations while still being partially embedded in the masterplanning team.

It is important to note that during the research, I deliberately maintained a certain outsider perspective, adhering to the value of observing participants and practices from a reflective distance (Greenwood & Levin, 2007).

Figure 4 illustrates my journey as an embedded researcher and highlights the teams I was part of during each study.
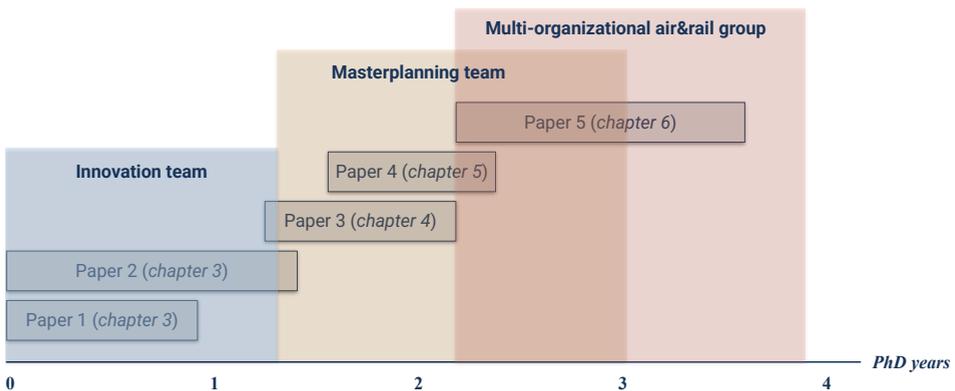
Figure 4. Overview of researcher's team involvement during the PhD

2.2 AR APPROACH

AR seeks to generate practical knowledge through engagement in research cycles of action and reflection (Coghlan, 2019; Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). The goal is not just to solve immediate problems but also to generate valuable learning and to enhance scientific understanding (Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). In AR, *knowing how* is deemed more important than *knowing that* (Greenwood & Levin, 2007).

The research cycle starts with understanding the context and purpose,

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followed by constructing, planning, acting, and evaluating activities (Coghlan, 2019) (Figure 5). Understanding the context and purpose is driven by questions concerning the rationale for action and research (Coghlan, 2019; Coughlan & Coghlan, 2002). Because the AR cycle occurs in real settings, the AR-researcher must know why the project is desirable and why there is a need for action. Additionally, the AR-researcher needs to understand why the project is worth studying and what new knowledge it can contribute. This is followed by the AR cycle, where issues are identified, action is planned and executed, and outcomes of the action are evaluated (Coghlan, 2019).

Knowledge generated through AR is closely tied to its specific context (Coghlan, 2019; Coughlan & Coghlan, 2002; Greenwood & Levin, 2007). Consequently, transferring insights from one context to another requires understanding both contexts and critical judgment on the similarity of conditions, processes, and structures (Greenwood & Levin, 2007).

Context & Purpose

Constructing

Equalizing Action

Planning Action

Taking Action
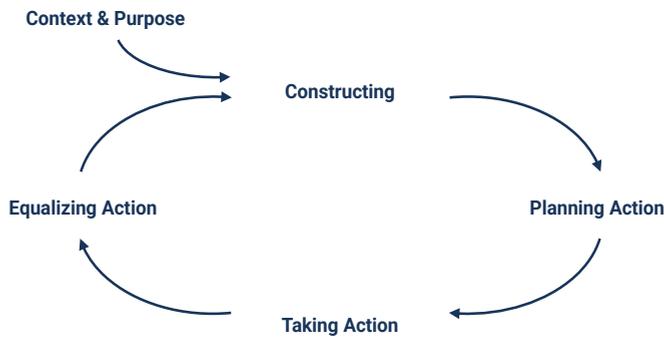
Figure 5. AR cycle according to Coghlan (2019)

Three practices of AR

AR incorporates three essential practices that contribute to its credibility and integrity (Reason & Torbert, 2001). These practices have inspired the structure of the three studies that form the main body of this PhD, as will be explained in section 2.3.

First-person practice in AR involves engaging in research individually, using self-reflection to explore one's own actions, values, and assumptions (Coghlan, 2019; Reason & Bradbury, 2008; Reason & Torbert, 2001). The aim of first-person practice is to deepen understanding through personal inquiry. This reflection can be enhanced through tools like journaling or reviewing recordings (Reason & Torbert, 2001) .

The second-person practice involves collaborative inquiry through dialogue with others, fostering mutual learning and joint sensemaking (Coghlan,

2019; Reason & Torbert, 2001). This practice engages a face-to-face group in collaborative inquiry and is central to the quality of the AR process and its outcomes (Reason & Bradbury, 2008; Reason & Torbert, 2001).

Third-person practice involves sharing insights that extend beyond the immediate context, thereby contributing to a broader understanding and change of the system (Coghlan, 2019; Reason & Torbert, 2001). It engages with surrounding organizations and communities through dissemination, publishing, and theory-building (Reason & Bradbury, 2008; Reason & Torbert, 2001).

2.3   STUDY DESIGN

This thesis should be read as a paper-based dissertation. In the thesis outline (Section 1.6), I have briefly explained that the papers have been incorporated into the chapters. They are presented in their original form, each containing an introduction, methodology, results, discussion, and conclusion. The papers are part of a story that is structured both methodologically and content-wise.

2.3.1 METHODOLOGICAL APPROACH

From a methodological perspective, I followed the AR convention of thinking in cycles (Figure 6) (Coghlan, 2019; Coughlan & Coghlan, 2002). The papers in Chapter 3 contribute to the 'context & purpose' phase for this thesis, with Section 3.2 specifically focusing on the rationale for the research and Section 3.3 addressing the rationale for action.

The three studies that follow are structured around distinct research cycles, with insights from one informing the next. Each study has its own chapter, including an introduction, the paper and a reflection. Instead of focusing solely on the typical phases of an AR cycle, I designed the research cycles by drawing inspiration from the three underlying practices that shape AR (first-, second-, third-person practices).

Research cycle 1, presented in Chapter 4, is approached from a first-person practice, where AR-researchers and practitioners reflect on their own travel experiences through autoethnography. Research cycle 2 (Chapter 5) is inspired by second-person practice, involving interaction between the AR-researcher and practitioners in the form of interviews. Research cycle 3 (Chapter 6) incorporates both second-person and third-person practices, examining interactions between practitioners and broader understandings of the ecosystem. Each research cycle concluded with a reflection on the

content (*what did I learn?*), the process (*how did I learn it?*), and the premises (*what assumptions influenced the learning?*) (Coghlan, 2019).

Although AR typically combines the three practices within a single AR cycle (Coghlan, 2019), this study has divided them across multiple AR cycles, with each research cycle corresponding to one or two practices. Each study shares the same unit of analysis (multimodal air journeys) (Yin, 2009) and takes place in comparable contexts. The primary difference are the informants or participants involved. This approach allows the three research cycles to be viewed as one overarching AR cycle in which the three practices converge.
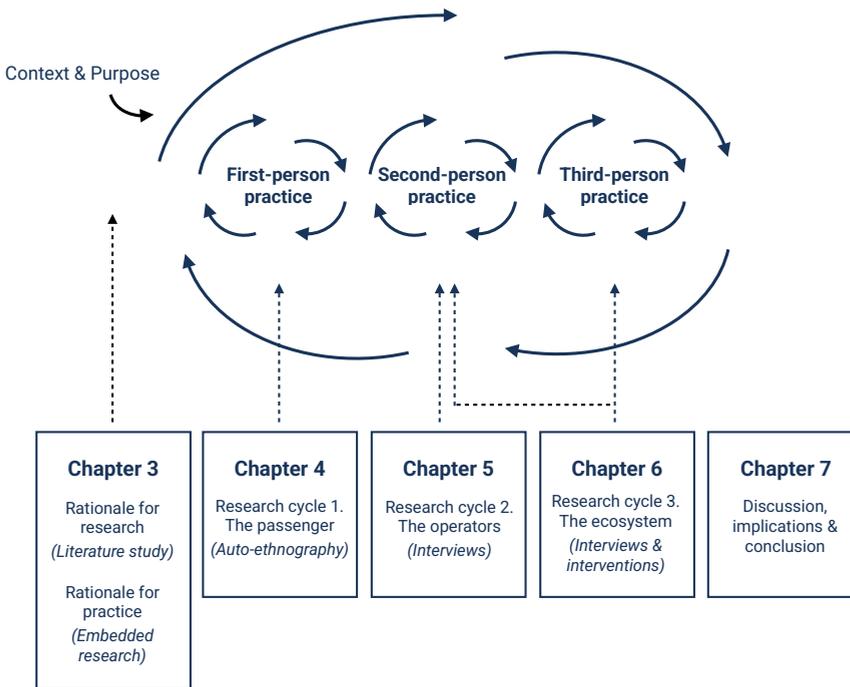
Figure 6. Methodological structure of the thesis, using AR and first-, second- and third-person practices

2.3.2 RESEARCH LENS

This study is grounded in the central objective of advancing the integration of transport modalities at airport hubs. To address this challenge, this thesis primarily adopts a SET lens, which serves as the scientific and interpretive framework throughout the thesis (Malterud, 2001).

SET (Vargo & Lusch, 2010, 2016) describes service ecosystems as relational systems in which value emerges from ongoing interactions between actors, guided by institutions and enabled by resource integration and co-creation.

Institutions and institutional arrangements – the rules, norms, meanings, and practices within an ecosystem – form the foundation for collaboration (Vargo & Lusch, 2016). Within this theory, all actors are understood as resource integrators who combine resources to produce service offerings (Vargo & Lusch, 2010, 2017). These actors can include a wide range of stakeholders, such as suppliers, institutions, and customers (Vargo & Lusch, 2010). From this perspective, a multimodal transport system can be seen as a service ecosystem in which diverse actors – airports, airlines, rail operators, regulators, and travelers – integrate resources to co-create seamless passenger journeys.

Tools from service design – which takes *"a deep dive into the ecologies of services, into the world of needs and experiences of users and providers"* (Mager, 2009, pp. 35) – were employed in studies aimed at understanding the design multimodal air journeys (Vink et al., 2020). Specifically, I utilized customer journey mapping and service blueprinting to analyze the current and potential delivery of multimodal air passenger experience (Bitner et al., 2008; Van Hagen & Bron, 2014).

Next, I applied a second lens of open innovation theory (Chesbrough, 2003), since I conducted my PhD within an airport organization and was curious about how new modes of transportation could be embedded in the organization.

The combination of SET and open innovation in the study of transport reflects the interdisciplinary character of this thesis, whereby the findings are interpreted in multiple academic fields. The research process progressed through three overarching topics, each informed by one or more of these lenses.

The passenger experience

First, the thesis studied the passenger experience in multimodal air travel through customer journey mapping (Van Hagen & Bron, 2014) and the product emotion framework (Desmet, 2003). The user experience, synonymous with the passenger experience in this thesis, is an important element of service design (Edvardsson & Olsson, 1996; Mager, 2009) and refers to how users perceive and respond to a service. In SET, the user plays a dominant role in creating value, as they engage with the service and value is generated through this interaction (Vargo & Lusch, 2010, 2016). Therefore, organizations involved must have a clear understanding of user needs (Edvardsson & Olsson, 1996; Vink et al., 2020). These needs encompass emotions, beliefs, preferences, comfort, behaviors, and achievements, and

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are highly context-dependent (ISO, 2019). The quality of the passenger experience is influenced by several interrelated factors, including process efficiency (Hernandez Bueno, 2021), clarity in the sequence and rationale of service interactions (Kirk et al., 2012), and the availability of comfort, services, and leisure options (Hernandez Bueno, 2021).

Delivery of multimodal air journeys

Second, the research explored how to effectively deliver the passenger experience. In this study, *"delivery"* refers to the actual provision of multimodal air travel services. More broadly, service delivery denotes how a service is operationally achieved (ISO, 2019), encompassing the processes, systems, and resources that ensure its execution. These interdependencies are represented through the layered structure of the service blueprint (Bitner et al., 2008; Papastathopoulou & Hultink, 2012). Because multimodal air travel services are made possible by multiple actors, I used service blueprinting that incorporates perspectives from various operators and approached service delivery as something enabled by the service ecosystem (Vargo & Lusch, 2016).

Development of multimodal air journeys

Third, the thesis investigated how multimodal air travel services can be developed in collaboration. Service development refers to the complete process of designing and creating a service offering, from initial concept to market launch (Cooper et al., 1994; Johnson et al., 2000).

In the context of multimodal air transport, service development is linked to service integration, as creating a multimodal travel experience relies not on designing entirely new services but on aligning existing ones (Babić et al., 2022; Bagamanova et al., 2022; Rongen et al., 2020). This aligns with SET, which states that services are often provided through ecosystems in which actors collaboratively integrate their resources to create value (Caridà et al., 2022; Edvardsson et al., 2014; Frow et al., 2019; Ostrom et al., 2015; Sklyar et al., 2019; Vargo & Lusch, 2008).

In this sense, development and integration are interdependent: the creation of new value propositions for travelers emerges from the integration of existing systems, processes, and actors. SET facilitated the understanding of multimodal service integration as a dynamic, multi-actor process that spans across organizations and systems (Figure 7) (Caridà et al., 2022; Ostrom et al., 2015; Vargo & Lusch, 2016; Vink et al., 2021). Benz (2024) and Stadler Benz & Stauffacher (2024) show that co-creation within service ecosystems plays a key role in integrating mobility services at multimodal hubs by

bridging institutional silos.
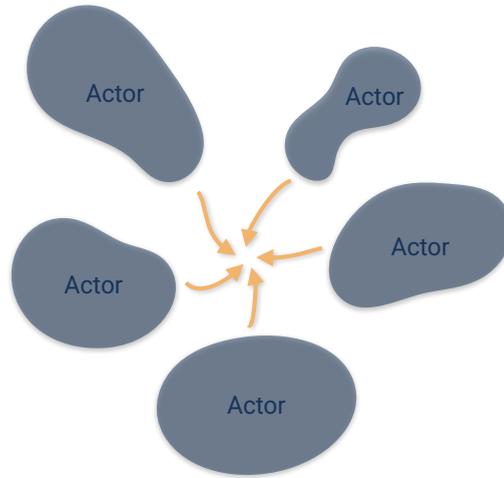
Figure 7. Visual of multimodal service integration in the ecosystem

While SET supports the understanding of integration across multiple organizations, my embedded position within the airport organization also led me to investigate how multimodal service integration is approached from the airport's perspective. To explore this, I also used the lens of open innovation theory (Chesbrough, 2003, 2006). According to this theory, each organization in the ecosystem must tap into external knowledge to effectively realize integrated multimodal services (Figure 8). Open innovation defines innovation as *"generated by accessing, harnessing, and absorbing flows of knowledge across the firm's boundaries"* (Chesbrough, 2017, p. 35).

Accessing is described by Chesbrough (2020, p. 87) as *"seeking out external knowledge"*. In the context of multimodal air integration, this phase requires less emphasis, as one can assume that such external knowledge is often present due to the sector's structure, which is characterized by long planning horizons and capital-intensive systems (Chwiłkowska-Kubala & Huderek-Glapska, 2020). Since multimodal transport focuses on connecting existing transport systems rather than discovering new ones, relevant knowledge is typically already available, making the active search for it a lower research priority.

Harnessing is defined as the activity of: *"A world of opportunity awaits the company that can harness ideas from its surrounding environment to advance its own business"* (Chesbrough, 2003, p. 195). In the broader literature, this process is often described as leveraging (Chesbrough, 2003) or unleashing

(Mascitelli, 2000) external knowledge. Understanding the harnessing process is essential for examining how travel modalities are integrated at airport hubs.

Absorbing, the third and final phase in open innovation, is described by Chesbrough (2020, p. 23) as *"the facet which takes the generated, disseminated inputs from the organization (or society) and puts them to work, embedding the innovation in an organizational unit and business model that can deliver, scale, and sustain the innovation"*. Understanding how an organization draws on (external) knowledge from ecosystem partners is crucial for both comprehending and enhancing the integration of travel modalities at airport hubs.
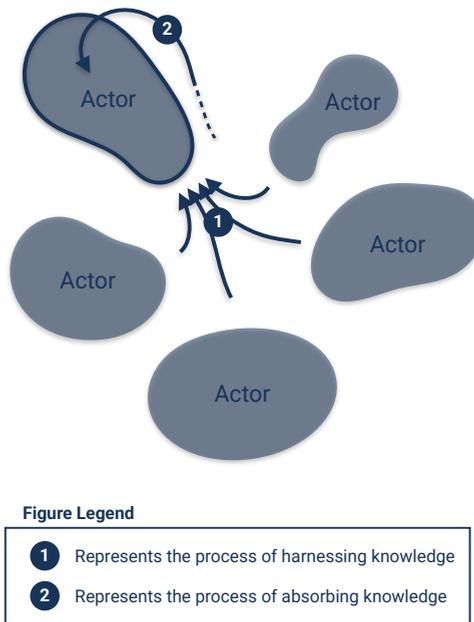
Figure 8. Harnessing and absorbing knowledge according to open innovation theory (Chesbrough, 2017)

To summarize, my study of the development of multimodal air journeys was conducted with two theories as a lens. SET was used to examine how multiple actors co-integrate multimodal transport through interorganizational collaboration. Open innovation theory offered a complementary perspective by exploring how individual actors harness and absorb external knowledge in the ecosystem to support integration within their own organizations.

In this thesis, the applied research lens provided a conceptual foundation

for understanding multimodal air travel integration as a design challenge. It offered insights into how multimodal air travel can be designed, delivered, and further developed in real-world contexts (Figure 9).
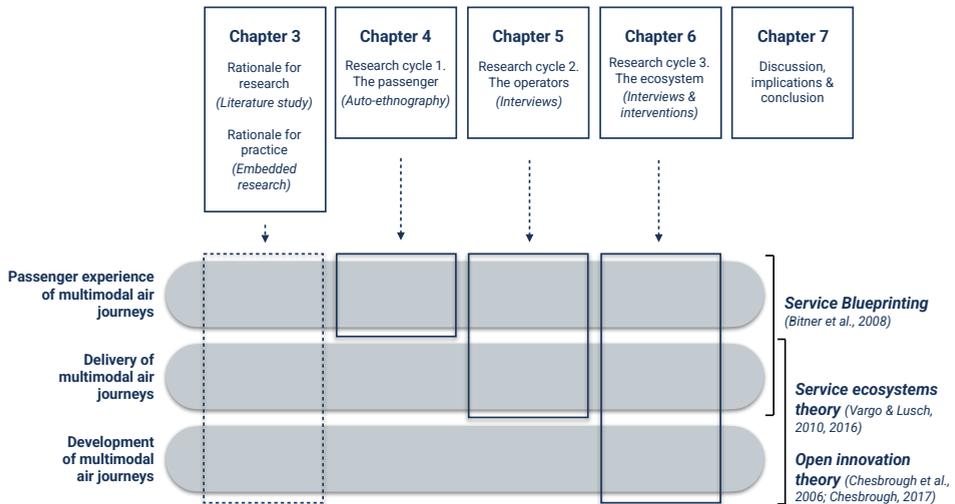
Figure 9. overview of the central concepts of the research lens (far left) added to the illustration of the thesis structure

When applying the research lens to the methodological structure shown in Figure 6 (Section 2.3.1), it results in the framework outlined in Figure 10. This framework highlights the main focus of each chapter and illustrates how it was developed from a methodological perspective.
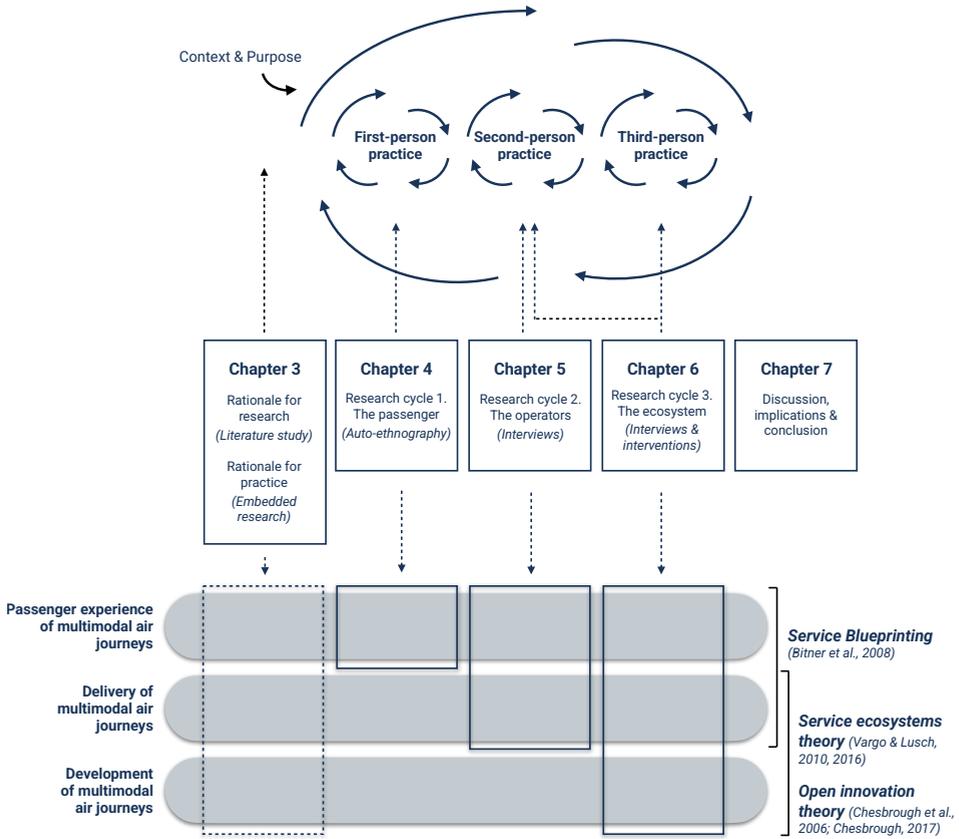
Figure 10. Overview of the methodological approach and design lens of the thesis

3

Where it connects

It begins with a question,
born in moments of reflection.
What drives multimodality today?
What contexts and purposes lead our way?

By stepping into their stride,
we leave assumptions at the side.
Each journey blurs the lines we drew,
and moving through, we create them too.

Beneath the doing lies the why,
designed by those who stand nearby.
Through open words and searching eyes,
layers fall and systems rise.

We create what none could do alone,
from viewpoints far beyond their own.
By dropping all that thought protects,
we find new meaning where it connects.

CHAPTER 3. CONTEXT & PURPOSE

3.1 INTRODUCTION

Innovators are told, "Think outside the box." Qualitative scholars tell their students, "Study the box. Observe it. Inside. Outside. From inside to outside, and from outside to inside. Where is it? How did it get there? What's around it? Who says it's a 'box'? What do they mean? Why does it matter? Or does it? What is not a 'box'? Ask the box questions. Question others about the box. What's the perspective from inside? From outside? Study diagrams of the box. Find documents related to the box. What does thinking have to do with the box anyway? Understand this box. Study another box. And another. Understand box. Understand. Then, you can think inside and outside the box. Perhaps. For a while. Until it changes. Until you change. Until outside becomes inside – again. Then, start over. Study the box." – Patton (2015, p. 35)

The passage from Patton's work (2015) emphasizes that deep and continuous engagement with context shapes qualitative research. He describes how qualitative researchers first aim to understand the factors that influence a situation and how various perspectives define it. In the context of this study, this involves examining the broader field of multimodal air transport, identifying gaps in understanding, and clarifying why certain actions warrant further inquiry.

This chapter supports that effort by first exploring the current state of knowledge through a scoping review, presented in a published paper (section 3.2). A scoping review is well-suited for broadly mapping the field of multimodal transport and gaining orientation within it (Arksey & O'Malley, 2005). It is appropriate at the outset of an AR process, as it helps to reveal areas that remain unexplored by researchers, stakeholders, and within the wider context (Coghlan, 2019). Thus, the scoping review in section 3.2 serves to clarify the purpose of the research.

This chapter also outlines the rationale for the actions described in the remainder of the thesis, as further detailed in a published paper (section 3.3). This rationale is drawn from the researcher's experiences and observations in an embedded role within the airport environment, which forms the central context of this research.

Together, these two papers serve as the foundation for the subsequent empirical AR cycles, grounded in both scientific insights and practical insights into the exploration of multimodality from an airport perspective (Figure 11).
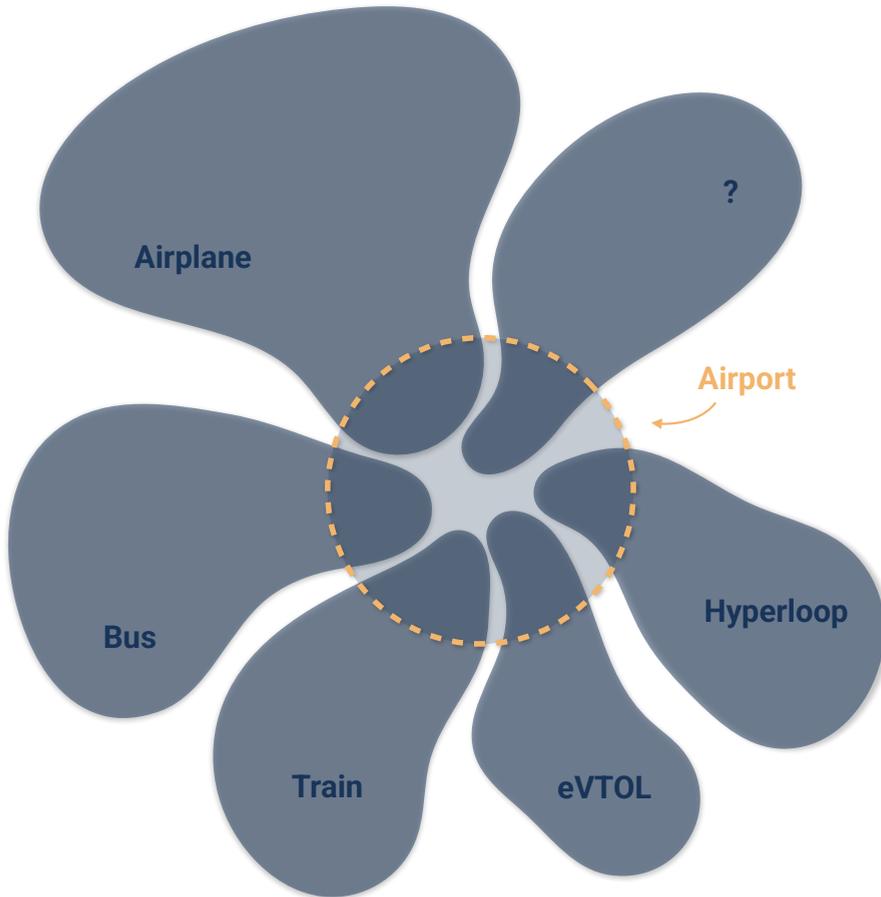
Figure 11. Framing multimodality through the airport perspective

3.2 TRANSFORMING AIRPORT HUBS INTO FUTURE-PROOF MULTIMODAL TRANSPORT HUBS

ABSTRACT

Developments in sustainability and digitisation outline a future of mobility, with multimodal transport becoming the new normal. Travel modalities will no longer be the focal point of mobility, but passenger experiences and the services that provide these will. In a mobility landscape where the passenger experience is key, and multi-leg trips are the norm, Multimodal Transport Hubs are essential players as they can facilitate high-quality intermodal transfers for passengers. However, this advanced application of Multimodal Transport Hubs does not yet exist in practice.

By employing a scoping review, this research approaches the transformation from an airport hub into a Multimodal Transport Hub, as airport hubs physically unite several transport infrastructures but only offer transfers with high-quality services within air traffic and not to, from and between other modalities.

Because airport hubs have features such as a complex stakeholder landscape, long development times, reliance on independent transport operators and uncertainty about the added value of integrating new travel modalities, modality innovation at airport hubs can be perceived as a systemic design challenge. This research identified a lack of theoretical knowledge regarding harnessing and integrating alternative modalities at airport hubs to transform them into fully integrated Multimodal Transport Hubs.

Keywords: mobility, transport, multimodal, hubs, airport hubs, innovation

INTRODUCTION

The complex systems of transport and mobility are developing fast, and two important trends are more sustainable forms of mobility and increasing digitisation (Ceder, 2021; Lyons, 2018). First, society's increasing demand for sustainable solutions is significant for the mobility industry. For example, fossil fuels are replaced directly by biofuels and indirectly by electric, hydrogen, and solar technologies. Second, the advent of digitisation, powered by Information and Communication Technologies (ICT), sweetens the mobility system by making passenger travel faster, cheaper, safer, and more efficient (Ceder, 2021). These trends result in new modalities often characterised by CO2 neutrality, autonomy, sharing and connection (Nikitas et al., 2020; Docherty et al., 2018; Sprei, 2018; Kane & Whitehead, 2017).

Transport modality innovations based on new technologies are subject to long feasibility timelines. It often also involves the construction of entire

(eco)systems, including infrastructure and new stakeholders, making implementation more difficult because significant investments and complex development and construction processes are involved. Examples are illustrated by the improbability of a shortly, full-scale launch of autonomous vehicles and the hyperloop concept (Nikitas et al., 2017). In other respects, the technological feasibility of electric vertical take-off and landing aircraft (eVTOLS) has been partially validated. However, many potential barriers must be overcome before full-scale implementation can be reached (Cohen et al., 2021). We conclude that assessing new and alternative travel modalities and selecting the appropriate ones is challenging due to a complex stakeholder landscape, with long innovation timelines, in the context of a complex mobility system undergoing continuous and significant changes.

The developments in the mobility industry are more drastic than just incremental innovations because they give the use and application of mobility a new meaning in some cases. One of the principal systemic changes currently affecting the mobility system is the Mobility-as-a-Service (MaaS) concept, which proposes a future mobility system that offers a subscription where passengers can book a personalised service in which a range of travel modalities are bundled (Canale et al., 2019; Hensher, 2017). Under the MaaS proposition, *"transport will be increasingly organised around the 'service' of mobility rather than the 'medium' (modality) to be used"* (Canale et al., 2019, p.7). In other words, the passenger's experience and service are put centre stage instead of the mode of transport.

In addition, transitions to a future mobility system are characterised by other features that bring about more than just improvements to the system. Namely, the infusion of the mobility system with passenger information via ICT (Lenz & Heinrichs, 2017; Docherty et al., 2018) and the adaption of transport schedules to travellers' needs creating the option to choose from multiple trips (Porter et al., 2015). These features reinforce the importance of multimodal future travel journeys emphasising greater passenger convenience and comprehensiveness (Docherty et al., 2018). Multimodal transportation is *"an organic combination of two or more modes of transport. It captures and integrates the advantages of various modes of transportation and is an advanced mode of transportation"* (Huang & Mu, 2018, p. 256).

The mobility industry can be perceived as a high-order system that consists of multiple subsystems based on different transport modalities, such as planes, trains, buses and bicycles. Travellers change modality at the intersection of these transport systems in so-called transit hubs, defined as the gathering point of various travel modalities (Li & Xu, 2019), such as airport hubs, rail

hubs, or public transit hubs. The rise of multimodal travel highlights the importance of paying attention to the intersections of transport subsystems and accordingly creating well-organised Multimodal Transport Hubs (MTHs) (Rongen, 2020), as confirmed by the EU Commission that states that *"...airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multimodal connection platforms for passengers"* (European Commission, 2011, p.6). MTHs are designed to merge the services of several modalities at specially designated locations (Anderson et al., 2017). A systemic design perspective may support the transformation of current transit hubs into MTHs as multiple transport subsystems will be united in one high-order system at the MTH (Jones, 2020).

Airport hubs have the potential to transform into MTHs as they bring together different modalities. But, concerning service integration (e.g., ticking, reservation, information, planning), they only focus on linking one dominant mode, namely airplanes. However, there is considerable societal pressure to reduce air travel and, where possible, opt for more sustainable modes of transport. To illustrate, the European Commission decided upon legislation regarding 2050 targets, e.g. using low-carbon sustainable fuels within air transport and substituting the majority of medium-distance passenger transport with rail transport (European Commission, 2020).

These developments, on the one hand, pressure air travel to and from airport hubs. On the other hand, offer an opportunity for airport hubs to start linking and truly integrating more different transportation subsystems. For airports to remain a relevant element in the mobility system and to facilitate and stimulate the transition to a new, more societally responsible transport system, their current function as a transit hub focusing mainly on air travel, should be reshaped into an MTH that unites existing transport flows and incorporates new transport modalities into its business, serving passengers in their journey.

By employing a scoping review, this research aims to provide insight into the available literature about the transition of airport hubs into a multimodal future and associated systemic design perspectives, by answering the question: *What is known from existing research about multimodality innovation for futures at airport hubs?*

The rest of the paper is structured in four parts. The first chapter outlines the method employed in this research. This is followed by a section in which the main themes and results of the literature are discussed. The third section summarises the results in a discussion. In the fourth and final section, we outline implications for further research.

METHOD

To gather the insights presented in the remainder of this paper, we used a scoping review approach, which helps to identify gaps in existing literature, following the methodology as applied by Arksey & O'Malley (2005). A scoping review is an iterative approach, which makes it possible to include newly acquired knowledge in the literature search (Arksey & O'Malley, 2005). As a starting point, the research question has been divided into critical keywords, respectively *"Multimodal Transport Hubs"*, *"Multimodality at airport hubs"*, and *"Airport hub innovation"*. Table 1 presents an overview of the themes, keywords, synonyms, and literature questions applied in the scoping review. The scoping review will finish with a separate section on previous systemic design practices to complement the reviewed literature in this research.

Table 1. Overview of the search strategy applied in the scoping review.

Research question	Key parts research question	Literature questions	Themes	Key words	Synonyms
What is known in existing literature about multi-modality innovation for futures at airport hubs?	Multi-modality hubs	*What is the definition of Multimodal Transport Hubs and what will be their role in the future?*	Multimodal transport hubs	Multimodal transport; hubs; definition	Intermodal; center – station – airport – node; characteristics – explanation - interpretation
	Futures at airport hubs	*Why should and how can airport hubs prepare for the multimodal future of mobility?*	Development of airport hub into MTH	Multi-modality; airport; development	Intermodal; trans-formation
	Airport hub innovation	*What are the traits of airport innovation?*	Airport hub innovation	Airport; innovation	Large organisation; drivers and barriers

Initially, the search strategy examined perfect matches of keywords in the titles of the papers, and in case of no results, articles were content-wise

reviewed for keyword matches. We limited the search to papers in English, published after 2015 and accessible through the electronic database Google Scholar. A backward snowballing strategy, using the reference list to identify new relevant papers (Wohlin, 2014), subsequently led to other electronic databases and, in some cases, to well-known and highly cited papers published earlier than 2015. The relevance of the papers was assessed by matching paper abstracts with the stated literature question.

MULTIMODAL TRANSPORT HUBS

In literature, there are several meanings and definitions associated with the term Multimodal Travel Hub (MTH) (Rongen, 2020), which we need to map to understand what properties airports should acquire to transition to truly multimodal transport hubs.

Current transit hubs are designed by considering different transport modalities, resulting in a unique classification of modalities for each transit hub (Heddebaut & Palmer, 2014). At airport hubs, modalities are classified according to land- and airside modalities, whereby airside modalities are separated by passport and security checks (Marquez, 2019). Railhubs offer land modalities and cover long distances and cross borders. Public transit hubs are often regionally focused and merely connect to modalities on land (Calzada-Infante et al., 2020).

However, the emergence of new land- and airside modalities invalidates current classifications and may not apply to future MTHs. Consider the example of the high-speed rail (HSR) that appears at airport hubs, which may require passengers to pass through security and passport controls due to border crossings, which were previously only required to enter the airside (Jones et al., 2020). Meanwhile, air transport innovations such as electric aircraft, hydrogen planes, and urban air mobility are expected to be feasible in the short future (Schäfer et al., 2019). Therefore, air transport may become bound by fewer rules, as it will increasingly cover distances within national borders and, therefore, no longer demands passport checks.

Because the properties of and demands on MTHs are highly dependent on the type of modalities they integrate, based on the literature review, we created a classification of transport modalities that is applicable to MTHs. Namely: 1) ultra-long, 2) long, 3) medium and 4) short hauls (see the top row in Table 2). First, modalities that are classified as ultra-long distances typically range from 5000 to 10.000 km and include international travel, in most cases overseas, and the associated means of transport are mostly planes (Pirie, 2016) and boats. Second, long-haul modalities typically range

from 200 to 5000 km, across borders of countries or states, wherein air transport is a common modality, besides the most common alternative of HSR (Pirie, 2016). Third, medium-distance modalities cover ranges from 50 to 200 km, and include, for example, railway and bus lines (Metelka & Janos, 2021). Following this, for the purpose of this research, we define local scales as travel modalities within a range of 50 km.

In addition to a range-based categorisation of modalities, Table 2 also provides a typology of passenger transit hubs that we recognised in literature, and distinguishes between types of modalities, typical range and crossing international borders. Although all scales of modalities unite at seaports, this type of hub is excluded from this research for two reasons: firstly, passengers do not have to transfer during their ultra-long trip (which is often a cruise trip), and secondly, long-distance travel by boat takes many days or even weeks.

In the coming years, we anticipate on the emergence of new travel modalities exclusively for long, medium and short distances. We thereby consider ultra-long-haul modalities as constant, namely airplanes and boats. Long and medium distances will include existing modes of transport (like planes, boats, rail, bus and car) and innovations such as electric planes, eVTOLS, hyperloop and self-driving cars (Nikitas et al., 2017).

Table 2. Overview of passenger transit hubs by distinguishing between the types of modalities, typical range and border crossing.

		Scales			
		Ultra-long (e.g. airplanes, boats)	Long (e.g. airplanes, boats, high-speed rail, trains)	Medium (e.g. high-speed rail, train, ferry, bus, car)	Short (e.g. car, bus, metro, moterbike, bike, ferry, scooter)
	Crossing international borders	International	International / national		Local
	Typical range	5000 - 10.000 km	200 - 5000 km	50 - 200 km	< 50 km
Examples					
Seaport	Seaports for passenger travel are often used for cruise activities (Jeevan et al., 2019).	X	X	X	X
Airport hubs	Top worldwide airport hubs ranking in 2022 regarding connectivity: FRA, IST, AMS, CDG, MUC, LHR (Airports Council International Europe, 2022)	X	X	X	X
Regional airports	For example, the smaller airports in the Netherlands: Rotterdam The Hague Airport, Eindhoven Airport and Lelystad Airport (Schiphol | regional airports, 2022).		X	X	X

Table 2. (Continued)

	Scales				
		Ultra-long (e.g. airplanes, boats)	Long (e.g. airplanes, boats, high-speed rail, trains)	Medium (e.g. high-speed rail, train, ferry, bus, car)	Short (e.g. car, bus, metro, moterbike, bike, ferry, scooter)
Railway hubs	Examples of railway hubs: Berlin Central Station, Zürich Hauptbahnhof, and Amsterdam Central Station (Calzada-Infante, et al., 2020).		X	X	X
Public transit hubs	Where the switch can take place from regional and national public transport to urban public transport and vice versa. (Gemeente Amsterdam, 2021).			X	X
Regional hubs	The place where the trans-fer takes place from car to public transport or shared mobility, such as Park + Ride (Karamychev & Van Reeven, 2011).			X	X
Neighbour-hood hubs	A neighborhood hub is a collection of (e Amsterdam, 2021; Schreier et al., 2018).			X	X
Micro-mobility hubs	An example is given by the Citi Bike station (Kaufman et al., 2015).				X

INFRASTRUCTURE AND SERVICE INTEGRATION

Prior research states that successful MTHs integrate both infrastructure and service elements (Bell, 2019; Monzón et al., 2016; Chauhan et al., 2021). With the infrastructure integration of multimodal transport, we mean the facilities required to operate the transport modalities (such as railways, highways, and runways) and connecting elements such as buildings and moving walkways (Li & Loo, 2016; Canale et al., 2019). The service quality of MTHs from the passenger perspective refers to services that facilitate a seamless interchange between multiple modes of transport, like *"…transfer environment, accessibility, signposting, safety, security, public utilities, comfort & convenience, etc."* (Chauhan et al., 2021, p. 48). High-quality service can be achieved when transaction, reservation, information and planning services from different modes of transport are integrated (Veeneman et al., 2020). In a future that emphasises the mobility experience and the services that provide them, rather than the individual travel modalities, MTHs should facilitate high-quality intermodal transfers, which also means improving the integration of services (Chauhan et al., 2021).

One example of existing transit hubs that offer a simple service are the Park + Ride service, *"P + R facilities integrate the private car into the public transport system"* (Karamychev & van Reeven, 2011, p.455), and the Dutch OV-chipkaart public transit card which integrates ticketing and transactions for intermodal public transport journeys within the Netherlands (Joppien et al., 2012). However, in the event of delays or cancellations, the traveller is in the lead of creating an alternative trip. In that respect, railway hubs, public transit hubs and the Park + Ride service score low on the integration of passenger services.

Figure 1 shows an overview of the positioning of current transit hubs according to the number of combined travel modalities and the degree of passenger service integration. The conclusion can be drawn that despite the increasing need for service-supported multimodal journeys, existing transit hubs do not integrate infrastructures and services of multiple travel modalities to facilitate a seamless passenger-oriented intermodal transfer. We argue that transit hubs need to move to the upper right corner of the figure because complete infrastructure and service integration of several travel modes enhances the poor guidance of unplanned interruptions to the multimodal journey (Donners, 2018) and the overall quality of the transfer.
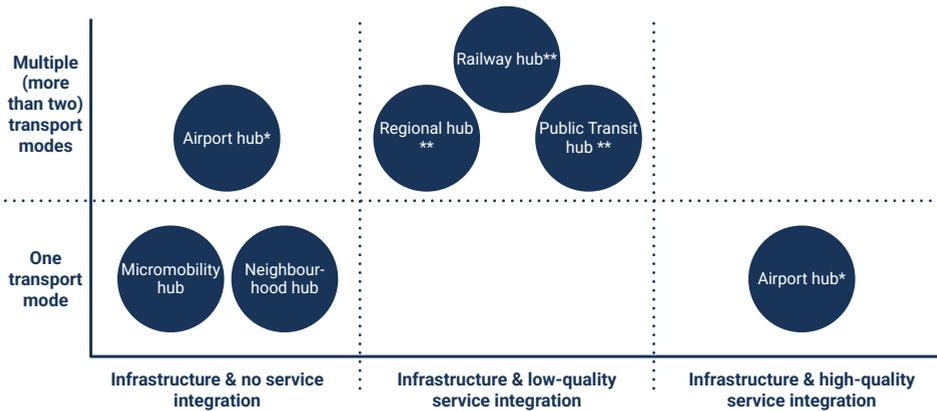
* Airport hubs integrate the physical elements of transport modalities and facilitate transfers between air transport modalities with high-quality service since they incorporate all service elements mentioned by Chauhan et al. (2021) and Veeneman (2020).

** Railway hubs, public transit hubs, and the regional hub score low on the service integration since the traveller is in the lead of creating an alternative trip in case of delays or cancellations.

Figure 1. Degree of multimodal integration at transit hubs. The vertical axis represents the number of travel modalities at the transit hub, and the horizontal axis shows the infrastructure and service integration degree. High-quality service is met if all the elements mentioned by Chauhan et al. (2021) and Veeneman et al. (2020) are integrated.

AIRPORT HUBS

Airport hubs, the exclusive players to include ultra-long-distance modalities, do not score high on passenger service integration of multiple modes in Figure 1. An explanation is that (ultra-)long distances are inherently inflexible (Araghi et al., 2022), as they require pre-booked trips due to high costs and the involvement of multiple stakeholders. Instead, short distances are much more flexible for different reasons. So these two transport ranges, ultra-long-distance modalities versus short-distance modalities, have entirely different working practices. Therefore, cooperation between airport hubs and transport operators of each scale is necessary to integrate services of all modalities. These partnerships can ensure smooth passenger transfers whereby new journeys are automatically created in the event of congestion, e.g. a train delay leads automatically to a flight rebooking, which is currently merely happening in rare cases (Donners, 2018; Li et al., 2018).

Next to that, the increasing demand for sustainable transport puts extra pressure on airport hubs. Fortunately, airports' coverage of all modality ranges offers opportunities to create connections between ultra-long and long/medium scale modalities and substitute high-emission transport with

alternative modalities.

This research focuses on airport hubs that fall under the Hub-and-spoke model, in which the hub collects passengers through long and medium-distance flights at small airports (spokes) and then transfers them to ultra-long flights (Zgodavová et al., 2018). The central hub in this model has the most potential to become a long-haul MTH with new modalities due to the presence of all modality ranges. The greatest challenge and impact lie in a shift from air transport to alternative travel modalities at long and medium distances, as argued above.

DEVELOPMENT OF AIRPORT HUBS INTO MTHS

More knowledge is required on developing airport hubs and MTHs to guide us with a systemic design approach in helping airport hubs transition to an MTH.

Airport hub development

The continuous development of existing airports is not effortless. Chwiłkowska-Kubala & Huderek-Glapska (2020) are among the few to research the barriers to airport improvement by distinguishing between internal and external barriers. They categorise the internal barriers to airport improvement into management, organisational structure and finances. First, airport management plays an essential role in strategic decision-making processes. Second, the organisational structure is a barrier to airport development when there is a lack of good ownership, political involvement, safety regulations and handling activities. Third, financial aspects such as high costs and high time-intensiveness of investments are bundled into the financial barrier. Furthermore, airport hubs are occasionally forced to develop their infrastructure without knowing future needs.

Next, to internal barriers, Chwiłkowska-Kubala et al. (2020) note external barriers to improving airport hubs, including the restriction on infrastructure expansion and the complex stakeholder field. They show that the air transport sector is bound by fixed procedures, and according to the theory of architectural knowledge (Henderson & Clark, 1990), this hinders organisational change.

These barriers signify that the airport hub cannot be flexible regarding innovations due to its organisational structures and external barriers. Complex systems like airport hubs must *allow the path forward to reveal itself* (Snowden & Boone, 2007) since they deal with incomplete information and elusive answers. Therefore, airport hubs must seek early engagement

with future societal developments and trends, technological innovations, new modalities, and transport services to prepare in time for possible futures.

MTH development

MTHs, similar to airport hubs, deal with limited time to absorb new technologies (Gil et al., 2011), know long development lead times, and have many stakeholders slowing down the innovation process (Yatskiv & Budilovich, 2017).

Specifically, to transform into an MTH, transport operators should work together through shared development strategies and information systems to accelerate the efficiency of multimodal transport (Zhang et al., 2018). Moreover, MTHs must connect travel modes' networks and arrange information facilities, create short walking and times distances, and handling of luggage between the modes of transport (Janic, 2011). Barriers are the regulations between different mobility stakeholders, different design standards among transport operators, incomplete infrastructure, high development costs, absence of open information interfaces, and lack of integrated operations (Li & Loo., 2016; Huang & Mu, 2018).

When former competitors and stakeholders with conflicting needs are brought together with systemic design practices, and, for example, operational coordination, integral tickets, and interchange discounts are realised, those barriers might be combated (Li & Loo, 2016).

AIRPORT INNOVATION

This section delves deeper into the traits of airport innovation to understand the setbacks of innovation at airports, which are characterised by the Innovator's dilemma (Christensen, 1997), open innovation process (Chesbrough, 2003) and uncertain futures at airports.

Innovator's dilemma at airport hubs

Airport hubs can be regarded as large - and often established - companies that are good at their core business. As a result, their architectural knowledge tends to become embedded in their organisation's structure, making them slow and inflexible in innovation (Henderson, 1990). However, airport hubs must reorganise their business if they want to incorporate new modalities into their portfolio, also referred to as architectural innovation (Henderson, 1990). The phenomenon at play here is the Innovator's dilemma introduced by Christensen (1997), which says that large, established firms have difficulty

adapting to new markets, allowing new and small firms to drive business away.

A critical nuance is the distinct position of airport hubs compared to large organisations, referred to by Henderson (1990) and Christensen (1997). Airport hubs are characterized by long development times, physical capacities, stakeholders, and capital (Chwiłkowska-Kubala et al., 2020). Therefore, it is implausible that a small start-up could quickly grow into a large airport hub. However, airport hubs still must consider two threats to their position. Firstly, suppose airport hubs refuse to see the potential of modality innovations. In that case, mobility operators may develop into a market in which airport hubs will become irrelevant, such as the emergence of vertiports at locations other than airports (Tripathi et al., 2022). Next, airport hubs risk that rival airports will successfully facilitate modality innovations, such as the air&rail case in Frankfurt (Li et al., 2018).

Open innovation at airports

Airport hubs depend on mobility operators for infrastructure and service integration of modes of transport, as the airport hubs only have a facilitating role. Due to this reliance, modality innovation at airports, and in general also at MTHs, need traits of the open innovation approach that advocates collaboration with external parties (Chesbrough, 2003). Large companies that struggle with radical innovations can shift into new industries through open innovation. This also applies to airport hubs since a continuous engagement with external innovations supports airport hubs in innovating for the future (Sune & Gibb, 2015).

Chesbrough describes open innovation as *"innovation that is generated by accessing, harnessing and absorbing flows of knowledge across the firm's boundaries"* (Chesbrough, 2017, p.35). Airport hubs must be aware and have access to alternative modalities, then be able to assess and choose (harness) the promising modalities and finally find a way to absorb new modalities within the organisation smoothly.

Innovate for futures

The long development times of infrastructure at airports and new modalities, combined with the uncertain future of mobility, make it challenging for MTHs to decide which travel modalities to engage with. In complex systems such as airport hubs, we cannot predict what future we're heading towards, partly because the external conditions are constantly changing (Snowden & Boone, 2007). A possible way to deal with this is to take possible future

scenarios into account (Medvedev et al., 2017). To support the development of scenarios, organisations often apply a foresight approach, in which a future joint vision is established through an iterative approach (Cassingena Harper, 2003). Working towards futures in complex contexts is a challenging activity in which it is especially important to observe patterns develop and estimate their potential value (Snowden & Boone, 2007). One way of dealing with this ties in with Chesbrough's (2017) activity of harnessing external knowledge, namely *"to probe first, then sense, and then respond"* (Snowden & Boone, 2007).

Other methods that can be thought of that may be interesting for approaching an uncertain future are the creation of visions (Corwin et al., 2020) and frames (Bergman, 2017).

3

SYSTEMIC DESIGN PERSPECTIVES & APPROACHES

The above literature highlights several properties of transforming an airport hub into an MTH and suggests that such a transition may benefit from a systemic design approach. First, the literature shows that multimodal travel hubs have properties of complex systems, as they consist of many dynamically related elements (Snowden & Boone, 2007), and they even integrate entire subsystems (Jones, 2020). Secondly, consequently, many stakeholders are or need to be involved in changing the system (Jones & Ael, 2022). Thirdly, the challenge involves contributing to changing the current mobility system around airports into a new system, which means a transition from a steady state to a new, initially ill-defined, more desirable state (Loorbach 2022). And fourth, the desired future state of the new system, the MTH, is uncertain and will most likely emerge over time (Snowden & Boone, 2007). All these properties of the challenge at hand (embracing complexity, multi-stakeholder, transition and uncertainty) align very well with a systemic design approach. Jones and Ael (2022, P.3) suggest applying systemic design practices because of its holistic view that integrates *"design, research and method skills for complex contexts"*.

Many systemic design practices may be relevant to addressing this phenomenon. For example, established methods have been carried out in similar contexts, such as the antifragility at MTHs (Nieuwborg et al., 2021) and the interconnection of transportation systems (Jehn & Rae, 2015). Questions that can be answered are *"how to create high-quality transfers"*, *"how to incorporate stakeholders' conflicting needs"*, and *"how to seek early engagement with future innovations"*.

In addition, systemic design can offer critical perspectives with regard to the

necessity and desirability of transforming airports into multimodal hubs, and whether or not there are more desirable and responsible paths to be taken.

The reviewed literature on airports and mobility presumes that airport hubs should seek to maintain their dominant position in the mobility industry. Nieuwborg et al. (2021) emphasise the role that MTHs play in the spread of viruses at an international level. An exciting paradox occurs here that points us to a holistic, systemic design approach in which antifragility might be a condition for MTHs. One may even wonder whether it is necessary and desirable to have dominant airport hubs or MTHs. In recent years, the trend of flight shame has increased, perceiving air travel as bad (Flaherty & Holmes, 2020). Though we would argue that transforming airport hubs into truly integrated MTHs it is likely to increase the uptake of other transport modalities than air travel for the medium and short haul. And that a considerable part of the learnings of transforming airports into truly integrated MTHs, can also benefit the development of other and new MTHs.

The work of Nieuwborg et al. (2021) shows how a difference in perspective leads to a different elaboration of future research possibilities. They describe airport hubs as MTHs, but we argue that MTHs do not yet exist due to a lack of infrastructure and passenger service integration of multiple travel modes. Our different point of view creates opportunities for future research in this particular mobility system. A practical approach to this phenomenon, similar to design processes due to its iterative nature, is Action Research (AR). According to Greenwood & Levin (2007, p.54), *"AR rests on the premise that reality is interconnected, dynamic, and multivariate and always more complex than the theories and methods that we have at our disposal."* Knowledge is collected in AR through a circular and participative process, stimulated by questions and problems that relate to existing contexts (Scaratti et al., 2018). Insights and knowledge resulting from the AR cycles may lead to an intervention that supports airport hubs in making thorough and substantiated decisions in their transformation.

CONCLUSION

The raison d'être of this paper originates from developments in the mobility industry and environmental burdens that pressure airport hubs to transform into MTHs. A scoping review was conducted to uncover the literature on multimodality innovation for futures at current transit hubs, particularly airport hubs.

This produced several primary insights. First, there is the increasing

importance of MTHs facilitating a passenger travel mode interchange that includes both infrastructure and passenger service aspects. Airport hubs were identified as an interesting case to transform into a passenger-oriented MTH if they incorporate relevant alternative travel modalities into their business.

However, three elements make the transition to an MTH complex. First, airport hubs deal with complex ecosystems and long development times of infrastructure. Hence, airport hubs must commit to alternative modalities on time. Second, the uncertain future of the mobility industry and the long development times of infrastructure and new modalities make it challenging to understand which modalities will be relevant in the future. And third, airport hubs depend on modality operators and are therefore bound to partnerships to gain insight into the potential value of modalities and provide intermodal transfers at a later stage.

This research identified a knowledge gap regarding transforming airport hubs into MTHs that facilitate intermodal passenger transfers by accessing, harnessing, and absorbing modalities into the existing business.

FUTURE RESEARCH

Future research, among which in practice, should be conducted to discover what high-quality services entail and contribute to the development of better techniques for modality engagement for airport hubs. This research suggests applying a systemic design approach to arrive at impactful and important theories, frameworks, methods or tools. Action Research is a suitable approach for follow-up work to arrive at a selection of criteria, the appropriate level of engagement and the degree of absorption with new modalities at airport hubs. In particular, it is interesting to investigate what high-quality intermodal transfers entail, methods for MTHs to strengthen the formerly critical transfer points, strategies to work towards uncertain futures from the airport's perspective and approaches to unite conflicting needs of stakeholders. In addition, we want to encourage future work to take a critical look at the attitude adopted in the researched literature. We are particularly curious about more work examining the position of airport hubs in the future. In addition, we encourage critical work on the ambition to transform airport hubs into multimodal hubs instead of making air traffic more sustainable.

REFERENCES

Airports Council International Europe. (2022, juni). Airport industry connectivity report 2022. https://www.aci-europe.org/downloads/resources/CONNECTIVITY%20REPORT%20

2022.pdf

Anderson, K., Blanchard, S. D., Cheah, D., & Levitt, D. (2017). Incorporating equity and resiliency in municipal transportation planning: case study of mobility hubs in Oakland, California. Transportation Research Record, 2653(1), 65-74.

Araghi, Y., van Oort, N., & Hoogendoorn, S. (2022). Passengers preferences for using emerging modes as first/last mile transport to and from a multimodal hub case study Delft Campus railway station. case Studies on Transport Policy, 10(1), 300-314.

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. International journal of social research methodology, 8(1), 19-32.

Bell, D. (2019). Intermodal mobility hubs and user needs. Social sciences, 8(2), 65.

Bergman, N. (2017). Stories of the future: Personal mobility innovation in the United Kingdom. Energy research & social science, 31, 184-193.

Calzada-Infante, L., Adenso-Díaz, B., & Carbajal, S. G. (2020). Analysis of the European international railway network and passenger transfers. Chaos, Solitons & Fractals, 141, 110357.

Canale, A., Tesoriere, G., & Campisi, T. (2019). The MAAS development as a mobility solution based on the individual needs of transport users. PROCEEDINGS OF THE INTERNATIONAL CONFERENCE OF COMPUTATIONAL METHODS IN SCIENCES AND ENGINEERING 2019 (ICCMSE-2019). https://doi.org/10.1063/1.5138073

Ceder, A. (2021). Urban mobility and public transport: Future perspectives and review. International Journal of Urban Sciences, 25(4), 455-479.

Chauhan, V., Gupta, A., & Parida, M. (2021). Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction of public transport. _ Transport Policy_, _102_, 47-60.

Chesbrough, H. W. (2003). Open innovation: The new imperative for creating and profiting from technology. Harvard Business Press.

Chesbrough, H. (2017). The future of open innovation: The future of open innovation is more extensive, more collaborative, and more engaged with a wider variety of participants. Research-Technology Management, 60(1), 35-38.

Christensen Clayton, M. (1997). The Innovator's Dilemma: When new technologies cause great firms to fail. Harvard Business School Press, Boston.

Chwiłkowska-Kubala, A., & Huderek-Glapska, S. (2020). The sources of barriers to airport development: A dynamic capabilities perspective. Research in Transportation Business & Management, 37, 100587.

Cohen, A. P., Shaheen, S. A., & Farrar, E. M. (2021). Urban air mobility: History, ecosystem, market potential, and challenges. IEEE Transactions on Intelligent Transportation Systems, 22(9), 6074-6087.

Corwin, S., Zarif, R., Berdichevskiy, A., & Pankratz, D. (2020). The futures of mobility after COVID-19. Deloitte Insights.

Docherty, I., Marsden, G., & Anable, J. (2018). The governance of smart mobility. Transportation Research Part A: Policy and Practice, 115, 114-125.

Donners, B. (2018). Vergelijk vliegen met treinreizen voor korte afstanden: en hoe we vaker voor de trein kunnen kiezen. Royal HaskoningDHV.

European Commission. (2011). Roadmap to a Single European Transport Area: Towards a Competitive and Resource Efficient Transport System [White Paper]. Publications Office of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN

European Commission. (2020). Sustainable and Smart Mobility Strategy—Putting European Transport on Track for the Future (COM(2020) 789 final). https://eur lex.europa.eu/resource.html?uri=cellar:5e601657-3b06-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF

Flaherty, G. T., & Holmes, A. (2020). Will flight shaming influence the future of air travel?. Journal of Travel Medicine, 27(2), taz088.

Gil, N., Miozzo, M., & Massini, S. (2012). The innovation potential of new infrastructure development: An empirical study of Heathrow airport's T5 project. Research Policy, 41(2), 452-466.

Gemeente Amsterdam. (2021, December 15). Hubsvisie Amsterdam. https://www.amsterdam.nl/parkeren-verkeer/hubs/

Harper, J. C. (2003). Improving links between tenant companies and higher education institutions: exploring emerging scenarios for Manchester Science Park. PREST, University of Manchester, 8.

Heddebaut, O., & Palmer, D. (2014). Multimodal city-hubs and their impact on local economy and land use.

Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. Administrative science quarterly, 9-30.

Hensher, D. A. (2017). Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change?. Transportation Research Part A: Policy and Practice, 98, 86-96.

Huang, S., & Mu, D. (2018, December). Discussion on the Development Strategy of China's Multimodal Transport Stations. In 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018) (pp. 256-262). Atlantis Press.

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transportation Research Part D: Transport and Environment, 16(2), 137-149.

Jeevan, J., Othman, M. R., Hasan, Z. R. A., Pham, T. Q. M., & Park, G. K. (2019). Exploring the development of Malaysian seaports as a hub for tourism activities. Maritime Business Review.

Jehn, M., & Rae, S. (2015). Ski2LRT uses Systemic Design to transform winter community in Edmonton.

Jones, W., Kotiadis, K., Paola Scaparra, M., & O'Hanley, J. (2020). Using simulation to improve the customer experience at Eurostar. Impact, 2020(1), 7-11.

Jones, P. (2020). Systemic Design: Design for Complex, Social, and Sociotechnical Systems. Handbook of Systems Sciences, 1-25.

Jones, P., & Ael, V. K. (2022). Design Journeys through Complex Systems: Practice Tools for Systemic Design. BIS Publishers.

Joppien, J., Niermeijer, G., Niks, T., & Kuijk, J. (2013). Exploring new possibilities for user-centred e-ticketing. University of Technology.

Kane, M., & Whitehead, J. (2017). How to ride transport disruption–a sustainable framework for future urban mobility. Australian Planner, 54(3), 177-185.

Karamychev, V., & van Reeven, P. (2011). Park-and-ride: Good for the city, good for the region?. Regional Science and Urban Economics, 41(5), 455-464.

Kaufman, S. M., Gordon-Koven, L., Levenson, N., & Moss, M. L. (2015). Citi Bike: the first two years.

Lenz, B., & Heinrichs, D. (2017). What can we learn from smart urban mobility technologies?. IEEE Pervasive Computing, 16(2), 84-86.

Li, L., & Loo, B. P. (2016). Towards people-centered integrated transport: A case study of Shanghai Hongqiao Comprehensive Transport Hub. Cities, 58, 50-58.

Li, X., Jiang, C., Wang, K., & Ma, J. (2018). Determinants of partnership levels in air-rail cooperation. Journal of Air Transport Management, 71, 88-96.

Li, Z., & Xu, W. A. (2019). Path decision modelling for passengers in the urban rail transit

hub under the guidance of traffic signs. Journal of Ambient Intelligence and Humanized Computing, 10(1), 365-372.

Lyons, G. (2018). Getting smart about urban mobility–aligning the paradigms of smart and sustainable. Transportation Research Part A: Policy and Practice, 115, 4-14

Marquez, V. (2019). Landside| Airside: Why Airports Are the Way They Are. Springer.

Medvedev, A., Alomar, I., & Augustyn, S. (2017). Innovation in airport design. Aviation, 21(1), 23-28.

METELKA, S., & JANOŠ, V. (2021, May). Demand variation in regional transport. In 2021 Smart City Symposium Prague (SCSP) (pp. 1-5). IEEE.

Monzón, A., Hernández, S., & Di Ciommo, F. (2016). Efficient urban interchanges: the City-HUB model. Transportation Research Procedia, 14, 1124-1133.

Nieuwborg, A., Hiemstra-van Mastrigt, S., Melles, M., Santema, S., & Zekveld, J. (2021). Designing for Pandemic Antifragility in Multimodal Transport Hubs.

Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era. Sustainability, 12(7), 2789.

Nikitas, A., Kougias, I., Alyavina, E., & Njoya Tchouamou, E. (2017). How can autonomous and connected vehicles, electromobility, BRT, hyperloop, shared use mobility and mobility-as-a-service shape transport futures for the context of smart cities?. Urban Science, 1(4), 36.

Pirie, G. (2016). Geographies of air transport in Africa: aviation's 'last frontier'. In The Geographies of air transport (pp. 263-282). Routledge.

Porter, B., Linse, M., & Barasz, Z. (2015). Six transportation trends that will change how we move. Forbes, January.

Rongen[1], T. (2020). A qualitative analysis of multimodal hub concepts in Dutch national transport and land-use policy.

Schäfer, A. W., Barrett, S. R., Doyme, K., Dray, L. M., Gnadt, A. R., Self, R., ... & Torija, A. J. (2019). Technological, economic and environmental prospects of all-electric aircraft. Nature Energy, 4(2), 160-166.

Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Keßler, S., & Möser, G. (2018). Analysis of the impacts of car-sharing in Bremen, Germany. Retrieved from https://northsearegion. eu/ share-north/news/impact-analysis-of-car-sharing-in-bremen-english -report-published/ (Consulted on: 30-05-2022)

Snowden, D. J., & Boone, M. E. (2007). A leader's framework for decision making. Harvard business review, 85(11), 68.

Sune, A., & Gibb, J. (2015). Dynamic capabilities as patterns of organizational change: An empirical study on transforming a firm's resource base. Journal of Organizational Change Management.

Sprei, F. (2018). Disrupting mobility. Energy Research & Social Science, 37, 238-242.

Tripathi, M., Mandal, M., & Wadhwa, R. (2022). Air Taxis: A Technological Breakthrough to Beat the Traffic Woes. Communications of the Association for Information Systems, 50(1), 15.

Wohlin, C. (2014, May). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In Proceedings of the 18th international conference on evaluation and assessment in software engineering (pp. 1-10).

Yatskiv, I., & Budilovich, E. (2017). A comprehensive analysis of the planned multimodal public transportation HUB. Transportation research procedia, 24, 50-57.

Zgodavová, Z., Rozenberg, R., & Szabo, S. (2018, August). Analysis of Point-to-Point versus Hub-and-Spoke airline networks. In 2018 XIII International Scientific Conference-New Trends in Aviation Development (NTAD) (pp. 158-163). IEEE.

Zhang, X. Q., Cui, Y. R., Li, Y., & Liang, X. F. (2018). Research on layout of multimodal transport center in Jinan City. In E3S Web of Conferences (Vol. 38, p. 01040). EDP Sciences.

3.3 THEMES FOR AN AIRPORT HUB IN THE TRANSITION TOWARDS A MULTIMODAL TRANSPORT HUB – AN EMBEDDED RESEARCHER'S PERSPECTIVE

ABSTRACT

Future mobility systems will likely incorporate more multimodal journeys. These multimodal journeys integrate multiple modes of transport, and their higher future prevalence highlights the importance of paying attention to the modality transfers within journeys. To carefully facilitate these transfers, we advocate the creation of passenger-oriented Multimodal Transport Hubs (MTHs), which integrate both infrastructure and services of multiple travel modalities to ensure high-quality transfers between the different modes of transport. This study is part of a research project investigating how Airport Hubs can transform into MTHs and aims to learn in practice how the case study FlyHub deals with new travel modalities and how FlyHub integrates these into its ecosystem. Through the presence of an embedded researcher in the case study context, performing the explorative pre-step of the Action Research approach, the study builds an understanding of the context and the rationale for possible succeeding cycles of action and research. Accordingly, we identified five themes that either stimulate or thwart the transition of FlyHub into an MTH. The five themes are 1) recognition of the importance of innovation and long-term outlook, 2) limited exploration possibilities, 3) the MTH concept being (too) abstract, 4) multi-system transition going slow, and 5) changes and transitions being a struggle for power.

Keywords: mobility; multimodal; airport; transition

1. INTRODUCTION

The current mobility system is undergoing substantial changes driven by two critical trends: the growing demand for sustainable solutions and digitisation. The former involves the rise of eco-friendly mobility options, like biofuels and electric, hydrogen, and solar technologies. At the same time, the latter is propelled by Information and Communication Technologies (ICT), aiming to make passenger travel faster, cheaper, safer, and more efficient (Ceder, 2021). As a result, we see the emergence of cross-modality and cross-operator mobility services (X-mobs), which allow passengers to plan, book and pay for their journey across different mobility operators and travel modalities (Veeneman et al., 2020). An example of an X-mob service is Mobility-as-a-Service (MaaS), which offers a personalised subscription to passengers to use a range of travel modalities (Canale et al., 2019).

If these trends persist, future mobility systems will likely incorporate more multimodal journeys, which *"capture and integrate the advantages of various modes of transportation"* (Huang & Mu, 2018, p.256). The rise of multimodal

travel highlights the importance of paying attention to the transfers between travel modalities, as those are the critical points where disruptions may occur (Monzón et al., 2016). Travellers transfer between modalities in so-called transit hubs, such as Airport Hubs, Rail Hubs, or Public Transit Hubs (Toet et al., 2022). These locations are nodes where different transport subsystems, each linked to a means of transport, meet. In this study, we follow the definition of transit hubs given by Li and Xu (2019) as *"the gathering point of various travel modalities"*.

To facilitate optimal transfers within multimodal journeys, we advocate the creation of passenger-oriented Multimodal Transport Hubs (MTHs). At these highly developed transit hubs, the services of several travel modalities come together (Anderson et al., 2017) and are offered bundled to passengers. Integrating transaction, reservation, information and planning services of different transport modes (Veeneman et al., 2020) is an example of combined services that facilitate a high-quality transfer for passengers at an MTH. In addition, for a well-functioning MTH, its infrastructure is also an essential asset. These facilities are required to operate the travel modalities (such as rail tracks, highways, and runways) and connecting elements such as buildings and moving walkways (Canale et al., 2019; Li & Loo, 2016). An advanced application of MTHs, where infrastructure and services are aligned to integrate multiple modes of transport fully, is very limited in practice.

The creation of passenger-oriented MTHs is encouraged by the EU Commission, which stated that *"...airports, ports, railway, metro and bus stations, should increasingly be linked and transformed into multimodal connection platforms for passengers"* (European Commission, 2011, p.6). Airport Hubs have the potential to transform into MTHs, as these bring together the infrastructure of multiple travel modalities and already provide high-end integration for air travel. Our work focuses on Airport Hubs instead of smaller and regional airports, as the Hubs cater to airlines/alliances using the Hub-and-spoke model. Airlines that operate according to this model collect passengers through long and medium-distance flights at airports (spokes) and transfer them at their hub into (ultra-long distance) second-leg flights (Zgodavová et al., 2018). According to previous research (Toet et al., 2022), ultra-long distances typically range from 5000 to 10.000 km, long from 200 to 5000 km, and medium from 50 to 200 km. In addition to these ultra-long-range flights, of which the passengers want to journey onwards, Airport Hubs often feature several short (with a range of up to 50 km), medium and long-range travel modalities. Thus, in terms of the presence of travel modalities and infrastructure, Airport Hubs have the potential to become MTHs.

However, most current Airport Hubs focus on integrated services within air travel rather than between different travel modes. To become MTHs, Airport Hubs must facilitate seamless transfers between diverse travel modes and become part of a passenger-centric mobility system. Therefore, Airport Hubs should accommodate high-quality multimodal transfers by integrating infrastructure and services from various transport operators. Figure 1 illustrates how an Airport Hub physically connects the infrastructure of several mobility systems and how an MTH also integrates services. Prior research (Toet et al., 2022) proposes adopting Chesbrough's model (2017) to access, harness, and absorb new modalities into their business to become MTHs.

Example of a transit hub: Airport Hub

At Airport Hubs, various transport subsystems come together, having adjacent infrastructure, but each subsystem operates indecently and provides its own services.

Multimodal Transport Hub

At MTHs, the services of each travel modality are fully integrated and overlapped, enabling passengers to experience a seamless multimodal journey.

Airplane

Car

Bus

Train

Airplane

Bus

Car

Train

?

?

Services: such as transaction, reservation, information and planning services defined by Veeneman (2020)

Infrastructure: such as rail tracks, highways, and runways, buildings and moving walkways (Canale et al., 2019; Li & Loo, 2016)

Figure 1. An abstract visual of Airport Hubs and MTHs.

This study is part of a project sponsored by FlyHub and ClickNL, which was established to investigate how Airport Hubs can transform (themselves) into MTHs. This paper investigates themes that arise when an Airport Hub explores new travel modalities, serving as a starting point for subsequent studies. It documents the themes one of the authors identified during her immersion in the FlyHub case study from September 2021 to February 2023. The central research question is: *What themes arise when an Airport Hub aims to innovate with new travel modalities in order to transform into an MTH?*

2. METHOD

The embedded researcher applied an Action Research (AR) approach to investigate how Airport Hubs deal with the (potential) introduction of new travel modalities. The AR approach is about *"research in action, rather than research about action"* (Coughlan, 2002, p.222), meaning that researchers actively participate in practice, with the underlying notion being that *"the best way to understand something is to try to change it"* (Greenwood & Levin, 2007, p.18). AR is considered a suitable method for gaining insider knowledge of an organisation since it stimulates researchers to become part of the object of study (Bartunek & Louis, 1996).

The AR approach builds on the spiral process explained by Coughlan (2002). This process is visualised in Figure 2 and presents the AR cycle as consisting of three parts: a pre-step, the six main steps of the action research cycle, and the meta-step to monitor. This paper documents themes arisen in the pre-step to the AR cycle, in which the embedded researcher built up an understanding of the context and the rationale for possible succeeding cycles of action and research. The researcher's experiences included collaborations of FlyHub with Hyperloop, Urban Air Mobility (UAM), Electric Flying Consortiums, and Air-Rail connections.

The remainder of this chapter discusses data collection and analysis, why a case context description was added, and the background and position of the embedded researcher.
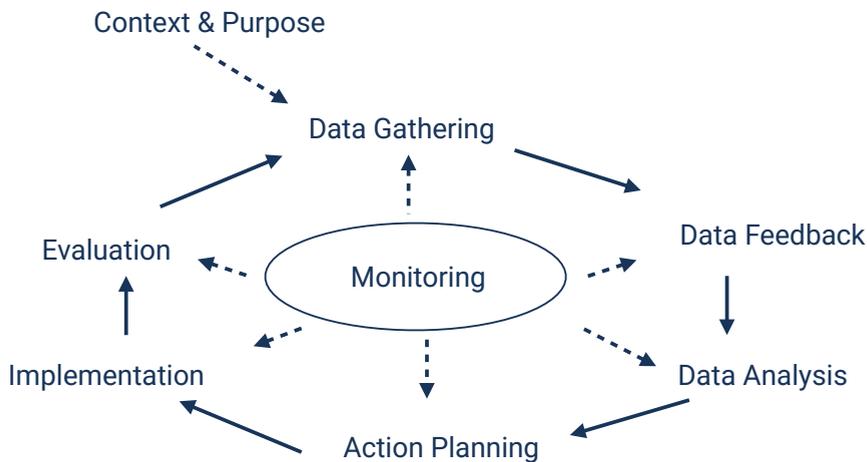
Figure 2. The AR cycle. Source: Coughlan (2002)

2.1 Data collection

A typical way to gather data in an AR process is *"through active involvement in the day-to-day organisational processes relating to the AR project"* (Coughlan, 2002, p.231). The data were collected between September 2021 and February 2023. The data sources comprised interviews with innovation managers, executives and project members, observations of meetings and day-to-day work, informal and formal documents, and e-mails and chat exchanges with (internal) stakeholders.

Informants included project teams and innovation managers that managed the innovation team's portfolio, but data was also gathered by initiating and actively participating in project teams. The data initially emerged from the smaller context of the innovation team and later also originated from the broader department and project teams associated with multimodality practices.

The observations and interviews were captured through journal keeping, allowing the researcher to capture thoughts, ideas, impressions, and decisions (Coughlan, 2002; Herr & Anderson, 2005).

2.2 Data analysis

The data analysis approach consisted of four steps, also visualised with examples in Table 1.

1. Anonymisation: Personal information, such as name, e-mail address and company, were anonymised. The company was given the pseudonym 'FlyHub', and all the data was stored in a software package for qualitative data analysis (Atlas.ti).

2. Meaning units: Due to the extensive raw data set, we have selected the meaningful parts of the content to perform an insightful analysis, referred to as meaning units. (Giorgi & Giorgi, 2003; Graneheim & Lundman, 2004).

3. Coding: The next step was to shorten the length of the meaning units without affecting their content (Lindgren et al., 2020). This being an explorative study, we coded the (condensed) meaning units with an open coding strategy, in which categories and themes emerge from the raw data, with the researcher being open to all possible directions (Khandkar, 2009; Wicks, 2017). The coding process was iterative, adding, merging and deleting codes until the codes were stable (Miles & Huberman, 1994).

4. Identifying themes: The next step was to identify factors, mechanisms or subthemes that either stimulated or thwarted the introduction of new modalities or the transition of FlyHub into an MTH and cluster these according to themes. On the report of Graneheim & Lundman (2004, p.107), a theme is *"a thread of an underlying meaning through, condensed meaning units, codes or categories, on an interpretive level".*

Table 1. An illustration of the data analysis process, starting with the raw data (far left column) and subsequently applying codes (second column) to elucidate the emergence of sub-themes (third column) and themes (far right column).

Meaning unit	Code	Subtheme	Theme
"We're not stopping UAM because it is coming. If we decide to market UAM, we can influence how we can use it best."	Influence innovations	Stakeholders want to retain power	Stakeholders operate from their own goals
"[airlines] will remain part of the scene"	Attractiveness of aviation	Airport focus on aviation	
"Innovation at FlyHub is slightly different [than at start-ups] because the culture of failure is difficult. Projects are very complicated, and many stakeholders are involved"	Big consequences of failure	Testing is difficult at big airports	Big airports have limited exploration possibilities
"easier to start at regional airports. Fewer regulations, airlines etc."	Less strict regional airport regulation	Collaborations with regional airports for innovation	

2.3 The importance of the context

Greenwood and Levin (2007) point out that one should be careful in generalising the knowledge gained in AR projects. Insights from AR studies, including this research, are context-bound. Theory formation in AR projects entails moving from specific cases to broader generalisations (Eden & Huxham, 1996), making it crucial to actively interpret and conceptualise practical experiences in similar contexts. To assess the transferability of knowledge, it is essential to identify both the similarities and differences between the new context and the original context where the knowledge originated (Greenwood & Levin, 2007; Shenton, 2004). Hence a *"thick description"* of the case should communicate the contextual factors (Lincoln & Guba, 1985, p.214). We describe this study's case context below.

2.3.1 Transfer infrastructure and services

This research focuses on FlyHub, a major European Airport Hub that facilitates a global Hub-and-Spoke network of destinations. FlyHub has the infrastructure and services to offer integrated services for high-quality transfers between air modalities. FlyHub's infrastructure also features an integrated railway station with access to the (inter)national (highspeed) rail network and which is a transfer station for national trains. FlyHub provides infrastructure and, to a lesser extent, services for transfers between rail modalities. The same applies to bus modalities at FlyHub, since its infrastructure is in place, but the (transfer) services provided could be more extensive. Thus, apart from physical proximity and a few (pilot) projects, transfers between different travel modalities are not facilitated with integrated services as defined by Veeneman et al. (2020).

In addition to ultra-long and long-distance modalities, FlyHub is served by a range of short and medium-range travel modalities: it is accessible via private transport (car, taxi, motorcycles and bicycles) and public transport (train and bus). Furthermore, FlyHub is spatially constrained as its geographical location is close to the central urban area it serves.

2.3.2 Organisational context

This research was initially part of the portfolio of FlyHub's innovation team, embedded in the strategy and planning business unit. During the research period, FlyHub and aviation were (still) recovering from the Covid-19 pandemic. As a result, a significant reorganisation had just altered the staffing of business units, departments and teams at the start of this study. As COVID-19 faded, FlyHub, like other major Airport Hubs, struggled to accommodate the rapidly growing passenger numbers due to severe staff shortages and significant operational issues. Following a switch at the top leadership of FlyHub, the innovation team shifted within the research period to short-term innovations that directly contribute to the operational recovery.

2.4 The embedded researcher

In qualitative research, like AR, the researcher's background and position influence the content, approach, and interpretation of the research (Giorgi & Giorgi, 2003; Greenwood & Levin, 2007; Malterud, 2001). Hence, transparency about the motives, beliefs, background, and prior knowledge of the (embedded) researcher is recommended (Malterud, 2001; Shenton, 2004). The embedded researcher joined FlyHub in September 2021 with limited prior knowledge of the company's complexity. She was familiar with

FlyHub, had travelled through it several times, and conducted a prior study at an airline operating from FlyHub.

The researcher's worldview aligns with pragmatism, acknowledging the subjective perception of the objective world (Cornish & Gillespie, 2009; Morgan, 2007). AR aligns with this perspective, recognising that *"reality is interconnected, dynamic, and multivariate and always more complex than the theories and methods that we have at our disposal."* (Greenwood & Levin, 2007, p.54).

The embedded researcher initially approached multimodality practices from an outsider's perspective but later transitioned towards being an insider, as is common in AR projects (Herr & Anderson, 2005). This shift was facilitated by available interim roles within the organisation. However, despite becoming embedded, the researcher maintained some distance from internal stakeholders, as required in AR, to observe their actions critically (Greenwood & Levin, 2007).

3 RESULTS

The study found five distinct themes concerning issues either stimulated or thwarted 1) the identification, selection, and integration of new travel modalities and 2) the transition of FlyHub into an MTH. These themes can be seen as an expression of the latent content of the data (Graneheim & Lundman, 2004). In this chapter, we elucidate these themes, exploring their underlying meanings with support from relevant data evidence.

3.1 Theme: recognition of the importance of innovation and long-term outlook

We identified five indicators that innovation was considered necessary and important by FlyHub during the research period. The recognition of innovation was widely supported within FlyHub and encouraged embracing complex long-term issues, such as new travel modality adoption. This innovative attitude, way of working, and long-term outlook can also be positive for transforming an Airport Hub into an MTH.

First, FlyHub has a long history of innovation and proudly advocates its roots as a pioneer in aviation that go back over 100 years. During the research period, the innovation team was part of the strategy and planning department, whose director reported directly to the CEO of FlyHub. Also, it was noticed by the researcher that FlyHub had *"innovation managers"* scattered throughout each department (e.g. Asset Management, Operations, IT and Data, Security, and Commercial). Hence, innovation was caught as a

core value manifested in organisational roles throughout the organisation.

Second, FlyHub's board of directors, including the CEO, directly monitored the innovation team's portfolio. Once every few months, the directors met to decide on investments, experiments, and focus points, guided by the innovation team. One of the innovation managers argued that *"It's better to have the directors meet for short periods more frequently than to try to be "efficient" by having a 12-hour marathon once a year. An annual meeting may be efficient for the directors but could represent a high cost of delay for the projects waiting for approval or funding of next steps"* (12/2021). The embedded researcher observed that during innovation decision-making processes, the CEO was active, prepared well, and made decisions quickly.

The extensive portfolio of the innovation team seems further evidence of the recognised value of innovation. An innovation executive explained that the innovation team focused on six distinct themes (09/2021), and the portfolio owed its size to, among other things, the improvement drive of the innovation team. This ambition to have an impact was well cited by an innovation executive (10/2021): *"The answer to every critical question is always: I don't know, but based on my mission, I will make sure it will work."*

Fourth, the long-term focus of the innovation projects indicates the recognition of the importance of innovation. Even though FlyHub focused on all innovation horizons throughout all business units, the innovation team specifically worked towards long-term innovations (innovation executive, 09/2021). An innovation manager highlighted their focus on future complex problems, even those yet to appear. Thereby, FlyHub recognised lengthy innovation timelines for major transformations, like infrastructure and modalities development. FlyHub's innovation team tackled these projects through exploration and problem-mapping. Hence, learning a hypothesis was most important for the innovation team, as indicated by an innovation executive (05/2022). Consequently, once a project was ready for implementation, it was handed over to the business owners within FlyHub. The innovation hub's explorative core is evident in the frequently asked question: *"What is the hypothesis from the point of view of viability, desirability & feasibility?"* (innovation executive, 05/2022).

As a final point, FlyHub's emphasis on complex long-term problems and its extensive innovation portfolio argued for focused long-term innovation processes. The embedded researcher observed FlyHub's innovation team constantly identifying and scoping focus areas and goals. Next, the innovation team developed a distinctive approach, including creating an inspiring long-term vision. An innovation executive explained (09/2021) that creating

a vision helped to enthuse internal and external stakeholders to work together towards this goal. This suggests that FlyHub's innovation team had the knowledge, motivation, and skills to involve internal and external stakeholders to transform into an MTH.

3.2   Theme: limited exploration possibilities

This theme reveals how FlyHub's exploration towards becoming an MTH is restricted by the numerous constraints faced by Airport Hubs due to complex processes and involved parties. A possible approach is to first pilot and implement travel modalities at regional airports through strategic partnerships.

The embedded researcher witnessed stringent security measures at FlyHub during the research period. First, an innovation manager illustrated this by referring to the low number of performed experiments *"due to FlyHub's ecosystem"* (2022). Second, the embedded researcher observed that the government drew up strict requirements for the certification of new aircraft, which made it challenging to carry out demo flights with new aircraft, such as hydrogen, electric and UAM. The embedded researcher experienced this consequence as demo flights with electric aircraft were cancelled twice due to certification problems (retrieved from chat, 06/2022). Nevertheless, an innovation executive underlined the prospects of future experiments at FlyHub: *"[the] government can indeed create pilot space as we did with drones on airside in 2020"* (06/2022).

Moreover, an innovation manager stressed the significant consequences of failure for FlyHub (2022): *"Innovation at FlyHub is slightly different [than at start-ups] because the culture of failure is difficult. Projects are very complicated, and many stakeholders are involved".* Being a major Airport Hub, when things go wrong, they go wrong fast, especially when the ongoing aviation operation is involved. Therefore, FlyHub's secure environment prevents serious consequences but hinders modality experimentation.

Besides, the embedded researcher noticed strict rules curbing Airport Hubs' monopolistic position, which complicated the exploratory phase of new travel modalities. These rules mandated predetermined operation rates for years. Based on this, the tariffs for new modalities were pre-determined by the established rates, and consequently, considerably low rates could not be set for new modalities. Additionally, rate agreements between airports were prohibited due to the *"European cartel prohibition,"* which prohibited contact between other companies (legal staff, 05/2022). Thus, when FlyHub wanted to test and promote new travel modalities, this was limited by strict

legislation.

Next, a strategy employee cited that the *"Biggest disadvantage of UAM & Hyperloop is laws and regulation"* (06/2022). This means that the laws and regulations at that time only approved existing travel modalities and therefore caused implementation hurdles for new modalities at FlyHub.

Finally, FlyHub itself also proved reluctant to experiment with new travel modalities, as these required severe investments in infrastructure and costs. To illustrate, a strategy employee called the potential investment in the hyperloop instead of a pilot *"a start"* (05/2022), as commitment beyond the experiment phase would be required by FlyHub. Besides, mobility innovations included long development times, inhibiting transition progress: *"You have to order an extra wagon for luggage now, then you will have it in, say, eight years"* (strategy employee, 07/2022). Hence, FlyHub was disinclined to build entirely new infrastructure, knowing development would take years when they were uncertain about the added value of the travel modality.

Despite all these counteracting factors on introducing new modalities and collaborating with other parties, practitioners mentioned how FlyHub created strategic partnerships with regional airports to stimulate innovating with modalities. Regional airports were attractive partners for FlyHub, as these had fewer and less strict rules because of fewer flight movements. Consequently, introducing new modalities was "*easier to start at regional airports,*" (innovation executive, 04/2022) as experiments had more freedom.

3.3 Theme: the MTH concept being (too) abstract

The third theme addresses that the MTH concept was too abstract during the research period, as there was no set structure for dealing with new modalities, and the added value of an MTH for FlyHub was hard to grasp. This made it difficult for FlyHub to focus on transitioning to an MTH.

First, the MTH focus of the innovation team was mainly on exploring new travel modalities, as the MTH concept implied at that time that multiple modalities should be integrated at one location. As such, the innovation team identified, monitored, assessed, experimented with, and implemented new modalities, although these activities gradually overlapped without a predetermined structure. An innovation manager (04/2022) mentioned that *"identifying and selecting new forms of mobility is a tough task"*, suggesting there was no straightforward approach to deal with new modalities. However, it was observed that new modalities were assessed on feasibility, desirability, and viability. But no explicit assessment criteria were set for these principles, reflecting the conceptual nature of modalities' added value

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for FlyHub during the study.

Second, multiple FlyHub employees acknowledged that the MTH transition entails more than introducing new travel modalities. For instance, an innovation executive (04/2022) highlighted the potential of new travel modalities to create promising revenue streams and business models: *"New business models for FlyHub? Can UAM cause that, for example?".* Furthermore, the question surfaced whether the MTH concept should and could be spread over multiple airports, captured by an innovation manager: *"Can FlyHub create mini hubs and integrate them into one large hub?"* (09/2021). The diverse interpretation of the MTH concept highlights its significant potential value within FlyHub. However, it also demonstrates the challenge of fully understanding it and reaching a shared perspective.

The abstract essence of the MTH concept is evident, among other things, in its limited focus within the innovation team. Consequently, the person in charge of the MTH focus was replaced five times in 16 months. This may have contributed to no substantial progress on MTH projects during the research period, as reflected by this statement of an innovation executive (11/2022): *"I have informed X that I currently have no resourcing on the multimodal hub and therefore, I will not be able to scope and frame an exploration for a while".*

Also, no inspiring long-term vision existed to engage internal and external stakeholders, despite the innovation team's belief in the importance of such a vision for radical innovation projects. Consequently, the embedded researcher had to actively promote MTH activities and projects to attract participants within FlyHub. This was experienced whilst organising an MTH symposium supported by the innovation executive, who cited (06/2022): *"I was looking at the response rate and invitee list and I think it is worth the try to create a bit more PR for the event internally to prevent a low show/no show".*

What further limited long-term, highly innovative projects, such as MTH, was FlyHub's tremendous operational problems endured during the research period, as referred to in the method section. Consequently, the innovation team had to shift its focus to short-term developments: *"Part of the pivot we are going through is having a clear focus and priorities as a team"* (innovation executive, 11/2022). Therefore, the innovation team disengaged from the MTH concept as its added value was too abstract to matter today.

3.4 Theme: multi-system transition going slow

This theme represents that the transition of Airport Hubs into MTHs requires multiple stakeholders to collaborate in a multi-system transition. Unfortunately, this transition goes very slowly due to the many stakeholders

involved.

The embedded researcher observed three indicators of FlyHub's strong connection with internal and external stakeholders during the research period. First, FlyHub was perceived as a large organisation with an internal power structure and many employees. Second, FlyHub's own ecosystem encompassed various parties essential for its operation, such as air traffic control, airlines, handlers, and security. Third, FlyHub was part of a larger external ecosystem linked to all modalities, political, and business structures in its surrounding environment. This made FlyHub an integrator in a larger ecosystem. A strategy employee captured this complex multi-system environment as: *"FlyHub is definitely an ecosystem: it has its own ecosystem and is [also] part of an ecosystem"* (06/2022).

Thus, during the research period, FlyHub relied on other stakeholders in the broader ecosystem to facilitate the significant organisational shift towards becoming an MTH, providing integrated infrastructure and services for multimodal journeys. A strategy employee confirmed players' reliance on the network with integrated luggage solutions at FlyHub: *"Without (firm) commitments from the carriers and the network manager, investing in an integrated baggage solution is not yet meaningful"*. This was also the case with electric and hydrogen aircraft since charging equipment had to be at the desired destination (innovation executive, 04/2022). Therefore, we stress that FlyHub's transition towards an MTH demands synchronised actions and investments from many stakeholders.

The embedded researcher observed that in FlyHub, MTHs were often explored and co-created in extensive collaborations involving many stakeholders, such as other airports and airlines. Furthermore, there were collaborations with parties outside of FlyHub's core focus, such as rail operators, Hyperloop start-ups and UAM operators: *"We will investigate together how we could design (partial) solutions and scenarios that support the needs of our intermodal customers"* (an MTH consortium member, 10/2022).

Unfortunately, such collaborations also brought challenges and questions. One of the questions was how to organise such extensive alliances since collaborating with many stakeholders proved difficult, as stakeholders each had their interests (strategy employee, 06/2022). Besides, the embedded researcher observed that clear communication within collaborations was often lacking. Moreover, there were difficulties coping with the investments involved, as the transition towards an MTH is about the system's interest as a whole, meaning not one party is responsible. The embedded researcher noticed the utilisation of subsidies to manage the high transition costs:

"Complex projects often go beyond airports, you often need subsidies for that" (innovation manager, 11/2021).

Additionally, substantial operational disparities between modalities posed challenges in integrating two travel modalities. For instance, a strategy employee working on air-rail integration noted trains and planes as *"water and oil"* (11/2022). Pricing differences further complicated the integration of their ticketing services. Moreover, MTH's international focus required cooperation with stakeholders from other countries, which was even more complicated according to a strategy employee (11/2021): *"Within countries works well, no difficult collaborations and such."*

3.5 Theme: changes and transitions being a struggle for power

This theme reveals how stakeholders' evolving power positions during the transition impede change. The embedded researcher observed resistance to change as parties sought to retain power. In addition, FlyHub's influential position significantly impacted the success of other parties.

During the research period, aviation developments took the lead and directed actions through the airport terminals towards landside developments. This was addressed by a strategy employee (12/2021): *"Landside is often a bit of a waiting game for airside. Don't think about it until you know what's coming your way".* Consequently, FlyHub mainly focused on aviation during the research period, which caused aviation as FlyHub's means to maintain its power.

Next, FlyHub also aimed to exert power on new modalities to incorporate them into existing (power) structures: *"We're not stopping UAM because it is coming. If we decide to market UAM, we can influence how we can use it best"* (innovation executive, 08/2022). More, FlyHub's employees frequently highlighted the many advantages of aviation over other means of transport, such as *"super-efficient"* (innovation manager, 09/2021), *"flexible"* (strategy employee, 06/2022), and *"universal"* (strategy employee, 07/2022). These advantages made shifting their focus outside the aviation industry less attractive.

FlyHub responsibilities as an Airport Hub, where aviation activity steered airport development, indicate aviation's inherent power. Following this, airlines, as operators of this primary modality, were perceived as FlyHub's critical stakeholders: *"[airlines] will remain part of the scene"* (strategy employee, 06/2022). Focusing FlyHub's business on aviation and airlines was an instrument of maintaining its current power as an Airport Hub.

Next to FlyHub's focus on aviation during the research period, the hub-

and-spoke model was also considered an essential property of FlyHub. As a result, new modalities were assessed based on the fit with the operational and business model of the hub, which principle is to transfer passengers between flights. Therefore, FlyHub only attempted to add modalities into its business to serve the hub-and-spoke model. This would allow FlyHub to maintain its current position, which meant facilitating transfers and bringing different transport operators together at FlyHub's location.

But also new modality operators invested in FlyHub's transition to attain a power position. The embedded researcher observed a common way to secure businesses when collaborating, namely through non-disclosure agreements (NDA). NDA's are a form in which parties agree to treat sensitive business information confidentially, as explained by an innovation executive (05/2022): *"Then a partner is willing to share much information."* This information on businesses and operators was crucial for FlyHub to assess the extent to which investments or spatial reservations needed to be made. Besides, the embedded researcher noticed a transport operator investing in UAM aircraft development and infrastructure to ensure availability when the transport operator requires it.

Finally, FlyHub had a particular position of power that could influence the success of other parties:*"If we don't work with X, X may become less interesting. It also gives [third parties] PR if we work with them"* (innovation manager, 07/2022). Accordingly, FlyHub regularly received requests to sign 'letters of intent', indicating interest in future collaborations. A start-up said about the 'letter of intent': *"something that would help us enormously in the next phase of our company: raising capital."* Thus, next to controlling their power, the embedded researcher observed that major players like FlyHub could impact the success of new, smaller stakeholders.

4   DISCUSSION

Our research focussed on studying in and from practice the corresponding research question: *What themes arise when an Airport Hub aims to innovate with new travel modalities in order to transform into an MTH?* We identified five themes as 'threads of underlying meaning' following Graneheim & Lundman (2004, p.107). Below, we discuss the five themes from three different angles.

During the research period, the MTH concept aligned well with FlyHub's focus on handling complex future innovations. FlyHub emphasised innovation, which was widely supported across business units and endorsed by the CEO. However, the MTH concept remained abstract, and the dedicated innovation

team eventually redirected its focus. The abstraction can be attributed to the multifaceted nature of the MTH transition. It involves dealing with new travel modalities whose added value is unknown (at the time) and simultaneously requires a multi-system transition involving many players. The embracement of new travel modalities through accessing, harnessing, and absorbing, as advocated by Toet et al. (2022), seemed to have fewer rigid boundaries with slightly different activities in practice. The activities identified through our study included identifying, monitoring, assessing, experimenting with, and implementing new modalities. However, FlyHub had no set structure for managing these activities. Besides, FlyHub's transition towards an MTH faced challenges due to limited exploration possibilities in its stringent environment, leading the organisation to promote exploration at small airports. Moreover, the embedded researcher observed the first steps of the multi-system transition towards an MTH, which was found to have a slow pace due to numerous stakeholders seeking to maintain their positions of power. Furthermore, the results suggest that accessing new modalities and innovations, known in this study as 'identifying' and 'monitoring' activities, requires less attention due to the slow development of multi-systems and the power position of FlyHub.

We emphasise that the insights from this research derive from the observations made by the embedded researcher within the context of FlyHub. To ensure transparency and traceability in the data collection and analysis process, we have thoroughly substantiated the results by clearly illustrating how they emerged from the data. Examples of sources are text messages and e-mail phrases. In addition, we have presented the prior knowledge and background of the embedded researcher. We recognise its potential influence on data collection and analysis, which is considered essential in qualitative research (Malterud, 2001). During the research period, the researcher's role evolved from outsider to partial insider (Greenwood & Levin, 2007; Herr & Anderson, 2005). This shift created challenges in objectifying insights due to the establishment of bonds of trust through the AR approach. However, it also facilitated the acquisition of deeper insights. On top of that, it is vital to acknowledge that the researcher was an intervention agent, known within FlyHub as the *"Multimodal researcher"* or *"PhD candidate."* Consequently, the researcher's presence in FlyHub impacted the initiation of multimodal projects.

This research indicates that AR is suitable for establishing profound, long-term engagement with the research context. This contrasts with fast-paced methods driven by limited budgets, often used by design researchers. The cyclic nature of AR, encompassing multiple iterations (Coughlan, 2002), seems

well-suited and beneficial for the design research community, particularly when dealing with complex contexts. Nevertheless, as underscored in the method section, it is important to apply findings to other contexts apart from the one they emerged from for theory building. Consequently, the researchers strongly advocate for future investigations in diverse settings, such as other Airport Hubs beyond FlyHub, regional airports, or Rail Hubs. This approach should contribute to a deeper understanding of similar complex transitions, encompassing mobility systems centred around passenger journeys.

The findings have significant implications for researchers and practitioners. The following steps in this AR project involve gaining a deeper understanding of seamless multimodal passenger journeys at Airport Hubs. The knowledge acquired will be implemented in interventions that should enable multimodal travel at Airport Hubs as part of the transition to MTHs, followed by evaluations in the context. The embedded researcher will continue using AR to study and integrate (new) services of modalities within Airport Hubs.

Moreover, this case study has shed light on compelling research areas that warrant attention in future studies. Primarily, future research should focus on developing theoretical knowledge for Transport Hubs to deal with and implement new travel modalities effectively. Based on this study we see a possibility for exploring Chesbrough's open innovation approach (2017) to harness and absorb new travel modalities. Second, further investigation is needed to understand how Transport Hubs navigate various stakeholders' diverse perspectives and needs during the transition to MTHs. Gaining a deep understanding of how they should manage competing demands can benefit future decision-making and strategy development. Lastly, studying the added value of MTHs and the potential of Airport Hubs within the evolving ecosystem is crucial. Since the concept of MTHs is still abstract, applying systemic design practices to co-create with stakeholders from different disciplines offers research opportunities to shape an effective and sustainable vision of Airport Hubs as MTHs.

Our discussion on the themes yielded valuable and pertinent insights from our research, advocating for the pursuit of further steps in the AR process.

5 CONCLUSION

This research revealed five themes that emerged when FlyHub aimed to innovate with new travel modalities in order to transform into an MTH. These themes are:

1. recognition of the importance of innovation and long-term outlook,

2. limited exploration possibilities,

3. the MTH concept being (too) abstract,

4. multi-system transition going slow, and

5. changes and transitions being a struggle for power.

These themes suggest that transforming FlyHub into an MTH is beyond the scope of FlyHub alone. It requires a full ecosystem transition, layered in multi-levels and -systems, where parties must work together to embrace new modalities within the system, including at FlyHub.

3

REFERENCES

Anderson, K., Blanchard, S. D., Cheah, D., & Levitt, D. (2017). Incorporating equity and resiliency in municipal transportation planning: case study of mobility hubs in Oakland, California. Transportation Research Record, 2653(1), 65-74.

Bartunek, J.M. and Louis, M.R. (1996), Insider/Outsider Team Research, Sage, Thousand Oaks, CA.

Canale, A., Tesoriere, G., & Campisi, T. (2019). The MAAS development as a mobility solution based on the individual needs of transport users. Proceedings of the international conference of computational methods in sciences and engineering 2019 (ICCMSE-2019). https://doi.org/10.1063/1.5138073

Ceder, A. (2021). Urban mobility and public transport: Future perspectives and review. International Journal of Urban Sciences, 25(4), 455-479.

Chesbrough, H. (2017). The future of open innovation: The future of open innovation is more extensive, more collaborative, and more engaged with a wider variety of participants. Research-Technology Management, 60(1), 35-38.

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. International journal of operations & production management.

Cornish, F., & Gillespie, A. (2009). A pragmatist approach to the problem of knowledge in health psychology. Journal of Health Psychology, 14(6), 800-809.

Eden, C. and Huxham, C. (1996), ``Action research for management research'', British Journal of Management, Vol. 7, pp. 75-86.

European Commission. (2011). Roadmap to a Single European Transport Area: Towards a Competitive and Resource Efficient Transport System [White Paper]. Publications Office of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN

Giorgi, A. P., & Giorgi, B. M. (2003). The descriptive phenomenological psychological method.

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse education today, 24(2), 105-112.

Greenwood, D. J., & Levin, M. (2007). Introduction to Action Research (2nd ed.). Sage Publications Inc. Haraway D. Situated knowledges: the science question in feminism and the privilege of partial perspective. In Haraway D. Simians, cyborgs, and women: the reinvention of nature. New York: Routledge, 1991: 183–201.

Herr, K., & Anderson, G. L. (2005). The Action Research Dissertation A Guide for Students and Faculty. Sage Publications, Inc.

Huang, S., & Mu, D. (2018). Discussion on the Development Strategy of China's Multimodal Transport Stations. In 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018) (pp. 256-262). Atlantis Press.

Khandkar, S. H. (2009). Open coding. University of Calgary, 23, 2009.

Lincoln, Y.S. and Guba, E.G. (1985), Naturalistic Inquiry, Sage Publications, Newbury Park, CA.

Lindgren, B. M., Lundman, B., & Graneheim, U. H. (2020). Abstraction and interpretation during the qualitative content analysis process. International journal of nursing studies, 108, 103632.

Li, L., & Loo, B. P. (2016). Towards people-centered integrated transport: A case study of Shanghai Hongqiao Comprehensive Transport Hub. Cities, 58, 50-58.

Li, Z., & Xu, W. A. (2019). Path decision modelling for passengers in the urban rail transit hub under the guidance of traffic signs. Journal of Ambient Intelligence and Humanized Computing, 10(1), 365-372.

Lüscher, L. S., & Lewis, M. W. (2008). Organizational Change and Managerial Sensemaking: Working through Paradox. Academy of Management Journal, 51(2), 221-240.

Malterud, K. (2001). Qualitative research: standards, challenges, and guidelines. The lancet, 358(9280), 483-488.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. sage.

Monzón, A., Hernández, S., & Di Ciommo, F. (2016). Efficient urban interchanges: the City-HUB model. Transportation Research Procedia, 14, 1124-1133.

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. Journal of Mixed Methods Research, 1(1), 48-76.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. Education for information, 22(2), 63-75.

Toet, A., van Kuijk, J., & Santema, S. (2022). Transforming Airport Hubs into Future-Proof Multimodal Transport Hubs. In Relating Systems Thinking and Design (RSD11) Symposium: Possibilities and practices of systemic design.

Veeneman, W. W., Van Kuijk, J. I., & Hiemstra-van Mastrigt, S. (2020). Dreaming of the travelers' experience in 2040: Exploring governance strategies and their consequences for personal mobility systems. Towards user-centric transport in Europe 2: enablers of inclusive, seamless and sustainable mobility, 225-239.

Wicks, D. (2017). The Coding Manual for Qualitative Researchers (3rd edition). Qualitative Research in Organizations and Management: An International Journal, 12(2), 169–170. https://doi.org/10.1108/qrom-08-2016-1408

Zgodavová, Z., Rozenberg, R., & Szabo, S. (2018). Analysis of Point-to-Point versus Hub-and-spoke airline networks. In 2018 XIII International Scientific Conference-New Trends in Aviation Development (NTAD) (pp. 158-163). IEEE.

3.4   REFLECTION

The two papers presented in previous paragraphs present the purpose and context of the AR cycle (Coghlan, 2019) and formed the foundation of the research. It presents the literature I explored alongside the practical experience I gained from immersion in the field. In Patton's (2015) words, I studied *"the box"*: I developed an understanding of what the box represents, the context that has shaped it, and how both 'inside' and 'outside' thinking informs its meaning.

Through content reflection in 3.4.1 *(What did I learn?)*, process reflection in 3.4.2 *(How did I learn it?)*, and premise reflection in 3.4.3 *(What assumptions influenced my learning?)* (Coghlan, 2019), this section provides deeper insight into the contribution of the two papers to the overarching AR cycle of this thesis.

3.4.1 CONTENT REFLECTION

I approached the studies presented in this chapter with a question that emerged from reflections shared by me, my research team and the airport organization where I was embedded. Engaging with this question led me to the *"context & purpose"* papers presented in sections 3.2 and 3.3. They made me realize how complex the transition to a passenger-oriented multimodal airport transfer can be, also within a context that, on paper, has great potential. What struck me particularly is that the concept of a MTH, while politically endorsed by the EU as a key step towards sustainable mobility (European Commission, 2011, 2021), often turned out to be abstract and challenging to implement in practice.

This chapter made me realize that multimodal air transport extends beyond merely connecting different modes of transport physically. The true value for passengers seems to emerge from service integration – consider aspects such as planning, information provision, and ticketing (Veeneman et al., 2020) – which has primarily been established by operators within individual modalities rather than across them. This realization prompted me to explore the multimodal air travel experience from the passenger's perspective in a follow-up study (chapter 4).

In the paper presented in chapter 3.2, I argued that an airport cannot be considered a Multimodal Transport Hub (MTH). Upon reflection, this perspective requires some nuance. As noted in this chapter, examples of air&rail collaboration do exist, such as the dedicated AiRail terminal at Frankfurt Airport. However, such highly integrated initiatives remain the

exception rather than the rule. Consequently, the standard typology of an airport hub, as presented in the scoping review, does not by default imply the integration of services across multiple transport modes.

This chapter, particularly the embedded case study in section 3.3, highlighted for me the lack of a defined structure within the airport organization for addressing new modalities. I observed a lack of a long-term vision and also a dominant focus on operational challenges, which hindered strategic alignment on multimodality. Based on these findings, I perceived that multimodality was not yet structurally embedded within the airport organization. This insight indicated not only an innovation process challenge but also an organizational challenge: how can an (airport) organization transition to something new like multimodality?

While I approached Chesbrough's open innovation model (Chesbrough, 2003, 2006, 2017) from a singular organizational perspective, it became clear to me that the concepts of harnessing and absorbing do not naturally lead to integration between modalities in this context. Rather, they describe, show or illustrate how an organization positions itself concerning external developments, knowledge and ideas. In a system where collaboration among multiple parties is essential for service connection, an organizational framework focusing on a single organization appeared inadequate. This led me to expand my research design and to involve transportation providers as integral parts of the system and focusing on the multimodal air journey. After all, the transition to an integrated, passenger-centric multimodal travel experience is very unlikely to be attainable without the participation of key stakeholders.

Contribution to the thesis research questions

The findings from this chapter informed the development of my research approach, which focuses on understanding the passenger experience (chapters 4 and 5) and the involvement of multimodal stakeholders (chapters 5 and 6), as this chapter sought to understand the contexts and purposes that shape our direction.

3.4.2   PROCESS REFLECTION

I gained insights by conducting a scoping literature review to understand scientific gaps while, at the same time, being embedded in the organization.

Reflecting on the literature study, it provided me with a structured overview of how multimodality had been studied, helping to identify research gaps. However, the scoping review was limited by the scope of the databases,

search terms, and inclusion criteria used, which may have led to overlooking relevant contributions, especially from practice, such as Air&Rail travel.

Through the embedded AR approach, I learned alongside practitioners, enriching the outcomes. However, my own position and involvement inevitably influenced both the process and findings. By maintaining a reflective diary (Coughlan & Coghlan, 2002; McNiff & Whitehead, 2009), I captured observations and revisited them over time, deepening my understanding of both subtle shifts and bigger turning points. External changes, such as shifts in leadership and the impact of COVID-19, added complexity to the context. I entered the organization as an outsider (Greenwood & Levin, 2007), but over time, I became part of the team and thus more of an insider. My role as an innovation lead placed me in a unique position, enhancing my understanding of the organization and its context. It helped me differentiate between how innovation is planned and intended versus how it actually occurs in real-life applications.

The findings from the scoping review and the embedded AR approach can be viewed together, though they exhibit differences. The outcomes of the embedded AR study are context-specific, limiting their generalizability (Miles et al., 2014). In contrast, the scoping review is characterized by its exploratory nature and does not concentrate on a particular case; it aims to elucidate existing academic knowledge surrounding multimodality at airports. Additionally, my close involvement in the AR process poses potential risks of bias, while the single organizational scope restricts the range of perspectives considered.

3.4.3   PREMISE REFLECTION

My shift as an AR-researcher from being an outsider to a partial insider is evident in my AR diary, where I moved from describing the organization as *"they"* to referring to it as *"we."* This shift is known as crucial in AR, as it facilitates a shared understanding of where value lies for both theory and practice (Coghlan, 2019; Greenwood & Levin, 2007). Becoming a partial insider also fosters a greater sense of responsibility; the researcher becomes more invested in ensuring that the research leads to acceptable outcomes (Greenwood & Levin, 2007).

As I increasingly saw myself as part of the airport organization, I began to view multimodality more from the airport's perspective. While some individuals within the organization viewed the airport as an MTH due to the existing (infrastructure) connections between various modes of transportation, the broader organization remained primarily focused on air travel. An example

of this influence is my approach to multimodality, which I see as a means of connecting different transport modes within the airport hub, framed within the H&S model of which the airport in my study is a part.

The assumptions held by employees in the organization, particularly those of my direct peers, also influenced the learning process. One illustration of this influence is my placement within the innovation team, which was accustomed to adopting lenses to address airport challenges from a broader ecosystem perspective. By being embedded in this environment, I began to see the airport not as an isolated actor but as part of a broader, interconnected system. I came to understand that multimodality cannot be meaningfully grasped or advanced without adopting an ecosystem lens.

Second, within the innovation team, I focused on multimodality in the broadest sense, considering a wide range of both established and emerging transport modes. However, shifting priorities and internal realignments within the innovation team and the wider organization eventually led to the reassignment of the multimodality topic to the masterplanning team. The masterplanning team was responsible for developing a masterplan for the airport for 2030 and 2050. One of the key focus points within this masterplan was the development of air&rail integration at the airport. Although my transition into masterplanning was a logical step related to my research, it also influenced the study's direction, which from that point on increasingly concentrated on air&rail integration as a concrete expression of multimodal air transport.

This shift to another team deepened my understanding of a key challenge in AR: the need to continually renegotiate expectations and maintain alignment between the researcher and the organization (Coghlan, 2019). It taught me that learning in AR involves adapting to the evolving organizational landscape, questioning one's own assumptions, and navigating the tensions between academic aims and organizational realities.

3

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5

Where it connects

It begins with a question,
born in moments of reflection.
What drives multimodality today?
What contexts and purposes lead our way?

By stepping into their stride,
we leave assumptions at the side.
Each journey blurs the lines we drew,
and moving through, we create them too.

Beneath the doing lies the why,
designed by those who stand nearby.
Through open words and searching eyes,
layers fall and systems rise.

We create what none could do alone,
from viewpoints far beyond their own.
By dropping all that thought protects,
we find new meaning where it connects.

CHAPTER 4. RESEARCH CYCLE 1

4.1 INTRODUCTION

This chapter reports on the first AR cycle, which addressed the first research question: *"What are the properties of a passenger-oriented multimodal air journey?"* The study explored the design of multimodal air journeys from the passenger perspective and identified areas of need. While previous quantitative studies had outlined the ideal attributes of multimodal (air) journeys, they had not examined the underlying reasons why and how specific aspects matter to passengers. This chapter contributes to a deeper understanding by employing qualitative autoethnographic research and reflective interviews.

Understanding the passenger experience is essential, as positive experiences encourage repeat use and enable operators to sustain multimodal services (Schmitt & Gollnick, 2016; Van Lierop & El-Geneidy, 2016; Wang et al., 2017). In turn, successful multimodal air journeys can enhance airports' competitive position by expanding airline catchment areas and strengthening network connectivity (Chiambaretto & Decker, 2012; Givoni & Banister, 2006; Janic, 2011; Jiang et al., 2017; Li et al., 2018; Román & Martín, 2014). Therefore, this research examined how passengers perceive multimodal air journeys and identified opportunities for improvement in collaboration with field experts. The chapter focuses specifically on factors influencing the passenger experience during the journey, rather than on pre-departure considerations such as booking decisions, costs, frequency, travel time, or reliability (Avogadro et al., 2023; Babić et al., 2024; International Union of Railways, 2022; RLI, 2020). The analysis gives special attention to the multimodal transfers, as these play a crucial role in determining the overall quality of multimodal air journeys (Babić et al., 2022; Chauhan et al., 2021; Durand & Romijn, 2023).

Building on the previous study (Chapter 3), which concentrated on the airport and explored a broad range of modalities, the present study examines multimodal air journeys as currently offered by transport operators. Although more stakeholders are involved here than in the airport-focused analysis, the study takes a more concrete form by investigating connections between two modes of transport – mainly air&rail, and in one case air&bus – at the airport (Figure 12).

Methodologically, the study adopted a first-person practice approach in AR (Coghlan, 2019; Reason & Bradbury, 2008; Reason & Torbert, 2001). Together with a research assistant, I engaged in first-person practice by experiencing multimodal air journeys and documenting our observations, reasoning, and behaviors through audio recordings (Coghlan, 2019). In addition,

practitioners from the air&rail ecosystem were invited to participate in first-person inquiry by recording their observations and reflections in a structured travel journal. Journaling, a recognized method for developing first-person skills (Coghlan, 2019), provided access to practitioners' lived experiences, the questions these experiences raised, and the insights that emerged. Involving practitioners also constituted a system intervention, intended to foster awareness and stimulate initial engagement with the change process toward multimodal air journeys.

Throughout the paper in this chapter, a multimodal air journey is referred to as MJIAT (multimodal journey involving air travel).
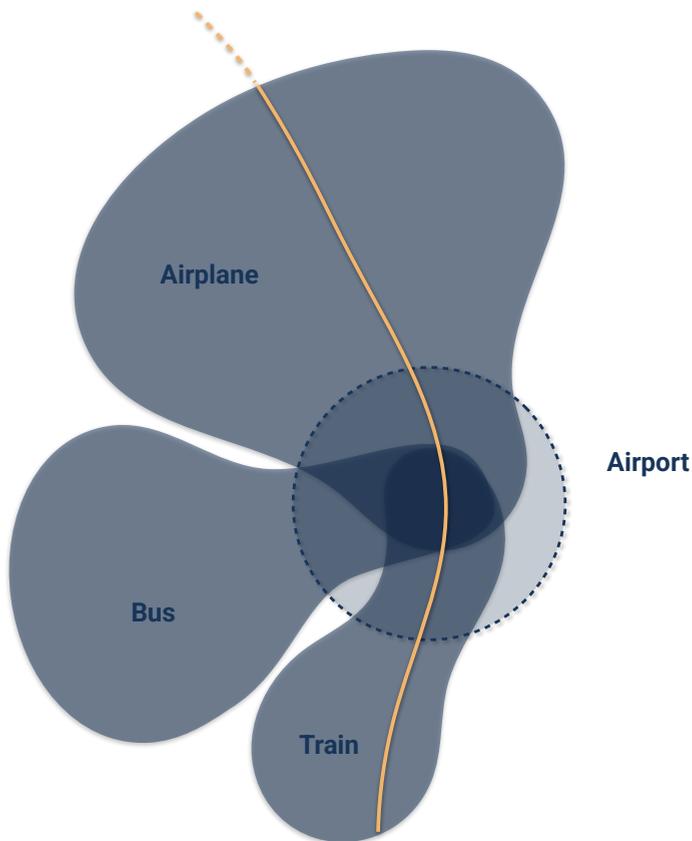
Figure 12. Studying multimodality through the passenger perspective

4.2 ON THE MOVE: UNDERSTANDING PASSENGER EXPERIENCE AND JOURNEY INTEGRATION IN MULTIMODAL TRAVEL AT EUROPE'S AIRPORTS

ABSTRACT

The rise of multimodal travel underscores the need to design a cohesive journey that considers the passenger experience from start to finish. Achieving this requires integrating diverse travel modes and coordinating infrastructure and mobility services, especially at major transport hubs.

This research employs qualitative methods to study passengers' experiences in multimodal travel involving air transport in-depth. Using autoethnographic and interview methods, researchers and practitioners undertook a total of 26 multimodal journeys involving air transport at four European airport hubs to study the travel phases these journeys and factors influencing the experience.

The findings indicate that multimodal journeys involving air transport differ significantly from traditional air-to-air journeys. Multimodal passengers encounter friction as they must cross more system boundaries compared to single-mode travel, with each system governed by its own distinct rules and regulations. Consequently, multimodal journeys require different passenger flows, infrastructure, and services than air-to-air journeys.

This research identified eight journey integration factors that impact the passenger experience of multimodal journeys involving air transport: (1) journey explanation and preparation, (2) personalized and pro-active assistance, (3) wayfinding, (4) proximity of modalities and facilities, (5) multimodal transfer services, (6) balanced transfer time, (7) waiting environments, and (8) in-travel comfort.

Importantly, the passenger experience in multimodal journeys involving air transport is influenced by passengers' expectations and cannot be understood in isolated segments, as travel phases are interdependent. This highlights the importance of designing multimodal journeys involving air travel as cohesive units and emphasizes the crucial role of collaboration among actors across transport systems.

Keywords: multimodal; intermodal; passenger experience; travel; airports; service design

1. INTRODUCTION

In recent years, transport has increasingly shifted its focus toward multimodal systems, where different modes of travel are combined within a single journey (Babić et al., 2022; Rodrigue, 2024). This development has created a growing need for seamless integration between transport modes

and mobility services, allowing passengers to plan, book, and pay for their journeys across various mobility operators and travel modes (Gebhardt et al., 2016; Veeneman et al., 2020).

This shift has been driven by advancements in digitalization and sustainability, which enable travel to become faster, safer, more efficient, cost-effective, and to produce fewer CO2-emissions (Butler et al., 2020; Docherty et al., 2018; Nikitas et al., 2020). Specifically, digitalization can enable flexible and passenger-centric mobility services that put passenger experience centre stage, instead of the mode of travel (Canale et al., 2019; Ceder, 2021; Docherty et al., 2018). This emphasis on passenger experience highlights the need to design travel as a coherent journey from departure to arrival, considering the passenger's perspective rather than segmenting it by individual modes of transportation (Babić et al., 2022; Jittrapirom et al., 2017).

For airport hubs and airlines, it is advantageous to explore multimodal travel from departure node to arrival node (see Figure 1 and 2), given the current increasing societal and governmental pressure to reduce the environmental impact of aviation (European Commission, 2011). This pressure is driving the replacement of short-haul flights with more sustainable alternatives like trains and buses.

In the aviation sector, two main network structures are commonly used to organize transportation. First, the point-to-point network model (Figure 1) connects each airport node directly to others, treating all nodes and links as similar in supply, demand, and capacity (Wang et al., 2024). In this system, passengers enter the air transportation network via the landside area (letter A) of the departure node airport. They proceed to the airside area which is bounded by passport and security checks (Marquez, 2019), travel to the arrival node airport (letter B), and exit the (air-)network (letter C).

Second, the hub-and-spoke model (Figure 2) organizes air transportation around central hubs, which serve as key nodes in the network (Kwasiborska et al., 2021; Wang et al., 2024). In this system, passengers enter the (air-) network via the landside area at the departure node airport (letter A) and are then transferred to central hubs (letter B). From there, they are directed to the arrival node airport (letter C) before exiting the air-network via landside (letter D).
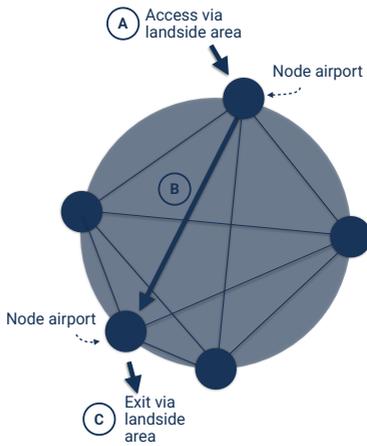
Figure 1. Point-to-point network
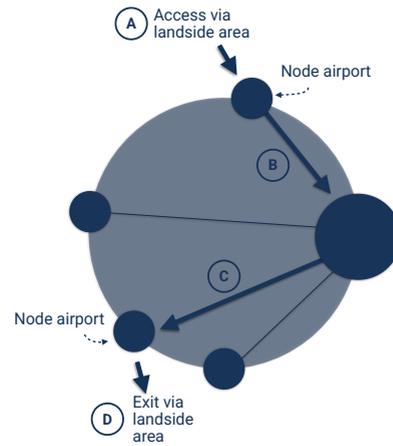
Figure 2. Hub-and-Spoke network

Airport hubs facilitating the hub-and-spoke model can leverage this system by integrating more sustainable modes of transportation, such as trains and buses, into the network (Chiambaretto & Decker, 2012). These alternative modes could also function as spokes and, when fully integrated, may serve as replacements for existing flight connections, thereby seamlessly connecting to long-haul flights and enhancing the connectivity and sustainability of both airports and airlines (Chiambaretto & Decker, 2012; Givoni & Banister, 2006; Román & Martín, 2014). This integration requires the presence of train and bus infrastructure at airport hubs, as research shows that the proximity of the train station to the airport is crucial for successful cooperation between air and rail operators, shorter transfer times, and improved transfer services (Li et al., 2018).

1.1 Multimodal travel involving air transport

The mobility industry can be seen as a high-order system composed of multiple subsystems, each based on different transport modalities such as airplanes, trains, buses, and bicycles (Schmitt & Gollnick, 2016; Toet et al., 2022).

While travelers to and from airports always combine different modes of transport (Schmitt & Gollnick, 2016), multimodal travel shifts the focus from individual trip segments to an integrated journey (Allard & Moura, 2016; Babić et al., 2022; Bagamanova et al., 2022; Huang & Mu, 2018; Rodrigue, 2024; Schmitt & Gollnick, 2016). Multimodal travel, with its increased integration, represents an advancement over intermodal travel, in which multiple modes of transportation are used but each operates independently

with its own services, such as ticketing and information (Babić et al., 2022; Rodrigue, 2024). In contrast, multimodal transport offers a single integrated ticket across different modalities, to ensure seamless journeys (Babić et al., 2022; Li et al., 2018; Román & Martín, 2014) and provides connection insurance to mitigate disruptions or missed connections during the journey (Román & Martín, 2014). This paper examines the concept of the multimodal journey involving air transport (MJIAT), referring to multimodal travel from departure node to arrival node (see figure 1 and 2). Throughout the paper, we use the abbreviation MJIAT for conciseness. Air&rail, as well as air&bus, exemplifies a practical application of MJIAT.

The services facilitating MJIATs differ per airport hub and operator (Li et al., 2018). For example, airlines like Air France and Swiss, at the time of writing provide full baggage handling for their MJIATs. Additionally, Frankfurt Airport features a dedicated air&rail terminal, and partnerships between air and rail companies offer priority treatment at airport security. These initiatives suggest that instances of multimodal integration involving air transport are emerging, though they are not very common, and in not all MJIATs the legs are integrated to the fullest extent. This builds on previous research (Toet et al., 2022) that frames airports as not yet fully developed Multimodal Transport Hubs (MTHs) due to incomplete integration, especially on the service layer, but sometimes also lacking in infrastructural alignment.

There is a considerable body of studies on air transport and multimodal travel that examines the factors that influence the choice for a specific way of traveling, such as time, fares, and schedules (Avogadro et al., 2023; Babić et al., 2024; International Union of Railways, 2022; Pels et al., 2003; RLI, 2020). However, less studied is how to ensure and raise the quality of the multimodal journey, even though this plays a crucial role in determining whether passengers will reuse or even consider multimodal options in the future (Lai & Chen, 2011; Schmitt & Gollnick, 2016; Van Lierop & El-Geneidy, 2016; Wang et al., 2017). Specifically, passenger satisfaction with the overall journey is closely linked to the transfer experience during multimodal travel (Babić et al., 2022; Chauhan et al., 2021; Durand & Romijn, 2023). Therefore, this study focuses on the passenger experience of MJIATs, from the departure node to the arrival node. To achieve this, it is essential to understand what properties of MJIATs affect the passenger experience.

1.2 Passenger experience

We consider passenger experience to be related to the concept of user experience. The ISO organization defines user experience as the *"user's perceptions and responses that result from the use and/or anticipated use*

of a system, product or service" (ISO, 2019, p.4). In the context of travel, the passenger is considered a user of the travel service. The perceptions and responses that user experience encompasses include emotions, beliefs, preferences, comfort, behaviors, and accomplishments (ISO, 2019), which arise from external stimuli (Desmet, 2003). These perceptions and responses are highly contextual, meaning that the experience depends on where, when and with what purpose interactions take place (ISO, 2019; Roto et al., 2011).

The quality of a passenger experience is often defined by a combination of aspects. One key element is the efficiency of the process (Hernandez Bueno, 2021). Kirk et al. (2012, p. 8) underscore the importance of *"understanding the activities, the sequence of activities and the reason why they were carried out"* to improve the passenger experience at airports. At the same time, previous studies show that mandatory airport procedures, such as security checks, can cause stress (Kim et al., 2020). In addition to process efficiency, other features, such as comfort, services, and shopping opportunities, also play a role in shaping passengers' perceptions (Hernandez Bueno, 2021).

1.3 Multimodal passenger experience

Multiple authors stress that integrating multimodal journeys at hubs requires consideration of both infrastructure and services (Bell, 2019; Chauhan et al., 2021; Monzón et al., 2016; Toet et al., 2022). We reviewed existing literature to identify factors from both categories that affect the passenger experience. The review was conducted using Scopus and Google Scholar, applying keyword searches such as 'multimodal,' 'transfer,' 'level of integration,' 'passenger experience' and their synonyms. The review was structured in three steps: first, we examined passenger journey experiences with transfers at airport hubs; second, we synthesized factors around mobility hubs; and finally, we focused on multimodal passenger experience factors at airport hubs, particularly concerning air&rail and air&bus transfers.

1.3.1 Multimodal infrastructure for passenger experience

From the literature, we identified four clusters of passenger experience factors related to the infrastructure of the (multimodal transport) hub: (1) wayfinding and signage, (2) hub facilities, (3) waiting environment, and (4) hub design.

First, wayfinding and signage help passengers navigate efficiently through the transfer environment (Nielsen et al., 2021; Wang et al., 2020). Clear information and signage within the terminal are critical for enhancing the passenger experience at airport hubs, making services easier to find and use (Allen et al., 2020).

Second, the presence of hub facilities, such as shops and restaurants, enhances the overall attractiveness of a hub (Hickman et al., 2015). Additionally, passengers prioritize safety and security, both within the hub and its surrounding areas, as some of the most significant factors influencing their experience (Eboli & Mazzulla, 2015; Hernandez & Monzon, 2016). Furthermore, facilities designed specifically for passengers with impairments contribute to the hub's overall appeal (Eboli & Mazzulla, 2015).

Third, well-maintained waiting areas, which include adequate seating and shelters, can contribute to a positive passenger experience (Eboli & Mazzulla, 2015).

Finally, airport hub design encompasses both ambiance and layout, which includes characteristics such as a clean and spacious terminal, pleasant lighting, and optimal acoustic quality. These factors are fundamental in shaping the passenger experience (Geng et al., 2017; Wattanacharoensil et al., 2016). When these design elements fail to meet expectations, they can negatively impact passenger satisfaction (Geng et al., 2017). According to Hernandez and Monzon (2016), the walking experience is influenced by environmental factors and distance, with positive experiences frequently associated with shorter walking distances. Given that walking distances are constrained by fixed infrastructure, enhancing passenger comfort during extended walks can be achieved by improving the walking environment with amenities such as air conditioning and rain shelters (Hernandez & Monzon, 2016; Wang et al., 2020). Moreover, for effective multimodal cooperation, the proximity of train and bus stations to airports is crucial, as co-locating these hubs offers passengers greater convenience and reduces transfer times (Li et al., 2018).

1.3.2   Multimodal services of passenger experience

Our review of existing literature resulted in five clusters of passenger experience factors associated with the services of the (multimodal transport) hub: (1) journey process information, (2) personal communication, (3) special transfer services, (4) ticketing services, and (5) transfer coordination.

First, keeping passengers informed about flight status and the movement of their baggage provides a sense of autonomy (Allen et al., 2020; Hernandez Bueno, 2021). Access to real-time information is critical for keeping passengers informed throughout their journey, thereby enhancing their sense of control (Cascajo et al., 2019; Watkins et al., 2011). Holistic information for trip planning enables passengers to make informed decisions and manage their journey effectively (Antwi et al., 2020; Babić et al., 2022).

Second, communication between passengers and airport personnel significantly influences airport satisfaction (Antwi et al., 2020; Lubbe et al., 2011).

Third, special transfer services include options such as baggage handling and shuttle services. Babić et al. (2022) and Wang et al. (2020) argue that baggage services should be integrated within the airport feeder system, allowing passengers to check in hold baggage at the departure station. However, Román and Martín (2014) found that baggage handling is more appreciated by leisure passengers, as business passengers typically do not travel with hold baggage. They also noted that costs associated with expanding baggage handling systems at stations pose a significant challenge, as passengers are often hesitant to pay additional fees for these services.

Finally, transfer coordination, including fast movement and minimal waiting times, is crucial for the multimodal passenger experience (Abenoza et al., 2019; Babić et al., 2022; Hernandez Bueno, 2021; Wang et al., 2020). While short transfer times are essential for connectivity, excessively long waits are inconvenient, and too short waits may cause stress due to the risk of missed connections (Jiang et al., 2022; Román & Martín, 2014; Song et al., 2018).

1.4 Aim and research question

From the previous research we conclude that designing MJIATs as integrated experiences is crucial. Although previous studies provide insights into the factors that influence the (multimodal) passenger experience, these studies mostly focus on passenger satisfaction, which is only one aspect or a result of the overall travel experience. Moreover, only a few studies address multimodal travel with airports as integrated parts of the trip, and most studies rely on existing literature and quantitative research methods such as passenger surveys.

This highlights the need to study MJIAT experiences to better understand the travel phases of these journeys, the factors that influence the passenger experience, and how airports currently facilitate MJIATs. Hernandez Bueno's (2021) emphasis on the need to study passenger experiences in context to inform passenger-centered design solutions, further underscores the need for a qualitative research approach in this matter. This could complement and expand the existing (mostly quantitative) discourse.

This paper presents an in-depth qualitative study in response to growing calls within the transportation research community to complement predominantly quantitative methods with qualitative studies, thereby

offering a more comprehensive understanding of travel behavior (Farinloye et al., 2019; Julagasigorn et al., 2021). As argued by Eisenhardt and Graebner (2007, pp. 25-26), qualitative research plays a key role in theory building by providing rich empirical data that generates accurate, interesting, and testable theories, serving as an essential complement to traditional deductive research.

This study identifies the phases that form the backbone of MJIATs, and which other factors influence the multimodal passenger experience, thereby enabling researchers to further study these journeys, as well as practitioners to develop effective multimodal travel solutions. This research aims to address the following questions: *1) How are MJIATs structured in terms of travel phases?* and *2) Which properties of MJIATs affect the passenger experience, and in what ways?*

By examining these questions, this study seeks to provide insights into how MJIAT can become a more attractive alternative for traditional air-to-air travel by optimizing for passenger needs and expectations.

2 METHOD

Given the variability of multimodal travel involving air transport and associated services, this study adopts an exploratory case study (Patton, 2015). The case study method is widely recognized for its effectiveness in investigating phenomena within real-life contexts (Yin, 2003). We opted for qualitative methods as these allow for the uncovering of the *"why and how"* of the elements affecting the passenger experience (Miles et al., 2014). As long-distance multimodal travel through airports is an emerging phenomenon, qualitative research is a very suitable approach, as it can help to inductively uncover unknown factors. Patton (2015) argues that surveys and performance indicators are insufficient for discovering new insights, as they are usually based on predetermined hypotheses and established metrics.

For data collection, we utilized two qualitative methods of data collection to capture detailed experiential data: autoethnography and reflective interviews (Figure 3). Autoethnography was chosen for its extended researcher engagement with the phenomenon (an MJIAT in this case). Autoethnography makes it possible to study situational and experiential variables that might remain hidden in large-scale surveys (Adams et al., 2017; Wall, 2006). The study involved two researchers and nine transportation practitioners who acted as passengers to gather behavioral, sensory, and emotional data (Eccles & Arsal, 2017). The intention of involving practitioners was to

combine personal travel experiences with professional expertise, the latter leading to the informants being more sensitized (Sanders & Stappers, 2012) to the studied phenomenon and enabling more nuanced reflections on the operational aspects of MJIATs. In service design, our autoethnographic approach corresponds to what is often referred to as mystery shopping, where researchers act as customers and document their own service experiences, although in our case the focus was not evaluative but rather exploratory (This is Service Design Doing, n.d.). After the data collection by practitioners, reflective interviews were conducted to enhance data quality, address discrepancies in documentation, and ensure that salient observations were captured.

The unit of analysis (Yin, 2003) was the MJIAT, examined across various cases at different airport hubs. Each case represented a specific MJIAT, with transfers occurring at major airport hubs. The emphasis was placed on the journey as a whole rather than on the specific hubs, thus treating the airport hubs as contextual elements influencing the MJIAT.
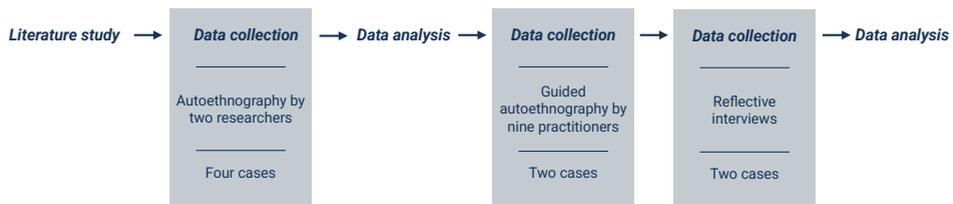
Figure 3. Overview of the method followed

2.1 case selection

We adopted a comparable case sampling strategy, intending to select cases with relevant characteristics (Miles et al., 2014), while also diversifying the execution of the MJIATs offered. Airports providing MJIATs were selected through a two-step process to meet the study criteria.

In the first step, criteria for journeys to be included in the study were:

- MJIAT: in addition to an air journey, the journey should feature one leg of train or bus transport, a single integrated ticket, and connection assurance.
- Transfer at airport hub: the transfer location in the journey should be an airport serving as a hub in the hub-and-spoke model, as these were seen as having the largest potential to integrate various long-haul travel modalities in the future.

- Substitution potential: the train or bus leg should connect destinations within the airline's network, with potential for substitution of short-haul flights in the long term.

- Modality proximity: airport hubs facilitating the multimodal transfer should feature integrated train or bus stations, as literature indicates that close proximity of the connected modalities is an important enabler for multimodal hubs (Li et al., 2018)

- Passenger volume: the airport hub facilitating the multimodal transfer should handle more than 20 million passengers in 2019 (Airport Council International, 2022), to ensure comparable operational complexities, including security processes.

- Location: journeys should take part within Europe to ensure alignment with EU regulations and to minimize travel challenges posed by COVID-19 restrictions during November and December 2022.

Based on these criteria, we identified six MJIATs with multimodal transfers facilitated by these airport hubs: Amsterdam Airport Schiphol (AMS), Charles de Gaulle Airport Paris (CDG), Frankfurt Airport (FRA), Helsinki Airport (HEL), Zurich Airport (ZUR), and Vienna Airport (VIE).

In the second step, the multimodal service offerings of these MJIATs were assessed: 1) comprehensive baggage handling for multimodal passengers, 2) dedicated multimodal touchpoints (referred to as MM touchpoints), and 3) specialized transfer services (Table 1).

For the first round of data collection (autoethnography by two researchers) this led to the selection of cases at AMS, CDG, FRA, and HEL. AMS, CDG, and FRA were selected as they included two of the three multimodal services, while the journey at HEL included a bus connection instead of a train, introducing a valuable variation. The MJIATs were selected for the sequence from train/bus-to-plane (instead of plane-to-train/bus) because in these journeys the airport transfer is more critical, as passengers then must navigate mandatory airport procedures such as check-in, baggage handling, and security checks.

The data collection in the second round (guided autoethnography by nine practitioners) then focused on the MJIATs through CDG and AMS. Again, the journey through CDG was selected for the integrated baggage handling it offered, which is identified in the literature as a crucial factor for successful MJIATs and one of the most significant barriers to effective implementation.

On the other hand, the journey through AMS was selected to investigate in the reverse direction compared to the first round of data collection (plane-to-train), to enhance understanding of its level of integration and the factors influencing it.

Table 1. Comparison of additional services at different airport hub

Multimodal service offerings	AMS	CDG	FRA	HEL	ZUR	VIE
Full baggage handling	-	V	-	-	V	-
Dedicated multimodal touchpoints, such as an air&rail terminal	V (at departure station)	V (at departure station)	V (at airport station)	-	-	-
Special transfer services, such as dedicated fast lanes for multimodal travelers	V	-	V	V	-	-

The selected journeys took place within Europe, meaning there was no immigration and border control. The journeys made are presented along with their order and timing in Table 2. Case 2 and case 5 are identical journeys, although offered by different airline operators that collaborate through code-sharing.

Table 2. Overview of the travel schedule of cases 1 – 6

	Departure node	Hub airport	Arrival node
Data collection round 1: Autoethnography by two researchers			
Case 1. Train – airport (AMS) - Plane	ZYR Train Station (Brussel, Belgium)	AMS Airport (Amsterdam, the Netherlands)	BER Airport (Berlin, Germany)
		Planned transfer time: 1.5 hours	
	6/11/2022	6/11/2022	6/11/2022

	Departure node	Hub airport	Arrival node
Case 2. Train – airport (CDG) - Plane	ZYR Train Station (Brussel, Belgium)	CDG Airport (Paris, France)	MUC Airport (Munich, Germany)
		Planned transfer time: 3 hours	
	25/11/2022	25/11/2022	25/11/2022
Case 3. Train – airport (FRA) - Plane	ZMU Train Station (Munich, Germany)	FRA Airport (Frankfurt, Germany)	RIX Airport (Riga, Latvia)
		Planned transfer time: 2.5 hours	
	28/11/2022	28/11/2022	28/11/2022
Case 4. Bus – airport (HEL) - Plane	TKU Bus Station (Turku, Finland)	HEL Airport (Helsinki, Finland)	AMS Airport (Amsterdam, the Netherlands)
		Planned transfer time: 2.5 hours	
	01/12/2022	01/12/2022	01/12/2022
Data collection round 2: Guided autoethnography by nine practitioners			
Case 5. Train – airport (CDG) - plane	ZYR Train Station (Brussel, Belgium)	CDG Airport (Paris, France)	AMS Airport (Amsterdam, the Netherlands)
		Planned transfer time: 2.5 hours	
	22/03/2024	22/03/2024	22/03/2024
Case 6. Plane – airport (AMS) - train	FRA Airport (Frankfurt, Germany)	AMS Airport (Amsterdam, the Netherlands)	ZYR Brussel South-Midi Train Station (Belgium)
		Planned transfer time: 2 hours	
	21/03/2024	21/03/2024	21/03/2024

2.2 Data collection

To investigate the phases and experiences of MJIATs, data was collected in two rounds (also shown in Table 2). Round 1 involved four different train/ bus-to-plane journeys, each independently examined by two researchers using autoethnography. This phase generated eight journey datasets (four journeys, collected by two researchers). In the remainder of this article, these researchers are referred to as 'researcher-passengers'.

Round 2 aimed to confirm and complement the findings from round 1, and to include different perspectives from the practitioners. To this end, nine practitioners from the air and rail sectors participated in guided autoethnography. Drawing on their prior knowledge of MJIAT, the practitioners provided nuanced and sensitized insights (Sanders & Stappers, 2012). Unlike round 1, which exclusively focused on train/bus-to-plane journeys, round 2 included journeys in both directions. This phase resulted

in 18 journey datasets (two journeys, collected by nine practitioners). In this article, these practitioners are referred to as 'practitioner-passengers'.

2.2.1 Data collection round 1: autoethnography

In round 1 of the data collection, two researcher-passengers assumed the role of passengers during four distinct train/bus-to-plane journeys. These included the first author of this article and a research assistant, both experienced in multimodality research. While they were familiar with airports, neither had previously transferred at the selected hubs or undertaken a MJIAT. Desk research conducted during case selection informed their expectations regarding aspects such as baggage handling, touchpoints, and priority lanes, posing potential biases. An analytical framework, outlined in Section 2.3, details the expectations of data collectors and is designed to minimize potential subjective influences on the results.

Using autoethnography combined with the think-aloud method (Adams et al., 2017; Boren & Ramey, 2000), the researcher-passengers documented their behavioral, sensory, and emotional experiences throughout the journey (Eccles & Arsal, 2017).

Prior literature has indicated that events leading up to the transfer can impact experiences in subsequent phases of a journey (Hernandez Bueno, 2021). Therefore, data collection already began at the departure node (train/bus station) and continued until the airport gate, capturing key phases and influential properties of the MJIAT via audio recordings, photographs, and notes.

The journeys were conducted in November and December 2022, with planned transfer times of 1.5 hours at AMS, 3 hours at CDG, 2.5 hours at FRA, and 2.5 hours at HEL (see Table 2). One researcher-passenger carried hold baggage, while the other traveled with hand baggage only, in order to diversify the passenger experiences. To ensure independent observations and to reduce mutual influence, they undertook the journeys separately, with rest days between trips to facilitate immediate transcription of audio recordings.

The trips were booked through the respective airlines (KLM, Air France, Lufthansa, and Finnair). A train delay occurred in case 1 but did not disrupt the connection, while in the other cases no delays occured.

2.2.2 Data collection round 2: guided autoethnography

Round 2 of the data collection involved nine Dutch practitioners from government, rail and aviation operators, and infrastructure managers. Each

participating company contributed at least one practitioner, with most providing two. These individuals were selected because they were actively engaged in strategic initiatives to develop air&rail journeys in Europe, giving them valuable expertise on MJIATs. Although none had prior first-hand experience with MJIATs, their professional knowledge allowed for more in-depth and nuanced insights (Sanders & Stappers, 2012). Participation was voluntary, with all practitioner-passengers providing informed consent (see Table 3 for an overview of their organizations).

The practitioner-passengers employed guided autoethnography through service safaris, supported by one of the researcher-passengers from the first round of data collection (AT, the first author) and the second author (JK), who both traveled with them during their journeys (This is Service Design Doing, n.d.). Using diaries designed by the first author (Visser et al., 2005), practitioner-passengers documented their observations through photographs and notes, guided by reflective prompts to describe key phases and properties influencing their experiences.

Following the experiences from round 1, informants were asked to go through the booking process before the actual travel. Although the booking process itself was not analyzed, as it fell outside the scope of this study, it was important that all practitioner-passengers completed the steps up to the point of payment. The first author (AT) then finalized the bookings to ensure consistent travel arrangements (e.g., same flights) across groups. This approach ensured that all practitioner-passengers had the same level of information as actual passengers would receive when booking a journey.

Furthermore, data collection covered the journey from the departure node (train/bus station or airport) until the arrival node (airport gate or train platform). Journeys took place in March 2024 (Table 2) and included train-to-plane (case 5) and plane-to-train (case 6) sequences, with planned transfer times of 2 hours at AMS and 2.5 hours at CDG.

The practitioner-passengers traveled in groups, as classified by the first author (AT). Each group consisted of members from different organizations, with one practitioner-passenger in each group carrying hold baggage to compare experiences (Table 3). This arrangement encouraged cross-sector perspectives while reducing mutual influence. The practitioner-passengers were asked to document their observations immediately after each journey to ensure clarity and prevent confusion with later experiences.

Unexpected flight delays during round 2 provided additional insights into how disruptions impact passenger experiences. Despite these delays, the connections were successfully made.

To capture all insights and address possible discrepancies in documentation, reflective interviews were conducted a few days after the journeys. Each interview, lasting approximately 30 minutes, was guided by structured yet conversational questions (Patton, 2015), such as: *"How would you describe your experience of the journey and why?"*; *"What aspects should be improved as quickly as possible?"*; *"What aspects of the journey did you find particularly positive?"*; and *"Looking back, what made the biggest impression on you?"*

The interviews, conducted via videoconferencing in the practitioner-passengers' native language (Dutch), allowed practitioner-passengers to reflect while their experiences were still fresh in their minds. To avoid bias, the first author did not review the journey data prior to the interviews.

Table 3. Overview of practitioner-passengers and the data collection groups. Practitioner-passengers are coded with the first letter of their organization.

Practitioner-passengers	Organization	Hold baggage	Group 1	Group 2	Group 3	Group 4
A1	Airline operator	-		V		
A2	Airline operator	-	V			
AI1	Airport infrastructure manager	-			V	
AI2	Airport infrastructure manager	Yes				V
R1	Rail operator	-		V		
R2	Rail operator	Yes			V	
RI1	Rail infrastructure manager	-				V
RI2	Rail infrastructure manager	Yes	V			
G1	Government	Yes		V		

2.3 Data analysis

Thematic analysis was used by applying the six-phase approach described by Braun and Clarke (2006), consisting of the following steps: 1) familiarizing with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, and 6) reporting findings.

Data familiarization involved transcribing audio recordings and notes from

round 1 and creating verbatim transcripts of the diaries and refining the interview transcripts from round 2.

This was followed by the generation of initial codes, conducted iteratively using an analytical framework. The framework was developed as a lens for data analysis, aiding in the interpretation of the material and providing a reference for understanding specific situations (Malterud, 2001).

The framework consists of two key models. First, it incorporates the foundational elements of customer journey maps, which illustrate the journey from the user's perspective by highlighting its phases, the touchpoints that facilitate the journey, and the associated emotions (indicated by letter A in Figure 4) (Van Hagen & Bron, 2014). Second, the analytical framework incorporates the Product Emotions Model proposed by Desmet (2003), which posits that user emotions emerge from an appraisal process that evaluates a product based on a user's concerns, such as goals, attitudes, and standards (letter B). During data analysis, Desmet's model helped to analyze and indicate the presence of specific expectations, desires, or knowledge in the users, which may influence their experience.

Both models demonstrate that emotions are shaped by several elements, including the phases and touchpoints in customer journey maps, as well as product usage and user concerns in the Product Emotions Model. This study aims to identify the phases and properties of MJIATs that affect passenger experiences; therefore, the *"product"* in this context refers to the MJIAT itself. This journey includes phases and touchpoints from the customer journey map (Letter C). This led to the development of the study's analytical framework (Letter D in Figure 4), in which the journey phases, touchpoints, but also (unforeseen) circumstances, of the MJIAT are appraised based on user concerns, resulting in the emergence of user emotions.

The analytical framework facilitated the generation of codes, which were applied first to the data from round 1 of the collection and later to round 2. Its application is detailed below and illustrated in Table 4.

- Step 1: Identify meaning units (Graneheim & Lundman, 2004) with a focus on appraisals.
- Step 2: Condense meaning units and assign codes describing the appraisal.
- Step 3: Assign an 'Emotion' code based on the categories from Desmet's model (2003).
- Step 4: Link the identified emotion code to the corresponding

Figure 4. Buildup of analytical framework, based on customer journey map and Product Emotions Model.

A *Customer journey map (Based on Van Hagen & Bron, 2014)*

B *Product Emotions Model (Based on Desmet, 2003)*

D *Analytical framework*
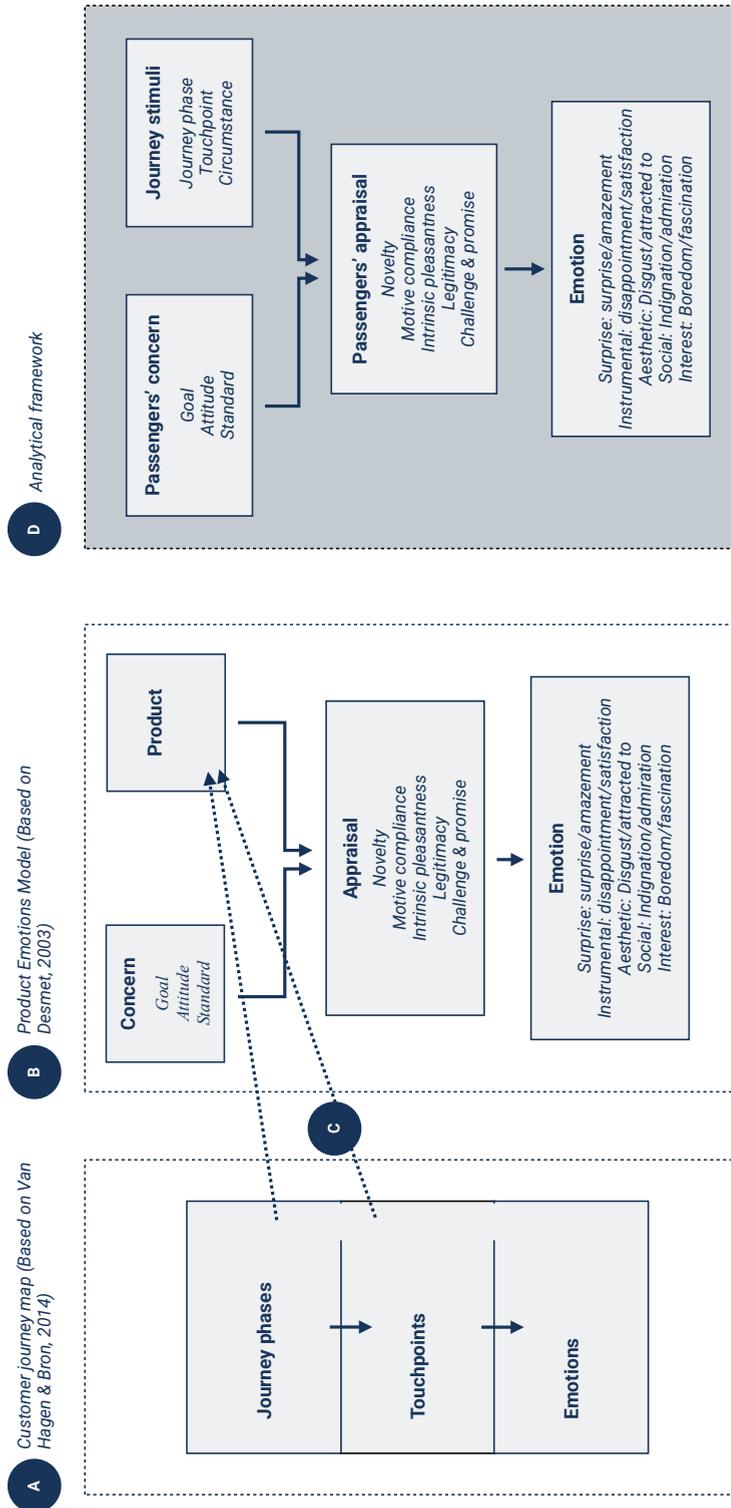
'Concern' category (goal, attitude, or standard) and assign a code describing the concern.

- Step 5: Identify the relevant codes for the condensed meaning unit that correspond to the subcategories 'phase', 'touchpoint', and 'circumstance', all of which fall under the broader category 'journey stimuli'.

Table 4. Example of Step-by-step guide for applying the analytical framework in data analysis

Step 1. Meaning unit	Step 2. Passenger's appraisal	Step 3. Emotion	Step 4. Concern (goal, attitude or standard)	Step 5. Journey stimuli (phase, touchpoint, circumstances)
"We only have an hour to go, and I still have to check in my bag. The train didn't say anything at all about checking in; they just said, 'Sorry, we're delayed…'" (researcher-passenger, case 1).	Short transfer time causing stress	Disappointed	Goal: Seamless trip	Phase 5): Arrival at airport station
"The MM touchpoint is really close to the platform, barely a two-minute walk, and I think that's really a big plus" (airline operator, case 5).	MM touchpoint next to platform	Satisfied	Goal: Seamless trip	Phase 3) go to platform

This process resulted in the identification of a total of 231 codes which were classified into categories and subcategories in accordance with the analytical framework. This showed that most of the codes were part of the appraisal category (158 codes). During the coding process, it was observed that not all subcategories of the analytical framework, specifically 'attitude concern', 'aesthetic emotions', and 'interest emotions', appeared to be present in the dataset. Additionally, no circumstances were identified that drastically affected the journey compared to the other journeys. The emotions identified within the dataset were further classified into positive

and negative categories.

This coding process provided insight into the phases of MJIATs and was followed by the third, fourth, fifth, and sixth steps of Braun and Clarke's (2006) thematic analysis to uncover the properties that influence the multimodal passenger experience. In this process, patterns within the codes and (sub) categories derived from data collection round 1 were identified, reviewed, and refined (Braun & Clarke, 2006). The resulting patterns were established at the level of journey integration factors, representing critical aspects of service and infrastructure design that facilitate passenger-oriented MJIATs. Subsequently, the codes and (sub)categories from data collection round 2 were compared with the existing factors to identify similarities and uncover new elements, and if necessary new findings were integrated into the existing factors. Insights that differed more substantially from the established factors prompted the development of new factors. Finally, the data from round 1 were revisited to ensure consistency with the expanded set of factors. This analysis was conducted by the first author and reviewed by all co-authors.

Illustrative quotations from informants were compiled and paraphrased for clarity and translated to English. The final paper was reviewed and approved by all authors.

3   RESULTS

The results of the case studies are presented in three sections. Section 3.1 describes the phases of MJIATs and their effects on the passenger experience. Section 3.2 outlines the journey integration factors related to the passenger experience of MIJATs. Section 3.3 demonstrates how well the factors were grounded in the data sets to estimate their validity.

3.1   Phases of MJIATs

This chapter outlines the phases of MJIATs and how their components impact the passenger experience. Figure 5 illustrates the structure of train/bus-to-plane journeys (cases 1, 2, 3, 4, and 5), while Figure 6 depicts the plane-to-train journey (case 6).

Figure 5. Overview of the phases involved in the train/bus-to-plane journey for cases 1-5
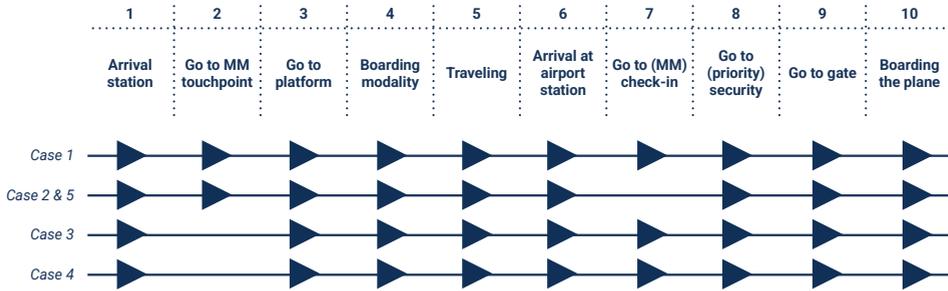
Figure 6. Overview of the phases involved in the plane-to-train journey for case 6
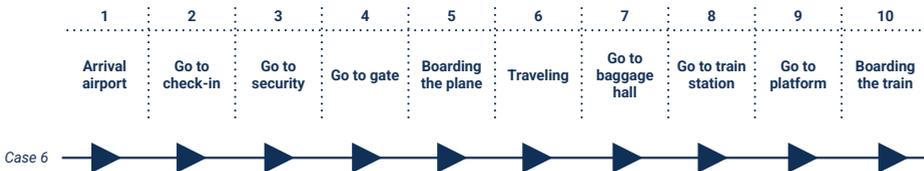
Figures 5 and 6 illustrate that MJIAT can consist of up to 10 phases; however, the number of phases may vary across different cases. We identified two main journey structures: the segmented MJIAT, where the two legs are primarily treated as separate journeys, and the partially-integrated MJIAT, where the phases are (partially) designed to function as one continuous journey. Understanding the structure of a MJIAT is crucial for improving the passenger experience, as this experience depends on the sequence of phases and their purpose (Hernandez Bueno, 2021; Kirk et al., 2021).

3.1.1 Segmented MJIAT (C1, C3, C4, C6)

The segmented journey structure was observed in both train/bus-to-plane and plane-to-train journeys (respectively cases 1, 3, and 4, and case 6). During these journeys, the airport procedures, including baggage handling and security screening, were conducted during the transfer at the airport, resulting in the trip feeling like two separate journeys (Figure 7).

In case 1 and 3, efforts had been made to make the journeys flow more smoothly into each other. In case 1, passengers used an MM touchpoint at the

train station for check-in (Phase 2), where airline staff provided information about the upcoming phases of the journey. In case 3, a special MM touchpoint at the airport hub allowed baggage check-in (Phase 7), offering a faster and more convenient process during the multimodal transfer at the airport.
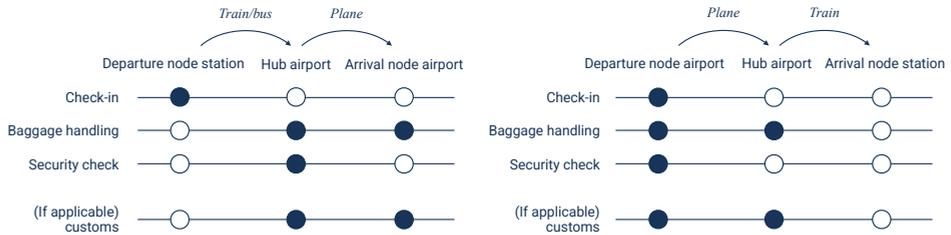
Figure 7. Division of airport procedures in segmented MJIATs, with the train/bus to plane sequence on the left and plane-to-train on the right

3.1.2   Partially-integrated MJIAT (C2 & C5)

In this journey structure, phases are designed to function as one continuous journey. This structure was observed in cases 2 and 5, where baggage check-in for the whole journey happened at the train station, at the same MM touchpoint as in case 1 (phase 2). This shift of baggage check-in from the airport to the node station, was seen as a convenience: *"I really see baggage check-in [at the station] as a big plus."* (airline operator, case 5).

Drawbacks of the partially-integrated structure included increased demands on train and bus stations regarding equipment, staffing, training, physical space, wayfinding, and an overall rise in travel time. While fewer steps were required at the airport, passengers still faced long waiting periods at the airport. Additionally, the need to check in baggage earlier at the train station further prolonged the journey, as described by a practitioner-passenger: *"And then we ended up waiting for a long time. I thought to myself, I saved time at the beginning of the journey; they could have planned the transfer with a shorter connection time as well. I wouldn't have had to arrive at that station in Brussels earlier if I had this time anyway."* (rail operator, case 5).
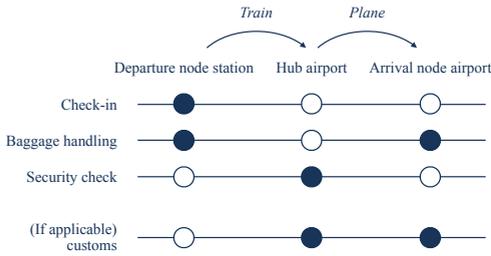
Figure 8. Division of airport procedures in partially-integrated multimodal train-to-plane journey

3.2 Journey integration factors

This section describes eight journey integration factors that influence the multimodal passenger experience. These factors were identified through thematic analysis within the analytical framework. Findings from data collection round 1 were compared with the data from case 5, with the guided ethnography by practitioner-passengers. Especially, case 6 provided new insights, potentially due to the reversed travel sequence (plane-to-train). Table 5 and Table 6 present an overview of identified journey integration factors across the travel phases, highlighting in which phases of the journey factors play a role.

Table 5. Overview of the factors affecting passenger experience in different travel phases of train/bus-to-plane journeys

Factor (affecting the MJIAT passenger experience)	Stimuli - travel phases of train/bus-to-plane journeys									
	1) Arrival station	2) Go to MJIAT touchp.	3) Go to platform	4) Boarding modality	5) Traveling	6) Arrival at airport station	7) Go to (MJIAT) check-in	8) Go to (priority) security	9) Go to gate	10) Boarding the plane
1) Journey explanation & preparation	V	V	V	V	V	V	V	V	V	V
2) Personalized & pro-active		V	V	V	V			V		V
3) Multimodal wayfinding	V	V	V	V		V	V	V	V	V
4) Proximity of modalities & facilities	V	V	V			V	V		V	
5) Multimodal transfer services		V					V	V		
6) Balanced transfer time		V			V	V	V	V	V	V
7) Waiting environment	V	V	V			V			V	V
8) In-travel comfort					V					

Table 6. Overview of the factors affecting passenger experience in different travel phases of the plane-to-train journey

Factor (affecting the MJIAT passenger experience)	Stimuli - travel phases of plane-to-train journeys									
	1) arrival airport	2) go to check-in	3) Go to security	4) Go to gate	5) Boarding the plane	6) Traveling	7) Go to baggage hall	8) Go to train station	9) Go to platform	10) Boarding the train
1) Journey explanation & preparation		V	V				V		V	V
2) Personalized & pro-active assistance		V	V	V		V	V	V		
3) Multimodal wayfinding	V	V		V				V	V	V
4) Proximity of modalities & facilities	V	V		V			V	V	V	
5) Multimodal transfer services			V				V			
6) Balanced transfer time			V		V	V	V		V	
7) Waiting environment				V	V				V	
8) In-travel comfort						V				

The following subsections detail each factor, addressing passenger concerns (goals and standards), the associated touchpoints, and their impact on the overall passenger experience.

3.2.1 Journey explanation and preparation

The findings indicate that journey explanation and preparation are critical for a stress-free journey and seamless multimodal transfer at the airport. Key touchpoints supporting this factor include terminal information, itineraries on boarding passes, app- or website-based information, real-time updates on screens across various transport modes (e.g., plane, train, bus), instructional videos, and assistance from staff members. The data emphasize the importance of these touchpoints, particularly at the start of the journey, as multimodal travel involves unfamiliar structures and rules compared to single-mode or non-integrated travel. One researcher-passenger reflected on the positive impact of receiving detailed instructions from airline staff during the transition phase, noting it contributed to a smoother experience: *"She provided detailed information about the train departure, the designated carriage number, seat allocation, and the terminal I needed to go to in Paris, so I received a lot of useful information."* (researcher-passenger, case 2).

Additionally, informants indicated that preparation for each subsequent

phase of the journey, such as knowing where to stand during train boarding, estimating walking distances, and locating key facilities, was essential for maintaining a *"stress-free"* experience.

Cases 4, 5, and 6 underscore the benefit of instructional videos that include information on passenger rights, schedules, and what is or isn't included in the journey. In case 4, the video was shown on the bus, and the researcher-passengers identified it as a positive aspect of the journey: *"I was on the bus, and then a video played showing everything you needed to do when you arrived at the airport. That was really helpful."* (researcher-passenger, case 4). In cases 5 and 6, a video was available online but not proactively shown on screens, resulting in passengers missing it due to a lack of awareness.

Transparency about delays emerged as another critical aspect of a positive passenger experience, as indicated by data from case 6. However, other cases showed a lack of tailored information for MJIATs. Informants observed that MJIATs remain relatively unfamiliar to staff, resulting in inconsistent communication and information provision during critical moments of the journey.

3.2.2 Personalized and pro-active assistance

Personalized and pro-active assistance plays a crucial role in ensuring a stress-free journey, particularly by facilitating smooth transfers and providing clear journey information. Key touchpoints found for this assistance include digital applications and trained staff at stations, at MM touchpoints, and in vehicles.

Personal assistance showed to positively impact the passenger experience by providing reassurance and a sense of acknowledgment: *"It's comforting when he confirms your name; then you know you're on the right bus"* (researcher-passenger, case 4). In cases 1, 2, and 6, MM touchpoints enabled personalized assistance, with specially trained staff guiding passengers through their journeys. However, in cases 1 and 6, communication fell short during delays, leaving passengers uninformed about the (possible) impact of the delay on their MJIAT.

In case 5, practitioner-passengers were disappointed that the pro-active support provided to air-only passengers was not extended to multimodal passengers. Their plane-to-train journey lacked information about the connecting train leg, and practitioner-passengers noted that recognizing them as transfer passengers would have improved their experience: *"I think it's mainly about getting recognition from the staff that you're a passenger who also needs to catch a train. I don't necessarily need a guarantee that I'll*

make it, but more that the staff member acknowledges, 'Hey, I know that; I'm aware that's one of the connections'." (rail operator, case 6).

3.2.3 Multimodal wayfinding

Our findings highlight that multimodal wayfinding reduces uncertainty throughout the passenger journey. Key touchpoints found for multimodal wayfinding include physical wayfinding screens at airports and stations, as well as digital tools such as apps, emails, websites, and operator logos.

The data revealed that current wayfinding systems often operate in silos, with distinct styles for each mode of transport and limited references to other modalities. Wayfinding that explicitly incorporates multimodal transfer signage in stations or airports improved the passenger experience, as illustrated by this researcher-passenger: *"Ah, there's flight number LH3465, yay! Oh, that's great. And right behind it, it says Lufthansa Express Rail, nice! Okay, I need to go to platform 20"* (researcher-passenger, case 3). Both physical and digital wayfinding at transit hubs (including airports, bus, and train stations) proved critical to the passenger experience, regardless of the journey phase.

However, wayfinding to MM touchpoints in cases 1, 2, and 6 was found to underperform, leading to confusion and frustration. As one practitioner-passenger remarked, *"I thought the air-rail terminal is super hard to find when you're not familiar with its location. I ended up Googling it myself"* (airport infrastructure manager, case 5).

Indirect communication, such as through apps, emails, websites, or screens, also played an essential role in providing cues and maintaining clarity. Notably, the 'multimodal wayfinding' factor emerged most frequently during journeys, suggesting immediate relevance. However, it was less prominently discussed in the reflective interviews, indicating that its importance may be more evident in the moment than in hindsight when reviewing the overall experience.

3.2.4 Proximity of modalities and facilities

Our findings indicate that the proximity of transfer modes and facilities plays a critical role in shaping a seamless multimodal transfer at the airport and a convenient journey overall. This proximity includes the physical location of transport modes and amenities, as well as infrastructure like moving walkways or people movers that facilitate transfers.

The data demonstrate that shorter walking distances between modalities positively impacted the passenger experience by simplifying transfers. For

example, one researcher-passenger in case 1 noted: *"The walking distance isn't far. You go up from the train station, follow the signs to departures, go up again, and then you're quickly at the priority lane"* (researcher-passenger, case 1).

Conversely, in case 6, the long walking distance was partially mitigated by a people mover, but the waiting time led to a negative overall experience: *"I thought it was a really long walk. We waited for a while, and then two people movers arrived, but we weren't allowed to enter them. I was actually shocked by that, actually, by the staff."* (airport infrastructure manager, case 6). These findings suggest that proximity can be enhanced by physically moving modalities closer to each other but also by features like moving walkways that reduce the perceived distance.

As discussed under the 'journey preparation and explanation' and 'multimodal wayfinding' factors, the hard-to-find location of the MM touchpoints in cases 1, 2, and 6 negatively affected the passenger experience. However, practitioner-passengers in case 5 observed that the MM touchpoint's proximity to the departing platform was a positive feature: *"The MM touchpoint is really close to the platform, barely a two-minute walk, and I think that's really a big plus."* (airline operator, case 5).

3.2.5 Multimodal transfer services

Our findings indicate that multimodal transfer services should reduce the friction that arises when transitioning between different transport systems, thereby supporting expectations for fast and efficient baggage check-in and seamless processes during airport transfers. Key touchpoints found that support these expectations include multimodal boarding passes, baggage handling services at MM touchpoints in train or bus stations, and priority lanes at airport security.

Baggage handling emerged as a significant aspect of MJIATs. This finding aligns with existing literature, which identifies baggage as an important factor for the passenger experience during transfers (Allard & Moura, 2016; Avogadro et al., 2023; Durand & Romijn, 2023; Janic, 2011) One researcher-passenger in case 1 expressed frustration when faced with checking in her baggage after a delayed train journey: *"We only have an hour to go, and I still have to check in my bag. The train didn't say anything at all about checking in; they just said, 'Sorry, we're delayed...'"* (researcher-passenger, case 1).

In contrast, in cases 2 and 6, passengers were able to check in their baggage at the start of the journey, which was perceived positively. A practitioner-passenger reflected on this benefit: *"I found the baggage handling a real plus,*

as it allowed me to board the plane feeling relaxed. It was much more relaxing than having to deal with my suitcase, since the number of steps in the transfer was significantly reduced this way." (airport infrastructure manager, case 5).

However, a lack of clarity about multimodal transfer services can result in confusion, as illustrated by one researcher-passenger's experience with an MM touchpoint during the transfer: *"I find it a bit strange that you're promised an MM terminal, but it was literally just picking up a label."* (researcher-passenger, case 3).

3.2.6   Balanced transfer time

A balanced transfer time was found to have an impact on the passenger experience, as passengers desire efficient multimodal transfers. Their expectations include timely transportation and transfer schedules that allow sufficient time for connections without causing excessive waiting.

Tight transfer schedules (also occurring as a consequence of delays) were found to create stress and a sense of lost control, as illustrated by a researcher-passenger: *"It already says it's 20 minutes late, which makes me a bit stressed since we only have a two-hour transfer. Will we make it, or won't we?"* (researcher-passenger, case 1). Conversely, excessively long waits also negatively impacted passenger satisfaction, as illustrated here: *"It's annoying that we have to wait so long now. Thankfully, I'm sitting in comfortable chairs. But I've been here for half an hour already, and boarding is still 1.5 hours away..."* (researcher-passenger, case 2).

Informants emphasized that well-organized airport operations and seamless backstage processes are key to creating optimal transfer times. A practitioner-passenger reflected on this efficiency: *"I thought everything went very well at the airport. The transition from the gate to the train was very smooth. It was quick and easy, and it was clear that this airport is really well-organized, especially when compared to a few other airports."* (rail operator, case 6).

The integration factors 'multimodal transfer services' and 'the proximity of modalities and services' contribute to minimizing the required transfer time.

3.2.7   Waiting environment

The waiting environment during transfers emerged as a factor influencing the passenger experience, as passengers appreciate a convenient trip. Key touchpoints contributing to a positive experience included comfortable seating, access to (commercial) facilities, and a covered area shielded from weather conditions. The experience of unpleasant waiting conditions caused

negative emotions, as illustrated by a practitioner-passenger: *"Well, it is what it is, it's very hot here, makes me feel like fodder."* (rail operator, case 5).

3.2.8 In-travel comfort

This factor refers to comfort and quality of service when traveling in the vehicles. Touchpoints contributing to in-travel comfort were identified as comfortable seating, catering services, and the availability of work-friendly conditions. For example, researcher-passengers were pleasantly surprised by the quality of train seating: *"I'm on the train and I have a first-class seat!"* (case 2). Practitioner-passengers noted distinctions between modes; one observed: *"The train wins for me on all fronts for these distances. It's quieter, you sit more comfortably, and there's more space."* (airport infrastructure manager, case 6).

While catering was available and appreciated on the airplane, its absence on the train left practitioner-passengers dissatisfied: *"I was very disappointed that there was no coffee or bar open, and that I wasn't even offered as an apology, just 'no, there isn't.' I think that's really something that was within your control. Compared to how it went the day before on the flight, with 'oh, we already have a jug of coffee because you have to wait,' it was quite a contrast."* (rail operator, case 5).

3.3 Grounding of journey integration factors

This section indicates the extent to which the factors are supported by empirical data (Eisenhardt, 1989). Table 7 shows which factors were mentioned (in dark grey) and which were absent (in white) in the data sets. From this, we can conclude that each factor is grounded in the data, with evidence of researcher triangulation (Malterud, 2001; Miles et al., 2014). We conclude that data saturation was reached in the second round of data collection, as no new information or factors emerged (Fusch & Ness, 2015). To strengthen the credibility of the findings, we applied triangulation by combining multiple methods – autoethnography and reflective interviews – which allowed for convergence of insights across different data sources (Fusch & Ness, 2015). Furthermore, the study included nine participants, which falls within the empirically supported range for reaching saturation in qualitative interviews (9–17) (Hennink & Kaiser, 2022). As each participant undertook the same multimodal journey, this yielded 26 data sets, ensuring sufficient breadth and depth of material given the participants' similar level of expertise and the focused study objectives. However, three factors exhibited disparities in their frequency of mention across cases and informants.

First, the factor 'in-travel comfort' was observed only in cases 2, 5, and 6.

In cases 2 and 5, which involved a train-to-plane journey with a transfer at CDG, most informants reported a comfortable experience in the train's first class. Although this factor was noted by practitioner-passengers in both cases (case 5 with train-to-plane and case 6 with plane-to-train), it was only recognized by researcher-passengers in case 2. This discrepancy may be explained by the fact that researcher-passengers tended to acknowledge comfort only when it exceeded their expectations and positively surprised them. In contrast, the practitioner-passengers were more focused on the differences in quality levels between transport modes, a perspective shaped by their expertise.

The factor 'journey explanation and preparation' was more prominent in the first five cases than in case 6. This difference can be attributed to the context of case 6, where the journey began at the airport. Airports typically include multiple contact points, such as security and baggage check-in, where passengers receive guidance and information about the next steps of the journey. In contrast, train and bus stations generally lack such procedures and, consequently, touchpoints. However, cases 1, 2, and 5 deviated from this norm, as passengers were required to visit an MM touchpoint at the station. This introduced a new phase and an unfamiliar structure for the upcoming phases of the journey, underscoring the need for journey explanation and preparation.

Lastly, the factor 'waiting environment' was less prominent in case 6. This was likely due to the travel delay on the plane, which reduced the available waiting time during the transfer and made it less relevant.

Table 7. An overview of the presence of journey integration factors in cases

Factors	train/bus-to-plane																	plane-to-train								
	Case 1		Case 2		Case 3		Case 4		Case 5									Case 6								
	R1	R2	R1	R2	R1	R2	R1	R2	A1	A2	AI1	AI2	R1	R2	RI1	RI2	G1	A1	A2	AI1	AI2	R1	R2	RI1	RI2	G1
1) explanation & preparation																										
2) Personalized & pro-active assistance																										
3) Multimodal wayfinding																										
4) Proximity of modalities & facilities																										
5) Multimodal transfer services																										
6) Balanced transfer time																										
7) Waiting environment																										
8) In-travel comfort																										

4 DISCUSSION

This study explored the integration of MJIATs and their impact on passenger experience across European cases. By analyzing six journeys through major airport hubs (AMS, CDG, FRA, and HEL), we identified eight key journey integration factors that shape the passenger experience. Building on our literature review, this paper presents the findings derived from an autoethnographic approach, in which two researchers and nine practitioners collected data during a total of 26 MJIATs aimed at addressing the research questions: *1) How are MJIATs structured in terms of travel phases?* and *2) Which properties of MJIATs affect the passenger experience, and how?*

4.1 Interpretation of findings

We found a fundamental distinction between air travel and MJIATs, based on the interaction among various transport subsystems. When passengers transfer between flights in Europe, they typically complete the security check, go through customs, and check baggage at the departure node airport, transfer at a hub airport, and then arrive at the arrival node airport. Upon exiting the air system, passengers claim their baggage and pass through customs at the arrival airport. In MJIATs, passengers enter a transport system at the departure node and then transfer to another system at the (multimodal) hub airport.

While air travel encompasses transfers within a single system, MJIATs requires passengers to navigate the boundaries between distinct transport systems, such as rail and air, each governed by its own environment, rules, and regulations (see Figure 9). This transition introduces friction, primarily due to mandatory air travel procedures. Multimodal passengers must complete these procedures within a limited timeframe, dictated by the minimum connecting time at airports, which is essential for competitive travel propositions. As a result, the airport procedures that already create stress in air-only journeys (Kim et al., 2020) lead to even greater stress for multimodal passengers.
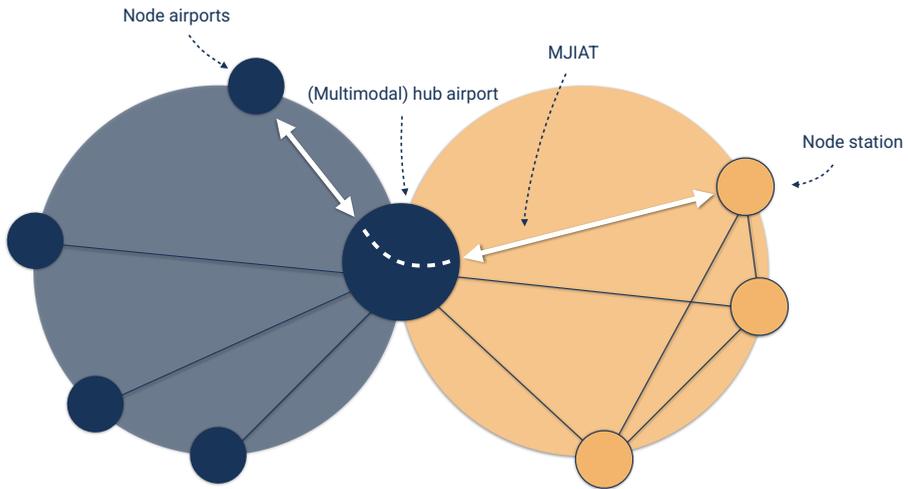
Figure 9. A visual representation of how two transport systems in MJIATs connect in both directions: train/bus-to-plane and plane-to-train/bus.

In the 'segmented MJIAT' structure, the mandatory airport procedures for train/bus-to-plane journeys primarily occur during the transfer. To alleviate transfer-related stress in this journey structure, efforts included MM touchpoints at the departure node or at the airport, providing personal assistance, and facilitating special baggage check-in at the airport.

In the 'partially-integrated MJIAT' structure the baggage check-in procedure is relocated to the beginning of the journey to streamline the transfer process. However, this modification was found to increase the demands on departure nodes (such as train and bus stations) concerning equipment, staffing, training, physical space, and wayfinding.

From a methodological standpoint, this study emphasizes the importance of firsthand experience for transportation researchers and practitioners, showing that personally experiencing MJIATs yields invaluable insights. The (guided) autoethnographic approach provided essential perspectives that can guide improvements in the passenger experience. The practitioners who performed the guided autoethnography emphasized the importance of personally experiencing MJIATs to enhance understanding of how it unfolds in real-world settings. As one practitioner-passenger stated, *"I think it's unanimous that traveling this way brings immense value, especially in terms of insights and understanding"* (airport infrastructure manager, reflective interview). This research illustrates that firsthand experience is essential for identifying opportunities to improve passenger-oriented MJIATs.

4.2 In relation to existing research

This article offers qualitative insights into MJIATs, enriching the previous primarily quantitative research, and providing additions to it. In addition to confirming existing findings, it deepens the understanding of the *"how"* and *"why"* behind factors affecting the passenger experience.

The results indicate that, in addition to three previously identified defining properties of MJIATs, namely, the connection of an alternative mode of transport to flights, a single integrated ticket, and connection insurance (Babić et al., 2022; Li et al., 2018; Román and Martín, 2014), MJIATs in practice show variability in the integration of modalities.

The identified journey integration factors 'journey explanation and preparation, 'personalized and pro-active assistance', and 'multimodal wayfinding' highlight the significance of the type, timing, and delivery of journey information in MJIATs. This is crucial not only because MJIATs are new to many passengers, but also due to differing rules and standards between transport systems. Passengers often rely on airlines for booking and may not be fully aware of the specifics of the train/bus part of the journey. This aligns with previous research emphasizing the importance of providing holistic journey process information to give passengers a sense of autonomy and support them in managing their journey (Allen et al., 2020; Antwi et al., 2020; Babić et al., 2022; Hernandez Bueno, 2021).

Our findings suggest that, rather than passengers wanting to *"manage the journey"* (as operators control the itinerary) it is more about *"expectation management"*, with passengers seeking clarity and confidence that the journey will proceed smoothly. Our study highlights the importance for MJIATs of providing information at train and bus stations, such as referencing the *"air"* leg via screens or staff. The positive impact of airport staff interaction on passenger satisfaction is well-documented (Antwi et al., 2020; Lubbe et al., 2011), but our findings extend this to train/bus station and airline staff, indicating they need to be informed and trained about MJIATs. Similarly, wayfinding and signage, critical for passenger experience at airports and stations (Allen et al., 2020; Nielsen et al., 2021; Wang et al., 2020), should clearly reference the MJIAT and be present at every phase. Furthermore, our findings suggest that information preparing passengers for specific steps of the journey can also be communicated during the journey itself, allowing passengers to receive information as needed without having to plan too far ahead.

The factor 'proximity of modalities and facilities', supported by Li et al. (2018), is confirmed by our study, showing that short distances can also be

achieved with moving walkways and that the location and visibility of MM touchpoints are integral to this factor.

The importance of treating multimodal passengers like regular air transfer passengers is emphasized by the factor 'multimodal transfer services'. This can be done through special transfer services such as priority at critical points like baggage check-in, security, and customs, as noted by Babić et al. (2022). While airport hubs often manage automatic baggage transfers, our findings suggest that MJIATs benefit from dedicated MM touchpoints and trained staff at train/bus stations and node airports.

The factor 'balanced transfer time' aligns with existing studies (Abenoza et al., 2019; Babić et al., 2022; Hernandez Bueno, 2021; Jiang et al., 2022; Román & Martín, 2014; Wang et al., 2020). Tight schedules were found to cause stress early in the journey, while long layovers led to dissatisfaction as passengers had to pass the time. This was particularly evident in cases 2 and 5, where baggage check-in was shifted to the train station at the start of the journey. Combined with long transfer times at the airport, this unnecessarily prolonged the total travel time.

The research shows that the quality of the 'waiting environment' can enhance the passenger experience, aligning with the findings of Eboli and Mazzulla (2015). We extend this knowledge by emphasizing that passenger expectations also play a significant role in this factor. When traveling in the train/bus-to-plane direction, the longest wait occurred at the airport, where facilities were generally adequate and met expectations. Due to the short connection time caused by the flight delay in case 6, there was limited data on the waiting environment in the plane-to-train direction. Further investigation into this situation would be valuable.

Lastly, the factor of 'in-travel comfort' revealed that passengers expect a certain level of comfort during their journey, and exceeding these expectations contributes to a positive experience. These expectations are partly shaped by the service level of the airline with which the booking is made. To our knowledge, this is discussed in studies on in-flight comfort and expectations (Blok et al., 2007) but not in the literature on MJIATs.

4.3 Limitations and future research

First, the study focused on four specific airport hubs in Europe. This approach ensured similar contexts, as the same EU regulations applied to all four cases, allowing for comparisons between observations. However, our approach cannot be replicated under exactly the same conditions. The focus of this study was to identify which factors play a role, rather than to capture

variability across contexts. Future research could build on these insights by conducting passenger interviews in varying contexts (e.g., across different routes, times of day, seasons, and traveler types).

Second, intercontinental flights often involve customs procedures during transfers, higher financial stakes (adding pressure to make connections), and longer flight durations, all of which can affect passengers' mental states. Consequently, the findings may not be generalizable to all multimodal travel connections or to all airport hubs globally. Replicating the study in different contexts, including airports outside Europe and journeys that encompass an intercontinental leg, could yield deeper insights into the passenger experiences for these journeys.

Third, future research could undertake a comparative benchmark between major airport hubs worldwide on the level of service integration. This could yield valuable insights into similarities and differences in multimodal integration at leading airport hubs, highlighting best practices and contextual factors that shape passenger experience and policy development.

Furthermore, in studying MJIATs, the unit of analysis could extend to the pre-trip phase, including travel choice and booking, as these stages shape passengers' overall perceptions. Incorporating these elements could complement our findings with a more comprehensive understanding.

While the autoethnographic approach yielded rich insights, it also carries the risk of bias, as the experiences of researcher- and practitioner-passengers may not fully represent the broader passenger population. To address this, the analytical framework was designed to surface passengers' concerns (focusing on their goals, attitudes, and standards) and these were explicitly incorporated into the analysis to ensure transparency. Furthermore, although the study generated 26 data sets from nine participants, the relatively small and homogenous sample may limit the extent to which saturation was achieved across more diverse passenger groups. Future research should therefore broaden the participant pool, and apply quantitative approaches such as Delphi tests and surveys, to test the transferability of these findings.

In this study the plane-to-train journey direction was explored in one case. While nine data sets were collected, the specific context of this case likely influenced the results, limiting the generalizability of the findings. We recommend studying this journey sequence at other airport hubs to gain a broader understanding of the phases involved and the factors influencing them.

A limitation of this study is that the primary purpose of our trips was exploratory and learning-oriented rather than driven by a pressing travel need. Although reaching the destination was still important, the stakes were lower than for typical passengers. In addition, factors such as whether someone travels alone, with colleagues, or with children may influence the experience. Future research should therefore take trip purpose and travel party composition into account.

Another important aspect to consider is the experience of passengers requiring special assistance. Their needs may differ substantially from those of other passengers, and future research should therefore pay particular attention to how multimodal integration accommodates this group.

Investigating the potential and impact of new technologies could provide valuable insights into improving the multimodal passenger experience. Emerging technologies such as mobile apps, digital wayfinding tools, AI assistance, biometrics, and autonomous baggage trolleys could significantly enhance MJIATs. Additionally, upcoming travel modalities, such as electric vehicles, autonomous transport, and possibly future options like hyperloop and electric vertical take-off and landing aircraft (eVTOLs) (Nikitas et al., 2020), promote new travel perspectives. These perspectives include ride-sharing, on-demand mobility services, and multimodal travel, focusing more on passengers and their journeys than on the means of transport (Docherty et al., 2018; Jittrapirom et al., 2017). This makes research on MJIATs experiences increasingly relevant, and incorporating new modes of transport in future studies would enhance this development.

5 CONCLUSION

The MJIATs examined in this study show varying degrees of integration. While varying journey structures observed aim to streamline the MJIAT for the passenger, friction arises during transfers due to certain mandatory processes at the airport, regardless of the direction of the journey. Our research shows that MJIATs differ significantly from traditional air-to-air travel, as multimodal passengers must navigate different transportation systems, each marked by boundaries that increase friction. A key takeaway is that MJIATs must be studied and designed as cohesive units, as passengers book the entire trip from the departure node (station/airport) to the arrival node (station/airport). The passenger experience cannot be understood in isolated segments, as each phase impacts subsequent phases.

Eight journey integration factors were identified that influence the passenger experience in MJIATs: 1) journey explanation and integration,

2) personalized and pro-active assistance, 3) multimodal wayfinding, 4) proximity of modalities and facilities, 5) multimodal transfer services, 6) balanced transfer time, 7) waiting environment, and 8) in-travel comfort. The extent to which these factors positively contribute to the experience in part depends on passengers' expectations.

Additionally, the analytical framework applied expands on passenger emotions, incorporating surprise, instrumental, and social emotions, thereby enriching the understanding of passenger satisfaction and offering actionable recommendations for transport operators and hubs.

The overlap in travel phases of MJIATs highlights the shared responsibilities among different actors and the need for collaboration. While airlines provide MJIATs, stations and airports play a crucial role in offering the infrastructure and services necessary for facilitating smooth transfers and cohesive journeys.

Affairs and Climate Policy via Click NL and the Royal Schiphol Group. Data collection round 2 was a component of a larger project concerning the 'Actieagenda Trein en Luchtvaart' and was funded by the five partners.

Data availability

Due to the data collected including personal elements and judgments that can be traced back to the researchers and practitioners to whom the transcripts belong, this study treats the data as confidential.

Declaration of generative AI in scientific writing

During the preparation of this work the first author used EditGPT for readability and grammar checks. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

6   REFERENCES

Abenoza, R. F., Cats, O., & Susilo, Y. O. (2019). How does travel satisfaction sum up? An exploratory analysis in decomposing the door-to-door experience for multimodal trips. Transportation, 46(5), 1615–1642. https://doi.org/10.1007/s11116-018-9860-0

Adams, T. E., Ellis, C., & Jones, S. H. (2017). Autoethnography. In J. Matthes, C. S. Davis, & R. F. Potter (Eds.), The International Encyclopedia of Communication Research Methods (1st ed., pp. 1–11). Wiley. https://doi.org/10.1002/9781118901731.iecrm0011

Allard, R. F., & Moura, F. (2016). The Incorporation of Passenger Connectivity and Intermodal Considerations in Intercity Transport Planning. Transport Reviews, 36(2), 251–277. https://doi.org/10.1080/01441647.2015.1059379

Allen, J., Bellizzi, M. G., Eboli, L., Forciniti, C., & Mazzulla, G. (2020). Latent factors on the assessment of service quality in an Italian peripheral airport. Transportation Research Procedia, 47, 91–98. https://doi.org/10.1016/j.trpro.2020.03.083

Antwi, C. O., Fan, C., Ihnatushchenko, N., Aboagye, M. O., & Xu, H. (2020). Does the nature of airport terminal service activities matter? Processing and non-processing service quality, passenger affective image and satisfaction. Journal of Air Transport Management, 89, 101869. https://doi.org/10.1016/j.jairtraman.2020.101869

Avogadro, N., Pels, E., & Redondi, R. (2023). Policy impacts on the propensity to travel by HSR in the Amsterdam – London market. Socio-Economic Planning Sciences, 87, 101585. https://doi.org/10.1016/j.seps.2023.101585

Babić, D., Colovic, A., Dožić, S., Kalić, M., Simić, T. K., Kukić, K., Ottomanelli, M., & Pilone, S. G. (2024). How to build a more sustainable passenger air transport system: Multimodal experience. Transportation Engineering, 16, 100245. https://doi.org/10.1016/j.treng.2024.100245

Babić, D., Kalić, M., Janić, M., Dožić, S., & Kukić, K. (2022). Integrated Door-to-Door Transport Services for Air Passengers: From Intermodality to Multimodality. Sustainability, 14(11), 6503. https://doi.org/10.3390/su14116503

Bagamanova, M., Mujica Mota, M., & Di Vito, V. (2022). Exploring the Efficiency of Future Multimodal Networks: A Door-to-Door case in Europe. Sustainability, 14(20), 13621. https://doi.org/10.3390/su142013621

Bell, D. (2019). Intermodal Mobility Hubs and User Needs. Social Sciences, 8(2), 65. https://doi.org/10.3390/socsci8020065

Blok, M., Vink, P., & Kamp, I. (2007). Comfortable flying: Comfort in aircraft interiors seen

through the eyes of the passengers (in Dutch). Tijdschrift Voor Ergonomie, 32(4), 4–11.

Braun, V., & Clarke, V. (2006). Using Thematic Analysis in Psychology. Qualitative Research in Psychology, 3(2), 77–101.

Butler, L., Yigitcanlar, T., & Paz, A. (2020). Smart Urban Mobility Innovations: A Comprehensive Review and Evaluation. IEEE Access, 8, 196034–196049. https://doi.org/10.1109/ACCESS.2020.3034596

Canale, A., Tesoriere, G., & Campisi, T. (2019). The MAAS development as a mobility solution based on the individual needs of transport users. 160005. https://doi.org/10.1063/1.5138073

Cascajo, R., Lopez, E., Herrero, F., & Monzon, A. (2019). User perception of transfers in multimodal urban trips: A qualitative study. International Journal of Sustainable Transportation, 13(6), 393–406. https://doi.org/10.1080/15568318.2018.1476632

Ceder, A. (Avi). (2021). Urban mobility and public transport: Future perspectives and review. International Journal of Urban Sciences, 25(4), 455–479. https://doi.org/10.1080/12265934.2020.1799846

Chauhan, V., Gupta, A., & Parida, M. (2021). Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction of public transport. Transport Policy, 102, 47–60. https://doi.org/10.1016/j.tranpol.2021.01.004

Chiambaretto, P., & Decker, C. (2012). Air–rail intermodal agreements: Balancing the competition and environmental effects. Journal of Air Transport Management, 23, 36–40. https://doi.org/10.1016/j.jairtraman.2012.01.012

Desmet, P. (2003). A Multilayered Model of Product Emotions. The Design Journal, 6(2), 4–13. https://doi.org/10.2752/146069203789355480

Docherty, I., Marsden, G., & Anable, J. (2018). The governance of smart mobility. Transportation Research Part A: Policy and Practice, 115, 114–125. https://doi.org/10.1016/j.tra.2017.09.012

Durand, A., & Romijn, G. (2023). Substitutiemogelijkheden van luchtvaart naar spoor in 2030 en 2040. Kennisinstituut voor Mobiliteitsbeleid.

Eboli, L., & Mazzulla, G. (2015). Relationships between rail passengers' satisfaction and service quality: A framework for identifying key service factors. Public Transport, 7(2), 185–201. https://doi.org/10.1007/s12469-014-0096-x

Eccles, D. W., & Arsal, G. (2017). The think aloud method: What is it and how do I use it? Qualitative Research in Sport, Exercise and Health, 9(4), 514–531. https://doi.org/10.1080/2159676X.2017.1331501

Eisenhardt, K. M. (1989). Building Theories from case Study Research. Academic Management Review, 14, 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building From cases: Opportunities And Challenges. Academy of Management Journal, 50(1), 25–32. https://doi.org/10.5465/amj.2007.24160888

Farinloye, T., Mogaji, E., Aririguzoh, S., & Kieu, T. A. (2019). Qualitatively exploring the effect of change in the residential environment on travel behaviour. Travel Behaviour and Society, 17, 26–35. https://doi.org/10.1016/j.tbs.2019.06.001

Fusch, P., & Ness, L. (2015). Are We There Yet? Data Saturation in Qualitative Research. Walden Faculty and Staff Publications, 455.

Gebhardt, L., Krajzewicz, D., Oostendorp, R., Goletz, M., Greger, K., Klötzke, M., Wagner, P., & Heinrichs, D. (2016). Intermodal Urban Mobility: Users, Uses, and Use cases. Transportation Research Procedia, 14, 1183–1192. https://doi.org/10.1016/j.trpro.2016.05.189

Geng, Y., Yu, J., Lin, B., Wang, Z., & Huang, Y. (2017). Impact of individual IEQ factors on passengers' overall satisfaction in Chinese airport terminals. Building and Environment, 112, 241–249. https://doi.org/10.1016/j.buildenv.2016.11.040

4

Givoni, M., & Banister, D. (2006). Airline and railway integration. Transport Policy, 13(5), 386–397. https://doi.org/10.1016/j.tranpol.2006.02.001

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: Concepts, procedures and measures to achieve trustworthiness. Nurse Education Today, 24(2), 105–112. https://doi.org/10.1016/j.nedt.2003.10.001

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Social Science & Medicine, 292, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hernandez Bueno, A. V. (2021). Becoming a passenger: Exploring the situational passenger experience and airport design in the Copenhagen Airport. Mobilities, 16(3), 440–459. https://doi.org/10.1080/17450101.2020.1864114

Hernandez, S., & Monzon, A. (2016). Key factors for defining an efficient urban transport interchange: Users' perceptions. Cities, 50, 158–167. https://doi.org/10.1016/j.cities.2015.09.009

Hickman, R., Chen, C.-L., Chow, A., & Saxena, S. (2015). Improving interchanges in China: The experiential phenomenon. Journal of Transport Geography, 42, 175–186. https://doi.org/10.1016/j.jtrangeo.2014.12.004

Huang, S., & Mu, D. (2018). Discussion on the Development Strategy of China's Multimodal Transport Stations. Proceedings of the 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018). Proceedings of the 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018), Chengdu City, China. https://doi.org/10.2991/tlicsc-18.2018.40

International Union of Railways. (2022). Customer experience by rail: State of the art and best practices with a vision 2030 case study. UIC. https://uic.org/IMG/pdf/cemp-report-customer-experience-by-rail-state-of-the-art-and-best-practices-with-a-vision-2030-case-study.pdf

ISO. (2019). ISO 9241-210 Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems (No. ISO 9241-210).

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transportation Research Part D: Transport and Environment, 16(2), 137–149. https://doi.org/10.1016/j.trd.2010.10.002

Jiang, F., Wang, L., & Huang, S. (2022). Analysis of the Transfer Time and Influencing Factors of Air-Rail Integration Passengers: A case Study of Shijiazhuang Zhengding International Airport. Sustainability, 14(23), 16193. https://doi.org/10.3390/su142316193

Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M. J. A., & Narayan, J. (2017). Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. Urban Planning, 2(2), 13–25. https://doi.org/10.17645/up.v2i2.931

Julagasigorn, P., Banomyong, R., Grant, D., & Varadejsatitwong, P. (2021). What encourages people to carpool? A conceptual framework of carpooling psychological factors and research propositions. Transportation Research Interdisciplinary Perspectives, 12, 100493. https://doi.org/10.1016/j.trip.2021.100493

Kim, M. H., Park, J. W., & Choi, Y. J. (2020). A Study on the Effects of Waiting Time for Airport Security Screening Service on Passengers' Emotional Responses and Airport Image. Sustainability, 12(24), 10634. https://doi.org/10.3390/su122410634

Kirk, P. J., Popovic, V., & Kraal, B. (2012). Towards a Taxonomy of Airport Passenger Activities.

Kwasiborska, A., Skorupski, J., & Yatskiv, I. (2021). Advances in Air Traffic Engineering. 6th International Scientific Conference on Air Traffic Engineering, Warsaw. https://doi.org/10.1007/978-3-030-70924-2

Lai, W.-T., & Chen, C.-F. (2011). Behavioral intentions of public transit passengers—The roles of service quality, perceived value, satisfaction and involvement. Transport Policy, 18(2),

318–325. https://doi.org/10.1016/j.tranpol.2010.09.003

Li, X., Jiang, C., Wang, K., & Ma, J. (2018). Determinants of partnership levels in air-rail cooperation. Journal of Air Transport Management, 71, 88–96. https://doi.org/10.1016/j.jairtraman.2018.06.002

Lubbe, B., Douglas, A., & Zambellis, J. (2011). An application of the airport service quality model in South Africa. Journal of Air Transport Management, 17(4), 224–227. https://doi.org/10.1016/j.jairtraman.2010.08.001

Malterud, K. (2001). Qualitative research: Standards, challenges, and guidelines. The Lancet, 358(9280), 483–488. https://doi.org/10.1016/S0140-6736(01)05627-6

Miles, M., Huberman, M., & Saldaña, J. (2014). Qualitative Data Analysis: A Methods Sourcebook (3rd ed.). Sage Publications.

Monzón, A., Hernández, S., & Di Ciommo, F. (2016). Efficient Urban Interchanges: The City-HUB Model. Transportation Research Procedia, 14, 1124–1133. https://doi.org/10.1016/j.trpro.2016.05.183

Nielsen, O. A., Eltved, M., Anderson, M. K., & Prato, C. G. (2021). Relevance of detailed transfer attributes in large-scale multimodal route choice models for metropolitan public transport passengers. Transportation Research Part A: Policy and Practice, 147, 76–92. https://doi.org/10.1016/j.tra.2021.02.010

Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial Intelligence, Transport and the Smart City: Definitions and Dimensions of a New Mobility Era. Sustainability, 12(7), 2789. https://doi.org/10.3390/su12072789

Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (Fourth edition). SAGE.

Pels, E., Nijkamp, P., & Rietveld, P. (2003). Access to and competition between airports: A case study for the San Francisco Bay area. Transportation Research Part A: Policy and Practice, 37(1), 71–83. https://doi.org/10.1016/S0965-8564(02)00007-1

RLI. (2020). Verzet de wissel: Naar beter internationaal reizigersvervoer per trein. Raad voor de Leefomgeving en Infrastructuur (Rli).

Rodrigue, J.-P. (2024). The Geography of Transport Systems (6th ed.). Routledge.

Román, C., & Martín, J. C. (2014). Integration of HSR and air transport: Understanding passengers' preferences. Transportation Research Part E: Logistics and Transportation Review, 71, 129–141. https://doi.org/10.1016/j.tre.2014.09.001

Roto, V., Law, E. C., Vermeeren, A. P., & Hoonhout, J. (2011). User Experience White Paper: Bringing clarity to the concept of user experience. Outcome of Dagstuhl Seminar 10373: Demarcating User Experience [White paper]. https://experienceresearchsociety.org/wp-content/uploads/2023/01/UX-WhitePaper.pdf?utm_source=chatgpt.com

Sanders, E., & Stappers, P. (2012). Convivial toolbox: Generative research for the front end of design. BIS Publishers.

Schmitt, D., & Gollnick, V. (2016). Air Transport System. Springer Vienna. https://doi.org/10.1007/978-3-7091-1880-1

Song, F., Hess, S., & Dekker, T. (2018). Accounting for the impact of variety-seeking: Theory and application to HSR-air intermodality in China. Journal of Air Transport Management, 69, 99–111. https://doi.org/10.1016/j.jairtraman.2018.02.008

This is Service Design Doing. (n.d.). Autoethnography [Method description]. https://www.thisisservicedesigndoing.com/methods/autoethnography

Toet, A., van Kuijk, J., & Santema, S. (2022). Transforming airport hubs into future-proof Multimodal Transport Hubs. Relating Systems Thinking and Design (RSD11) Symposium: Possibilities and practices of systemic design, Brighton, UK.

Van Hagen, M., & Bron, P. (2014). Enhancing the Experience of the Train Journey: Changing the Focus from Satisfaction to Emotional Experience of Customers. Transportation Research Procedia, 1(1), 253–263. https://doi.org/10.1016/j.trpro.2014.07.025

4

Van Lierop, D., & El-Geneidy, A. (2016). Enjoying loyalty: The relationship between service quality, customer satisfaction, and behavioral intentions in public transit. Research in Transportation Economics, 59, 50–59. https://doi.org/10.1016/j.retrec.2016.04.001

Veeneman, W. W., Van Kuijk, J. I., & Hiemstra-van Mastrigt, S. (2020). Dreaming of the Travelers' Experience in 2040: Exploring Governance Strategies and Their Consequences for Personal Mobility Systems. In B. Müller & G. Meyer (Eds.), Towards User-Centric Transport in Europe 2 (pp. 225–239). Springer International Publishing. https://doi.org/10.1007/978-3-030-38028-1_16

Visser, F. S., Stappers, P. J., Van Der Lugt, R., & Sanders, E. B.-N. (2005). Context mapping: Experiences from practice. CoDesign, 1(2), 119–149. https://doi.org/10.1080/15710880500135987

Wall, S. (2006). An Autoethnography on Learning About Autoethnography. International Journal of Qualitative Methods, 5(2), 146–160. https://doi.org/10.1177/160940690600500205

Wang, B., Loo, B., & Li, L. (2020). Situating High-Speed Railway Stations within Local Urban Contexts: Passenger Satisfaction with Intermodal Integration at the Hong Kong HSR Station. Built Environment, 46(3), 362–378. https://doi.org/10.2148/benv.46.3.362

Wang, B., Shen, G., Wang, X., Dong, Y., & Li, Z. (2024). Hub-and-Spoke Network Optimization with Flow Delay Cost: The case of Goods Delivery on Urban Logistics Networks in Eastern China. Mathematics, 12(10), 1496. https://doi.org/10.3390/math12101496

Wang, Y., Yan, X., Zhou, Y., & Xue, Q. (2017). Influencing Mechanism of Potential Factors on Passengers' Long-Distance Travel Mode Choices Based on Structural Equation Modeling. Sustainability, 9(11), 1943. https://doi.org/10.3390/su9111943

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transportation Research Part A: Policy and Practice, 45(8), 839–848. https://doi.org/10.1016/j.tra.2011.06.010

Wattanacharoensil, W., Schuckert, M., & Graham, A. (2016). An Airport Experience Framework from a Tourism Perspective. Transport Reviews, 36(3), 318–340. https://doi.org/10.1080/01441647.2015.1077287

Yin, R. (2003). case study research—Design and methods (3rd ed.). SAGE Publications.

4.3   REFLECTION

This first AR cycle provided insights into what entails a passenger-oriented multimodal air journey. Through content *(What did I learn?)*, process *(How did I learn it?)*, and premise reflection *(What assumptions influenced my learning?)* (Coghlan, 2019), this section revisits how the study evolved, what was learned, and how these insights contribute to both theory and practice.

4.3.1 CONTENT REFLECTION

By stepping into the passenger's stride, I learned how the experience of multimodal air travel differs from traditional air travel. Although I was theoretically familiar with the complexities of multimodality, I was surprised by how this complexity translates into the passenger experience. The study from this chapter led me to understand that multimodal air travel cannot function as a collection of separate travel segments; it requires fundamentally different design principles at both the infrastructure and service levels. Learning that different stages of the journey are closely interconnected made me realize that including the purchase and booking phases of a multimodal air journey in the study of passenger experience could be valuable.

In addition, in the previous chapter, the focus was on the development of MTHs, while this chapter discusses multimodal air journeys. Initially, this may seem inconsistent, but the difference lies in the perspective. Chapter 4 approached the topic from the viewpoint of the airport as an actor, whereas this chapter adopts the perspective of the passenger. From a passenger's standpoint, (instances of) multimodal air journeys exist at a few airports, but they remain few and usually only partially integrated. Therefore, it is more accurate to say that while multimodal air journeys do exist, most airports cannot yet be considered fully developed MTHs, and neither is it known what it takes to become a fully developed MTH.

What struck me most was the extent to which passengers encounter boundaries while transferring between transport systems. I found that there is no common standard for easing these boundary crossings. I identified two structures of multimodal air travel: segmentation and partial integration. In the cases I studied, I discovered that we, as passengers, often had to *"reinvent"* ourselves during our journeys each time we switched modes. This process was sometimes stressful and often confusing. This realization highlighted that the current system does not structurally recognize the multimodal air traveler, which, I learned, plays a crucial role in the passenger experience.

It is not necessarily about exerting control over every part of the journey but about feeling that the system acknowledges and supports the passengers throughout the whole journey. Even small signs of recognition, in the form of signages, can contribute to a more seamless and satisfying experience. It made me realize that in future research (Chapter 5 and 6), I also needed to examine the perspectives of operators to understand why things are the way they are.

Another important lesson was that integration practices are context dependent. Measures designed to enhance the multimodal air passenger experience in a bus that serves only air&bus passengers – such as centralized communication about baggage procedures at the airport – may create confusion in a train filled with regular rail passengers. Some of these regular rail passengers may need to go to the airport but are not traveling on a combined air&rail ticket. Including the outlier air&bus case (Miles et al., 2014) provided insights into what is specific to multimodal air travel and unique to air&rail travel.

Although my design background undoubtedly influenced this perspective, these insights led me to approach multimodal air transport delivery and development from a design standpoint in the following chapters. Among other things, this led me to the service blueprinting technique, which I apply and explain further in the next chapter (Chapter 5). Additionally, the context dependence and diverse practice implementations made me realize that truly understanding this complexity requires deep and lengthy research within the context (Chapter 6). By enhancing my understanding of journeys – not only as a researcher but also in collaboration with practitioners – I believe we can intentionally blur existing lines to create new journeys.

Contribution to the thesis research questions

This chapter focused on the first research question: *"What are the properties of a passenger-oriented multimodal air journey?"* The chapter identified eight journey integration factors that shape the passenger experience in multimodal air travel: journey explanation and preparation, personalized and proactive assistance, wayfinding, proximity of transport modes and facilities, multimodal transfer services, balanced transfer times, waiting environments, and in-travel comfort. Furthermore, the passenger experience depends on the seamless connection between travel phases and alignment with expectations. This underscores the need to design multimodal air journeys as cohesive experiences, supported by collaboration across transport systems.

4.3.2 PROCESS REFLECTION

By exploring the passenger experience through qualitative first-person practice, I developed new hypotheses to inform future research. Guided by the idea that we often *"do not know what we do not know"* (Coghlan, 2019, p. 167), I tried to remain open to what might surface during the journey. Experiencing the journey myself led to a nuanced understanding of the factors that shape user experience. What stood out to me, for instance, was how even small uncertainties or benefits could disproportionately shape the experience. Only by stepping into the role of the passenger could I grasp the disconnect between the designed service and the actual lived experience of it.

The act of traveling was also valuable for the practitioners involved. Several participants believed they understood multimodal air journeys beforehand, but during the field study, they realized they had overlooked key aspects, illustrating the importance of firsthand experience. For example, they discovered that the way information is provided during air&rail disruptions differed from their initial assumptions. Insights surfaced during spontaneous conversations among themselves while they were on the go. However, these conversations were unstructured and may have favored dominant voices. Mixed-methods such as passenger satisfaction surveys could have complemented the field notes (Miles et al., 2014). An ethnographic approach with longer shadowing of passengers might also have generated more diverse perspectives.

Furthermore, the reliance on my own travel experiences and those of practitioners inevitably introduces subjectivity and does not represent all passengers. The aim, however, was not generalizability but to use an autoethnographic perspective to examine how multimodal air journeys are structured, which properties shape the experience, and how such insights might inform future interventions. While less generalizable than findings from surveys or experiments (Miles et al., 2014), the value lies in understanding the journey from within, through the lived perspective of a passenger.

Practitioners were engaged in the autoethnographic research to draw on their sector knowledge and generate *"sensitized insights"* (Sanders & Stappers, 2012). Their embedded perspective enriched the data by clarifying the rationale behind actions and sharpening observations, while also supporting organizational change. It was therefore important for this study that both the practitioners and I undertook the journeys ourselves, as we were positioned to translate insights into action.

To support this reflective process, I employed Desmet's (2003) method of emotion mapping to design the informant journals used in the practitioners' guided autoethnography, which was effective. The practitioners used their journals to document moments throughout the journey, revealing emotional reactions and contextual insights that might have remained hidden. What I hadn't anticipated was how the act of writing made practitioners more reflective. This approach enabled all participants in the study, including myself, to learn through immersion, as well as through pausing and giving meaning to experiences after they occurred. Yet the reliance on written self-reporting also meant that some experiences may have been simplified or overlooked.

4.3.3 PREMISE REFLECTION

As an AR-researcher, I already had a conceptual understanding of multimodal air journeys, and this prior knowledge may have influenced my experience. My expectations were shaped by what I had studied in advance, which could have led me to interpret certain situations differently than someone approaching the journey without that background. For instance, I knew that I would have security priority in case study 1, which may have caused me to experience less stress than someone unaware of that fact. Similarly, I was actively looking for a lounge in case study 2, which likely made me more disappointed when I found that there wasn't one.

By conducting the research through autoethnography, I remained open to the unknown. However, certain assumptions that made travel feel quite ordinary to me may have gone unnoticed, as I did not explicitly mention them. Additionally, I undertook several trips, with the first journey being the most authentic. Each subsequent trip was undertaken with slightly more knowledge than the one before.

The practitioners I involved in the study had assumptions rooted in the logic of their own organizational systems. Airline practitioners were well-versed in the air system, while rail practitioners shared knowledge about train travel. I noticed that as they traveled together, the assumptions they held revealed how deeply these were shaped by the structures and routines of their daily work. Traveling together seemed to create a space where those assumptions could be uncovered and discussed. Observing how deeply practitioners' assumptions were rooted in their respective systems made me realize that multimodal air integration is something that needs to be actively co-constructed between actors who operate from very different mental models.

Additionally, traveling appeared to strengthen the relationships among the participants. A tangible example of this was their seemingly awkwardness[i] at the start of the journey, contrasted with the warm hugs they exchanged when saying goodbye at the end. Witnessing the shift from initial formality to genuine connection among participants helped me realize that the journey itself functioned as a soft intervention that enabled mutual understanding through shared experience.

4

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i   observed by me but perhaps not recognized by others

4

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5

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6

Where it connects

It begins with a question,
born in moments of reflection.
What drives multimodality today?
What contexts and purposes lead our way?

By stepping into their stride,
we leave assumptions at the side.
Each journey blurs the lines we drew,
and moving through, we create them too.

Beneath the doing lies the why,
designed by those who stand nearby.
Through open words and searching eyes,
layers fall and systems rise.

We create what none could do alone,
from viewpoints far beyond their own.
By dropping all that thought protects,
we find new meaning where it connects.

CHAPTER 5. RESEARCH CYCLE 2

5.1 INTRODUCTION

Once you know what you want to achieve, you can work towards its realization and implementation. This chapter explores how a good multimodal air passenger experience can be translated into practice.

Research cycle 1, described in the previous chapter, explored the passenger experience from the perspective of travelers and examined the structure of multimodal air journeys. These journeys extend beyond the airport boundaries and require coordination across various transport modes. They are not delivered by a single actor; rather, they are co-created by a network of transport operators, hub operators and other actors.

To move from insight to implementation, it is important to understand the perspectives of those responsible for shaping these journeys. Despite increasing academic attention to user-centered and multimodal travel, we still know little about practitioners' viewpoints.

This chapter adopts a second-person practice in AR (Coghlan, 2019; Reason & Bradbury, 2008; Reason & Torbert, 2001), engaging directly with transport professionals through in-depth interviews. It explores how transport and airport hub operators interpret, navigate, and respond to designing passenger-oriented multimodal air journeys (Figure 13). Their insights provide not only practical knowledge but also a deeper understanding of the human and organizational side of multimodal service integration.
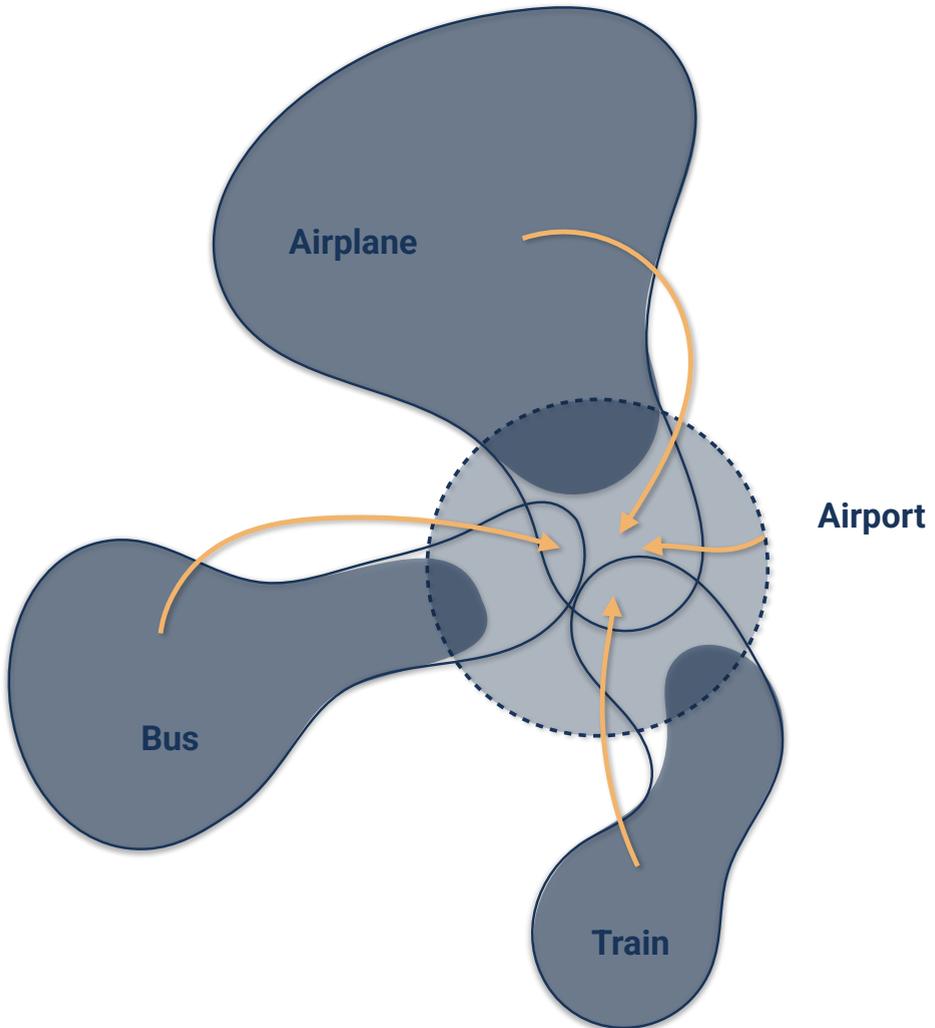
Figure 13. Studying multimodal integration from operator's perspectives

5.2 KEY FACTORS AND DELIVERY MECHANISMS FOR PASSENGER-ORIENTED MULTIMODAL AIR JOURNEYS: A EUROPEAN PRACTITIONERS' PERSPECTIVE

ABSTRACT

Integrating air transport with alternative modes of transport holds great promise for substituting short-distance flights in regions like Europe, provided that the benefits of existing transport networks are preserved. Effective multimodal integration requires collaboration among transport operators and hubs to enhance the passenger experience. This study explored the perspectives of these practitioners across Europe through an interview-based case study, identifying key factors for a passenger-oriented multimodal air journey and examining the mechanisms that influence their delivery.

The findings reveal five Passenger Experience Factors (PEFs) that contribute to a successful passenger-oriented multimodal air journey: 1) integration of booking systems; 2) whole journey guidance; 3) transfer time and ease; 4) baggage management; and 5) disruption management.

We found that delivering these PEFs necessitates support processes within and between organizations to align, including IT, infrastructure, scheduling, operations, commercial, interorganizational, and strategic efforts. Additionally, external conditions – such as market dynamics and regulatory frameworks – play a pivotal role in either enabling or constraining these efforts. We discovered that these underlying support processes converge in delivery mechanisms that influence the provision of PEFs for multimodal air travel.

The findings emphasize that while airlines often lead in shaping the multimodal experience, progress is hindered by fragmented responsibilities, misaligned incentives among operators, and market competition. It is crucial to recognize that delivering passenger-oriented multimodal journeys requires effective cross-system collaboration, and that a regulatory framework must be established to create conditions for more sustainable transportation integration.

1. INTRODUCTION

Transforming airports into Multimodal Transport Hubs (MTHs) is presented as a promising strategy to reduce CO2 emissions (European Commission, 2021), alleviate airport congestion (Janic, 2011), and improve the competitive positioning of airports (Janic, 2011; Román & Martín, 2014). MTHs integrate

both physical infrastructure and service elements of multiple modes of (long-distance) transport (Bell, 2019; Chauhan et al., 2021; Janic, 2011; Monzón et al., 2016; Toet et al., 2022).

The integration of air transport with alternative transport modes holds promise for regions like Europe, where the Trans-European Transport Network (TEN-T) is planned (European Union Agency for Railways, 2024; Regulation (EU) 2024/1679 on Union Guidelines for the Development of the Trans-European Transport Network, 2024). High-speed rail (HSR) can emit up to 80% less CO_2 than air travel (Eurocities, 2024; European Union Agency for Railways, 2024). Buses are also more sustainable than flights for short distances, although this depends on the occupancy rate (Baumeister, 2019). Buses offer the additional benefit of significant operational flexibility in scheduling and network coverage (Vuchic, 2007).

While HSR and buses provide a more environmentally friendly alternative to short-distance flights, aviation retains advantages due to its extensive network and seamless connections to long-distance air travel (Li et al., 2018). Integrating sustainable transport modes with air travel through multimodal air journeys, while preserving the strengths of existing transport networks, can reduce airport congestion and enhance passenger experience and environmental performance (European Environment Agency., 2021; Jiang et al., 2022; Yang & Zhang, 2012).

Central to this endeavor is the transition within our economy from a focus on products to the development of purpose-driven systems, where interconnected services and user-centered design play a key role (Meroni, 2016). An example of this shift is the movement from uniform travel experiences to the design of multimodal journeys that emphasize the passenger experience (Camacho et al., 2016; Canale et al., 2019). Achieving such high-quality multimodal integration requires collaboration among the relevant transport organizations to provide a passenger-oriented experience (Docherty et al., 2018; Toet et al., 2023).

Despite increasing research on user-centered transport and multimodal travel, little is known about what transport practitioners consider essential for shaping multimodal air journeys around airport hubs. While existing academic studies primarily focus on the passenger perspective, understanding practitioners' viewpoints is important for two reasons. First, practitioners possess valuable knowledge shaped by their field experience (Malterud, 2001b). Second, their decisions and actions in real-life are influenced by their understanding of what constitutes a successful multimodal air journey. This means practitioners have crucial insights that

can enhance our understanding of the mechanisms that enable or hinder the delivery of multimodal air journeys. This highlights the need for a qualitative study of practitioners' perspectives, as qualitative research is particularly well-suited to capturing the complexities of differing viewpoints and uncovering underlying challenges (Miles et al., 2014).

Through an interview-based case study, this study examines the perspectives of transport and hub operators across Europe and aims to contribute to the knowledge necessary for the successful delivery of passenger-oriented multimodal air journeys. The research is structured around two questions: *1) which passenger experience factors do practitioners consider essential for a successful multimodal air journey?*; and *2) What influences the effective delivery of these passenger experience factors to travelers in Europe?*

This study uses the Service Blueprinting framework (Bitner et al., 2008) as a lens to study the delivery of passenger-oriented multimodal air journeys. Service Blueprinting puts forward the notion that underlying support processes are essential for delivering user-centered services (Papastathopoulou & Hultink, 2012). It highlights the importance of a cross-functional approach in service creation, emphasizing that all organizational components must align towards the common goal of delivering coherent services. For multimodal air journeys, this alignment is crucial also between transport organizations, as multiple parties contribute to the creation of these integrated travel experiences (Toet et al., 2023).

The paper is organized as follows: Chapter 2 reviews the literature on transport systems and multimodal passenger experiences, while also outlining the theory of Service Blueprinting. Chapter 3 details the research methodology, and Chapter 4 presents the findings derived from the interviews. Finally, Chapter 5 discusses the implications and formulates conclusions.

2. BACKGROUND

2.1. Transport networks

The transport system can be conceptualized as a network of interconnected transport subsystems, each fulfilling a specific function within the broader network (Aleta et al., 2017; Geurs et al., 2016; Kivela et al., 2014). An example of an interconnected transport system is the TEN-T project of the European Union (EU), which covers the main transport routes within the EU and exemplifies the integration of transport systems into a cohesive network, enabling seamless transitions between modes of travel (European

Union Agency for Railways, 2024; Nechyporuk et al., 2022; Regulation (EU) 2024/1679 on Union Guidelines for the Development of the Trans-European Transport Network, 2024). These transport systems include rail networks, aviation, buses, automobiles, and more, each dependent on its physical infrastructure, operational practices, and regulatory frameworks.

In the aviation sector, two main network structures are commonly used to organize transport. First the point-to-point network connects origin-destination pairs directly, making it attractive for direct routes. However, it struggles with traffic distribution, leading to imbalances on certain routes and capacity limitations, which increases overall costs due to the need to serve less profitable connections (Wang et al., 2024). The second network structure is the hub-and-spoke model, which uses larger, more significant hubs to serve smaller, non-hub nodes (Givoni & Banister, 2006; Wang et al., 2024). This model leads to fewer direct connections while allowing for more efficient use of the connections between hub and node airports, thereby enabling economies of scale on hub-to-hub routes (Wang et al., 2024). Disadvantages to this model are the additional capacity required for transfers at hubs, and the extra time needed for these transfers (Wang et al., 2024). In both types of networks, air transport passengers begin and end their journeys at node or hub airports, where they enter or exit the air system through airport procedures, including passport and security checks (Marquez, 2019).

Unlike air travel, rail networks are designed for intercity passenger transport and typically operate without security and passport checks. In Europe, the rail system evolved as a collection of national networks primarily focused on domestic travel (Bairras & Ardaiz, 2025; Rli, 2020), allowing passengers to board and disembark at multiple stations, often conveniently located in city centers (Vassallo & Fagan, 2007). However, rail transport is strongly dependent on physical infrastructure for its operations and for specific routes it follows. This reliance on infrastructure explains why building (high-speed) rail systems requires significant investment in both infrastructure and railway stations (Doomernik, 2015). While passengers frequently transfer between different train legs during their journeys, rail systems typically do not provide the same guarantees for missed connections as airlines do. This is because different legs of a long-distance international train journey are often operated by different companies, a legacy of their historical evolution as independent national networks (Rli, 2020).

Next, bus networks designed for longer distances generally operate on more flexible routes, often with designated stops, and are less reliant on physical

infrastructure compared to rail transport. However, the reliability of these services is influenced by traffic conditions encountered along the route (Vuchic, 2007).

The TEN-T project places emphasis on HSR as a critical foundation for sustainable multimodal transport (Nechyporuk et al., 2022). Airport hubs using the hub-and-spoke model can take advantage of this by incorporating trains but also buses as 'spokes' in their network, as long as the physical infrastructure of a modality is available near or preferably at the airport (Li et al., 2018). This integration enhances the connectivity and sustainability of the transport systems (Román & Martín, 2014).

2.2. Multimodal passenger experience

The growing emphasis on passenger experience and service-oriented approaches (Bitner et al., 2008; Meroni, 2016) has prompted research into the factors that define a seamless multimodal air journey (Camacho et al., 2016; Canale et al., 2019). The Mobility-as-a-Service (MaaS) concept is an example of multimodal transport in which mobility services across different providers are connected to enable a smooth passenger experience (Guidon et al., 2020). Previous research defines multimodal (air) journeys as those journeys that connect air travel with train or bus transport, with a single integrated ticket for seamless travel (Babić et al., 2022; Li et al., 2018; Román & Martín, 2014) and connection insurance to mitigate disruptions or missed connections (Román & Martín, 2014). Multimodal transport differs from intermodal transport in that it features a higher degree of integration among organizations (Babić et al., 2022; Rodrigue, 2024). Assessing the existing literature, we found that integrating multimodal air journeys requires attention to both service factors and physical infrastructure aspects (Bell, 2019; Chauhan et al., 2021; Monzón et al., 2016; Toet et al., 2022)

Several service-related factors influence the passenger experience. First, comprehensive journey information empowers travelers to plan journeys according to their preferences, while real-time flight updates enhance their perception of control (Allen et al., 2020; Antwi et al., 2020; Cascajo et al., 2019; Hernandez Bueno, 2021; Watkins et al., 2011). Research suggests that communication of this information by staff further contributes to a positive travel experience (Antwi et al., 2020; Lubbe et al., 2011).

In addition to information provision, integrated ticketing simplifies the booking process by allowing a single purchase for an entire multimodal journey, thereby reducing complexity for passengers (Babić et al., 2024; Hickman et al., 2015; Román & Martín, 2014; Wang et al., 2020).

Moreover, minimizing friction during transfers is important in multimodal air travel. Key services include baggage integration (e.g., check-in at the departure station), dedicated multimodal touchpoints with trained staff to assist passengers, and transfer services (e.g., priority access at airport security) (Babić et al., 2022; Jiang et al., 2022; Li et al., 2018; Wang et al., 2020).

Last, these transfers should be coordinated to ensure smooth multimodal connections. While short transfer times can induce stress, excessively long layovers may result in inefficiencies and inconvenience, negatively affecting the overall travel experience and attractiveness of product (Jiang et al., 2022; Román & Martín, 2014; Song et al., 2018).

From an infrastructure perspective, we identified three categories of factors that influence the passenger experience of multimodal air journeys. First, wayfinding and signage help travelers navigate efficiently through the transfer environment, making services easier to find and use (Allen et al., 2020; Nielsen et al., 2021; Wang et al., 2020).

Second, the environment of a hub – characterized by shops, restaurants, well-maintained waiting areas, and safety and security measures – enhances the overall attractiveness of the transfer (Eboli & Mazzulla, 2015; Hernandez & Monzon, 2016; Hickman et al., 2015).

Third, the design of airport hubs, including terminal layout and walking conditions, significantly impacts the passenger experience (Geng et al., 2017; Wattanacharoensil et al., 2016). The train and bus stations should be located at or near the airport hubs, as proximity to these transport options is generally preferred (Li et al., 2018).

Finally, comfort during longer walks can be enhanced with amenities such as air conditioning and shelters (Hernandez & Monzon, 2016; Wang et al., 2020).

While existing research explores the passenger perspective, there is a gap in the literature regarding the viewpoints of transport practitioners. Comparing their perspectives with previously researched factors helps reveal misalignments between design and user needs. This highlights the need for further study on how multimodal collaborations are structured and implemented in practice.

2.3. Multimodality through service design

To make passenger-oriented multimodal travel a reality, actors from different transport systems must collaborate (Babić et al., 2022; Toet et al., 2022, 2023) and for airports to transition into MTHs, ecosystem-wide

collaboration is required (Toet et al., 2023).

Li et al. (2018) describe that varying levels of collaboration exist among different transport operators, categorizing these partnership levels by elements such as frequent flyer programs, code-sharing agreements, integrated ticketing systems, schedule coordination, and end-to-end services. Previous research indicated that establishing such collaborations introduces challenges, as organizing large-scale alliances is difficult due to the differing interests of operators (Toet et al., 2023). Additionally, challenges related to investment responsibilities (Toet et al., 2023), revenue sharing (Babić et al., 2022), and responsibility sharing (Babić et al., 2022; European Parliament and of the Council, 2024) were identified. Furthermore, collaboration between transport operators for multimodality is hindered by data-sharing issues, as there are no common rules and standards between transport systems, resulting in data being collected and made available in different formats (Babić et al., 2022, 2024; Finger et al., 2019). Li et al. (2018) emphasize the need to understand the driving forces behind these collaboration challenges in multimodal air travel.

As the passenger experience gains prominence, a holistic perspective, like service design, to the delivery of passenger-oriented multimodal air journeys, becomes increasingly relevant (Bitner et al., 2008; Mager, 2009). Applying a service design lens to the delivery of multimodal air travel enables studying the collaboration challenges between transport and hub operators that must be addressed.

One specific service design technique, Service Blueprinting, shows how the various service components are interconnected and maps out the characteristics of the service delivery process (Bitner et al., 2008; Shostack, 1984). This enables stakeholders to understand what the service entails and their respective roles in its delivery (Bitner et al., 2008). Service Blueprinting has been used in transport studies to redesign in-flight service processes (Nam et al., 2018).

The method builds on customer journey mapping, which visually represents the sequence of customer interactions throughout a service experience (Rosenbaum et al., 2017). Service Blueprinting extends the customer journey map by adding three layers (Figure 1): onstage/visible contact employee actions (interactions between customers and onstage employees or self-service technologies), backstage/invisible contact employee actions (interactions between customers and backstage employees), and support processes (underlying support processes not directly linked to customer interactions) (Bitner et al., 2008; Chakrabarti, 2019). The layers of the

Service Blueprint are connected through vertical lines that indicate the interdependencies within the organization that ensure effective service delivery (Bitner et al., 2008). This makes the Service Blueprint a valuable framework for this study, which aims to identify how organizations deliver passenger-oriented multimodal air journeys.

Physical Evidence

Customer Actions

Line of Interaction

Onstage/ Visible Contact Employee Actions

Line of Visibility

Backstage/ Invisible Contact Employee Actions

Line of Internal Interaction

Support Processes
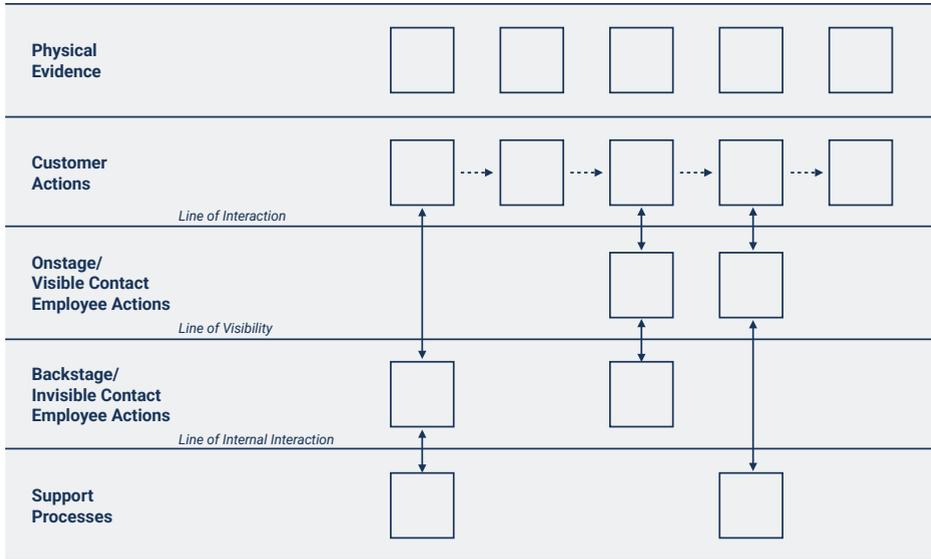
Figure 1. Service Blueprint framework (Bitner et al., 2008)

3. METHOD

3.1. Qualitative, interview-based

To align with the exploratory nature of the study, a qualitative research approach was adopted (Miles et al., 2014; Patton, 2015; Silverman, 2009). This approach facilitated a deeper understanding of the complexities involved in developing multimodal air journeys, capturing data characterized by *"richness and holism"* (Miles et al., 2014). Data were collected through semi-structured interviews with key multimodal transport practitioners and analyzed using thematic analysis (Braun & Clarke, 2012). Interviewing is a suitable method because the purposeful selection and analysis of information-rich cases yield context-sensitive and in-depth insights that surpass the researcher's direct observational capabilities (Patton, 2015). Interviewing experts provides valuable insights into the domains in which each expert operates and highlights their influence within their respective fields (Döringer, 2021).

3.2. Case selection & informants

We conducted interviews with the practitioners involved in delivering the four most advanced multimodal air journeys offered through European airport hubs. This study purposefully focused on the European context (Miles et al., 2014; Patton, 2015; Silverman, 2009; Yin, 2003), where EU climate policies promote a shift from air travel to more sustainable modes of transportation (Chiambaretto & Decker, 2012; European Commission, 2011). The short intercity distances make trains and buses viable alternatives to short-haul flights (Schmitt & Gollnick, 2016).

A multiple-case study requires a consistent contextual setting to facilitate meaningful cross-case comparison and support theoretical generalization (Yin, 2003). Therefore, regions outside the EU were excluded due other contextual settings (such as limited HSR infrastructure, reliance on competitive transport rather than integrated approaches, and differing governance systems (Nash, 2010; UIC, 2024; Veeneman, 2023; Wan et al., 2016; Zhou et al., 2018).

To select these cases, we conducted a review of European hub airports featuring multimodal air journeys based on predefined inclusion criteria (see Table 1) (Yin, 2009).

Table 1. Inclusion criteria for the selection of airport hubs

Inclusion criteria for the selection of Airport hubs
The airport hub features an integrated train or bus station, as literature highlights the importance of proximity between transport modes in facilitating passenger-oriented multimodal connectivity (Li et al., 2018).
The airport hub operates within a hub-and-spoke network, as hub airports were considered to have the greatest potential for integrating long-distance travel with other (short and medium distance) transport modes.
The airport hub is located within in the EU to align to ensure similarity in regulations.
The airport hub handles over 20 million passengers in 2019 to ensure comparable levels of operational complexity, including security processes.

Next, we assessed the multimodal air journeys available at the selected airport hubs. Journeys were selected exclusively if they met the three journey criteria and at least one of the service criteria. Based on this assessment, four cases were selected for further investigation (Table 2). Cases 1, 2, and 3 were comparable (Miles et al., 2014) in terms of journey characteristics and service offerings, while case 4 was an outlier due to the inclusion of a bus as the ground transport mode (Miles et al., 2014). Including an outlier case

is valuable, as it can enhance the robustness of the findings when patterns are consistently observed in the comparable cases but not in the contrasting case (Miles et al., 2014).

Table 2. Inclusion criteria for journey selection

Journey inclusion criteria (all must be met)	Case 1	Case 2	Case 3	Case 4
Journey consisted of an air leg and one leg of train or bus transport (Toet et al., submitted).	Train	Train	Train	Bus
Journey was offered via a single integrated ticket (Babić et al., 2022; Li et al., 2018; Román & Martín, 2014).	V	V	V	V
Provides connection insurance for travelers (Román & Martín, 2014).	V	V	V	V
Service inclusion criteria (at least one must be met)				
Offers comprehensive baggage handling for multimodal air travelers.		V		
Dedicated multimodal touchpoints with trained staff.	V	V	V	
Makes use of specialized transfer services, such as priority at airport security.	V		V	V

Data were collected through semi-structured interviews with key transport practitioners actively involved in delivering passenger-oriented multimodal air journeys at four European airport hubs. Following a purposive informant sampling strategy (Miles et al., 2014; Patton, 2015) for each case, the key representatives from airlines, airports, and rail operators were selected and interviewed (see Table 3). During the recruitment of the informants, we found that case 1 involved two rail practitioners sharing responsibilities for multimodal operations, whereas case 4 included only airline and airport practitioners, as the bus service was operated by the airline. For confidentiality reasons, the names of the cases and practitioners are not disclosed.

These interviews represent a carefully targeted selection of key individuals directly responsible for the development and delivery of the multimodal air journeys studied. Since such journeys are still relatively rare in practice, it is not always publicly clear which individuals are involved. Identifying and reaching the right practitioners therefore required considerable time and effort. This focused approach enabled the study to capture rich, experience-

based insights from the most relevant experts in the field. Furthermore, the total number of interviewees (N=12) is within the empirically supported range of 9 to 17 interviews for achieving saturation in qualitative research (Hennink & Kaiser, 2022).

Table 3. Overview of the informants who were part of the interview study, by their type of company and case

Case	ID	Company type
Case 1 (Air&Rail journey)	Airline, C1	Airline operator
	Airport, C1	Airport infrastructure manager
	Train1, C1	Train operator
	Train2, C1	Train operator
Case 2 (Air&Rail journey)	Airline, C2	Airline operator
	Airport, C2	Airport infrastructure manager
	Train, C2	Train operator
Case 3 (Air&Rail journey)	Airline, C3	Airline operator
	Airport, C3	Airport infrastructure manager
	Train, C3	Train operator
Case 4 (Air&Bus journey)	Airline, C4	Airline operator
	Airport, C4	Airport infrastructure manager

3.3. Data collection

The semi-structured interviews utilized a general interview guide to ensure consistency among informants (Patton, 2015). The guide focused on two primary topics:

1. *The passenger experience of multimodal air travel: informants' perspectives on passenger-oriented multimodal air services, including strengths, areas for improvement, and rationales for current practices; and*

2. *The delivery of passenger-oriented multimodal air travel: the service's delivery process, critical success factors, challenges, and future enhancement plans.*

The interviews were conducted between February and October 2023 by the first author via Microsoft Teams. Sessions were recorded and transcribed. The interviews were conducted in English or in the shared native language of the interviewees. The duration varied from 40 to 60 minutes.

3.4. Data analysis

The interview transcriptions were thematically analyzed using the six phases established by Braun and Clarke (2006): (1) familiarizing with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) reporting findings.

Data familiarization involved listening to the recorded interviews, transcribing them verbatim, and reviewing the resulting transcripts. These transcripts were the primary data source for subsequent steps.

The coding phase was performed by using the Goia coding technique, and was conducted in iterative rounds (Magnani & Gioia, 2023). First, the primary author created first-order codes, in which the codes were represented by informants' understandings. This was done using the ATLAS.ti qualitative data analysis software. The first-order codes were reviewed by the other authors by using an analytical framework based on Service Blueprint theory (Figure 2) (Bitner et al., 2008), as a lens for interpreting the data (Magnani & Gioia, 2023; Malterud, 2001a).

The review of the first-order codes facilitated the creation of second-order codes (the researcher-based understandings), and led to the division of two main groups (Magnani & Gioia, 2023): Passenger Experience Factors (PEFs) (designated as A in Figure 2) and delivery mechanisms (letter B). The PEFs encompass codes that align with the four top layers of the Service Blueprint model – physical evidence, customer actions, onstage actions, and backstage actions – directly relating to the passenger experience. The delivery mechanisms illustrate how the PEFs are delivered through support processes, consistent with Service Blueprint theory (Bitner et al., 2008).

During the data analysis, we found that the delivery mechanisms consist of multiple categories of support processes and external conditions (letter C).

The first author identified the PEFs, mechanisms, and categories of support processes and external conditions, which were reviewed by all authors to ensure consistency and validity. Illustrative quotes from informants were collected and paraphrased for clarity (and translated if necessary). Finally, all authors reviewed the report.

4. RESULTS

This chapter presents findings on PEFs for multimodal air journeys and their delivery from practitioners' perspectives. The study identified five key PEFs as core objectives for successful multimodal air journeys: 1) integrated booking, 2) whole journey guidance, 3) transfer time and ease, 4) baggage

management, and 5) disruption management. For each PEF, we found mechanisms that influence its effective delivery.
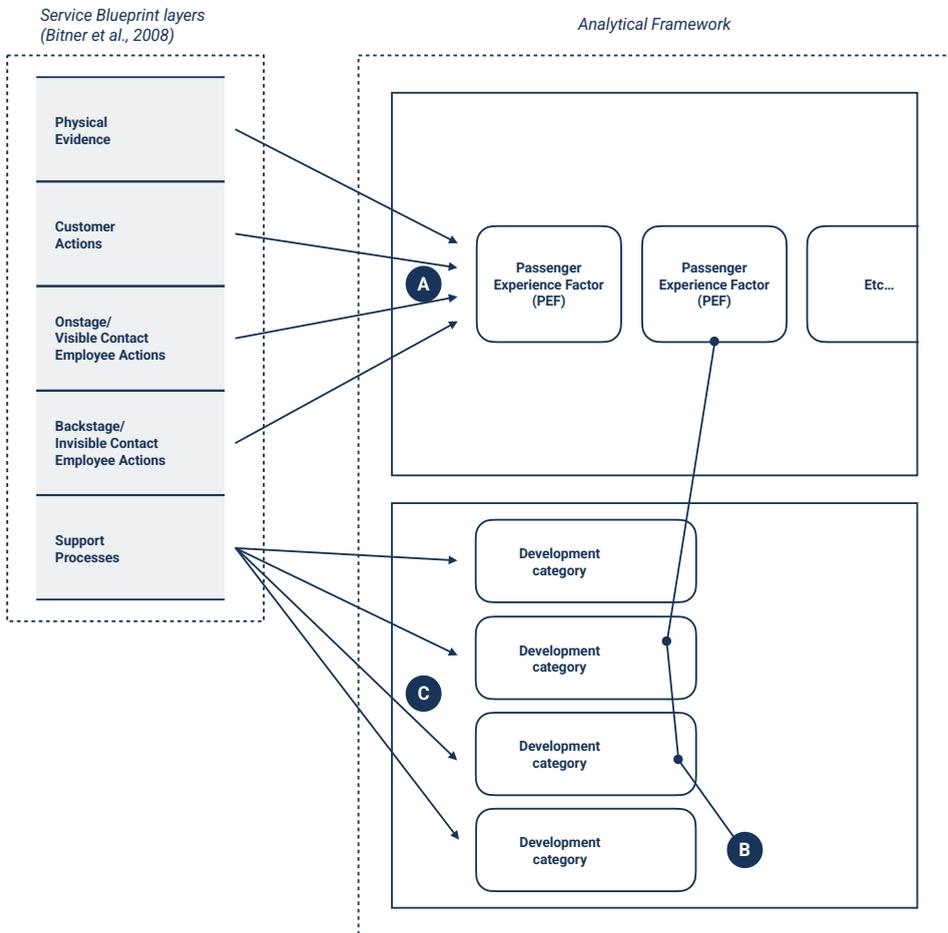
Figure 2. Analytical Framework based on the Service Blueprinting theory of Bitner et al. (2008)

An overview of these findings is presented in Figure 3. The top row displays the PEFs, and the vertical lines represent the delivery mechanisms and indicate the interdependencies between the support processes and external conditions. The categorization of the support processes is provided in Table 4, along with a definition of each category.

The remainder of this chapter concentrates on describing each PEF, followed by an explanation of the delivery mechanisms for each PEF.

5

Figure 3. An overview of how the delivery of PEFs in multimodal air journeys is driven by mechanisms of support process and external conditions.

Table 4. The categories of support processes and external conditions, along with working definitions

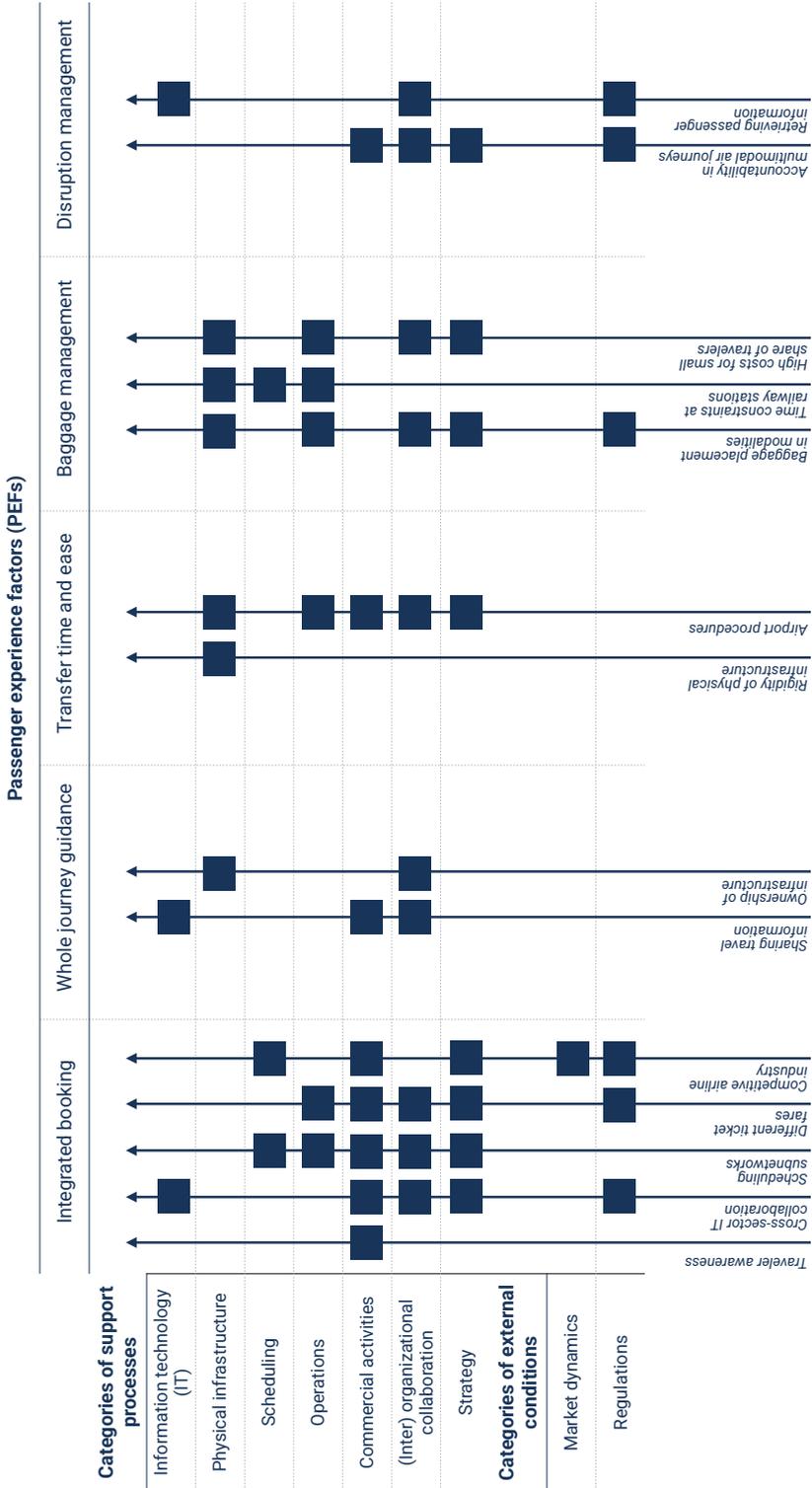| Categories of support processes	Definition
Information Technology	Use of computers, software and networks to create, manage and deliver transport. It enables the storage, processing and communication of data.
Physical infrastructure	Physical assets that support transport processes, such as roads, rails, stations and terminals (Toering et al., 2025).
Scheduling	Planning and timing of transport services and modalities.
Operations	Day-to-day activities required for the coordination of resources, processes, and personnel to ensure smooth execution of transport.
Commercial	Activities focused on business viability and value creation for the organization(s) involved, including efforts to market services, sell tickets and promote awareness of multimodal travel options.
(Inter) organizational	The internal structures and processes, and collaboration among actors, that enables an organization to function effectively.
Strategy	A high-level plan that defines the organization's goals and actions to achieve them.
Categories of external conditions	Definition
Market dynamics	Dynamics that influence the behavior of market actors, and covers aspects such as competition, consumer demand, pricing trends, market entry barriers, and evolving business models.
Regulations	The policies, legislation and regulations set by government bodies that affect the delivery of transport.

4.1. PEF: Integrated booking

The informants underscored that integrated booking is essential for the successful execution of multimodal air journeys. By consolidating various travel segments into a single itinerary, integrated booking simplifies the planning of these journeys. Key components of integrated booking include a single (digital) ticket that encompasses all modalities, a streamlined booking procedure, and reduced costs compared to separate tickets.

A significant advantage of integrated booking is the capacity to search for and reserve all trip segments through a single online platform. Informants highlighted the importance of eliminating the need for passengers to navigate multiple websites: *"I think this is the most important step in order to show the*

customer, OK, there is an option with the rail as a first or last segment." (Train, C3).

In addition to enhancing convenience, a single ticket functions as a unified contract for the entire journey, also providing financial benefits. Informants noted that integrated booking frequently offers discounts or bundled pricing compared to the purchase of separate tickets.

The research found that five mechanisms shape the delivery of integrated booking, which are outlined below.

4.1.1. Traveler awareness

Passenger awareness is a requirement in the adoption of integrated booking for multimodal air journeys. Informants highlighted that many travelers are unaware of the option to book these journeys as a single itinerary, which leads them to purchase separate tickets for train and air segments. Traditionally, trips are booked airport-to-airport, while multimodal options include connections from nearby rail stations. However, this lack of awareness about these possibilities prevents passengers from taking advantage of integrated tickets: *"The huge majority of clients buy a train ticket and then a plane ticket separately. And so, they take the risk of missing the connection."* (Train, C2).

Without sufficient knowledge about the option to book an integrated ticket, the demand for such services remains low, which in turn reduces the effectiveness of offering multimodal air journeys in the first place.

4.1.2. Cross-sector IT collaboration

Establishing integrated digital ticketing requires close collaboration between the air and rail sectors, but differences in their IT structures create challenges.

Airlines rely on standardized IT systems for information and code sharing, which are not commonly used in the rail industry. Our findings suggests that rail operators often adapt to airline standards to enable integrated booking: *"We align ourselves to the airline standard in order to sell our trains as flights. And I think this is the basic thing to sell this because the airlines are not willing to align to our standards, so therefore the railway companies need to align to the airline."* (Train, C3).

While airlines do have extensive experience collaborating within their own system, extending this cooperation to other transport systems to support integrated booking, requires significant adjustments in existing IT structures.

4.1.3. Scheduling subnetworks

The scheduling properties of different transport subnetworks do not align efficiently to enable integrated booking for all types of multimodal air journeys.

Informants noted that parts of the European air transport network, primarily those parts involving intercontinental travel, rely on early morning feeder flights to ensure timely connections with the western part of the world. To achieve these worldwide connections, the air travel industry has a long history of international cooperation among various air operators. In contrast, the rail sector has developed as national networks, transporting passengers from city to city. While trains in Europe can be efficient, travel times are often extended due to multiple stops along the way. Therefore, replacing feeder flights with buses or trains presents significant scheduling challenges: *"The first planes are taking off very early in the morning and the last ones are coming back very late. So if you come back with those planes, you don't have any train afterwards to go back home."* (Airport, C2).

Operating trains early in the morning or late at night would require increased rail service frequencies. However, this is constrained by the rail system's reliance on nighttime hours for maintenance, as one rail operator explained: *"Our trains can't run at night because we do maintenance, and if you want to cover all the hub sections, then we should have trains very early in the morning. So, departing very, very early from outbound stations or very late, it is technically impossible for us."* (Train, C2). Notably, informants indicated that rail operators have little incentive to run trains more frequently to connect with air transport, as it is not economically attractive for them as the numbers of transfer passengers are not high enough to justify running solely for that purpose.

4.1.4. Different ticket fares

Interviewees noted that variations in ticket fares across transport modalities present a challenge for airlines in implementing integrated booking for multimodal air journeys. In hub-and-spoke networks, a short-leg flight that is part of a multi-segment air journey with a hub transfer may be priced lower than the same flight when booked as a standalone point-to-point connection. To prevent fare abuse and protect revenue integrity, airlines enforce boarding checks. However, this becomes more complex when a single booking includes both a flight and a train segment, as rail systems typically do not have the same stringent boarding controls as airlines. As one airline representative explained: *"For example, for competitive reasons, the ticket from Amsterdam to New York via Frankfurt airport could be cheaper than the*

ticket from Frankfurt airport to New York. And if someone would be boarding the train or would pretend to board a train in Amsterdam just to get a cheaper fare out of the hub Frankfurt airport, yeah, that would be a problem." (Airline, C3).

To address this issue, informants from case 1 referred to the Air&Rail desk at Brussels South train station, where multimodal travelers must collect their boarding passes to ensure compliance with the full journey: *"If the passenger does not pick up his boarding pass at the [Air&Rail] desk, well, persons cannot board the train and cannot use the plane."* (Train 2, C1).

4.1.5. Competitive airline industry

The rise of multimodal air journeys is largely driven by airlines responding to sustainability pressures. Facing criticism for operating short-distance flights, airlines have started collaborating with other transport providers to offer integrated travel options. However, competition within the airline industry ensures that traditional flights will continue to coexist with these multimodal alternatives.

This competitive dynamic creates a disincentive for airlines to fully commit to integrated booking for multimodal air journeys. By offering such options, airlines risk losing passengers – and consequently revenue – to competitors operating through other hubs. One airline informant explained that airlines may even continue operating certain short-distance routes, despite the availability of multimodal alternatives, in order to protect their flight slots: *"If you don't have any other use for the [flight] slot, you may keep flying on a certain route because you want to protect the slot."* (Airline, C3).

According to informants, the absence of European or global legislation reinforces this situation, allowing airlines to prioritize competitive interests over fully depending on multimodal travel.

It is the case that when airlines recognize strategic value in offering multimodal options, they become more inclined to invest in seamless booking systems. As one informant observed, growing attention to multimodal transport allows airlines to extend their networks into regions that were previously unserved by air travel: *"It allows [the airline] to drain more customers by the train, let's say in the 300/400 kilometers around [the airport], where anyway you wouldn't have any aircraft."* (Airline, C2).

4.2. PEF: Whole journey guidance

Clear passenger guidance is essential for a smooth multimodal air journey, both in pre-travel preparation and in providing real-time assistance during

the journey. While this section focuses on overall journey guidance, transfer-specific considerations are discussed in PEF 3: Transfer time and ease.

Informants emphasized the need for clear multimodal instructions at the booking stage to ensure that passengers understand their journey details, including their rights and responsibilities. They explained that travelers may be unaware that they have booked a multimodal trip, leading to confusion upon arrival at a rail station. As one informant noted, *"A lot of those people simply don't realize that part of the journey is by train, so we really need to explain that better"* (Airline, C1).

Beyond pre-travel communication, clear wayfinding, baggage handling instructions, and real-time updates are essential, especially at airports and train stations. Informants stressed the need for reliable guidance throughout the journey to minimize uncertainty and improve the overall passenger experience. The importance of both digital and physical support tools, such as instructional videos, was explained: *"That instruction video is powerful; I think it is an essential component to help reassure passengers"* (Airline, C1).

These measures collectively contribute to a well-coordinated travel experience, reducing uncertainty and enhancing passenger confidence in multimodal air journeys. This study identified two delivery mechanisms that shape the provision of whole journey guidance services, as detailed below.

4.2.1. *Sharing travel information*

Effective passenger guidance in multimodal air journeys relies on information sharing between transport systems, which in turn depends on IT-system integration. However, technical limitations currently hinder this exchange. One airline informant highlighted that rail data cannot be directly incorporated into airline systems, requiring workarounds that complicate the process: *"Setting up communication between especially the rail partners and airlines is not an easy business. Airlines have been developing standards for inter-airline communication for 30 to 40 years. There's nothing like that on the rail side for example."* (Airline, C3).

4.2.2. *Ownership of infrastructure*

The lack of control over digital and physical infrastructure limits efforts to improve passenger guidance. For example, while transport operators strive to enhance wayfinding, signage and directional information are managed by station and airport authorities. This limits operators in their ability to implement changes:*"Most of the station [owners] don't like when the partners are playing with signage and everything, so they want to - and I can understand*

- have it the way they want." (Train2, C1).

4.3. PEF: Transfer time and ease

Informants identified the transfer as the most critical juncture in multimodal air journeys, emphasizing two key aspects: time and ease.

First, efficiency is crucial for multimodal air transfers, as passengers need sufficient time for security checks, baggage handling, and boarding, while remaining competitive with air-to-air connections. Longer transfer times may deter passengers who prefer air-only travel. Physical proximity between transport modes shortens distances, reduces the needed transfer times, and makes the journey more appealing to passengers.

Second, a passenger-oriented multimodal experience relies on transfers that make passengers feel at ease. Informants emphasized that this can be achieved through well-integrated touchpoints, such as check-in desks and baggage drop-offs, as well as through clear and intuitive wayfinding. Informants highlighted that air-only transfers generally offer better amenities, especially in waiting areas, compared to multimodal transfers. Train stations were often noted to lack the comfort found in airports, emphasized by this informant: *"You're at [the train station], and your train leaves in 1.5 hours. Where are you going to wait? At [the airport], you can comfortably wait at the gates with benches and all that. Here, there's nothing"* (Airline, C1).

Combined, these elements enhance the overall passenger experience. Below, we outline two delivery mechanisms identified in this study that influence these aspects.

4.3.1. The rigidity of physical infrastructure

Stations and airports were not originally designed with multimodal transport in mind, complicating the smooth transfer of passengers between different modes of transport. As one informant explained, *"This problem with the old infrastructure [...], they were not designed with the idea that one day you have to put some desk of air companies."* (Airport, C2). This results in long walking distances between different transport modes and complex station layouts, making improvements particularly challenging in terms of timelines and costs.

4.3.2. Airport procedures

Airport procedures, such as customs, security checks, and baggage handling, present significant hurdles for multimodal air travel. These processes, typically confined to only the departure airport in air-only travel, must be

performed during the transfer stage of multimodal air journeys – such as when passengers transfer from a train to a flight. This increases the time needed for transfers.

A potential solution suggested by an informant is to provide priority services during airport transfers to help streamline the process: *"One key thing for us is to provide a smooth connection throughout the terminal and security at the [airport]. So that's why we are offering priority services whenever you are catching a flight"* (Airline, C4). However, not all informants agreed with this solution, particularly those from the airline sector, noting that priority services are typically reserved for loyalty (high yield) members.

Another suggested solution for successful multimodal air transfers includes the creation of a dedicated transfer filter at airports, designed to facilitate smoother transitions between modes of transport. However, such a solution would require significant investment from airports.

4.4. PEF: Baggage management

The data highlighted baggage management as a key challenge in multimodal air journeys, with differing perspectives on how it should be handled. While some informants emphasized the importance of streamlining the baggage process throughout the entire journey, they argued that full integration across transport modes is not essential. Instead, they proposed practical solutions such as dedicated luggage racks on trains and specialized baggage handling at airports, all aimed at reducing the inconvenience of carrying luggage. For passengers facing long walking distances in terminals, a quick baggage drop-off after disembarking from the train was seen as particularly beneficial: *"we had some baggage drop off and delivery very close to the train platform. That is a strength that is very important for [the airport]."* (Airline, C3).

Others, however, advocated for a fully integrated baggage system, as is the case in air-to-air travel, where passengers would not need to handle their luggage between transport modes. They pointed to baggage service companies that already facilitate seamless transfers by offering check-in at train stations, allowing passengers to travel without the burden of managing their bags.

Despite differing opinions on the ideal approach, there was broad consensus on one key point: full integration without third-party involvement was generally considered unrealistic. The data revealed three underlying mechanisms contributing to this view, with one key message being that baggage handling in multimodal air travel is often expected to meet the same

standards as in air-to-air travel. This expectation, particularly expressed by informants from airlines, is seen as a significant barrier to achieving full multimodal air integration.

4.4.1. Baggage placement in modalities

A key challenge lies in determining where to place baggage on trains. While aviation security regulations mandate a controlled environment for checked baggage, informants pointed out that European trains are not designed to accommodate large volumes of luggage. As one informant explained: *"Did you ever realize that European trains don't tend to have our luggage cars anymore? And the air industry authorities require a controlled environment for checked baggage."* (Airline, C3). This highlights a significant issue in trying to integrate baggage management across different transport modes.

4.4.2. Time constraints at railway stations

Unlike planes at airports, where baggage handling is a well-established process, or buses at stations, trains are required to stop briefly at stations, making it nearly impossible to load or unload large volumes of baggage in such short durations. One informant explained: *"If you want to copy-paste the current experience passengers have had for decades [at the airport], that would mean that when the train arrives in the airport railway station, you have some handling of the bag – since the passenger wouldn't take care of this – that would pull the bag out of the train in probably 2 minutes. That's pretty challenging if you don't want to change the railway network [...], I don't think it's achievable."* (Airline, C2). Buses, on the other hand, offer greater flexibility as they are not bound to fixed tracks and can wait for delayed passengers when necessary.

4.4.3. High costs for small share of travelers

Implementing full baggage integration would require significant financial investment and additional personnel at multiple locations, and affecting the current rail network. However, multimodal air travel constitutes only a small part of the rail industry, making it challenging for operators to justify investments in dedicated multimodal touchpoints at stations and airports. One informant highlighted this issue: *"And then the nightmare of having the facilities set up at all [stations]. That all would have to be manned, that all would have to be staffed, would be extremely cost-intensive, and the space is not there."* (Airline, C3). This is further complicated by the involvement of large, established organizations, meaning that the employees of these organizations must also be persuaded to invest in multimodality.

4.5. PEF: Disruption management

Disruption management emerged as a crucial factor in ensuring passengers are well cared for during disruptions or are empowered to handle them independently, promoting both reliability and a sense of security. This aspect is closely linked to 'PEF 1: Integrated booking' and 'PEF 2: Whole journey guidance,' as passengers need to be kept informed about changes, potential actions, and their rights in the event of disruptions.

While disruption management is a standard practice in air travel, handling disruptions in integrated multimodal air journeys requires special attention. Interviewees stressed that passengers must be guaranteed connections and rebooking onto alternative transport options in case of missed transfers: *"That passengers on the train can be sure that they reach their flight and, if not, they will be rebooked and all that stuff. So that is taken care of"* (Airport, C3).

As one informant pointed out, passengers tend to prioritize assurance over speed. For long-distance travelers in particular, the security of knowing their needs will be addressed during disruptions was mentioned as more important than simply minimizing travel time: *"Mainly for long [distance] travelers, I think that they are not looking for the fastest option. I think they need to be as assured as possible"* (Airport, C2).

The findings reveal two key delivery mechanisms that play a role in disruption management, which are discussed below.

4.5.1. Accountability in multimodal air journeys

It was found that there are no clear rules regarding the ownership of multimodal air journeys, which is detrimental to the passenger in case of disruptions. One airline representative pointed out the problem: *"Normally, in a codeshare, the operating carrier causing the issue is also responsible for resolving it and compensating passengers. [...] But in this case, no one is responsible, and that simply doesn't work. You can't accept passengers on such intermodal connections without clear accountability. That's something we really need to address in Europe through legislation."* (Airline, C1). Consequently, the informants noted that in their cases, the airlines assume responsibility for managing disruptions, as this aligns with their role as the ticket vendor.

4.5.2. Retrieving passenger information

Transport operators need to have accurate data on who is on board a vehicle, so they can respond appropriately and communicate with passengers

affected by disruptions. As one informant explained, *"We brought in the IT teams to ensure everything was really robust in terms of the booking systems, so we know exactly who is on our train, and in managing disruption services. So now, we've taken a few steps to operate more efficiently"* (Train 2, C1). Beyond the technical challenges of different IT systems, regulatory frameworks also influence the feasibility of system integration. Establishing partnerships is essential for facilitating information exchange, but government regulations can complicate collaboration, especially for airports that hold a monopoly. As one informant pointed out, restrictive policies prevent airports from forming agreements with individual transport operators: *"Because of this monopoly situation and the agreements directly between [airline operator] and [rail operator], it's hard for us at the airport to get some data regarding even how many people are using this service"* (Airport, C2). Consequently, having a single operator manage the journey can complicate effective disruption management among all involved parties.

4.6. Groundedness of the findings

This section evaluates the extent to which the data supports each PEF and the categories of support processes and external conditions in the delivery of passenger-oriented multimodal air journeys (Eisenhardt, 1989). Figure 4 visualizes these connections: the first row indicates whether a PEF was mentioned by cases and informants (black) or not (white), while the first column shows mentions of each support category, providing insight into their perceived importance. The subsequent rows and columns illustrate the presence (dark grey) or absence (white) of relationships, as well as the cases and informants mentioning these connections.

Examining the first row reveals that all PEFs are substantiated by the data, with evidence of informant triangulation (Malterud, 2001a; Miles et al., 2014). Logically, case 4 lacks references to a train operator because this case involved a bus connection operated by the airline.

Analysis of the first column highlights variation in how strongly categories of support processes and external conditions are rooted in the data. While most categories were consistently mentioned, 'IT', 'scheduling', 'market dynamics', and 'regulations' appeared less frequently. These categories also exhibit fewer connections to PEFs in the subsequent columns.

A closer examination of the relationships between the categories and PEFs reveals several key patterns. First, 'IT' primarily influences PEFs related to information provision and sharing, such as 'integrated booking', 'whole journey guidance', and 'disruption management'.

Second, the category 'scheduling' has limited impact, appearing only in connection to 'integrated booking' (determining whether a journey is possible) and 'baggage management' (determining whether integrated baggage is feasible).

Third, the '(inter)organizational' category affect all PEFs, underscoring the importance of both internal and external collaboration in developing multimodal air journeys.

Next, 'market dynamics' impact only 'integrated booking', as its underlying elements (such as competition) largely determine whether an integrated journey is offered.

Furthermore, the category 'regulations' influence the PEFs 'integrated booking' and 'disruption management', and to a lesser extent, 'baggage management', as airline regulations require baggage to remain in controlled environments.

Finally, visualizing the connections between PEFs and support processes provides insight into which findings primarily apply to multimodal air journeys and which pertain mainly to air&rail (C1, C2, C3) or air&bus (C4) cases.

In case 4, integrated booking was mentioned less frequently because it was entirely managed by the airline. The connections with journey guidance were largely consistent across all four cases, suggesting that this aspect is not dependent on the mode of transport but is inherently important in any multimodal air journey. The importance of transfers appeared to be lower than in the air&rail cases. Additionally, baggage issues were less significant in the air&bus case and showed no connection to infrastructure, a link that was evident in the air&rail cases. Moreover, disruption management had minimal to no impact at the strategic, interorganizational, and regulatory levels in the air&bus case, which can again be attributed to the fact that the bus was entirely managed by the airline. Ultimately, the air&bus outlier case highlighted that infrastructure played a less critical role compared to the air&rail case.

The strongest relationships – with the highest number of informants and cases – are observed between 'commercial' and 'integrated booking', as well as between 'strategy' and 'integrated booking'. Following these, strong connections also emerge between 'market dynamics' and 'integrated booking', and between '(inter)organizational' and 'whole journey guidance'.

		Integrated booking				Whole journey guidance				Transfer time and ease				Baggage management				Disruption management			
		C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	A																				
	H																				
	T																				
Information Technology (IT)	A																				
	H																				
	T																				
Physical infrastructure	A																				
	H																				
	T																				
Scheduling	A																				
	H																				
	T																				
Operations	A																				
	H																				
	T																				
Commercial activities	A																				
	H																				
	T																				
(Inter)organizational collaboration	A																				
	H																				
	T																				
Strategy	A																				
	H																				
	T																				
Market dynamics	A																				
	H																				
	T																				
Regulations	A																				
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Figure 4. An overview of the presence of PEFs and the categories of support processes and external conditions in the data

5. DISCUSSION

Our findings indicate that practitioners in multimodal air transport considered five elements essential for a passenger-oriented journey: 1) integrated booking, 2) whole-journey guidance, 3) transfer time and ease, 4) baggage management, and 5) disruption management. These practitioner-identified priorities closely align with established research on the passenger experience.

Consistent with previous studies that have shown that integrated ticketing reduces perceived complexity (Babić et al., 2022; Román & Martín, 2014), our findings highlight that, according to practitioners, the primary benefit of simplified booking is the elimination of searches across multiple websites. Improving the booking process aligns with the EU's multimodal digital mobility services (MDMS) ambition to enable seamless cross-modal booking and ticketing, thereby enhancing user experience and interoperability.

Similarly, our results support earlier research indicating clear pre-trip and real-time information enhances passengers' sense of control and reduces perceived complexity (Allen et al., 2020; Antwi et al., 2020; Cascajo et al., 2019; Lubbe et al., 2011; Watkins et al., 2011). We expand this understanding by showing that practitioners noted passengers may not realize their journey is multimodal, suggesting that journey guidance should be continuous across legs and explicitly address transfers, rights, and responsibilities.

In line with prior studies that identify the transfer as a critical juncture (Babić et al., 2022; Chauhan et al., 2021; Durand & Romijn, 2023), our data underscore the importance of both the transfer time and ease. We found that airport-like amenities on the rail side could enhance the perceived quality of multimodal travel. While the co-location of modes is a prerequisite for transfers (Li et al., 2018), it was noted that this is insufficient without timetable coordination and integrated processes, such as check-in and baggage handling.

Regarding baggage management, previous research has demonstrated that integrated baggage systems reduce passenger effort (Babić et al., 2024; Román & Martín, 2014; Wang et al., 2020). However, practitioners in our study agreed with that point, however they viewed full air-to-air style integration as largely unfeasible. Instead, they emphasized pragmatic solutions, such as third-party baggage services, enhanced luggage racks on trains, faster handling, and real-time updates.

Finally, consistent with existing literature that identifies disruption management as key to maintaining passenger trust through timely communication (Antwi et al., 2020; Babić et al., 2024; Cascajo et al., 2019), our findings reinforce this understanding by showing that practitioners believe passengers value assurance over speed.

While multimodal air travel inherently requires collaboration between transport systems (Babić et al., 2022; Toet et al., 2022, 2023), the airline representatives we interviewed tend to seek orchestration – or even control – over the passenger experience. As they sell tickets through their channels, they feel responsible for ensuring that passenger standards remain consistent with their disruption policies, baggage management, and in-flight expectations.

Our data also indicate that practitioners perceive passengers as adjusting their expectations based on their primary mode of transport, specifically, the airplane within multimodal air journeys. This aligns with existing research that identifies air travel as the central mode in multimodal air travel (Babić et al., 2022). As a result, in the cases we studied, the air leg was what we would

call the 'baseline modality', the dominant mode in an integrated multimodal air journey. According to the informants, this baseline modality influences the passenger experience not only during transfers but also throughout the entire journey and sets passenger expectations. We found that these expectations include multiple aspects of the travel experience, including ticket booking, information provision, baggage handling, and passenger management during disruptions.

By uncovering the underlying mechanisms of delivering these PEFs to the passenger, we provide new insights into the intrinsic interdependence of services and physical infrastructure in multimodal air journeys. For instance, transfer services – including baggage handling, multimodal touchpoints, and priority lanes – rely on supporting infrastructure to function effectively. Similarly, while communication to the passenger is crucial, physical infrastructure plays a key role in its provision, such as through wayfinding. These insights closely align with existing literature on the role of service and physical infrastructure in multimodal air travel (Bell, 2019; Chauhan et al., 2021; Monzón et al., 2016; Toet et al., 2022). However, our findings show that this interdependence extends beyond infrastructure. We identified additional support process categories, including IT, scheduling, operations, commercial, (inter)organizational aspects, strategy, as well as broader external conditions such as market dynamics and regulations. All these categories are captured in underlying mechanisms and interconnected in the delivery of PEFs for multimodal air travel. Across these mechanisms we observed several recurring patterns that influence the overall delivery of multimodal air journeys.

Our findings indicate that the delivery of PEFs is hindered by the historical legacies of transport operators. While airlines primarily have a global focus, rail operators emerged from a national orientation (Bairras & Ardaiz, 2025; Vassallo & Fagan, 2007). Our research highlights the complexities arising from this disparity, demonstrating that the difference in focus presents a fundamental challenge for the delivery of multimodal air journeys, as the operational models and networks do not align with one another. We found that the long-standing operational histories of these operators predate the concept of multimodal air travel, meaning they are not designed or equipped to integrate with other transport systems. Working towards multimodality involves adapting physical infrastructure, such as station and airport facilities or the layout of transport vehicles like trains. However, adapting rail systems'

infrastructure is costly, time-intensive, and can impact existing transport networks (Doomernik, 2015). In line with Toet et al. (2023), we found that determining who should bear these costs is particularly problematic, as we gained further insight that the involved actors have little financial incentive due to the relatively low number of multimodal air travelers (Román & Martín, 2014). We found that this may be attributed to many passengers being unaware that multimodal air travel exists or that such journeys can be booked as a single itinerary.

Even though informants noted that airlines have substantial experience collaborating with various stakeholders, we found that this primarily occurs within the same system (e.g., inter-airline agreements). Cross-system collaboration, as required for multimodal air travel, presents challenges such as adapting standardized IT systems. This is especially important for data sharing, as highlighted in previous research (Babić et al., 2022, 2024; Finger et al., 2019). Our findings agree that effective information exchange between transport systems is critical for guiding passengers throughout their journey and ensuring that transport operators have accurate passenger data. We observed that data sharing enables operators to respond appropriately and provide necessary guidance in case of disruptions. We extend this knowledge by demonstrating that, in practice, there is no clear ownership of multimodal air journeys. While existing research has highlighted the issue of responsibility sharing (Babić et al., 2022; European Parliament and of the Council, 2024), we deepen this understanding by discovering that the airlines involved in this study assume responsibility for the entire journey.

The issue of revenue sharing, as discussed by Babic et al. (2022) and Finger et al. (2019), was not observed in our study. This is primarily because airlines currently pay rail operators a fixed fee to enable ticket sales. As a result, there is no dual-provider model from the passenger's perspective, as the ticket is simply purchased through the airline. However, we found that if future regulations allow passengers to buy tickets independently of a dominant provider, revenue sharing may become a relevant issue.

We did identify another revenue-related challenge: the discrepancy in ticket fares between different transport systems. Airlines utilize yield optimization based on entire journeys and enforce boarding checks to prevent fare abuse and protect revenue integrity. This practice is not typically applied in rail transport. We found that this discrepancy makes it less attractive for airlines to offer combined tickets, as it creates opportunities for passengers to exploit differences in airline pricing structures. Our findings show that existing solutions, such as multimodal touchpoints at departure stations,

require additional staff and infrastructure while also adding an extra step for passengers, making the journey more fragmented and operationally costly.

Returning to the idea that integrating more buses and trains with air travel can enhance sustainability (Baumeister, 2019; Eurocities, 2024; European Union Agency for Railways, 2024), our findings suggest a more nuanced reality. Driven by competition and capacity constraints in the airline industry, airlines tend to protect their airport slots, meaning they may continue operating the same routes even when a rail alternative is available. Literature further suggests that this can, in some cases, lead to increased emissions when airlines repurpose these freed-up slots for long-distance flights instead (Berveling et al., 2020; Rli, 2020). Our findings indicate that addressing this issue effectively requires regulatory intervention.

Although current regulations often constrain the delivery of key PEFs in multimodal air journeys – such as due to differing rules for disruption management among providers and strict baggage handling regulations – a new regulatory framework could instead facilitate progress. Such a framework can help align incentives, clarify responsibilities (for instance, regarding transfer times and ease), and ensure that data and ticketing systems are interoperable across modes. Policy measures should encourage operators to collaborate beyond their own systems and prioritize the passenger experience – not only by recognizing the importance of PEFs but also by placing the passenger at the center of delivering multimodal air journeys.

The study has several limitations that highlight opportunities for further exploration. First, it focuses exclusively on Europe, which limits the global applicability of the findings. Although the study does not aim to generate universal knowledge due to its qualitative nature (Miles et al., 2014), we encourage readers to reflect on the conclusions drawn from data collected at hub airports in Europe that handled over 20 million passengers in 2019, where EU regulations apply. The findings should not readily be generalized beyond comparable multimodal air transport settings – or at least not without careful consideration and interpretation of contextual factors – but we invite future research to investigate cases outside Europe, taking into account the distinct contexts and conditions in other regions.

Second, although the set of interviewees was limited to twelve practitioners involved in four advanced cases, this scope inevitably restricts the generalizability of our findings. The cases were selected because they represent the most advanced examples of multimodal transport in Europe at

the time of the research, but they cannot be assumed to reflect the full diversity of industry practice. In particular, the perspectives of airlines, rail operators, and bus companies not currently engaged in multimodal integration were not included, which limits insight into the reasons why broader adoption has been limited. Future studies including such perspectives across a wider range of contexts are necessary to provide more comprehensive and generalizable insights.

We included one outlier case (Miles et al., 2014) in this study that deviated from the air&rail connection, involving an air&bus connection fully operated by the airline. Although this resulted in fewer informants for the case, it provided valuable insights into what might have been specific for air&rail and which is more generalizable. Future research could explore a larger number of air&bus connections to build on these findings by examining services such as those offered by American Airlines on the U.S. East Coast.

The absence of direct input from bus operators also limits the study. Although the airline operated the bus leg in this case, including bus operators in future research could provide a more comprehensive understanding of operational and coordination challenges in multimodal transport.

Although additional connections between support processes and passenger experience factors may be conceivable, Figure 4 reflects only those relationships that emerged directly from the empirical data, specifically in response to the research question: *"What influences the effective delivery of these passenger experience factors to travelers in Europe?"* This study has therefore been deliberately limited to addressing this question. Future research could explore whether support processes also influence other factors or aspects beyond those identified in this study.

Furthermore, the concept of baseline modality emerged from the data, as informants explicitly mentioned it. However, this interpretation comes from practitioners' perspectives rather than those of passengers. Future research could explore whether baseline modality resonates with travelers, influences their expectations, or exists solely among practitioners. It would also be valuable to explore whether the concept of baseline modality applies to other service contexts, such as MaaS. The dynamics of multimodal services may vary depending on which modality is dominant, or whether a more balanced distribution of influence exists.

Additionally, collaboration emerged as a recurring theme and is critical for the delivery of multimodal air transport. Future research could delve deeper into how collaboration can be improved in practice, drawing from real-world examples and case studies.

More general, this study shows that practitioners, as creators of multimodal travel services, shape the passenger experience primarily based on organizational rationale rather than grounded in passenger-driven insights. While they demonstrate an understanding of passenger needs through identified PEFs their priorities are often influenced by operational and institutional considerations. Future studies that actively involve passengers – such as through co-creation workshops or experimental interventions – could offer a complementary perspective and help bridge the gap between practitioners' beliefs about what passengers value and what passengers experience. Additionally, further research could explore how passenger needs can be the guiding force in the service design and delivery process of multimodal air journeys.

6. CONCLUSION

Based on interviews with multimodal air transport practitioners, this study identifies five key PEFs for passenger-oriented multimodal air journeys: 1) integrated booking, 2) whole journey guidance, 3) transfer time and ease, 4) baggage management, and 5) disruption management.

Our findings reveal that delivering these PEFs requires more than just infrastructure and service integration across travel modes. A range of support processes within and between organizations must also align, such as IT, scheduling, operations, commercial, (inter)organizational, and strategy. In addition, external conditions – market dynamics and regulatory frameworks – play a pivotal role in either enabling or constraining these efforts.

We discovered that these underlying support processes converge in delivery mechanisms that influence the delivery of PEFs for multimodal air travel. By surfacing the interplay between PEFs, support processes, and external conditions, this study contributes to the literature on multimodal transport and the emerging discourse on passenger experiences. The findings provide valuable insights for future research to enhance the understanding of how support processes and external conditions manifest in real-world projects and explore potential solutions to effectively advance passenger-oriented multimodal air journeys.

In conclusion, while airlines often take the lead in shaping the multimodal experience, progress remains constrained by fragmented responsibilities, misaligned incentives among operators, and market competition. Delivering truly passenger-oriented multimodal air journeys requires not only effective cross-system collaboration but also a regulatory framework that creates the right conditions for integration and sustainability. Policymakers

should ensure that governance structures and incentives encourage cooperation across transport modes. Equally, operators must design and manage multimodal air transport with the passenger in mind, prioritizing seamlessness over the protection of individual systems or market positions.

Data availability

Due to the data collected including personal elements and judgments that can be traced back to the researchers and practitioners to whom the transcripts belong, this study treats the data as confidential. However, the data are available from the corresponding author upon reasonable request.

Declaration of generative AI in scientific writing

During the preparation of this work the first author used EditGPT for readability and grammar checks. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

References

Abugeddida, R., Donnellan, P., & Fallon, E. (n.d.). Analyzing.

Aleta, A., Meloni, S., & Moreno, Y. (2017). A Multilayer perspective for the analysis of urban transportation systems. Scientific Reports, 7(1), 44359. https://doi.org/10.1038/srep44359

Allen, J., Bellizzi, M. G., Eboli, L., Forciniti, C., & Mazzulla, G. (2020). Latent factors on the assessment of service quality in an Italian peripheral airport. Transportation Research Procedia, 47, 91–98. https://doi.org/10.1016/j.trpro.2020.03.083

Antwi, C. O., Fan, C., Ihnatushchenko, N., Aboagye, M. O., & Xu, H. (2020). Does the nature of airport terminal service activities matter? Processing and non-processing service quality, passenger affective image and satisfaction. Journal of Air Transport Management, 89, 101869. https://doi.org/10.1016/j.jairtraman.2020.101869

Babić, D., Colovic, A., Dožić, S., Kalić, M., Simić, T. K., Kukić, K., Ottomanelli, M., & Pilone, S. G. (2024). How to build a more sustainable passenger air transport system: Multimodal experience. Transportation Engineering, 16, 100245. https://doi.org/10.1016/j.treng.2024.100245

Babić, D., Kalić, M., Janić, M., Dožić, S., & Kukić, K. (2022). Integrated Door-to-Door Transport Services for Air Passengers: From Intermodality to Multimodality. Sustainability, 14(11), 6503. https://doi.org/10.3390/su14116503

Bairras, P., & Ardaiz, I. A. (2025). The slow and difficult implementation of high speed rail interoperability in Europe: The case of the Atlantic Corridor. Transportation Research Procedia, 82, 2546–2558. https://doi.org/10.1016/j.trpro.2024.12.204

Baumeister, S. (2019). Replacing short-haul flights with land-based transportation modes to reduce greenhouse gas emissions: The case of Finland. Journal of Cleaner Production, 225, 262–269. https://doi.org/10.1016/j.jclepro.2019.03.329

Bell, D. (2019). Intermodal Mobility Hubs and User Needs. Social Sciences, 8(2), 65. https://doi.org/10.3390/socsci8020065

Berveling, J., Zijlstra, T., Knoope, M., & Huibregtse, O. (2020). Op de Groene Tour. Kennisinstituut voor Mobiliteitsbeleid.

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008). Service Blueprinting: A Practical Technique for Service Innovation. California Management Review, 50(3), 66–94. https://doi.

org/10.2307/41166446

Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology, Vol 2: Research designs: Quantitative, qualitative, neuropsychological, and biological. (pp. 57–71). American Psychological Association. https://doi.org/10.1037/13620-004

Camacho, T., Foth, M., Rakotonirainy, A., Rittenbruch, M., & Bunker, J. (2016). The role of passenger-centric innovation in the future of public transport. Public Transport, 8(3), 453–475. https://doi.org/10.1007/s12469-016-0148-5

Canale, A., Tesoriere, G., & Campisi, T. (2019). The MAAS development as a mobility solution based on the individual needs of transport users. 160005. https://doi.org/10.1063/1.5138073

Cascajo, R., Lopez, E., Herrero, F., & Monzon, A. (2019). User perception of transfers in multimodal urban trips: A qualitative study. International Journal of Sustainable Transportation, 13(6), 393–406. https://doi.org/10.1080/15568318.2018.1476632

Chakrabarti, A. (Ed.). (2019). Research into Design for a Connected World: Proceedings of ICoRD 2019 Volume 2 (Vol. 135). Springer Singapore. https://doi.org/10.1007/978-981-13-5977-4

Chauhan, V., Gupta, A., & Parida, M. (2021). Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction of public transport. Transport Policy, 102, 47–60. https://doi.org/10.1016/j.tranpol.2021.01.004

Chiambaretto, P., & Decker, C. (2012). Air–rail intermodal agreements: Balancing the competition and environmental effects. Journal of Air Transport Management, 23, 36–40. https://doi.org/10.1016/j.jairtraman.2012.01.012

Docherty, I., Marsden, G., & Anable, J. (2018). The governance of smart mobility. Transportation Research Part A: Policy and Practice, 115, 114–125. https://doi.org/10.1016/j.tra.2017.09.012

Doomernik, J. E. (2015). Performance and Efficiency of High-speed Rail Systems. Transportation Research Procedia, 8, 136–144. https://doi.org/10.1016/j.trpro.2015.06.049

Döringer, S. (2021). 'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge. International Journal of Social Research Methodology, 24(3), 265–278. https://doi.org/10.1080/13645579.2020.1766777

Durand, A., & Romijn, G. (2023). Substitutiemogelijkheden van luchtvaart naar spoor in 2030 en 2040. Kennisinstituut voor Mobiliteitsbeleid.

Eboli, L., & Mazzulla, G. (2015). Relationships between rail passengers' satisfaction and service quality: A framework for identifying key service factors. Public Transport, 7(2), 185–201. https://doi.org/10.1007/s12469-014-0096-x

Eisenhardt, K. M. (1989). Building Theories from case Study Research. Academic Management Review, 14, 532–550.

Eurocities. (2024). Policy statement on prioritising fast and high-quality passenger train connection in Europe. https://eurocities.eu/wp-content/uploads/2024/10/FINAL-Policy-Statement-on-Prioritising-fast-and-high-quality-passenger-train-connections-in-Europe.pdf

European Commission. (2011). Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system (No. 144). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144

European Commission. (2021). Sustainable & Smart Mobility Strategy—Putting European Stransport on track for the future.

European Environment Agency. (2021). Transport and environment report 2020: Train or plane? Publications Office. https://data.europa.eu/doi/10.2800/43379

European Parliament and of the Council. (2024). Passenger rights in the context of multimodal

journeys. https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/767200/EPRS_BRI(2024)767200_EN.pdf

European Union Agency for Railways. (2024). Rail environmental report. Publications Office. https://doi.org/10.2821/243881

Finger, M., Montero, J., & Serafimova, T. (2019). Towards EU-Wide Multimodal Ticketing and Payment Systems.

Geng, Y., Yu, J., Lin, B., Wang, Z., & Huang, Y. (2017). Impact of individual IEQ factors on passengers' overall satisfaction in Chinese airport terminals. Building and Environment, 112, 241–249. https://doi.org/10.1016/j.buildenv.2016.11.040

Geurs, K. T., La Paix, L., & Van Weperen, S. (2016). A multi-modal network approach to model public transport accessibility impacts of bicycle-train integration policies. European Transport Research Review, 8(4), 25. https://doi.org/10.1007/s12544-016-0212-x

Givoni, M., & Banister, D. (2006). Airline and railway integration. Transport Policy, 13(5), 386–397. https://doi.org/10.1016/j.tranpol.2006.02.001

Guidon, S., Wicki, M., Bernauer, T., & Axhausen, K. (2020). Transportation service bundling – For whose benefit? Consumer valuation of pure bundling in the passenger transportation market. Transportation Research Part A: Policy and Practice, 131, 91–106. https://doi.org/10.1016/j.tra.2019.09.023

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Social Science & Medicine, 292, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hernandez Bueno, A. V. (2021). Becoming a passenger: Exploring the situational passenger experience and airport design in the Copenhagen Airport. Mobilities, 16(3), 440–459. https://doi.org/10.1080/17450101.2020.1864114

Hernandez, S., & Monzon, A. (2016). Key factors for defining an efficient urban transport interchange: Users' perceptions. Cities, 50, 158–167. https://doi.org/10.1016/j.cities.2015.09.009

Hickman, R., Chen, C.-L., Chow, A., & Saxena, S. (2015). Improving interchanges in China: The experiential phenomenon. Journal of Transport Geography, 42, 175–186. https://doi.org/10.1016/j.jtrangeo.2014.12.004

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transportation Research Part D: Transport and Environment, 16(2), 137–149. https://doi.org/10.1016/j.trd.2010.10.002

Jiang, F., Wang, L., & Huang, S. (2022). Analysis of the Transfer Time and Influencing Factors of Air-Rail Integration Passengers: A case Study of Shijiazhuang Zhengding International Airport. Sustainability, 14(23), 16193. https://doi.org/10.3390/su142316193

Kivela, M., Arenas, A., Barthelemy, M., Gleeson, J. P., Moreno, Y., & Porter, M. A. (2014). Multilayer networks. Journal of Complex Networks, 2(3), 203–271. https://doi.org/10.1093/comnet/cnu016

Li, X., Jiang, C., Wang, K., & Ma, J. (2018). Determinants of partnership levels in air-rail cooperation. Journal of Air Transport Management, 71, 88–96. https://doi.org/10.1016/j.jairtraman.2018.06.002

Lubbe, B., Douglas, A., & Zambellis, J. (2011). An application of the airport service quality model in South Africa. Journal of Air Transport Management, 17(4), 224–227. https://doi.org/10.1016/j.jairtraman.2010.08.001

Mager, B. (2009). Service Design as an Emerging Field. Designing Services with Innovative Methods, 1.

Magnani, G., & Gioia, D. (2023). Using the Gioia Methodology in international business and entrepreneurship research. International Business Review, 32(2), 102097. https://doi.org/10.1016/j.ibusrev.2022.102097

Malterud, K. (2001a). Qualitative research: Standards, challenges, and guidelines. The Lancet,

358(9280), 483–488. https://doi.org/10.1016/S0140-6736(01)05627-6

Malterud, K. (2001b). The art and science of clinical knowledge: Evidence beyond measures and numbers. The Lancet, 358(9279), 397–400. https://doi.org/10.1016/S0140-6736(01)05548-9

Marquez, V. (2019). Landside| Airside: Why Airports Are the Way They Are. Springer.

Meroni, A. (with Sangiorgi, D.). (2016). Design for services. Routledge.

Miles, M., Huberman, M., & Saldaña, J. (2014). Qualitative Data Analysis: A Methods Sourcebook (3rd ed.). Sage Publications.

Monzón, A., Hernández, S., & Di Ciommo, F. (2016). Efficient Urban Interchanges: The City-HUB Model. Transportation Research Procedia, 14, 1124–1133. https://doi.org/10.1016/j.trpro.2016.05.183

Nam, S., Ha, C., & Lee, H. C. (2018). Redesigning In-Flight Service with Service Blueprint Based on Text Analysis. Sustainability, 10(12), 4492. https://doi.org/10.3390/su10124492

Nash, C. (2010). European rail reform and passenger services – the next steps. Research in Transportation Economics, 29(1), 204–211. https://doi.org/10.1016/j.retrec.2010.07.025

Nechyporuk, M., Pavlikov, V., & Kritskiy, D. (Eds.). (2022). Integrated Computer Technologies in Mechanical Engineering - 2021: Synergetic Engineering (Vol. 367). Springer International Publishing. https://doi.org/10.1007/978-3-030-94259-5

Nielsen, O. A., Eltved, M., Anderson, M. K., & Prato, C. G. (2021). Relevance of detailed transfer attributes in large-scale multimodal route choice models for metropolitan public transport passengers. Transportation Research Part A: Policy and Practice, 147, 76–92. https://doi.org/10.1016/j.tra.2021.02.010

Papastathopoulou, P., & Hultink, E. J. (2012). New Service Development: An Analysis of 27 Years of Research *. Journal of Product Innovation Management, 29(5), 705–714. https://doi.org/10.1111/j.1540-5885.2012.00944.x

Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (Fourth edition). SAGE.

Regulation (EU) 2024/1679 on Union Guidelines for the Development of the Trans-European Transport Network, OJ L 2024/1679, 19.6.2024 (2024). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401679

RLI. (2020). Verzet de wissel: Naar beter internationaal reizigersvervoer per trein. Raad voor de Leefomgeving en Infrastructuur (Rli).

Rodrigue, J.-P. (2024). The Geography of Transport Systems (6th ed.). Routledge.

Román, C., & Martín, J. C. (2014). Integration of HSR and air transport: Understanding passengers' preferences. Transportation Research Part E: Logistics and Transportation Review, 71, 129–141. https://doi.org/10.1016/j.tre.2014.09.001

Rosenbaum, M. S., Otalora, M. L., & Ramírez, G. C. (2017). How to create a realistic customer journey map. Business Horizons, 60(1), 143–150. https://doi.org/10.1016/j.bushor.2016.09.010

Schmitt, D., & Gollnick, V. (2016). Air Transport System. Springer Vienna. https://doi.org/10.1007/978-3-7091-1880-1

Shostack, G. L. (1984). Designing Services That Deliver. Harvard Business Review, 84115.

Silverman, D. (2009). Doing qualitative research (3rd ed.). SAGE Publications.

Song, F., Hess, S., & Dekker, T. (2018). Accounting for the impact of variety-seeking: Theory and application to HSR-air intermodality in China. Journal of Air Transport Management, 69, 99–111. https://doi.org/10.1016/j.jairtraman.2018.02.008

Toering, A., De Bruijne, M., & Veeneman, W. (2025). Exploring governance challenges of sustainable infrastructure development on the nexus between energy and mobility. Npj Sustainable Mobility and Transport, 2(1), 1. https://doi.org/10.1038/s44333-024-00018-0

5

Toet, A., Van Kuijk, J., Boersma, K., & Santema, S. (2023, October 9). Themes for an airport hub in the transition towards a multimodal transport hub – an embedded researcher's perspective. IASDR 2023: Life-Changing Design, Milan, Italy. https://doi.org/10.21606/iasdr.2023.272

Toet, A., van Kuijk, J., & Santema, S. (2022). Transforming airport hubs into future-proof Multimodal Transport Hubs. Relating Systems Thinking and Design (RSD11) Symposium: Possibilities and practices of systemic design, Brighton, UK.

UIC. (2024). High-Speed Rail Atlas. International Union of Railways (UIC).

Vassallo, J. M., & Fagan, M. (2007). Nature or nurture: Why do railroads carry greater freight share in the United States than in Europe? Transportation, 34(2), 177–193. https://doi.org/10.1007/s11116-006-9103-7

Veeneman, W. (2023). Governance, COVID responses, and lessons on decision-making in uncertainty. In Transportation Amid Pandemics (pp. 441–450). Elsevier. https://doi.org/10.1016/B978-0-323-99770-6.00019-3

Vuchic, V. R. (2007). Urban transit systems and technology. John Wiley & Sons.

Wan, Y., Ha, H.-K., Yoshida, Y., & Zhang, A. (2016). Airlines' reaction to high-speed rail entries: Empirical study of the Northeast Asian market. Transportation Research Part A: Policy and Practice, 94, 532–557. https://doi.org/10.1016/j.tra.2016.10.014

Wang, B., Loo, B., & Li, L. (2020). Situating High-Speed Railway Stations within Local Urban Contexts: Passenger Satisfaction with Intermodal Integration at the Hong Kong HSR Station. Built Environment, 46(3), 362–378. https://doi.org/10.2148/benv.46.3.362

Wang, B., Shen, G., Wang, X., Dong, Y., & Li, Z. (2024). Hub-and-Spoke Network Optimization with Flow Delay Cost: The case of Goods Delivery on Urban Logistics Networks in Eastern China. Mathematics, 12(10), 1496. https://doi.org/10.3390/math12101496

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. Transportation Research Part A: Policy and Practice, 45(8), 839–848. https://doi.org/10.1016/j.tra.2011.06.010

Wattanacharoensil, W., Schuckert, M., & Graham, A. (2016). An Airport Experience Framework from a Tourism Perspective. Transport Reviews, 36(3), 318–340. https://doi.org/10.1080/01441647.2015.1077287

Yang, H., & Zhang, A. (2012). Effects of high-speed rail and air transport competition on prices, profits and welfare. Transportation Research Part B: Methodological, 46(10), 1322–1333. https://doi.org/10.1016/j.trb.2012.09.001

Yin, R. (2003). case study research—Design and methods (3rd ed.). SAGE Publications.

Yin, R. (2009). case Study Research: Design and Methods (Fourth Edition). Sage Publications.

Zhou, T., Tan, R., & Sedlin, T. (2018). Planning Modes for Major Transportation Infrastructure Projects (MTIPs): Comparing China and Germany. Sustainability, 10(10), 3401. https://doi.org/10.3390/su10103401

5.3   REFLECTION

This second AR cycle offered insights into what constitutes a passenger-oriented multimodal air journey and what is required to deliver such journeys across airport hubs. This section draws on content *(What did I learn?)*, process *(How did I learn it?)*, and premise reflections *(What assumptions influenced my learning?)* (Coghlan, 2019) to highlight learnings for the overarching AR cycle.

5.3.1 CONTENT REFLECTION

Beneath the actions of practitioners lies their underlying motivation. In this chapter, I aimed to understand the desires and actions of practitioners focused on enhancing the multimodal air passenger experience. This exploration uncovered new factors influencing the passenger experience, incorporating insights from experienced practitioners about their perceptions of a quality experience.

An important insight in this chapter is that, according to informants, part of the quality of a multimodal air journey is determined before departure. The integrated booking systems, identified by operators as one of the five key requirements for a good passenger experience, shifted my perspective on the journey. I understood that the journey experience starts long before departure. The study presented in this chapter highlighted more additional factors, such as disruption management and baggage handling, as independent challenges. Rather than solely examining infrastructure and services, as I did in the previous AR cycle (Chapter 4), I learned that passenger-centered design also includes underlying mechanisms such as IT systems, commercial incentives, and collaboration within and between organizations. The insight that collaboration can be fragmented even within modalities – for instance, between rail operators that operate across borders – prompted me to investigate co-creation practices among key multimodal stakeholders in the follow-up study (presented in Chapter 6).

To me, a key discovery in the study described in the current chapter was the concept of the baseline modality, which refers to the modality that predominates in the multimodal offering (often the air segment) and implicitly establishes the standard for the entire journey. This concept reshaped my understanding of multimodality; I no longer perceived it as a neutral collaboration among equals but as a system in which passenger expectations are continually (re)negotiated. Exploring whether the concept of baseline modality applies to other service contexts, such as MaaS, would be valuable for understanding MaaS and SET theory.

Although the study focused on the delivery of multimodal air travel, three out of the four cases examined involved air&rail travel. Case 4 was an outlier (Miles et al., 2014), as it concerned an air&bus connection. By including this outlier case, I gained insights into the differences between business models for multimodal air travel. For instance, integrated booking was mentioned less frequently in the air&bus case, as it was fully controlled by the airline. The significance of transfers also appeared to be lower compared to the air&rail cases. Furthermore, it was noteworthy that disruption management had little to no impact in the air&bus case at the strategic, inter-organizational, and regulatory levels, which can be linked to the underlying business model. Whole journey guidance seemed largely consistent across the four cases, leading me to conclude that it is not necessarily dependent on the mode of transport but is inherently important in any multimodal air journey. Additionally, baggage was a smaller issue in the air&bus case and showed no connection to infrastructure, whereas this link was prominent in the air&rail cases. Finally, the air&bus outlier case demonstrated that infrastructure appeared to play a less important role compared to the air&rail case.

While sustainability was central to the rationale for the study described in this chapter, the findings (Section 5.2) show that informants addressed it less explicitly when discussing multimodality. In one instance, sustainability was mentioned in relation to competitive aviation mechanisms, revealing conflicts between financial incentives and sustainability goals. This highlighted the need for clear laws and regulations and emphasized that no single party can drive this transition independently, reinforcing the importance of cross-system collaboration discussed in Chapter 3. This discovery underscored the need to clarify the goals being pursued, by whom, and for what reasons in follow-up research (Chapter 6).

Furthermore, while my inquiry in this chapter centered on the effective delivery of multimodal air travel, the discussion largely revolved around obstacles. Many informants expressed concerns about limitations in infrastructure, regulations, and internal processes, which neglected the absorption of external knowledge or exemplary practices from other modalities. This challenge led me to create space for design perspectives in the follow-up study by leveraging these frictions as a foundation for change and focusing on establishing a successful system.

Contribution to the thesis research questions

This chapter addresses the first research question: *What are the properties of a passenger-oriented multimodal air journey?* It also examines the second question: *What influences the effective delivery of a passenger-oriented*

multimodal air journey?

In response to the first question, this chapter identifies five factors that practitioners believe contribute to a seamless passenger-oriented multimodal air journey: 1) integrated booking, 2) whole journey guidance, 3) transfer time and ease, 4) baggage management, and 5) disruption management. These factors build upon those identified in research cycle 1 (Chapter 4).

Regarding the second question, I found that delivering such a journey necessitates the alignment of support processes (IT, infrastructure, scheduling, operations, commercial activities, inter-organizational collaboration, and strategic efforts) with external conditions (market dynamics and regulations). Various mechanisms operate between these processes and external conditions, influencing the delivery of a passenger-oriented multimodal air journey. To utilize these mechanisms effectively, it is essential to establish new regulatory frameworks, foster strong cross-system collaboration, and prioritize the passenger during the development and delivery of multimodal air journeys.

5.3.2 PROCESS REFLECTION

In this phase of the research, I employed a qualitative, second-person approach, which facilitated dialogical interactions with transport hubs and operators. Through in-depth conversations, I probed beyond surface-level answers to explore the reasoning behind them.

What struck me was how often my *"simple"* questions – such as what makes a good passenger experience – unlocked deeply held beliefs that shaped everyday decisions. For instance, the emphasis on retrieving passenger information during disruptions was not just a logistical concern; it was rooted in a broader belief about control and predictability in operations. At the same time, the dialogical nature of these interviews means that responses were often shaped in the moment (Silverman, 2009). The presence of the me as a conversational partner inevitably influenced what was shared and how (Patton, 2015).

The interviews served not only as a means of data collection but also as moments of reflection for informants. In some cases, they sparked follow-up conversations, leading me to realize that dialogue can function as a subtle form of intervention. This approach aligns with AR, where conversation is assumed to drive change (Coghlan, 2019). However, I adopted a second-person approach with transport hubs and operators, creating more distance from the airport where I was embedded. While insights and results were discussed with my research team – one member of which was affiliated with

the airport – and aside from informal conversations with airport employees, the learning points and reflections primarily remained within the research team at this stage (although they were later used to shape and enrich the subsequent AR study). Even though engaging in conversation prompts critical thinking and can be viewed as an intervention according to Coghlan (2019), the results in that regard were less visible.

Working with the service blueprint as a tool within the SET lens, it further enhanced my learning. It was valuable for visualizing and translating operational mechanisms to a higher, more conceptual level. When combined with the qualitative approach, the blueprint revealed how certain support processes and external conditions were intertwined. Together, these tools enabled me to understand not only what was happening but also why it mattered in the broader context of multimodal air integration by mapping the underlying support processes.

5.3.3   PREMISE REFLECTION

Several assumptions influenced my approach in this phase of the research and shaped my learning outcomes. One key assumption was that meaningful insights would primarily emerge from individuals directly responsible for multimodality within their organizations. Consequently, I employed a purposeful sampling strategy aimed at engaging those positioned to shape multimodal innovation. While this choice yielded rich and relevant data, it also resulted in delays, with some instances taking several months – up to eight in one case – to access the right individuals. In some organizations, responsibility for multimodality was clearly defined, while in others, it was more diffuse or evolving. In retrospect, I recognize that a more flexible sampling strategy, incorporating a broader range of perspectives within each organization, might have provided valuable insights and potentially expedited the access process.

Another assumption was that the selected cases – four frontrunner organizations in multimodal air travel – would provide the most progressive and relevant examples. While this focus was intentional, it raises the question of whether including other stakeholders, such as regulators or slower adopters, might have offered a contrasting perspective on the field. As with any research, the choices made inevitably shape the outcomes. It is important to acknowledge that this particular group of informants influenced my learning: the insights I gained from them were valuable but also highlight the need to explore the perspectives of other stakeholders in future research (Chapter 6).

During the interviews, it became evident that each operator primarily reasoned within the context of their own organization. While some participants recognized the limitations and needs of other systems, most perspectives remained constrained by institutional interests, and not by the needs of the passengers. I recognized that participants who appeared more forward-thinking often reported having not only an organizational mandate but also a strong personal motivation. This personal drive may have influenced the tone and content of their reflections, possibly leading them to present a more optimistic view than others. It also underscored that personal commitment could empower individuals to think beyond their organizational constraints.

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Where it connects

It begins with a question,
born in moments of reflection.
What drives multimodality today?
What contexts and purposes lead our way?

By stepping into their stride,
we leave assumptions at the side.
Each journey blurs the lines we drew,
and moving through, we create them too.

Beneath the doing lies the why,
designed by those who stand nearby.
Through open words and searching eyes,
layers fall and systems rise.

We create what none could do alone,
from viewpoints far beyond their own.
By dropping all that thought protects,
we find new meaning where it connects.

CHAPTER 6. RESEARCH CYCLE 3

6.1 INTRODUCTION

This chapter presents the final AR study, which combines elements of second-person and third-person practice in AR (Coghlan, 2019; Reason & Bradbury, 2008; Reason & Torbert, 2001) through interviews and co-creation sessions.

The previous AR cycles focused on understanding what constitutes a good multimodal passenger experience and explored the underlying processes and mechanisms that influence its delivery. These insights were drawn from autoethnographic field experiences and interviews with practitioners. The study presented in this chapter addresses gaps identified in these earlier studies, including the exploration of collaborations between multimodal stakeholders and the application of design and co-creation methods (Figure 14).

The primary aim of the study presented in this chapter was to investigate how stakeholders experience and enact air&rail integration in a real-world setting, using the SET lens. By utilizing co-creation sessions as interventions, the research sought not only to study integration processes but also to actively stimulate change at multiple levels. AR serves as a *"live case study"* (Coughlan & Coghlan, 2002), and the interventions were designed to trigger action both through their content and by being interventions themselves.

To extend knowledge beyond the involved group of practitioners, and in line with AR traditions, this study incorporates third-person practice by engaging individuals beyond direct second-person interactions. This was pursued through co-creation activities that focused on harnessing and absorbing (new) knowledge (Chesbrough, 2003, 2017, 2020) within organizations and by aiming to publish findings.
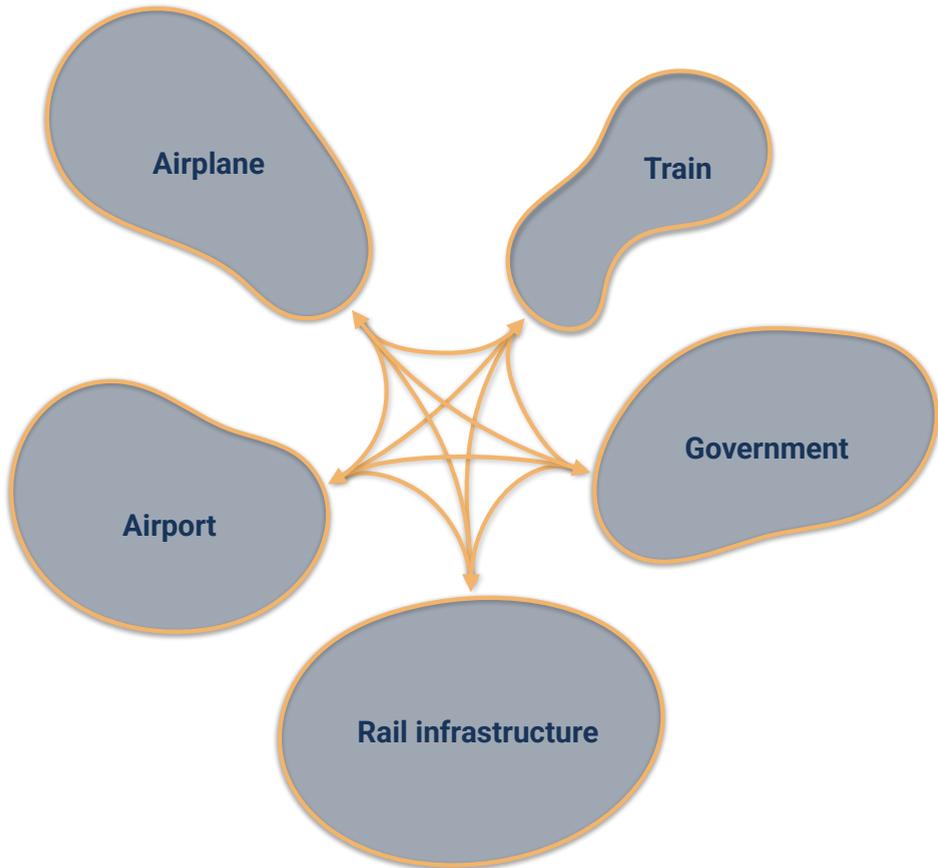
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Figure 14. Studying co-creation practices with multimodal stakeholders

6.2 TENSIONS IN AIR AND RAIL INTEGRATION BASED ON A EUROPEAN LONGITUDINAL CASE STUDY WITH STAKEHOLDERS

ABSTRACT

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.

Keywords: multimodal, air&rail; service ecosystems; travel; integration; co-creation; Action Research

1. INTRODUCTION

Passengers rely on multiple transport systems to reach their destinations, particularly for longer distances[1]. 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 2030[15]. 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 Atlas[16], and plans to optimize the HSR network are underway[14], the service quality of the air&rail product in Europe remains low[12]. 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 travel[19].

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 issues[20].

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 practice[11].

The study in this paper aims to address that gap by investigating how air&rail integration is experienced and enacted by stakeholders in 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 users[27]. 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) methodology[31] 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 AR[32], 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.

2. LITERATURE REVIEW

2.1. Multimodal air&rail transport

Air&rail travel can be viewed as an application of multimodal transport. Definitions of multimodal passenger transport differ in literature and are sometimes conflated with intermodal transport[2,13,33]. In this study, we adopt the definition by Babić et al.[2] and Rodrigue[3], 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 Rodrigue[3], 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 practice[2].

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 connections[12]. 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 forms[13], 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.

2.2. Characteristics of Air and Rail Systems

Air transport enables direct connections between airports without being affected by natural barriers such as oceans, mountains or distance[1]. However, air transport system's 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 destination[1].

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 network[38]. Airlines collaborate in this model through code-sharing[10]. As the hub-and-spoke model requires a transfer, efficient transfer times are necessary to facilitate efficient journeys for travelers[39]. 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 concessions[44]. The infrastructure is publicly owned, and an infrastructure manager (often a governmental agency) establishes the timetable based on operators' preferences[44]. Long-distance (international) rail governance is more fragmented, with different companies managing cross-border routes and national borders acting as regulatory and operational barriers[41]. Tracks in Europe are managed by various national or regional regulatory bodies overseeing safety requirements and determining (partly) railway timetables[44]. This complexity makes cross-border high-speed travel more challenging than national HSR routes.

In aviation an independent slot coordinator assigns and monitors airport access[45], while in European rail, timetabling is a nationally negotiated process shaped by political priorities and legacy arrangements[44]. These governance differences lead to planning friction, scheduling incompatibilities, and unclear ownership over shared operations, posing barriers to air&rail integration[22].

Air&rail integration can improve connectivity by linking airports to surrounding regions[20]. 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 networks[11]. 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 CO_2 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].

2.3. 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 procedures[37].

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 collaboration[12].

Moreover, cross-border integration efforts often suffer from fragmented interorganizational collaboration, with each actor seeking to maintain control over its own domain[52], 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 market[44], as highlighted by Regulation (EU) 2016/2338, which mandates the liberalization of domestic rail markets.

2.4. 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 experiences[37]. 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 Stauffacher[22] 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 themes[22].

However, these authors also describe that co-creation for multimodal integration is challenged by actors' limited resources and time[22], 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.

3. 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 system[31], 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.

3.1. 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 cycle[62]. The case was demarcated by the following properties[24]:

Context:

- Air&rail integration at a major European airport hub.
- The airport's proximity to the country's main borders 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 sampling[24] 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.

3.2. 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 practitioners[24] regarding air&rail travel. To ensure confidentiality, input from these practitioners and organizations, including observations and quotes, is kept anonymous. Whenever possible, the organization or sector from which a quote originates is disclosed without revealing too much about a person or organization.

3.3. Research set-up

The AR cycle consists of four main phases: constructing, planning action, taking action, and evaluating action[63] (Figure 1). This entire study, which encompasses multiple co-creation sessions, is considered as one AR cycle, with intermediate adjustments between sessions.
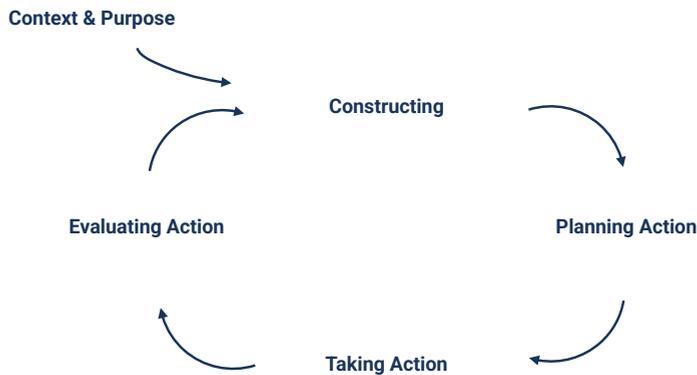

Figure 1. AR cycle phases[63]. The AR cycle starts with the context & purpose phase, followed by constructing the research cycle, planning action, taking action and evaluating action. This evaluation can lead to the start of a new cycle, beginning again with constructing the research cycle.

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 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 cycle[32]. 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 emphasize 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 practitioners[63]. Based on these intermediate evaluations, adjustments were made to subsequent sessions as needed[63] (Figure 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.
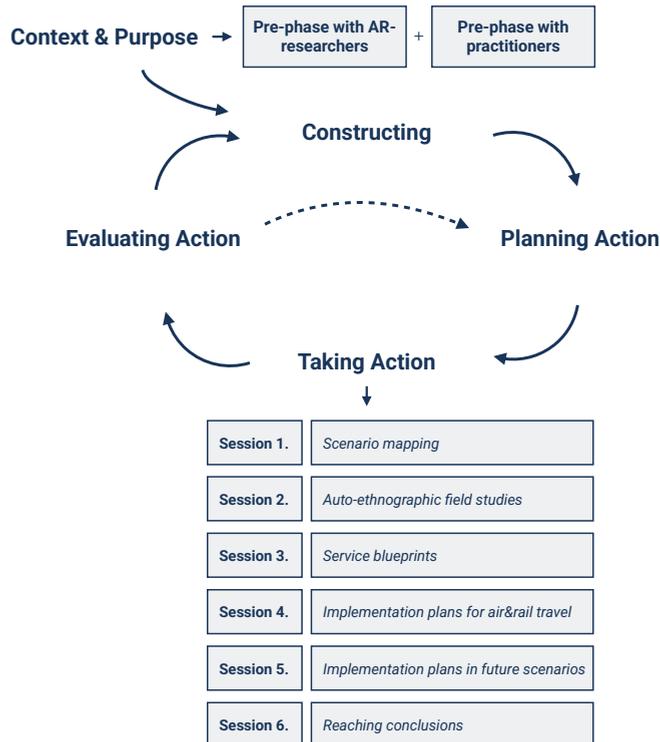
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Figure 2. The execution of the AR cycle in this project. *The context & purpose phase included two parts: one with AR researchers and one involving practitioners. This was followed by the execution of the AR cycle, where the taking action phase consisted 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.*

3.4. Data generation

Data was generated over 16 months throughout the AR cycle, supporting the research's process-oriented perspective, which required extended data collection[72]. During the constructing 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[37,76,7], auto-ethnographic field studies[73,74], service blueprinting[75], and the development of implementation plans (Figure 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 assumptions[31].

3.5. 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's[76] 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.ti[24], 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 codebook[24]. 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 separately[63] and that a *"thick description"* of the phenomenon is essential for understanding the context and establishing research credibility, dependability and transferability[78,79]. The report was reviewed by all authors to ensure a coherent and well-supported thematic synthesis.

Table 1. *The emerging 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, 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, 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, strategy	E.g., baggage issues in air-rail travel, many steps in air travel process, O&D travel time different for transfers travelers, 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, aim of sessions, external influence	E.g., subject-matter experts at the table, creating a shared understanding, considering current political context

4. 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.

4.1. 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.

4.2. 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 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 synergetic advantages.

4.3. 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.

4.4. 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 incurrent 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 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)

4.5. 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 seem 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 of 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.

4.6. 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 hours [of travel time] is correct for point-to-point travel, but not for transfers. The maximum for transfers is 2.5 hours 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.

4.7. 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 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)

4.8. 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 those in their organizations. While practitioners may have had acquired new knowledge through the co-creation sessions, their organizations had not, and ultimately, it is the organizations which 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 was 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)

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.

4.9. 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.

4.10. 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, Figure 3 visually illustrates the relationships between the tensions discussed in this chapter. These connections were informed by inferred causal relationships[24] 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 description to the connections.
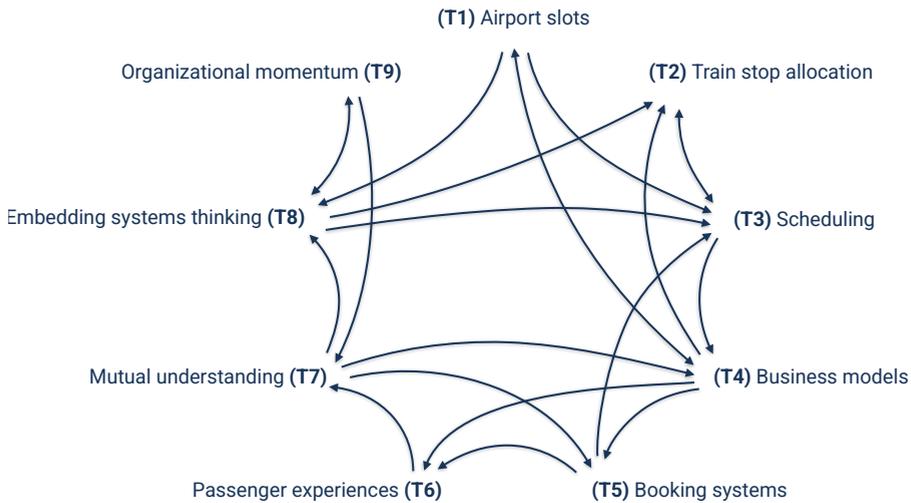
Figure 3. Interrelations between tensions. The figure shows the relations between the tensions identified in this study, highlighting their interdependence in the context of air & rail integration.

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.

5. 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.

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 commercial 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

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 framework[1], 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 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 Strategy[15] 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 Lusch[28] 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 Malshe[83] 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 providers[84], while the ORCHESTRA project[85] 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 entities[45], and this, along with capacity constraints, limits the potential for air&rail integration to reduce CO_2 emissions[41,50]. Tension 2 (train stop allocation) and Tension 3 (scheduling) highlighted similar issues, as rail networks are predetermined at the national governance level[44], 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 auctions[44].

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 research[5]. In the air sector, an example of a governing body is IATA, which makes decisions on topics where governments cannot reach consensus[43].

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 domains[52]. 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 sector[1] 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 relationships[12], further emphasizes 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 travel[2] (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[2,20]. 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 connectivity[20], 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 system[86], 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 factors[62]. 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 apply[24]. To help the assessment of the transferability of the results[24], a description of the co-creation sessions is provided in the Supplementary Information.

Moreover, the study was based on a purposively selected case[24] 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.

6. 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.

Competing Interest

Acknowledgements

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. assisted with the review and editing of the manuscript. All authors read and approved the final version.

Competing interests

The authors declare the following financial interests/personal relationships that may be considered potential competing interests: the first author, reports receiving financial support from the ClickNL fund (provided by the Dutch Ministry of Economic Affairs and Climate Policy and the Royal Schiphol Group) and the third author is employed by Royal Schiphol Group. The remaining authors declare no competing interests.

References

1. Schmitt, D. & Gollnick, V. Air Transport System. (Springer Vienna, Vienna, 2016). doi:10.1007/978-3-7091-1880-1.
2. Babić, D., Kalić, M., Janić, M., Dožić, S. & Kukić, K. Integrated Door-to-Door Transport Services for Air Passengers: From Intermodality to Multimodality. Sustainability 14, 6503 (2022).
3. Rodrigue, J.-P. The Geography of Transport Systems. (Routledge, 2024).
4. Bagamanova, M., Mujica Mota, M. & Di Vito, V. Exploring the Efficiency of Future Multimodal Networks: A Door-to-Door case in Europe. Sustainability 14, 13621 (2022).
5. Docherty, I., Marsden, G. & Anable, J. The governance of smart mobility. Transp. Res. Part Policy Pract. 115, 114–125 (2018).
6. Canale, A., Tesoriere, G. & Campisi, T. The MAAS development as a mobility solution based on the individual needs of transport users. in 160005 (Rhodes, Greece, 2019). doi:10.1063/1.5138073.
7. Guidon, S., Wicki, M., Bernauer, T. & Axhausen, K. Transportation service bundling – For whose benefit? Consumer valuation of pure bundling in the passenger transportation market. Transp. Res. Part Policy Pract. 131, 91–106 (2020).
8. Nikitas, A., Michalakopoulou, K., Njoya, E. T. & Karampatzakis, D. Artificial Intelligence, Transport and the Smart City: Definitions and Dimensions of a New Mobility Era. Sustainability 12, 2789 (2020).
9. Janic, M. Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. Transp. Res. Part Transp. Environ. 16, 137–149 (2011).
10. Jiang, C., D'Alfonso, T. & Wan, Y. Air-rail cooperation: Partnership level, market structure and welfare implications. Transp. Res. Part B Methodol. 104, 461–482 (2017).
11. Li, X., Jiang, C., Wang, K. & Ma, J. Determinants of partnership levels in air-rail cooperation. J. Air Transp. Manag. 71, 88–96 (2018).
12. Román, C. & Martín, J. C. Integration of HSR and air transport: Understanding passengers' preferences. Transp. Res. Part E Logist. Transp. Rev. 71, 129–141 (2014).
13. Chiambaretto, P. & Decker, C. Air–rail intermodal agreements: Balancing the competition

and environmental effects. J. Air Transp. Manag. 23, 36–40 (2012).

14. European Commission. Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144 (2011).

15. European Commission. Sustainable & Smart Mobility Strategy - Putting European Stransport on Track for the Future. (2021).

16. UIC. High-Speed Rail Atlas. (2024).

17. Veeneman, W. W., Van Kuijk, J. I. & Hiemstra-van Mastrigt, S. Dreaming of the Travelers' Experience in 2040: Exploring Governance Strategies and Their Consequences for Personal Mobility Systems. in Towards User-Centric Transport in Europe 2 (eds Müller, B. & Meyer, G.) 225–239 (Springer International Publishing, Cham, 2020). doi:10.1007/978-3-030-38028-1_16.

18. Finger, M., Montero, J. & Serafimova, T. Towards EU-Wide Multimodal Ticketing and Payment Systems. (2019).

19. European Commission. Multimodal Digital Mobility Service: Report. https://data.europa.eu/doi/10.2832/0079219 (2024).

20. Babić, D. et al. How to build a more sustainable passenger air transport system: multimodal experience. Transp. Eng. 16, 100245 (2024).

21. Rattanakijsuntorn, W., Suwannarat, B., Samittivate, N. & Nithikittiwat, C. Success Factors and Partnership Evaluation of Air–Rail Integration Development: A case of a High-Speed Rail Project Linking Three Airports in Thailand. Infrastructures 9, 115 (2024).

22. Stadler Benz, P. & Stauffacher, M. Co-creating multimodal transportation hubs in Switzerland: How to close the gap between actors across different scales, levels, and sectors. Multimodal Transp. 3, 100168 (2024).

23. Givoni, M. & Banister, D. Airline and railway integration. Transp. Policy 13, 386–397 (2006).

24. Miles, M., Huberman, M. & Saldaña, J. Qualitative Data Analysis: A Methods Sourcebook. (Sage Publications, 2014).

25. Patton, M. Q. Qualitative Research & Evaluation Methods: Integrating Theory and Practice. (SAGE, Los Angeles London New Delhi Singapore Washington DC, 2015).

26. Sklyar, A., Kowalkowski, C., Sörhammar, D. & Tronvoll, B. Resource integration through digitalisation: a service ecosystem perspective. J. Mark. Manag. 35, 974–991 (2019).

27. Vargo, S. L. & Lusch, R. F. Service-dominant logic: continuing the evolution. J. Acad. Mark. Sci. 36, 1–10 (2008).

28. Vargo, S. L. & Lusch, R. F. Institutions and axioms: an extension and update of service-dominant logic. J. Acad. Mark. Sci. 44, 5–23 (2016).

29. Ostrom, A. L., Parasuraman, A., Bowen, D. E., Patrício, L. & Voss, C. A. Service Research Priorities in a Rapidly Changing Context. J. Serv. Res. 18, 127–159 (2015).

30. McColl-Kennedy, J. R., Cheung, L. & Coote, L. V. Tensions and trade-offs in multi-actor service ecosystems. J. Bus. Res. 121, 655–666 (2020).

31. Coughlan, P. & Coghlan, D. Action research for operations management. Int. J. Oper. Prod. Manag. 22, 220–240 (2002).

32. Jones, P. Contexts of Co-creation: Designing with System Stakeholders. in Systemic Design (eds Jones, P. & Kijima, K.) vol. 8 3–52 (Springer Japan, Tokyo, 2018).

33. Reis, V., Fabian Meier, J., Pace, G. & Palacin, R. Rail and multi-modal transport. Res. Transp. Econ. 41, 17–30 (2013).

34. Huang, S. & Mu, D. Discussion on the Development Strategy of China's Multimodal Transport Stations. in Proceedings of the 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018) (Atlantis Press, Chengdu City, China, 2018). doi:10.2991/tlicsc-18.2018.40.

35. Chauhan, V., Gupta, A. & Parida, M. Demystifying service quality of Multimodal

Transportation Hub (MMTH) through measuring users' satisfaction of public transport. Transp. Policy 102, 47–60 (2021).

36. Toering, A., De Bruijne, M. & Veeneman, W. Exploring governance challenges of sustainable infrastructure development on the nexus between energy and mobility. Npj Sustain. Mobil. Transp. 2, 1 (2025).

37. Toet, A., van Kuijk, J. & Santema, S. Transforming airport hubs into future-proof Multimodal Transport Hubs. in (Systemic Design Symposium, Brighton, UK, 2022).

38. Wang, B., Shen, G., Wang, X., Dong, Y. & Li, Z. Hub-and-Spoke Network Optimization with Flow Delay Cost: The case of Goods Delivery on Urban Logistics Networks in Eastern China. Mathematics 12, 1496 (2024).

39. Zgodavova, Z., Rozenberg, R. & Szabo, S. Analysis of Point-to-Point versus Hub-and-Spoke airline networks. in 2018 XIII International Scientific Conference - New Trends in Aviation Development (NTAD) 158–163 (IEEE, Kosice, 2018). doi:10.1109/NTAD.2018.8551733.

40. Vassallo, J. M. & Fagan, M. Nature or nurture: why do railroads carry greater freight share in the United States than in Europe? Transportation 34, 177–193 (2007).

41. RLI. Verzet de wissel: naar beter internationaal reizigersvervoer per trein. (2020).

42. Bairras, P. & Ardaiz, I. A. The slow and difficult implementation of high speed rail interoperability in Europe: the case of the Atlantic Corridor. Transp. Res. Procedia 82, 2546–2558 (2025).

43. Eilstrup-Sangiovanni, M. Ordering global governance complexes: The evolution of the governance complex for international civil aviation. Rev. Int. Organ. 17, 293–322 (2022).

44. Broman, E. & Eliasson, J. Welfare effects of open access competition on railway markets. Transp. Res. Part Policy Pract. 129, 72–91 (2019).

45. Council Regulation on Common Rules for the Allocation of Slots at Community Airports. (1993).

46. Rothengatter, W. Competition between airlines and high-speed rail.

47. Wan, Y., Ha, H.-K., Yoshida, Y. & Zhang, A. Airlines' reaction to high-speed rail entries: Empirical study of the Northeast Asian market. Transp. Res. Part Policy Pract. 94, 532–557 (2016).

48. Yang, H. & Zhang, A. Effects of high-speed rail and air transport competition on prices, profits and welfare. Transp. Res. Part B Methodol. 46, 1322–1333 (2012).

49. Sun, X., Zhang, Y. & Wandelt, S. Air Transport versus High-Speed Rail: An Overview and Research Agenda. J. Adv. Transp. (2017).

50. Berveling, J., Zijlstra, T., Knoope, M. & Huibregtse, O. Op de Groene Tour. (2020).

51. Doomernik, J. E. Performance and Efficiency of High-speed Rail Systems. Transp. Res. Procedia 8, 136–144 (2015).

52. Toet, A., Van Kuijk, J., Boersma, K. & Santema, S. Themes for an airport hub in the transition towards a multimodal transport hub – an embedded researcher's perspective. in (Design Research Society, Milan, Italy, 2023). doi:10.21606/iasdr.2023.272.

53. Campos, J. & De Rus, G. Some stylized facts about high-speed rail: A review of HSR experiences around the world. Transp. Policy 16, 19–28 (2009).

54. Liu, Z. Planning and Policy Coordination in China's Infrastructure Development. (2005).

55. Veeneman, W. Governance, COVID responses, and lessons on decision-making in uncertainty. in Transportation Amid Pandemics 441–450 (Elsevier, 2023). doi:10.1016/B978-0-323-99770-6.00019-3.

56. Zhou, T., Tan, R. & Sedlin, T. Planning Modes for Major Transportation Infrastructure Projects (MTIPs): Comparing China and Germany. Sustainability 10, 3401 (2018).

57. Nash, C. European rail reform and passenger services – the next steps. Res. Transp. Econ. 29, 204–211 (2010).

58. Li, L. & Loo, B. P. Y. Towards people-centered integrated transport: A case study of Shanghai Hongqiao Comprehensive Transport Hub. Cities 58, 50–58 (2016).

6

59. Dooms, M., Verbeke, A. & Haezendonck, E. Stakeholder management and path dependence in large-scale transport infrastructure development: the port of Antwerp case (1960–2010). J. Transp. Geogr. 27, 14–25 (2013).

60. Malterud, K. The art and science of clinical knowledge: evidence beyond measures and numbers. The Lancet 358, 397–400 (2001).

61. Gerring, J. What Is a case Study and What Is It Good for? Am. Polit. Sci. Rev. 98, (2004).

62. Yin, R. case Study Research: Design and Methods. (Sage Publications, London, 2009).

63. Coghlan, D. Doing Action Research in Your Own Organization. (SAGE, 2019).

64. Garud, R., Tuertscher, P. & Van De Ven, A. H. Perspectives on Innovation Processes. Acad. Manag. Ann. 7, 775–819 (2013).

65. Sanders, E. B.-N. & Stappers, P. J. Co-creation and the new landscapes of design. CoDesign 4, 5–18 (2008).

66. Frow, P., Nenonen, S., Payne, A. & Storbacka, K. Managing Co-creation Design: A Strategic Approach to Innovation. Br. J. Manag. 26, 463–483 (2015).

67. Ansell, C. & Torfing, J. Co-creation: the new kid on the block in public governance. Policy Polit. 49, 211–230 (2021).

68. Ansell, C. & Gash, A. Collaborative Governance in Theory and Practice. J. Public Adm. Res. Theory 18, 543–571 (2008).

69. Roozenburg, N. & Eekels, J. Product Design: Fundamentals and Methods. (Wiley, 1995).

70. Kochanowska, M., Gagliardi, W. R., & With Reference To Jonathan Ball. The Double Diamond Model: In Pursuit of Simplicity and Flexibility. in Perspectives on Design II (eds Raposo, D., Neves, J. & Silva, J.) vol. 16 19–32 (Springer International Publishing, Cham, 2022).

71. d.school. An Introduction to Design Thinking: Process Guide. (2010).

72. Van De Ven, A. H. & Angle, H. An introduction to the Minnesota innovation Research Program. in Research on the Management of Innovation 3–30 (Oxford University Press, 1989).

73. Adams, T. E., Ellis, C. & Jones, S. H. Autoethnography. in The International Encyclopedia of Communication Research Methods (eds Matthes, J., Davis, C. S. & Potter, R. F.) 1–11 (Wiley, 2017). doi:10.1002/9781118901731.iecrm0011.

74. Wall, S. An Autoethnography on Learning About Autoethnography. Int. J. Qual. Methods 5, 146–160 (2006).

75. Bitner, M. J., Ostrom, A. L. & Morgan, F. N. Service Blueprinting: A Practical Technique for Service Innovation. Calif. Manage. Rev. 50, 66–94 (2008).

76. Braun, V. & Clarke, V. Using Thematic Analysis in Psychology. Qual. Res. Psychol. 3, 77–101 (2006).

77. Banoun, A., Dufour, L. & Andiappan, M. Evolution of a service ecosystem: Longitudinal evidence from multiple shared services centers based on the economies of worth framework. J. Bus. Res. 69, 2990–2998 (2016).

78. Malterud, K. Qualitative research: standards, challenges, and guidelines. The Lancet 358, 483–488 (2001).

79. Shenton, A. K. Strategies for ensuring trustworthiness in qualitative research projects. Educ. Inf. 22, 63–75 (2004).

80. Vargo, S. L. & Lusch, R. F. Why "service"? J. Acad. Mark. Sci. 36, 25–38 (2008).

81. Caridà, A., Colurcio, M., Edvardsson, B. & Pastore, A. Creating harmony through a plethora of interests, resources and actors: the challenging task of orchestrating the service ecosystem. J. Serv. Theory Pract. 32, 477–504 (2022).

82. Frow, P., McColl-Kennedy, J. R., Payne, A. & Govind, R. Service ecosystem well-being: conceptualization and implications for theory and practice. Eur. J. Mark. 53, 2657–2691 (2019).

83. Friend, S. B. & Malshe, A. Key Skills for Crafting Customer Solutions Within an Ecosystem:

A Theories-in-Use Perspective. J. Serv. Res. 19, 174–191 (2016).

84. Detti, A. et al. Federation and Orchestration: A Scalable Solution for EU Multimodal Travel Information Services. Sustainability 11, 1888 (2019).

85. ORCHESTRA Project. Initial Use cases for Multimodal Traffic Management. https://orchestraproject.eu (2022).

86. Meadows, D. H. Thinking in Systems: A Primer. (Earthscan, London, 2009).

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SUPPLEMENTARY NOTE 1. DESCRIPTION OF THE AR CYCLE AND EMBEDDED CO-CREATION SESSIONS

This information describes the AR cycle in practice. Prior to the cycle, AR-researchers and practitioners defined the context and objectives, shaping the agenda for action[1]. The cycle included six co-creation sessions, each detailed in this chapter. After the sixth session, researchers synthesized the outcomes and drafted preliminary conclusions, after which practitioners finalized the report and conclusions without further assistance from the AR-researchers.

1. Context & Purpose

1.1 Pre-phase with researchers

Two AR-researchers (the first two authors) facilitated the project, both experienced in multimodal travel research at airport hubs[2,3]. They proposed scenario-based design for addressing multimodal challenges, which involve long timelines[2], and high complexity[4]. They highlighted the need to explore how transport hubs manage stakeholder interests in the transition to MTHs, noting that addressing these tensions supports decision-making and strategy[3]. Through auto-ethnographic and interview studies, they defined a good multimodal air passenger experience (Toet et al., submitted) and examined perspectives of transport providers and airport hubs on delivering multimodal air journeys (Toet et al., in preparation). They organized the co-creation sessions around previously identified support processes for multimodal air travel (Toet et al., in preparation).

1.2 Pre-phase with practitioners

Before the AR cycle began, AR-researchers helped participating organizations define the project's objectives and ways to achieve these. The participating organizations had previously collaborated on an initial action plan and each had an understanding of desired air&rail travel. One key organization was absent due to other strategic priorities. Practitioners shared their long-term goals for air&rail integration: enhancing the sustainability of international transportation and reinforcing their strategic mobility positions. For the co-creation sessions, the practitioners aimed to create a shared understanding about air&rail travel and to explore possible solutions. Establishing these objectives collaboratively was essential for organizing related co-creation sessions. Practitioners refined the initial proposal developed by the AR-researchers, organizing co-creation sessions around five themes: customer experience, infrastructure, network, policy & regulations and bandwidth estimates (of effect on passenger numbers and investments).

2. Session 1. Scenario mapping

The objective was to conceptualize potential scenarios for 2040, that address uncertainties impacting the mobility sector, particularly air&rail travel. The integration of air&rail travel requires complex long-term decisions based on limited current information and uncertain future developments, making scenario planning an effective approach[2,4,5].

The setup was that members were encouraged to set aside their organizations' existing strategies and think freely about the forces shaping the future. A facilitator specialized in scenario development joined the AR-researchers to guide the discussion, exploring the certainties and uncertainties that could define potential futures for integrating air &rail travel.

The practitioners outlined possible futures through a combination of plenary discussions and small-group brainstorming.

This session helped to establish a shared understanding of the uncertainties and long-term developments surrounding future mobility contexts. These scenarios served as a reference framework for subsequent decisions and planning efforts.

3. Session 2. Auto-ethnographic field studies

The objective of this session was to focus on firsthand passenger experiences of air&rail journeys, helping practitioners identify challenges and opportunities of integrating air&rail travel[6].

The setup involved practitioners taking three trips guided by the AR-researchers: an international train ride, a plane-to-train journey, and a train-to-plane journey. It began with an international train journey, where practitioners were divided into two groups for a co-creation session to reach consensus on various quality levels of the passenger experience. This was followed by a site visit to an airport outside the project's scope, where touchpoints had been implemented to facilitate air&rail connections. These activities deepened their understanding of the passenger experience and the underlying support processes of different transport organizations. Equipped with these insights, practitioners embarked on the air&rail journeys, and they captured their insights into travel diaries. Follow-up interviews were conducted to document personal reflections.

This session deepened the understanding of passenger experiences and made the impact of fragmented systems tangible. Insights into travel time, comfort, and service differences informed the formulation of improvement areas in the sessions that followed.

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4. Session 3. Service blueprints

The objective of this session was to define requirements for improving the passenger experience based on insights from the field study. Using service blueprinting, practitioners mapped the components of the passenger journey that shape the travel experience[7].

The setup of the session was to divide the practitioners into groups, each tasked with developing service blueprints for air&rail along so-called ambition levels (negative, neutral, improved, ambitious, super ambitious). The service blueprint encompassed phases from starting node to destination node of air-to-rail, rail-to-air, and international train journeys. The groups identified passenger goals for each phase, the touchpoints encountered, and the corresponding frontstage and backstage actions for different levels of ambition in air&rail travel.

This session focused on developing service blueprints based on the ideal passenger experience identified in session 2. These blueprints served as a bridge between experiential insights (session 2) and policy-oriented implementation planning (session 4).

5. Session 4. Implementation plans for air&rail travel

The objective was for practitioners to develop implementation plans with clear ambition levels, outlining key considerations for air&rail integration and ensuring consensus on their quality. Each implementation plan, or *"option"* in scenario-based strategy development[5], defined different levels of air&rail integration. Between session 3 and session 4 a subgroup of practitioners met to discuss unresolved questions.

The setup involved creating the implementation plans in a plenary format, structured and inspired by predefined themes (explained in Context & Purpose): customer experience, infrastructure, network, and policy & regulations. Also, bandwidth estimates for passenger volumes and required investments were created for each implementation plan. Subsequently, practitioners discussed how each implementation would manifest at the different ambition levels (Supplementary Figure 1). For example, what would *"customer experience"* look like under the *"negative"* or *"super ambitious"* levels?

Initially, the session's agenda included a review of feedback regarding the future scenarios, but, due to prolonged discussions (such as about governance and business models), the scenarios were not addressed during this session.

This session consolidated the outcomes of session 2 and 3 into concrete implementation options, structured across different levels of ambition. The

discussions revealed how actors interpreted shared goals differently, leading to the explicit articulation of underlying tensions.

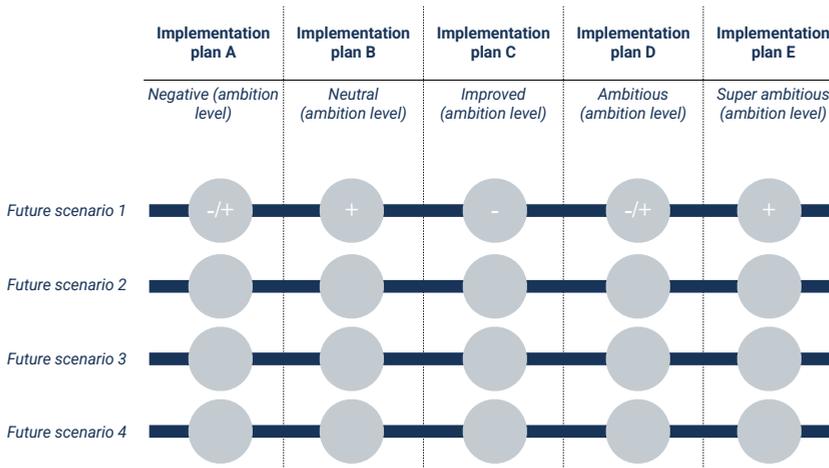| Themes of implementation plan	Implementation plan A	Implementation plan B	Implementation plan C	Implementation plan D	Implementation plan E
	Negative (ambition level)	Neutral (ambition level)	Improved (ambition level)	Ambitious (ambition level)	Super ambitious (ambition level)
Customer experience	?	?	?	?	?
Infrastructure	?	?	?	?	?
Network	?	?	?	?	?
Regulations	?	?	?	?	?
Bandwith estimates	?	?	?	?	?

Supplementary Figure 1. Structure of implementation plans. The figure illustrates how the implementation plans are composed, showing the related themes and ambition levels that form part of them.

6. Session 5. Implementation plans in future scenarios

The objective was to explore how different implementation plans might unfold in future scenarios.

The setup for this session began with a plenary review of the implementation plans, which had been refined in several meetings prior to this session by the same subgroup from the previous session. By session 5, the revised plans had garnered consensus among the practitioners. During the session, one AR-researcher presented the implementation plans on a large poster, and the group discussed the feasibility of the main themes (customer experience, infrastructure, network, and policy & regulations) and bandwidth estimations of each implementation plan within each future scenario (Supplementary Figure 2). The session concluded with a discussion of the main project conclusions.

This session tested the implementation developed in session 4 against the scenarios from session 1. This allowed practitioners to assess the robustness of their plans under different future conditions and identify key dependencies and bottlenecks.

	Implementation plan A	Implementation plan B	Implementation plan C	Implementation plan D	Implementation plan E
	Negative (ambition level)	Neutral (ambition level)	Improved (ambition level)	Ambitious (ambition level)	Super ambitious (ambition level)
Future scenario 1	-/+	+	-	-/+	+
Future scenario 2					
Future scenario 3					
Future scenario 4					

Supplementary Figure 2. Assessment of the implementation plans against future scenarios. The figure illustrates how different implementation plans and their ambition levels are assessed in relation to multiple future scenarios.

7. Session 6. Reaching conclusions

The objective was to reach consensus on possible implementation plans, with corresponding ambition levels, necessary steps to achieve each level, and draw general conclusions from the project along with key conditions for success.

The original setup was to present the final report of the project. However, it became clear in preceding sessions that this would be deferred due to ongoing discussions on several topics. Practitioners were provided with an early draft of the final report, prepared by the AR-researchers. In the lead-up to the session, practitioners expressed discomfort with this version and stated that further discussions were needed to achieve consensus. The AR-researcher and practitioners reflected on the project's results and process during a final interview.

This session was used to reach agreement on which insights could be formally documented. It marked a transition from co-creation to consensus-building, during which tensions between institutional interests became increasingly explicit.

8. Negotiating conclusions and documentation

After session 6, the AR-researchers processed feedback but faced conflicting positions and unresolved issues, with discussions and negotiations between the participating organizations being conducted through the facilitators. As facilitators, they could ask critical questions but could not propose or

enforce decisions.

The AR-researchers observed a shift from co-creation to negotiation. Discussions moved from documenting session events to what conclusions and actions were feasible and acceptable by consensus.

After three months and conversations with several practitioners, the AR-researchers handed over facilitation of the negotiations and documentation to two practitioners from the government administration organization.

The group of practitioners then refined the project's main conclusions while preparing a report for publication. This iterative process lasted approximately four more months, with several sessions held to reach consensus on the key conclusions.

References

1. Coghlan, D. Doing Action Research in Your Own Organization. (SAGE, 2019).
2. Toet, A., van Kuijk, J. & Santema, S. Transforming airport hubs into future-proof Multimodal Transport Hubs. (2022).
3. Toet, A., Van Kuijk, J., Boersma, K. & Santema, S. Themes for an airport hub in the transition towards a multimodal transport hub – an embedded researcher's perspective. in IASDR 2023: Life-Changing Design (Design Research Society, 2023). doi:10.21606/iasdr.2023.272.
4. Snowden, D. J. & Boone, M. E. A Leader's Framework for Decision Making. Harv. Bus. Rev. 10 (2007).
5. De Ruijter, P. Scenario Based Strategy: Navigate the Future. (Routledge, 2014).
6. Hernandez Bueno, A. V. Becoming a passenger: exploring the situational passenger experience and airport design in the Copenhagen Airport. Mobilities 16, 440–459 (2021).
7. Bitner, M. J., Ostrom, A. L. & Morgan, F. N. Service Blueprinting: A Practical Technique for Service Innovation. Calif. Manage. Rev. 50, 66–94 (2008).

6

SUPPLEMENTARY NOTE 2.
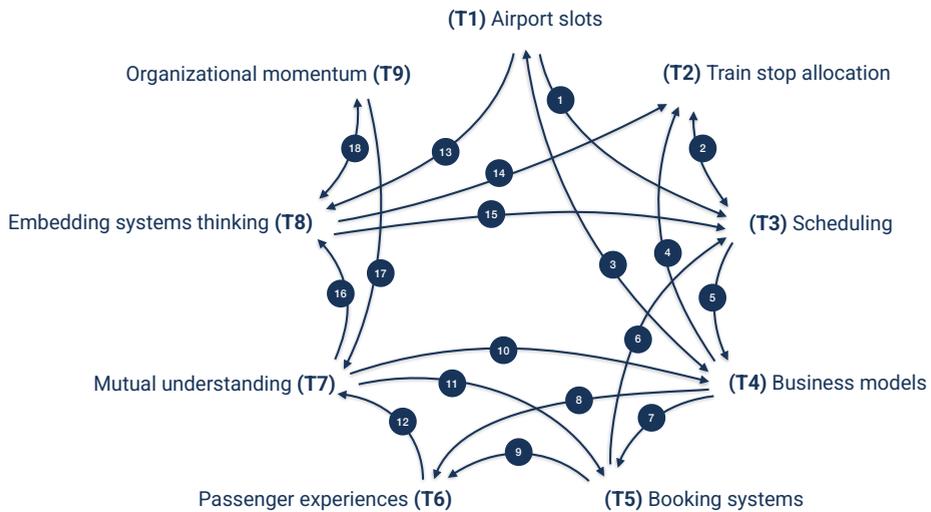
Supplementary Figure 3. *Interrelations between tensions. The figure shows the relations between the tensions identified in this study, highlighting their interdependence in the context of air & rail integration.*

Supplementary Table 1. *Description of the connections between tensions*

1	Airport slot regulations discourage rail operators from adjusting their schedules.
2	If the train doesn't stop at the airport, a good timetable is irrelevant. Similarly, if it does stop but runs infrequently, the service remains ineffective.
3	Airport slot regulations hinder the development of a viable business model and, in fact, benefit airlines under the current setup.
4	Rail operators' business models make airport stops unattractive due to low expected returns.
5	Misaligned scheduling logics between rail and air prevent the development of a joint business model.
6	When booking systems are not integrated, dynamic schedule alignment and real-time disruption management across modes become difficult.
7	Airlines benefit from maintaining control over the air&rail product, reducing both the need for and likelihood of fully integrated booking systems.
8	Diverging business models lead to different service priorities across stakeholders.
9	Fragmented booking systems can result in the service feeling fragmented, rather than a seamless passenger experience.

10	A fundamental lack of understanding of each other's economic logic made it difficult to develop joint strategies or share risks.
11	Limited mutual understanding hindered efforts to integrate passenger data sharing and joint disruption handling.
12	Differences in passenger experience reinforced misunderstandings between sectors.
13	The airport slot tension caused stakeholders to think from their own organizational logic rather than from a system-level perspective.
14 & 15	Due to the lack of authorization to make decisions at a system level, these tensions could not be addressed.
16	The absence of a shared language made it difficult for stakeholders to express system-level trade-offs.
17	Late involvement of some stakeholders led to a lack of mutual understanding.
18	Embedding systems thinking could help secure a mandate, while having a mandate also facilitates the embedding of system knowledge.

6

6.3   REFLECTION

The final AR cycle provided insights for a deeper understanding of how air&rail integration unfolds in reality. In this section, I will reflect on the findings through the perspectives of content *(What did I learn?)*, process *(How did I learn it?)*, and premise *(What assumptions influenced my learning?)* (Coghlan, 2019).

6.3.1   CONTENT REFLECTION

While previous studies primarily focused on identifying factors and conditions for passenger-oriented multimodal air travel, the study presented in this chapter shifted its focus to understanding and intervening in the multimodal system itself.

What surprised me during this phase was the persistence of certain patterns and the limited control that the involved organizations had over them. The six system-level tensions and three collaboration-level tensions that emerged revealed that the mismatch between the air and rail sectors is not only technical and logistical, but, perhaps more importantly, also institutional and political. The fact that aviation has no influence over train stops, that booking systems are fundamentally different, and that fragmentation exists within the rail system itself are manifestations of deeper systemic structures. I learned how these tensions appeared to be interconnected, and the findings suggest that addressing the tensions in scheduling, business models and fostering mutual understanding among stakeholders may have the most impact. It was from this paper that I began to grasp what it means to establish a working system of *"multimodality,"* focusing on the leverage points within these systems.

The concept of baseline modality gained new significance here. In Chapter 5, I learned that the baseline modality exists within the passenger experience, as noted by practitioners. However, this chapter's study also highlighted its relationship with power dynamics in multimodal collaboration. For instance, I discovered that airlines currently significantly influence the structure and offerings of the multimodal journey. This finding indicates that the baseline modality concept contributes to both an uneven passenger experience and unequal collaboration among multimodal stakeholders, the latter of which, in turn, continues to impact the uneven passenger experience.

From the perspective of open innovation (Chesbrough, 2003, 2006), this research cycle provided insights into how organizations manage new knowledge. I observed that harnessing knowledge – getting a grip on new

insights – was done differently by stakeholders because they had different goals: some viewed air&rail as a step toward sustainability, while others saw it as an opportunity for competitive advantage. It became clear that these different views made it hard to create a shared vision for the future. And although co-creation helped people understand each other better, achieving real structural alignment was still difficult.

I also noticed that the absorption of new knowledge – knowledge that was created during the co-creation sessions – appeared to gain value only when organizations could individually anchor it within their businesses. In this sense, absorption became sequential rather than collective: first learning collectively, then translating it to and anchoring it within the participating organizations. Each time something was processed in a participating organization, it generated new questions for the collective conversation.

While harnessing and absorbing are regarded as distinct activities in open innovation (Chesbrough, 2003, 2017, 2020), in this study, the boundaries between these activities were blurred. One organization may have already been in the absorbing phase, while another was still dealing with the new questions raised by the harnessing phase. For instance, the airline in this case was prepared to absorb new knowledge, while the rail operator remained in the harnessing phase.

This thesis illustrates that harnessing and absorbing activities in multi-stakeholder environments occur in multiple interrelated phases (see Figure 15):

1. First, knowledge must be harnessed within individual organizations, as Chesbrough (2003) suggests, to advance their own business interests.

2. Second, participating organizations must align on the perceived added value – not only for the joint development of multimodal air journeys but also for their respective strategic goals – through shared harnessing practices.

3. Third, the collectively harnessed knowledge must be absorbed into the business units of the individual stakeholders.

4. Fourth, this absorption process often engages new individuals or departments within the organizations who were not involved in the initial shared harnessing phase. As a result, knowledge is once again re-harnessed internally, but now from a broader and more informed base, which reactivates the cycle.

This iterative loop demonstrates that harnessing and absorbing are not linear, one-off stages, but rather dynamic, cyclical processes that evolve as collaboration deepens.
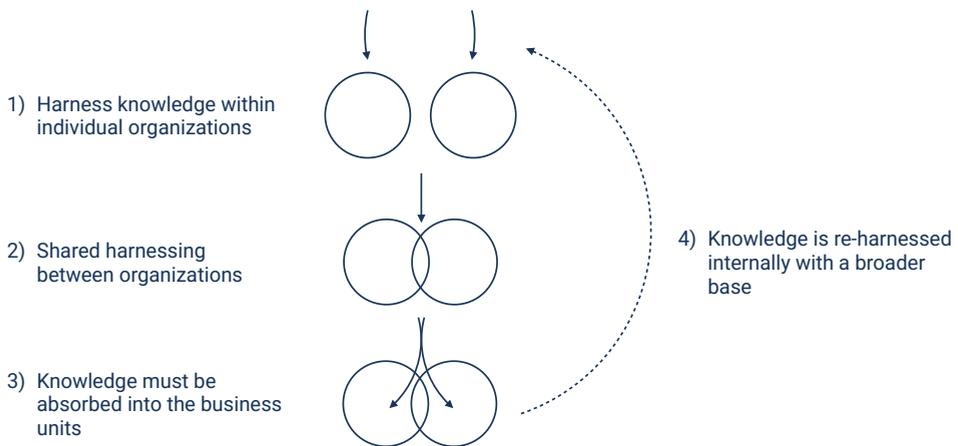
1) Harness knowledge within individual organizations

2) Shared harnessing between organizations

3) Knowledge must be absorbed into the business units

4) Knowledge is re-harnessed internally with a broader base

Figure 15. Cyclical process of harnessing and absorbing knowledge

In the reflection in Chapter 3 (Section 3.3), I articulated the need to investigate how an airport, as an organizational entity, can transition toward multimodality. In this context, it is important to underscore that the subsequent chapters (Chapters 4, 5, and 6) adopted a broadened focus. I chose to investigate how organizations – such as airports, operators, rail infrastructure managers, and government – can collaboratively navigate this transformation, rather than analyzing it from the perspective of a single entity (the airport).

One participant made the following statement about working toward multimodality: *"I believe change only happens when people are allowed to dream, when they believe this could actually make the world a bit better."* This statement resonated with me because it illustrated that vision without institutional space has little power. While the earlier chapters addressed the rigidity of systems, the complexity of processes, and the constraining nature of regulations, this chapter demonstrates that successful multimodal air integration requires strategic and policy alignment. The public administration body intentionally participated in the co-creation sessions, adopting an equal position alongside other stakeholders instead of acting as

a hierarchical umbrella organization for the involved parties. By engaging as an equal actor with operators, the airport, and the rail infrastructure manager, it became clear that regulation and legislation must be regarded as adaptive elements in the development of multimodal air transport. The findings from this research cycle highlight that having the right people, support processes, and an organizational mandate is important, but their impact depends on regulatory and legislative frameworks that facilitate collaboration towards multimodality.

Contribution to the thesis research questions

This chapter addresses the second and third research questions: *What influences the effective delivery of a passenger-oriented multimodal air journey?* (RQ2) and *What tensions arise when stakeholders engage in the (co-)creation of integrated multimodal air journeys, and how can these be mitigated?* (RQ3). While this chapter touches on the passenger experience, it does not provide new insights beyond what was identified about passenger experience in the previous two AR cycles.

The study engaged stakeholders in the co-creation of integrated multimodal air journeys, and several tensions emerged. These tensions can be traced back to the support processes identified in the previous AR cycle (Chapter 5) and are grouped into four themes that influence delivery, according to practitioners: customer experience, infrastructure, network design, and regulatory conditions.

System-level tensions include no control over airport slots, conflicting priorities in train stop allocation, misaligned scheduling, different business models, fragmented booking systems, and different passenger experiences. Collaboration-level tensions involve limited mutual understanding, challenges in embedding systems thinking in organizational processes, and differences in organizational momentum.

These tensions can be mitigated by fostering co-creation sessions to build shared understanding, appointing an orchestrator to coordinate activities and decision-making, and establishing supportive regulatory frameworks.

6.3.2 PROCESS REFLECTION

The preparation and execution of this third research cycle, especially the five co-creation sessions, took more time than expected due to the dynamic context and multiple stakeholders involved. This provided me with deep insights into real-world collaboration. In line with Coughlan & Coghlan's (2002) assertion that AR cannot be fully planned, I noticed how the process

was influenced by political shifts, changing organizational priorities, and the necessity for multiple departments to review and agree on both the original project plan and the final report. These delays slowed progress but also allowed me to understand the impact of interdependence in decision-making processes within large organizations.

The co-creation process demonstrated the potential for applying structured approaches from participatory or service design in future work. Participants were encouraged to express their ideas without immediately reverting to negotiation discussions. However, as discussions became more complex and organizational interests emerged, I noticed that collaboration shifted to more formal, hierarchical interactions. During this process, my role evolved from facilitator to observer, and I eventually stepped back as facilitator, as it became more of a negotiation and mediation process taken over by the government stakeholder in the project. This experience taught me that co-creation has its limits, particularly when institutional interests begin to dominate. It also helped me realize that while structured design approaches are powerful for generating ideas and building shared understanding, sustaining co-creation over time in the multimodality context requires careful attention to governance and decision-making. Alternative methods such as ethnographic observation (Miles et al., 2014; Silverman, 2009) could have provided more independent insights into the dynamics of the *"as is''*-situation. However, this study would probably not have existed if it was not designed as a live intervention. This design enabled participants to engage in joint exploration and co-creation, offering opportunities for them to collaboratively develop solutions. And it also provided insights that go beyond the status quo, from the *"what is"* to the *"what can be"*.

A key takeaway from the attempts to co-publish results with participating organizations was the challenge of reaching consensus on what could be made public. The need for shared approval often tempered the richness of the findings, as detailed insights were omitted to accommodate all stakeholders. This illustrates a limitation of AR: while co-created knowledge is highly relevant for practice, some findings may be softened or excluded to keep everyone on board. In response, in the paper presented in this chapter (Section 6.2), I chose to highlight the tensions and interaction dynamics while deliberately omitting the action steps proposed by practitioners. Requiring organizational approval for these details could have compromised the depth of the findings, whereas focusing on tensions allowed me to elevate the analysis to an academic level.

6.3.3   PREMISE REFLECTION

This AR cycle built strongly on previous research cycles. Consequently, I entered with certain assumptions already established, particularly regarding support processes and the role of collaborative learning. I chose to present these elements to practitioners in a structured manner while still allowing them to shape the content. However, it is important to acknowledge that my framing may have influenced the practitioners, leading them to provide input that ultimately affected my learning.

I was also aware of a fundamental principle in AR: *"everything you do is an intervention, and you need to be sensitive to the impact that asking questions and observing may have on your fellow participants"* (Coghlan, 2019, p. 139). My presence as an embedded researcher influenced participant behavior during the co-creation sessions, as I organized, prepared, and facilitated the sessions. Although the organizations involved were already collaborating on air&rail integration, the structured, cross-organizational nature of this effort was largely initiated by my supervisor at the embedded airport. Thus, the topics discussed, and the themes deemed important were largely shaped by my research, which may have unintentionally prevented certain tensions from surfacing or resolved them too early in the process.

Additionally, broader societal and political developments may have impacted the strategic choices of the participating organizations. While I did not observe explicit evidence for this, there was an interesting shift in political attitudes during the sessions – particularly a less favorable climate for air&rail integration – which have affected how some operators positioned themselves.

6

7

This chapter reflects on the dissertation by following the AR tradition of evaluating the study's content, process, and premises (Reason & Torbert, 2001). It examines the theoretical contributions of the findings (content reflection), analyzes the methodological choices and research dynamics (process reflection), and explores the assumptions and contextual developments that influenced the research (premise reflection). The chapter concludes with a discussion of the research's trustworthiness, implications for future inquiry, and practical recommendations for professionals.

CHAPTER 7. REFLECTION AND IMPLICATIONS

7.1 CONTENT REFLECTION: THEORETICAL CONTRIBUTION

Reflecting on this research, I recall an image shared by one of my supervisors early in the PhD. He showed an image illustrating how small the contribution of a doctoral thesis appears within the broader body of knowledge at first glance. It seems like just a small bump, barely crossing the edge of what is already known. However, I discovered that this seemingly minor addition beyond the edge of existing knowledge is not easily attained. But when found, it enriches existing research in a profound and hopefully worthwhile extent.

At the outset of this research, the theoretical foundation regarding multimodal integration at airports was limited. Over time, the theme of multimodality evolved and gained more attention, both within this study and in the wider academic and societal context. This thesis addressed several gaps that emerged at different stages of the research process.

Simultaneously, new literature on multimodality, air&rail integration, passenger experience, and mobility governance has emerged over the years. This growing body of work confirms the relevance of the topic and provides a framework against which to position the findings. This section will not provide a detailed list of the contributions the thesis has made to the field, as this is already provided in the published papers in chapters 3, 4, 5 and 6. This section explains how the work contributes to existing knowledge at a higher level and identifies the disciplines to which it offers new perspectives.

The airport

This thesis positions airports as essential nodes in facilitating multimodal air travel where both the physical and operational dimensions of integration converge. In doing so, this work aligns with literature that emphasizes airports as key junctions for modal convergence (Anderson et al., 2017; Chiambaretto & Decker, 2012; Rongen et al., 2020; Schmitt & Gollnick, 2016) while also expanding on this by focusing on their strategic and organizational functions.

This research confirms that complexity in multimodal air travel arises during transfers between systems, although these transfers could enhance the passenger experience (Edwards, 2011; Monzón et al., 2016; Rongen et al., 2020). While the airport provides passengers access to the air system and facilitates air-to-air transfers within a single transport system, multimodal transport necessitates a transfer between two *different* systems. These transfers require passengers to navigate different operational and

institutional domains, which can be particularly stressful due to existing airport stressors such as security checks, customs procedures, and baggage handling (Li et al., 2018). As a result, passengers may feel lost, lacking a clear sense of connection or responsibility, even when the journey is offered under a single integrated contract.

Research shows that the quality of the transfer significantly shapes the overall travel experience and is a key factor in the success of multimodal air travel integration (Babić et al., 2022; Chauhan et al., 2021; Durand & Romijn, 2023; Jiang et al., 2022; Rongen et al., 2020). It therefore also influences whether passengers choose or reuse multimodal options (Lai & Chen, 2011; Schmitt & Gollnick, 2016; Van Lierop & El-Geneidy, 2016; Wang et al., 2017). This calls for airports to take on a new role that enables seamless transfers, blurs the boundaries between modalities, and supports passengers as they switch between systems.

To function effectively as MTHs, airports must go beyond facilitating airside operations. Their responsibilities extend to investing in infrastructure for other modalities – such as station location, facilities, waiting environment and hub design – as well as coordinating operations and ensuring information continuity (Bell, 2019; Chauhan et al., 2021; Monzón et al., 2016). However, this thesis goes further than infrastructure considerations. Consistent with the findings of Li et al. (2018), it asserts that physical proximity between transport modes is inadequate; true integration requires alignment of organizational and operational processes. While these processes may not always be physical, they converge where transport systems intersect: the airport.

In the thesis, I argued that airports can strategically benefit from multimodal air connectivity, as it extends their catchment areas and provides relief from capacity constraints and congestion (Babić et al., 2024; Chiambaretto & Decker, 2012; Janic, 2011; Jiang et al., 2017). However, I showed – particularly in Chapter 6, during the co-creation process of the third AR cycle – that most attention was directed toward air and rail operators, despite the benefits for airports. During the study, air and rail operators were viewed as the primary stakeholders within the service ecosystem, as their resources were most important for integrating air&rail travel and their interests were most at stake. Airports, along with rail infrastructure managers and governments, were found to play a more supportive and facilitative role in this process. This contribution to SET illustrates that resource integration does not occur in a *"fundamentally similar"* manner among all actors, as noted by Vargo and Lusch (2011), and emphasizes the importance of carefully assessing the

roles of different actors. This thesis conceptualizes airports as facilitative operators at the intersection of systems, positioning them uniquely to manage multimodal coordination, particularly in terms of information and service provision. This thesis aligns with recent MaaS research emphasizing the importance of hubs as critical connectors, with calls for further investigation into infrastructure and hub integration into MaaS platforms (Wu et al., 2025).

I argue that future multimodality research should no longer consider airports and other transit hubs as peripheral infrastructure. Instead, they should be recognized as active agents that facilitate and shape multimodal air transport systems. This recognition is crucial because airports lie at the intersection of multiple transport systems, and thus embody the transfer in multimodal air travel.

Passenger expectations

Although multimodal air travel aims to focus on the experience of the entire journey (Camacho et al., 2016; Canale et al., 2019; Docherty et al., 2018), this study reveals that, in practice, the transport modes themselves continue to shape passengers' perceptions. Specifically, industry professionals noted that passengers tend to form their expectations based on the mode they perceive as dominant. In the case of multimodal air travel, this is almost always the airplane. This finding aligns with earlier research (Babić et al., 2022).

This dominant mode, or as I call it the *"baseline modality"*, serves as the reference point against which passengers evaluate various aspects of their journey. It influences their assessment of service quality, their expectations for disruption management, and their perception of travel and waiting times. In multimodal air journeys, the experience is frequently compared to air-to-air transfers. This affects the experience of multimodal air journeys: if expectations are based on aviation standards, deviations are likely to cause dissatisfaction (Babić et al., 2022; Lai & Chen, 2011; Van Lierop et al., 2018; Van Lierop & El-Geneidy, 2016).

This thesis shows that passengers may not always recognize the multimodal nature of their journey, such as not realizing one leg is by train rather than plane. Even when aware, they typically use air travel as their primary reference point.

The finding of the baseline modality may also apply to MaaS journeys, a concept that encourages passengers to shift from car use to urban public transport (Alyavina et al., 2022; Guyader et al., 2021; Jittrapirom et al., 2017). In the context of MaaS, the car is likely to serve as this baseline modality, shaping passengers' expectations throughout the journey.

A complication in achieving a seamless passenger experience is the absence of a uniform phase structure in multimodal air travel. As Chapters 4 and 5 show, the implementation and integration of multimodal air journeys vary significantly across locations, echoing Li et al. (2018), who identify multiple levels of air&rail service integration. This inconsistency makes it difficult for passengers to form uniform expectations, and the resulting fragmentation limits both the understanding and recognition of multimodal air travel as a coherent concept.

Next, the findings in this thesis show that passenger experience is shaped not only by personal expectations but also by how effectively the system acknowledges, responds to, and sometimes even challenges those expectations.

Furthermore, the thesis underscores that passenger acceptance is critical to the success of multimodal air travel. If passengers do not perceive air&rail journeys as equal to or better than existing air-to-air journeys, adoption will remain limited. This aligns with the innovation characteristic of 'relative advantage' from Rogers' diffusion of innovation theory (2003). It also corresponds with research on value creation in service innovation, which suggests that value is only created after customer acceptance (Vargo & Lusch, 2008). To my knowledge, no adoption research has been conducted on the specific relationship between air and rail legs within a multimodal air journey, only on separate journeys (Sauter-Servaes & Nash, 2009).

The concept of baseline modality contributes to SET by illustrating how, in the transition towards multimodal service ecosystems, feedback loops (Meadows, 2008) and existing institutions (Vargo & Lusch, 2016) – such as rules and agreements – help maintain the established order of a transport system composed of multiple subsystems. At the same time, the baseline modality concept emphasizes the need for adaptation of the system (aligning with As'ad et al., (2024)), involving activities such as integrating stakeholders' resources to develop new viable business models, IT systems, and schedules that embrace multimodal travel and make it the new norm. Multimodal air travel creates a fundamentally different experience compared to traditional air travel, resulting in a new form of mobility that is still being defined.

The backbone of multimodal air journeys

The academic literature provides many definitions of multimodality. Research has been emphasizing the choice between different modes of transport (Allard & Moura, 2016; Timmer et al., 2023), and focused on the integration of multiple modes within a single journey (Allard & Moura, 2016;

Bagamanova et al., 2022; Huang & Mu, 2018; Schmitt & Gollnick, 2016). This thesis demonstrates that, in the context of multimodal air travel, the practical emphasis lies on combining PT transport modes within a single trip, in which multiple parties collaborate (Babić et al., 2022; Rodrigue, 2024). While some literature uses the term intermodal transport, this thesis adopts the definition by Babić et al. (2022) and Rodrigue (2024) who distinguish multimodal transport by its provision of integrated services, whereas intermodal transport requires passengers to independently coordinate between modes.

The findings show that multimodal air journeys are being integrated in practice, but rarely on equal terms. In the studied cases, the aviation component dominates, with the train largely functioning as an extension of the air system. This demonstrates that the baseline modality concept applies not only to passenger experience but also to the collaboration between actors working on multimodality. These findings respond and contribute to the call by Vargo & Lusch (2017) to examine how keystone actors establish and maintain their positions in a service ecosystem, as aviation appeared to often assume the dominant role over rail.

Although this aviation-led structure creates challenges in coordination between operators, at the same time it results in passengers being provided with disruption management in the event of delays (Jiang et al., 2017; Li et al., 2018). Previous research has shown that this type of support and reliability plays a role in passengers' decisions regarding their choice of transport (Babić et al., 2022; European Parliament and of the Council, 2024; RLI, 2020; Yuan et al., 2021). Consequently, this thesis shows that misintegration of resources, in which one of the actors plays a dominate role, manifest across levels of the ecosystem: at the micro level (Mustak & Plé, 2020) through fragmented experiences and uneven service standards; at the macro level (Mustak & Plé, 2020) through tensions between airlines, rail operators, and other stakeholders struggling to align responsibilities, business models, and IT systems. In doing so, the thesis directly addresses the research agenda set out by Mustak and Plé (2020), who call for greater attention to the consequences of misintegration and non-integration. The case of air&rail integration illustrates that airlines use resources in ways that primarily aligns with their own interests (aligning with Mele et al. (2018)), but at the same time considers the needs of their passengers. The result is a paradoxical form of misintegration: suboptimal and asymmetric for the well-being (Frow et al., 2019) of the multimodal service ecosystem, but one that can simultaneously leave air&rail passengers with air-level disruption management services.

However, I anticipate that if multimodal air journeys continue to be offered in this way, the baseline modality in terms of the passenger experience – as discussed in the section above – is likely to remain unchanged.

At the same time, the findings show that actors still approach multimodal air journeys from within their own system boundaries. They may consider their own passengers' needs, but struggle to collectively center the multimodal passenger. As a result, challenges at both micro and macro levels stem from an organization-centric rather than a passenger-centric approach.

This study contributes to transport research by first identifying what passengers value during their journeys and then examining how those priorities can be met in practice. To better understand this dynamic, I developed a set of Journey Integration Factors and Passenger Experience Factors (PEFs). Existing literature discusses clusters of passenger experience factors: wayfinding and signage (Allen et al., 2020; Nielsen et al., 2021; Wang et al., 2020), hub facilities (Eboli & Mazzulla, 2015; Hernandez & Monzon, 2016; Hickman et al., 2015), waiting environment (Eboli & Mazzulla, 2015), hub design (Geng et al., 2017; Hernandez & Monzon, 2016; Li et al., 2018; Wattanacharoensil et al., 2016), journey process information (Allen et al., 2020; Antwi et al., 2020; Babić et al., 2022; Cascajo et al., 2019; Hernandez & Monzon, 2016; Watkins et al., 2011), personal communication (Antwi et al., 2020; Lubbe et al., 2011), special transfer services (Babić et al., 2022; Román & Martín, 2014; Wang et al., 2020), ticketing services (Babić et al., 2022; Hickman et al., 2015; Román & Martín, 2014; Wang et al., 2020), and transfer coordination (Abenoza et al., 2019; Babić et al., 2022; Hernandez Bueno, 2021; F. Jiang et al., 2022; Li et al., 2018; Román & Martín, 2014; Song et al., 2018). This thesis contributes by illustrating how these factors influence the multimodal experience and at which journey phases they are relevant. These factors help explain how the passenger experience is formed and can be improved, while also offering opportunities for future research to validate and quantify these insights further.

It is important to recognize that, within SET, value appraisal is considered complex (Kleinaltenkamp et al., 2012), because value is phenomenologically determined by beneficiaries, that is, by those who receive and use the service (Vargo & Lusch, 2008). This means that the integration factors and PEFs identified in this study can differ from one passenger to another and from one actor to another. Each actor serves different customer groups who value different aspects. Such diversity complicates the transition from a fragmented transport system to a coherent multimodal service system. This thesis contributes to (As'ad et al., 2024) by highlighting that in the multimodal

service ecosystem, actors must understand a new type of passenger, whose preferences are not yet known and need to be shaped by new purposes, worldviews, and norms.

Additionally, this study identifies backstage processes that are essential for delivering these specific aspects of the multimodal passenger experience. Existing literature has addressed several of these processes, such as physical infrastructure (Li et al., 2018; Mujica Mota et al., 2020), business models (Mujica Mota et al., 2020), operational processes (Mujica Mota et al., 2020; Yuan et al., 2021), scheduling (Allard & Moura, 2016; Román & Martín, 2014; Yuan et al., 2021), and information systems (Allard & Moura, 2016; Mujica Mota et al., 2020; Yuan et al., 2021). This thesis dives deeper and contributes by illustrating how a combination of support processes and market dynamics and regulations influences the collaboration to delivering passenger-oriented multimodal air journeys.

Multi-level boundaries

Initially, this thesis conceptualized the transport system as a high-order system composed of multiple subsystems based on different modalities (Aleta et al., 2017; Geurs et al., 2016). It then reframed multimodal transport as a more robust service ecosystem in transition (following As'ad et al. (2024)), where existing subsystems should be reshaped and interconnected. The findings contribute to transport studies and SET by demonstrating that the current practices of multimodality examined in this thesis exist at the boundary between reconfiguration – through new agreements and pilot programs – and transition, which requires a shared purpose and worldview (As'ad et al., 2024).

This thesis deepens the understanding of how transport subsystems differ and shows that these distinctions can be attributed to historical legacies (Bairras & Ardaiz, 2025; RLI, 2020; Schmitt & Gollnick, 2016; Vassallo & Fagan, 2007), longstanding partnerships (Schmitt & Gollnick, 2016), and the internal structure and organization of each transport system. While transport literature highlights visible system boundaries (Marquez, 2019; RLI, 2020; Wang et al., 2024), this thesis finds that various support processes – such as IT systems, infrastructure, scheduling, operations, commercial activities, (inter)organizational structures, and strategies – also play a role in the emergence of integration frictions. These support processes are essential for organizations to identify which internal teams and departments need to be involved in multimodal air collaboration. Furthermore, they provide a framework for agreements within and outside organizations that delineate responsibilities and specify which processes must be aligned or shared.

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Inter-organizational structures were found to present a specific set of boundaries that must be overcome when actors from different transport systems attempt to collaborate. This thesis identified these boundaries as a lack of mutual understanding and resistance between the parties (Jiang et al., 2017; Yang & Zhang, 2012)

Friction also arises from the structure within transport systems. For example, transport provided by different train operators may introduce fragmented passenger experiences, as a delay from one provider may lead to a missed connection with another operator (RLI, 2020). This internal fragmentation shows that passengers face boundaries not only between modalities but also within a single mode.

Furthermore, fragmentation occurs at the national level: each country manages its own networks, infrastructure, regulations, and planning systems (Vassallo & Fagan, 2007). These differences complicate cross-border cooperation especially for the rail sector (RLI, 2020).

This thesis also identified regulatory boundaries that affect the integration of multimodal air transport. These boundaries arise from mismatches between legal frameworks, such as differences in passenger rights, liability regimes, and service obligations across countries and transport modes.

A contribution of this thesis is the conceptualization of service ecosystem boundaries as multi-level. This work extends the research of Razmdoost et al. (2023) by demonstrating that boundaries occur not only between service ecosystems but also within the confines of a multimodal service ecosystem. Furthermore, the thesis shows that multi-level boundaries are crucial for understanding why ecosystems stagnate. These multi-level boundaries encompass modal distinctions, inter-organizational collaboration, intra-modality, national systems, and regulatory frameworks, providing a understanding of the challenges of integration in practice. Rather than coexisting, these boundaries intertwine with one another, highlighting their multi-level nature. The thesis illustrates how such boundaries are created, defended, or potentially opened up.

Furthermore, the findings indicate that MaaS research must also account for multi-level boundaries – for example viewing different payment methods and fragmented information systems (Kamargianni et al., 2016) as boundaries – albeit at a smaller scale where cross-national boundaries are typically absent.

In order to deal with the complexity of multi-level boundaries, this thesis advocates for adopting an innovative, whole-system mindset to address these various layers of boundaries.

Orchestration as key to integration

While transport literature highlights the importance of infrastructure, service integration, and modal cooperation in advancing multimodal travel (Babić et al., 2022; Bell, 2019; Chauhan et al., 2021; Monzón et al., 2016), this thesis shows that integrating multimodal air travel systems constitutes a complex, system-level challenge. With no single actor controlling the full value chain, the integration of multimodal air transport cannot rely on bilateral cooperation between transport operators. This study identifies the absence of a coordinating body with the mandate and capacity to align decision-making across interdependent stakeholders as a key barrier. Without such orchestration, collaboration remains fragmented, reinforcing siloed operations and limiting the development of integrated services.

Some forms of orchestration have been investigated in multimodal transport, such as digital routing platforms (Detti et al., 2019) or traffic management systems (ORCHESTRA Project, 2022), but these typically focus on operational or data-level coordination. This thesis shows that strategic and structural orchestration is also necessary, particularly in the context of multimodal air transport, where the value chain spans organizational and sectoral boundaries.

Furthermore, this thesis identifies that many barriers to multimodal air travel can be traced back to financial incentives. This observation aligns with the understanding that the stakeholders involved are companies that must maintain financial sustainability[i]. While the literature discusses the cost of infrastructure (Campos & De Rus, 2009; Doomernik, 2015; Rattanakijsuntorn et al., 2024; Rodrigue, 2024), this study adds that financial barriers also arise from factors such as misaligned business models and complex revenue-sharing arrangements (aligning and contributing to Babic et al., 2022; Finger et al., 2019).

Within SET, coordination enables resource integration among actors, particularly when they pursue different goals and perspectives (Caridà et al., 2022; Edvardsson et al., 2014; Frow et al., 2019; Ostrom et al., 2015; Vargo & Lusch, 2016). Applied to multimodal air travel, this thesis demonstrates that the absence of a coordinating actor results in persistent misalignment of resources and reinforces power asymmetries that hinder cooperation (contributing to Mele et al., 2018 and Mustak & Plé, 2020). Unaddressed asymmetries create structural frictions that disadvantage either passengers or specific actors, confirming concerns raised in recent literature (Babić et

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i   State-owned companies must also be financially sound, as legislation mandates equal treatment for both private and public companies (refer to article 107 in TFEU (European Union (2012).

al., 2022; European Parliament and of the Council, 2024).

This thesis also advances the debate on MaaS. MaaS research highlights the integration of multiple operators through viable revenue allocation (Kamargianni et al., 2016), the need for cross-sector collaboration and public–private partnerships (Guyader et al., 2021) and identifies unclear stakeholder power structures as a persistent obstacle (Wu et al., 2025). The thesis shows that, in the context of multimodal air travel, the lack of an actor with both the authority and capacity to coordinate decision-making among interdependent stakeholders poses a fundamental challenge.

The thesis suggests the necessity of ecosystem-level orchestration. It enhances the broader debate on orchestration in service ecosystems and transport studies by demonstrating that: 1) orchestration is crucial for overcoming the dominance of the baseline modality among operators; and 2) effective orchestration demands an ecosystem perspective rather than relying on single-organization solutions.

The impact of policy, legislation and regulation

Existing research highlights the absence of regulations as a barrier and the introduction of new regulations as a stimulus for innovation in the transport sector (Babić et al., 2022; Finger et al., 2019; Ongkittikul & Geerlings, 2006). Other studies indicate that existing regulations can hinder transitions, such as the shift from short-haul flights to rail (Berveling et al., 2020; RLI, 2020). In much of this literature, regulations are treated as fixed constraints that limit innovation and integration.

This thesis contributes by conceptualizing policy, legislation, and regulation not as static constraints but as adaptable instruments in the development of service ecosystem development, in this case in multimodal air transport. Building on Vink et al. (2020), who frame institutions as design materials in service ecosystem design, the study demonstrates how institutional arrangements should be actively reconfigured. This reframing advances transport studies by positioning regulation as a central design material in transport systems. Methodologically, the thesis also responds to the call by Vink et al. (2020) for more systemic service design studies through a longitudinal, multi-perspective, and action-oriented approach.

This study contributes by identifying two ways to view regulatory frameworks as flexible. First, the proposal for a governing body at the European level to support and promote multimodal air transport aligns with existing research on policies for multimodal air transport (Babić et al., 2024; Givoni & Banister, 2006; Li et al., 2018). This body would engage with the regulatory

framework at a systems level, addressing the full range of policies, legislation and regulations that shape multimodal mobility development. An example of how such a governing body could operate is the TEN-T policy (Regulation (EU) 2024/1679), which focuses on planning and developing multimodal transport infrastructure within the EU.

Second, this thesis introduces an innovative mindset and the application of design approaches in developing multimodal air transport. Involving governments as equal partners alongside operators, airports, and infrastructure managers in co-creation sessions gives the opportunity to treat regulation as an integral part of the design and innovation process. This collaborative approach can help overcome barriers and generate new solutions for multimodality.

Cyclical innovation process

The findings reveal that designing entirely new systems often seems more straightforward than adapting existing ones. This is primarily because existing systems contain a great deal of architectural knowledge that has become embedded in the organization's structure (Henderson & Clark, 1990), making change difficult. However, this study suggests that innovation can thrive within these structures when designers and industry professionals engage in collaborative processes and remain open to alternative perspectives. This aligns with Schumpeter's view of innovation as a recombination of existing elements rather than designing something new (Schumpeter, 1934). Moreover, it corresponds with the work of Koskela-Huotari et al. (2016), who conceptualize innovation as the reconfiguration of service ecosystems, where actors co-create value by integrating resources.

To explore knowledge dynamics in multimodal service development, this study applied the theory of open innovation (Chesbrough, 2003, 2006), in combination with SET (Vargo & Lusch, 2016). This thesis contributes to SET by operationalizing how resource integration unfolds in practice, not only through inter-organizational exchange but also through the sequential processes of harnessing and absorbing knowledge within organizations (Figure 16). Taillard et al. (2016) state that shared intentions are needed for action in service ecosystems. This thesis contributes by showing that knowledge, and consequently such intentions, only gains value when absorbed by different organizations, making absorption a parallel process.

This research indicates that organizations may engage in harnessing and absorbing knowledge flows at different times. Some may be ready to absorb external knowledge, while others are still in the process of knowledge

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harnessing, which can hinder collective progress. This deepens existing literature, which writes about how value creation is also influenced by internal processes in organizations (Caridà et al., 2022; Stadler Benz & Stauffacher, 2024). Furthermore, it complements the work of Koskela-Huotari et al. (2016) by showing how institutional reconfiguration unfolds in practice. While their research emphasizes innovation as a negotiated effort among multiple actors, this study reveals that dynamics are also influenced by asynchronous internal processes. This enhances SET by showing that institutional change depends not only on collective agreements but also on the internal capacity of organizations to embed the new knowledge.

At the same time, this thesis extends open innovation theory by moving beyond its traditional intra-organizational focus (Chesbrough, 2006) and focusing on open innovation through cross-organizational collaboration (Figure 16). This broader view on open innovation has been discussed in literature (Chesbrough et al., 2006; Koskela-Huotari et al., 2016; Portuguez-Castro, 2023), and Chesbrough (as mentioned in Chesbrough & Bogers, 2013) has called for further research on inter-organizational open innovation within networks. This study seized that opportunity by exploring what can be learned about open innovation when organizations integrate their resources within a service ecosystem on a peer level (Vargo & Lusch, 2016). The findings of this thesis provide initial insights into this phenomenon, demonstrating that insights from co-creation do not automatically translate into action; they must be absorbed by teams and embedded into internal processes. Additionally, this thesis indicates that harnessing knowledge does not originate solely from an organization; it gains meaning when organizations collectively agree upon it. This underscores the necessity for structured follow-up and ongoing engagement to gradually disseminate insights.
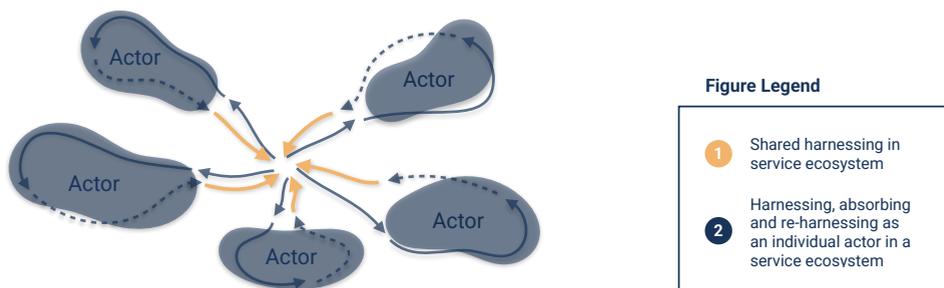

Figure Legend

1. Shared harnessing in service ecosystem
2. Harnessing, absorbing and re-harnessing as an individual actor in a service ecosystem

Figure 16. Harnessing and absorbing knowledge in the multimodal air ecosystem

7.2 PROCESS REFLECTION

This thesis is the result of a research process in which insights developed over time. This chapter describes how the research process may have influenced the findings.

Methodological connection

The methodological connection of the AR cycles is illustrated in Figure 17. The 'context and purpose' phase of each AR cycle is enriched by insights from the preceding research cycle, creating a new, more comprehensive 'context and purpose' for the subsequent AR cycle. This approach facilitates an iterative deepening of both the problem definition and the direction of potential solutions.

The representation in Figure 17 is a simplified version of reality. Each day, week, and month, along with every conversation, interview, journey, and co-creation session, can be viewed as a stand-alone AR cycle that has influenced the next research cycle.

Nevertheless, one must be aware that the first 'context and purpose' phase (Chapter 3) was developed while I was embedded within the innovation team. This position provided privileged access to data, tacit knowledge, and trust among participants; however, it also risked reducing my distance and may have introduced confirmation biases (Miles et al., 2014; Shenton, 2004). Similarly, in later phases, my dual role as both embedded researcher and member within the masterplanning team and the multi-organizational air&rail working group shaped not only the insights generated but also the direction in which the research cycles evolved. The methodological 'connection' was therefore a process actively co-produced through my participation.

While the published papers presented in Chapters 3, 4, 5, and 6 can be understood independently, their methodological contribution lies within the overall narrative presented in this thesis.
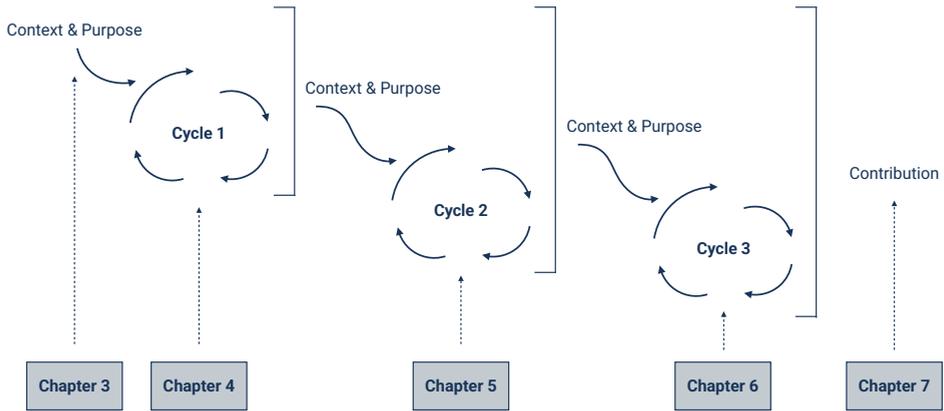
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Figure 17. The interconnectedness of the AR cycles

Qualitative research approach

Through my qualitative AR approach, I gained valuable insights by exploring the problem, the context, the organizations, and the people involved at a deeper level. This qualitative research method aligns well with my design discipline, as both approaches engage with the interpretation of human actions and recognize that insights deal with bias. Rather than viewing this as a limitation, both traditions accept that such subjectivity reflects the reality of practice. My presence in the field shaped the outcomes and enriched my understanding, while the flexibility of qualitative research allowed me to respond to developments in practice. As Miles et al. (2014, p. 11) state, *"the inherent flexibility of qualitative studies gives further confidence that we really understand what is going on".*

Furthermore, qualitative research is context-dependent (Miles et al., 2014), which enriches the findings but also poses a risk of limited generalizability beyond the studied setting. Moreover, the qualitative approach proved well-suited to the topic of multimodal integration. As reflected in research cycle 1 (Chapter 4), multimodal integration cannot be achieved through a universal solution; rather it is a design challenge that must be continuously adapted to specific modalities and travel contexts. This necessitated a flexible and responsive research approach, which qualitative methods provided. Furthermore, this study confirms that qualitative methods are effective for identifying hypotheses for further research (Malterud, 2001b). For instance, the concept of baseline modality emerged through in-depth conversations, observations and experiences, as well as by recognizing patterns in collaboration. However, since this finding is hypothesis-induced in this study, it would benefit from further exploration and validation through

follow-up qualitative studies in multiple settings, as well as mixed-methods or quantitative studies, to further develop the concept and assess its broader applicability.

Engaging with researchers who held different methodological views highlighted that qualitative research is not always well understood or equally valued. Throughout the PhD project, I often found myself justifying and defending the credibility of qualitative inquiry, including its interpretive depth, contextual sensitivity, and capacity to generate grounded insights. Navigating resistance from researchers unfamiliar with qualitative approaches taught me the importance of methodological openness. Rather than viewing methods as competing, I learned that they could serve as complementary tools with different aims. This is especially relevant in interdisciplinary research, such as this PhD work, where insights are drawn from the strengths and limitations of various methodological traditions.

AR approach

In methodological terms, the choice of an AR approach was deliberate, as it facilitated a practice-embedded and longitudinal inquiry process. However, it is important to acknowledge that other methodological strategies could have been employed, each with distinct implications. For instance, a case study design might have provided greater analytical distance and enhanced opportunities for comparison (Miles et al., 2014), but it would likely have limited the direct connections with practice that AR enabled. It is worth noting that I did study multiple comparable cases within the AR method (Chapters 4 and 5). What distinguishes my approach is the use of AR to feed insights back into the airport, aiming to learn from these cases and drive organizational change. While a survey or experimental design might have yielded more generalizable results, it would have offered less exploratory depth and contextual richness.

By opting for AR, this study prioritized depth, engagement, and organizational learning over breadth and generalizability. This choice was logical given the collaborative nature of the PhD, conducted in partnership with an airport. This close collaboration means that the findings should be interpreted as situated contributions (which may have the potential for broader application) rather than universally applicable results.

Conducting AR requires long-term engagement. Looking back, the airport's involvement was essential to the realization of this PhD; its willingness to support both the research and the interventions made the work possible. My embedded position allowed me to study multimodality and contribute to its

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advancement, as the airport shared a similar ambition. We worked hard to secure resources and stakeholder time for the intervention study in Chapter 6. As an AR researcher, maintaining a balance between action and theory can add pressure and involve more work.

AR with multiple organizations

Besides being embedded at an airport organization, my approach involved conducting AR across multiple organizations as well. This raises the question of whether the project fits within the traditional boundaries of AR, which typically occurs within a single organizational setting (Coghlan, 2019; Reason & Bradbury, 2008). This thesis addressed that challenge by building relationships with the involved actors, extending the research over time, and encouraging participants to discuss session outcomes within their organizations. However, distributing the research effort across several organizations limited the depth and intensity of involvement achievable in one organization (the airport).

At the same time, applying AR with multiple organizations added considerable value to the research when viewed through the SET lens (Vargo & Lusch, 2010, 2016) adopted in this thesis. AR introduces a practice-based perspective that foregrounds collaboration, negotiation, and intervention across organizational boundaries. This combination provided a way not only to observe but also to intervene in the ecosystem and demonstrates how AR can provide a methodological structure for fostering change.

Cases and participants connection

The research process followed a gradual transition from a first-person to a third-person practice (Coghlan, 2019; Reason & Bradbury, 2008; Reason & Torbert, 2001), reflecting how my own understanding evolved over time. Early in the study, I realized – through the framing in Chapter 3 – that including the passenger experience and adopting an ecosystems perspective would be essential to understanding multimodal air integration.

In research cycle 1 (Chapter 4), working from a first-person perspective allowed me to understand the passenger experience.

In research cycle 2 (Chapter 5), I began to expand my perspective by engaging with practitioners. These second-person insights helped me understand how professionals interpret and navigate the challenges of multimodal air travel. However, the involvement of other stakeholders – such as passengers and policymakers – was not included, which may have constrained the diversity of perspectives.

By research cycle 3 (Chapter 6), I adopted a third-person perspective, enabling me to examine the broader air&rail system and how integration unfolds (or fails) across organizations and infrastructures. Focusing on a single case provided deeper insight into the internal processes of harnessing and absorbing knowledge in practice and how these processes contribute to or hinder innovation. However, this choice to concentrate on a longitudinal, single case also restricts the generalizability of the findings to other airports or contexts (Miles et al., 2014).

Throughout this progression, my understanding of multimodality matured from an experiential, passenger-centered view to a more systemic perspective. Figure 18 illustrates the thesis's transition from first-person practice across multiple cases to third-person practice within a single case.
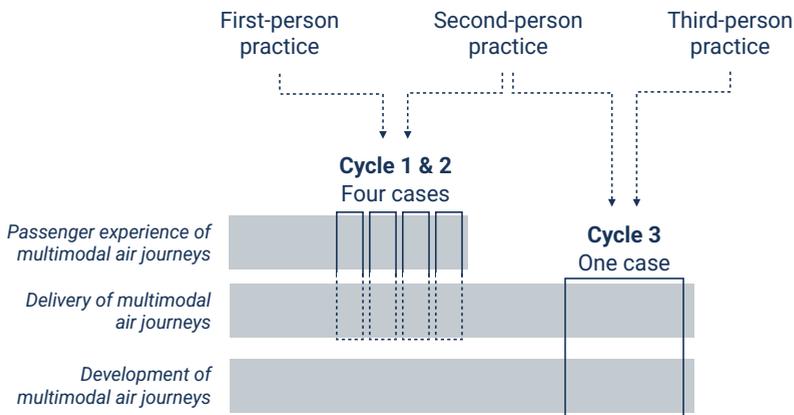

Figure 18. From first-person practice across multiple cases to third-person practice within one case

Outlier case

The air&bus case, as an outlier in this study, helped me identify elements specific to air&rail connections. I found that air&rail integration is hindered by conflicting schedules, business models, and operations. In contrast, the air&bus case proved to be more flexible and potentially a more feasible short-term solution, offering a simpler passenger experience since all bus travelers were part of an air multimodal journey.

Drawing firm conclusions about the differences between air&rail and air&bus would require multiple bus cases, as integration varies by context. Although this study included only one case, the outlier proved valuable: contrasting it with air&rail helped distinguish challenges inherent to multimodal integration from those specific to rail, thereby enriching the

overall understanding of multimodal air travel.

Design approaches

Design-based methods enriched my learning by combining structured exploration with reflections. Participatory co-creation sessions (Jones, 2018; Ramaswamy & Ozcan, 2018; Sanders & Stappers, 2008) facilitated open idea generation before organizational dynamics took over. As noted in existing literature (Jones, 2018), design co-creation is a suitable method within AR for engaging stakeholders meaningfully.

AR and design are closely connected, as both rely on multiple cycles of reflection, revision, and adjustment before arriving at an outcome (Swann, 2002). Throughout this PhD research, the Service blueprinting design approach (Bitner et al., 2008) helped clarify underlying operational mechanisms and support processes. In addition, Desmet's emotion mapping (Desmet, 2003) which I used to create the travel diaries (Visser et al., 2005), added a personal and experiential layer that surfaced otherwise hidden insights. However, design methods are also sensitive to interpretation, which is why I have applied reflection (at the end of each paper) and member checking (in Chapter 6), following Miles et al. (2014).

Reflecting on my evolving role

At the start of this research, undertaking multimodal air journeys provided me with a fresh perspective on the system, one that I could not have maintained later. These experiences offered concrete examples that proved valuable in discussions with researchers and professionals, enhancing both my understanding and credibility. However, they also shaped my viewpoint; I may have treated local experiences as representative, while multimodal air travel varies greatly worldwide.

Over time, my approach evolved from first-person reflection to third-person inquiry. What began as diary-based self-reflection expanded into dialogues and conferences that helped me frame broader questions about system integration and collaboration. In research cycle 3 (Chapter 6), my shift from facilitator to observing participant demonstrated that stepping back can be a powerful way to study the dynamics of the system under investigation.

Publishing research

Publishing in transport journals taught me that a qualitative, design-oriented approach can be challenging in a field dominated by quantitative studies. This experience showed that linking design research with transport studies is still emerging, requiring careful justification of methodological choices.

7.3   PREMISE REFLECTION

"Qualitative inquiry is personal. The researcher is the instrument of inquiry. What brings you to an inquiry matters." – Patton (2015)

During this PhD, I learned that meaning is shaped by context and values, and that my role was part of the learning process. I examined this in each AR cycle through premise reflections. This chapter more broadly reflects on how my assumptions evolved and were shaped through interaction with others.

Shifting perspective on multimodality

An assumption that shaped my learning process was my initial view of multimodal air integration as primarily an infrastructural issue, with the airport hub as the logical focus of the research. This perspective was influenced by my project's involvement with the airport organization.

Over time, my focus shifted to the multimodal air journey from departure to arrival nodes. This change was essential for understanding the complexities of multimodal air integration. I realized that the key questions were not only about adding new transport modes but also about how existing systems connect and how passengers experience multimodal connections at airports.

Sustainability motivation

At the start of this thesis (Chapter 1 and Section 2.1), I identified sustainability as a key motivation for replacing short-haul flights with air&rail and air&bus connections. However, this thesis did not examine sustainability directly and makes no claims about its effects, leaving this as an important direction for future research. I relied on existing literature, which led me to assume that integrating air&rail in certain ways could contribute to more sustainable travel solutions.

During my research, I found that replacing short-haul flights with rail links to long-haul flights is unlikely to yield major sustainability gains in the current context. As Emmerink et al. (2024) note, the environmental costs of short European flights are already better internalized than those of long-haul flights, making the latter the main target for improvement. However, I treated long-haul flights as a constant (see Chapter 3), as no new modes are expected in the near term. Working within a hub airport where short-distance rail links were already established further justified focusing on alternatives connected to long-haul travel.

What I did observe, is that integrating multimodal air journeys becomes particularly complex when sustainability is treated as a non-negotiable

requirement (Chapter 6). At the same time, I argued that even if we cannot fully resolve the sustainability challenge at present, we can still work towards enhancing the passenger experience. Doing so may encourage travelers to modify their behaviors over time, hopefully leading them to fly less.

Philosophical positioning

An assumption that shaped my learning process was my pragmatic research philosophy, which led me to explore how different actors understand and shape multimodality. If the study had been conducted from a more positivist perspective, it likely would have focused on measurable outcomes, such as average transfer times or CO_2 savings, while paying less attention to passenger experiences and practitioner perceptions.

Design background

My design background shaped my learning by directing attention to practical solutions. I learned that achieving real change often requires strategic commitment or even organizational restructuring. It is interesting to consider how the research might have evolved within a strategy team rather than an innovation team. Being embedded in the innovation team enabled a design-driven, exploratory process that emphasized experimentation and learning over predefined outcomes.

Involved people

My understanding of the topic was shaped by the people I worked with. My shift toward the masterplanning team of the airport where I was working connected me with the person who would later become the key internal representative for the project. His involvement underscored the importance of defining a project's context and purpose collaboratively (Coghlan, 2019) and reinforced my constructivist view that meaning emerges through interaction.

As noted in the premise reflection of research cycle 2 (Section 5.3.3), my assumptions about participant selection shaped the outcomes.

Researcher and participant

The findings were shaped by my dual role as researcher and participant within the airport organization, requiring reflection on the consequences of my actions (Coghlan, 2019; Coughlan & Coghlan, 2002). My presence may have initiated projects or collaborations around multimodality that might not have occurred otherwise. Additionally, my involvement may have shaped the findings, as noted in the premise reflection of research cycle 3 (Section

6.3.3), where I explain how my design of the co-creation sessions may have prevented certain tensions from surfacing.

My role as facilitator may have also affected the dynamics between participating organizations in research cycle 3. Along with the other AR researcher, I created a setting where power dynamics were less pronounced, which might have hidden tensions that would have emerged in a traditional environment.

To reduce the influence of my position and critically examine my assumptions, I sought external reflection throughout the research process. In weekly one-on-one conversations and monthly group meetings, I discussed the project's progress with my PhD supervisors, who provided different perspectives and emphasized various aspects in data interpretation. These moments of external reflection helped me maintain an outsider's perspective on the research.

Parallel projects outside the dissertation

Finally, this dissertation presents only part of the work during my four-year PhD. Besides the paper on the embedded research period within the airport (Section 3.3), I was involved in several other AR projects not included here.

Nevertheless, these projects contributed inevitably to my learning process, knowledge development, and evolving assumptions. For example, I initiated and guided the creation of a wayfinding video for air&rail passengers at the airport. This project provided insight into how service integration is achieved in multimodal air travel and highlighted the numerous departments and organizations involved, even in seemingly simple initiatives.

I also participated in a project focused on designing a physical service desk for air&rail passengers, which enhanced my understanding of the requirements for implementing such facilities, including costs, coordination, and the stakeholders involved.

Additionally, I observed an exploratory study on expanding the airport train station, aimed at improving the transfer between train and plane travel. This experience deepened my understanding of the spatial, infrastructural, and financial considerations that underlie such developments.

Throughout my PhD, I also actively disseminated the research by presenting my work and facilitating a workshop at international conferences.

Although these activities are not formally included in the dissertation, they played an important role in shaping my understanding of multimodal integration and influenced the direction and content of the studies.

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7.4   TRUSTWORTHINESS OF THE STUDY

This section evaluates the trustworthiness of the study's findings. The discussion is organized according to the criteria of credibility, dependability, confirmability, and transferability (Guba, 1981; Miles et al., 2014; Shenton, 2004).

7.4.1 Credibility

This study employed several strategies to enhance the credibility of its findings. Credibility refers to the extent to which the results provide a truthful representation of the investigated reality (Guba, 1981; Miles et al., 2014; Shenton, 2004).

Use of appropriate methods

Credibility is strengthened when researchers can justify their methodological choices (Shenton, 2004). Chapters 1 (Introduction) and 2 (Research Design) explain why a qualitative AR approach was deemed appropriate for this study. Within that approach, three methods were applied, each serving a specific purpose:

- Autoethnography, to interpret situational and experiential factors (Adams et al., 2017; Wall, 2006);
- Interviews, to obtain rich, holistic data and thick descriptions (Miles et al., 2014);
- Co-creation and participant observations, to generate insights of both scientific and practical relevance (Coghlan, 2019).

Thick descriptions

Each case context was described in detail (Geertz, 1973; Miles et al., 2014), providing readers with insights into the characteristics of the setting and units of analysis.

Prolonged engagement in the field

The total PhD research spanned four years, during which I was embedded within the airport organization. This extended engagement allowed me to observe, build relationships, and interpret findings (Guba, 1981). Furthermore, I was involved in the multi-organizational air&rail working group for 16 months, which provided deeper insight into the dynamics between organizations. Reflections were recorded in research diaries, and as internal staff became familiar with my presence, they grew more open during conversations.

Selection of informants

Instead of using random sampling, this study employed purposeful sampling, which is common in qualitative research (Miles et al., 2014; Patton, 2015) and fits AR (Coghlan, 2019). This approach allowed for the involvement of individuals with relevant experience in multimodal integration.

Voluntary participation and transparency

Each participant was approached individually and given clear information about the research's purpose. The informed consent forms explained that participation was voluntary and that participants could withdraw at any time. This approach contributes to greater honesty and openness in data collection (Shenton, 2004).

Researcher background

The role of the researcher as an embedded AR-researcher is discussed in Sections 3.2 and 6.2. At the end of each research cycle, premise reflections were used to examine how the researcher's assumptions evolved throughout the study. This is important in qualitative research, as the researcher is the primary instrument for both data collection and analysis (Patton, 2015).

Threats posed by embedded position

One potential threat to the credibility of this research was my dual role as both participant and researcher within the airport context. As noted by Coughlan & Coghlan (2002), this involvement may have compromised objectivity. The close alignment with a single organization (the airport) increased the risk of underrepresenting the perspectives of other parties, such as rail and airline operators or policymakers. To mitigate this threat, three strategies were employed:

- Reflexivity: Research journals were maintained throughout the study, and reflections were conducted after each research cycle, focusing on content, process, and assumptions. Findings were discussed with the research team to identify blind spots.
- Triangulation: Data were gathered from multiple sources (interviews, internal documents, emails, transcripts) and from various types of stakeholders (operators, infrastructure parties, policymakers). In AR cycles 1 and 3, multiple researchers were involved in data collection and analysis to reduce bias.
- Member checks (Malterud, 2001; Miles et al., 2014): The informants and practitioners were asked to review the findings and give

permission for publication. In some cases, this led to adjustments in phrasing to improve accuracy.

7.4.2   DEPENDABILITY

Dependability refers to the consistency of the research process and the extent to which others can trace, understand, and evaluate the study through critical reflection (Shenton, 2004; Miles et al., 2014). This study was highly dependent on me as the researcher, the participants and organizations involved, and the contexts in which the research was conducted. To address this dependency, the papers provided detailed descriptions of my role, the participants, and the organizational and contextual settings.

Furthermore, the research process is documented in detail in the method sections of the papers, allowing future researchers to replicate the study under similar conditions (Shenton, 2004).

7.4.3   CONFIRMABILITY

Confirmability refers to the degree to which the findings are rooted in the participants' experiences rather than influenced by the researcher's assumptions (Miles et al., 2014; Shenton, 2004). In this thesis, findings are substantiated with participant quotations presented in the papers, making the interpretations traceable to the original input. In research cycle 1, participant experiences and views were directly incorporated through the use of diary data (Patton, 2015; Shenton, 2004; Visser et al., 2005). The methods and procedures are described in detail within the individual papers, in line with the recommendations of Miles et al. (2014). Additionally, research cycle 3 emphasizes tensions between actors to portray participant perspectives with greater accuracy and depth.

Readers should note that some of the passenger experiences described also reflect my experiences, as I traveled as a passenger and drew on these autoethnographic insights in Chapter 4. To ensure transparency, I have made my assumptions explicit in the premise reflections throughout the dissertation.

7.4.4   TRANSFERABILITY

This section discusses the relevance of the dissertation's findings beyond the cases and organizational setting of the research (Greenwood & Levin, 2007; Malterud, 2001b; Miles et al., 2014). It does not aim to produce universal knowledge, as that is considered impossible for any study (Malterud, 2001b). As typical in AR, the outcomes are context-specific; however, meaningful

insights can still be derived for other contexts (Coghlan, 2019). Each paper provides a description for assessing potential transferability, and this chapter encourages readers to consider the insights from this study and to explore where similar dynamics might apply (Miles et al., 2014).

From air&rail to multimodal

This dissertation focused on multimodal air journeys, primarily air and rail travel, but I would argue that a number of insights apply more broadly, to multimodal travel that includes PT segments.

The journey structures identified in research cycle 1 (segmented and partially integrated journeys) are generalizable to other multimodal travel forms, if they involve similar transfer procedures like customs or security checks. In this regard, the findings are also relevant to other modes of transport (such as buses) that connect to HSR services with cross-border controls.

The journey integration factors (research cycle 1), and passenger experience factors (research cycle 2) are particularly relevant in the air transport system due to its complexity, but they also apply to improving transitions between different transport systems that operate under a single contract.

Research cycle 2 also demonstrated that support processes are fundamental to the development of multimodal air transport systems and require cross-sector coordination. These processes are a core component of PT systems and must be aligned to facilitate broader multimodal transport. However, certain tensions regarding station improvements and train halts are specifically relevant for air&rail journeys due to the train's dependence on infrastructure.

Research cycle 3 revealed that differences in business models create significant tension in air&rail collaboration. The transferability of this tension depends on the mode type and form of integration. For example, when a bus service is directly operated by an airline or rail operator, it integrates more easily into the existing model, minimizing potential tensions.

From airport to transit hub

Although this study primarily focuses on multimodal journeys involving air travel, the findings also offer insights that may be relevant for other types of transit hubs, such as major railway stations.

For example, the journey integration factors and passenger experience factors identified in research cycles 1 and 2 – such as ease of transfer, information provision, waiting areas, and travel assistance – are generally applicable to any hub where multiple transport modes converge.

Similarly, the underlying support processes necessary for organizing multimodal air travel are broadly relevant to the development of PT systems. These processes are not limited to airport hubs but are equally important at other nodes where cross-sector collaboration is essential.

However, it is important to acknowledge that airports possess unique institutional, commercial, and regulatory characteristics – such as customs procedures, strict boarding protocols, and international slot governance – that may limit the direct transferability of some findings.

From Europe to global

Several insights presented in this study are rooted in the European context. First, the integration of air and rail transport in Europe is significantly influenced by the presence of HSR networks, national railway operators, and cross-border regulations within the EU. These factors establish institutional frameworks for collaboration but also introduce integration frictions. For example, challenges include coordinating timetables between national rail operators and international airlines, and a lack of unified ticketing systems between rail operators due to their national history.

Additionally, the European focus on sustainability and modal shift plays a role. From a policy perspective, multimodal cooperation between air and rail is actively promoted as an alternative to short-haul flights, creating pressure on transport actors to collaborate. At the same time, new European regulations on passenger rights, communication systems, and market liberalization make the institutional environment more complex than in regions where transport systems are fully state-owned or entirely market-driven.

7.5 IMPLICATIONS FOR FUTURE RESEARCH

Based on the findings and limitations of this thesis, several avenues for future research are identified.

Research in other contexts

Most of the cases in this study took place in Europe and primarily focused on air&rail connections. Future research could explore airports outside of Europe or journeys with an intercontinental component to examine how passenger experiences and operational structures differ in other parts of the world.

Follow-up studies on modality integration at various types of transit hubs would be valuable to investigate which findings hold true or require refinement at (smaller) transit hubs.

Research with other modalities

Future research could further explore the role of cars in multimodal air travel. Although cars are currently excluded from the scope of this thesis – since they are not coordinated by operators and regulators, ticketed, and therefore fall outside the H&S model – they may become relevant in contexts where rail connections are absent, such as in rural areas. In long-distance multimodal air travel, the potential lies less in privately owned cars, as passengers transferring at an airport hub may not have access to a private vehicle, and more in shared or autonomous vehicles. I assume that this would require large-scale deployment of (autonomous) shared mobility systems beyond urban contexts, building on – and extending far beyond – existing MaaS concepts and the current state of autonomous vehicles.

Additionally, future studies could examine how emerging modes, such as electric aircraft or hyperloop, might be integrated into multimodal air journeys. The insights from this thesis may provide a foundation for understanding the conditions under which these new modes can be combined with flights in the H&S system, or in the wider mobility system. Future research could expand on this by incorporating other modalities and enhancing the development of sustainable and passenger-oriented multimodal air travel.

Diversifying participants and perspectives

Engaging a broader and more diverse group of participants – including passengers from various target groups and transport professionals with different backgrounds – can enhance the understanding of integrating

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passenger-oriented multimodal air journeys. Replicating the intervention study (research cycle 3) with other organizations, such as different rail companies and airlines, could provide an opportunity to further validate and assess the robustness of the findings.

Further exploration of concepts

Concepts identified in this study warrant deeper investigation. For example, the idea of the baseline modality emerged from input provided by professionals, and it would be valuable to investigate whether this concept resonates with passenger behavior. Additional research is needed to explore how regulations as variables can be managed and whether policy interventions or orchestrators can play a role in this process.

Design methods in transport sector

The design approaches used in this study enhanced my understanding of how the activities of harnessing and absorbing are operationalized in the practice of multimodal air transport integration. These findings suggest that design-based methods, when applied iteratively and contextually, can surface barriers and opportunities that may otherwise remain hidden. Future research could further explore how collaborative design processes can support structural alignment in other areas of the transport sector, particularly at the intersections of multiple stakeholders and modalities.

Design of MTHs

Future research on the design of MTHs could enhance our understanding of how spatial and service elements work together to facilitate seamless air transfers. This thesis demonstrates that infrastructure and services are both important and also interconnected. Design-oriented studies could build on this thesis, as well as existing work (Hernandez & Monzon, 2016; Stadler Benz & Stauffacher, 2024), by examining what an ideal MTH looks like in practice. Such research would aid in translating requirements into concrete design principles for future hubs.

Impact of digitalization

Future research could focus on the impact of digitalization and technologies that support sustainable transport. Advances in digitalization and AI are changing passenger behavior, which may lead to differences in the implementation of certain Journey Integration Factors from research cycle 1 (Chapter 4) – such as personalized support and wayfinding – through new digital applications.

Environmental impact and behavior

Future research should empirically investigate the sustainability outcomes of multimodal air travel solutions. This includes measuring CO_2 emissions, energy use, and practical modal shifts. Additionally, research could explore how an improved passenger experience in multimodal air journeys influences behavioral changes over time, such as the willingness to avoid short-haul flights or reduce overall flying frequency, building on the research of Berveling et al. (2020).

7.6 RECOMMENDATIONS FOR PRACTICE

A final quality criterion in qualitative research is understanding the study's contributions to practitioners (Miles et al., 2014). In this chapter, I provide practitioners with practical guidance for integrating multimodal air journeys at airports. These findings primarily focus on air&rail travel; however, when expressed more generally, they can also apply to other forms of multimodal air travel. I will present action-oriented recommendations for airport organizations, infrastructure managers, airlines, rail operators, other PT providers, and policy bodies.

7.6.1 RECOMMENDATIONS FOR PASSENGER-ORIENTED MULTIMODAL AIR JOURNEYS

To offer multimodal air journeys in a passenger-oriented manner, transport providers must address several key aspects:

- **Create traveler awareness.** Passengers may not be familiar with what a multimodal air journey entails. Clear communication can help prevent travelers from booking separate tickets, which would exclude them from transfer guarantees. This awareness can be enhanced by integrating information into booking systems.

- **Coordinate information provision among all involved parties.** Establish clear agreements on who provides what information to passengers and at which stage of the journey. This is especially crucial during modal transfers, as information systems of modalities converge here, and passengers require consistent communication.

- **Inform staff about multimodal air travel options.** Equip airline and railway and bus personnel with the knowledge needed to effectively support and guide passengers during their multimodal air journeys.

- **Provide a consistent quality experience across all modes of**

transport. This helps prevent any negative perceptions of one mode from overshadowing the overall experience, as explained by the baseline modality concept.

- **Provide direct rail connections to the airport.** An air&rail journey becomes viable only when the train stops directly at the airport. Without this connection, transfers can become cumbersome, increasing the likelihood of traveler drop-off.

- **Align timetables to ensure balanced transfer times.** Passengers should have enough time to transfer comfortably between travel modes without excessive waiting. Achieving this requires coordination among operators, airports and stations.

- **Ensure that internal systems and operational processes are compatible across transport providers.** Due to the complexities due to different IT systems, providers may need to implement workarounds that facilitate real-time information sharing, especially during disruptions. This coordination is important for ensuring a reliable multimodal experience.

- **Collaborate with baggage services to simplify luggage handling in multimodal air transport.** Door-to-door baggage pick-up and delivery by baggage companies can reduce costs and eliminate the need for infrastructure changes that require baggage check-in at the train station. Outsourcing baggage services to third-party providers simplifies this baggage process; however, an agreement on cost allocation is necessary. Currently, these expenses are mainly covered by travelers, which could be a consideration for future arrangements. Additionally, it is crucial to ensure that sufficient luggage storage is available in train coaches, allowing passengers to keep an eye on their belongings.

- **Explore brand-integrated partnerships.** Airlines should consider partnerships with transport providers that operate under their brand or service concept. This approach allows for a fully managed journey within the airline's business model, eliminating complications from systemic mismatches between travel modes. For short distances, a high-quality bus service can serve as an effective alternative when rail is not a viable option.

Additionally, several recommendations involve actions that airport and transit hub organizations can implement:

- **Develop clear signage for multimodal air travelers.** Provide

visual and textual cues specifically designed for passengers transferring between train, bus, and air transport. Signage should benefit from directly naming the type of travel (such as air&rail) and should reduce confusion for regular airport users.

- **Educate airport and station staff in the fundamentals of air&rail travel.** Ensure that personnel are equipped to assist passengers with transfer-related questions effectively.

- **Minimize transfer times through infrastructure design.** Reduce walking distances between modes of transport as much as possible. Where this is physically unfeasible, install moving walkways or people movers to enhance flow.

- **Offer services such as special baggage handling, fast-track security, and clear information provision.** Treat multimodal air travelers as transfer passengers and align facilities accordingly in coordination with transport providers.

- **Optimize processes such as security screening and passport control.** While this may seem like a general airport concern, a streamlined flow is particularly crucial for ensuring feasible travel times within multimodal itineraries.

- **Provide comfortable waiting areas with seating, food, and beverages**. While such amenities are standard in airport terminals, they are often lacking at train stations, where air&rail travelers may face extended waiting times.

7.6.2 POLICY RECOMMENDATIONS

The following recommendations focus on actions that national or European governments should undertake:

- **Invest in a reliable rail system to ensure punctuality and sufficient capacity.** A dependable network will encourage more passengers to consider rail as an alternative to short-haul flights. When passengers switch from air to rail transport because they find it more attractive, complex interventions such as the reduction of airport slots become less important.

- **Support the development of air&rail travel through targeted subsidies or financial incentives.** This can lower the barriers to collaboration between transport providers and enable viable services during the initial implementation phase.

- **Establish a European governing body.** This body should structurally drive the development of multimodal air mobility, with

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a mandate to harmonize and renew policy and regulations across transport modes, countries, and sectors.

- **Act as a facilitator or appoint an independent orchestrator to resolve stalled negotiations.** This is particularly important in strategic, financial, or operational discussions where conflicting interests hinder effective decision-making.

- **Support the formation of alliances between airlines and rail operators to align timetables.** Focus on the key corridors for air&rail travel to airports with high volumes of early and late intercontinental flights. Promote shared business models in which revenues and risks are distributed fairly, ensuring mutual benefit from well-integrated services.

7.6.3 RECOMMENDATIONS FOR COLLABORATION BETWEEN (MULTIMODAL) STAKEHOLDERS

In addition to the above-mentioned recommendations, successful multimodal air integration requires effective collaboration among stakeholders. The following recommendations outline how organizations can enhance this collaboration through their working methods and internal processes:

- **Promote experiential learning by having professionals from various sectors undertake a multimodal air journey.** This hands-on participation has proven valuable in this thesis, fostering a shared understanding of the multimodal air passenger experience and building mutual trust among stakeholders.

- **Facilitate internal anchoring and long-term learning.** Instead of relying on a single mandate, organizations can build momentum through repeated co-creation cycles that progressively integrate knowledge. By institutionalizing follow-up actions, organizations reduce the need to repeatedly harness and absorb knowledge, while increasing the likelihood that emerging ideas develop into widely supported, actionable strategies.

- **Strive for continuity in stakeholder participation throughout collaborative processes.** Whenever possible, involve the same individuals in co-creation and design activities. Frequent changes in participants can result in repeated discussions and hinder progress as multimodal air integration is a complex task. When changes are unavoidable, ensure a proper handover and embed knowledge within the organization between sessions.

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CHAPTER 8. CONCLUSIONS

The aim of this dissertation was to contribute to the integration of different transport modes at airport hubs, with a focus on designing passenger-oriented multimodal air journeys. It offers contributions to transport studies, SET, and open innovation (as discussed in Section 7.1). The findings are directed to both researchers and mobility professionals involved in developing such multimodal air journeys.

In the early phase of the research, I identified existing gaps to understand why multimodal integration at airports remains limited. In Chapter 3, I demonstrated that the concept of the MTH often remains abstract in practice, highlighting the necessity including multiple organizations to address multimodality at airports effectively. It became clear that both in practice and in literature, a shared understanding of what constitutes a good multimodal passenger experience was needed. Ongoing digitalization highlights the importance of prioritizing traveler needs within multimodality. Additionally, I found a lack of approaches for managing and innovating modal integration at airports. Together, these insights formed the basis for three guiding principles that shaped this research:

1. A continued focus on understanding the passenger needs within a multimodal air journey.

2. An ecosystem perspective to understand the complexity of multimodal integration at both the journey delivery and development levels.

3. A pursuit of recommendations regarding harnessing and absorbing multimodality to support the design of multimodal air journeys at airports.

These principles guided the research and present a picture of how progress can be made toward the integration of multimodal air journeys.

8.1   A 'GOOD' MULTIMODAL PASSENGER EXPERIENCE

This thesis enhances the understanding of the passenger perspective in multimodal contexts by identifying determinants of the multimodal air travel experience. It emphasizes the importance of individual-level factors such as guidance (including journey explanation and preparation, as well as personalized and proactive assistance), wayfinding, ease of transfer (including the proximity of transport modes and facilities, multimodal transfer services, balanced transfer times, and waiting environments), and comfort (both during transfers and throughout travel legs). Additionally, the thesis identified operational factors such as booking integration, disruption

management, and baggage processes. I discovered that these operational factors were mainly managed in silos across different transport modes. The research indicates that the passenger experience is influenced by the seamless connections between travel phases, and it highlights the importance of including the pre-phase (booking and preparation) in the overall travel experience. This underscores the need to design multimodal air journeys as integrated, end-to-end experiences.

8.2   INFLUENCE ON EFFECTIVE DELIVERY OF PASSENGER-ORIENTED MULTIMODAL AIR JOURNEY

This thesis also provides insight into integration challenges by linking practitioner perspectives to underlying support processes. The research indicates that delivering a passenger-oriented multimodal air journey requires, besides infrastructure and service integration, attention to support processes such as IT, scheduling, operations, commercial strategies, inter-organizational collaboration, and overall strategy. Additionally, market dynamics and regulations – which is beyond the direct control of operators and hub owners – play a role in delivering passenger-oriented multimodal air journeys.

Chapter 5 revealed that support processes and external factors converge in delivery mechanisms (such as scheduling subnetworks, competitive airline industry, airport procedures), illustrating their impact on multimodal air travel delivery. It is essential to establish regulatory frameworks and promote cross-system collaboration to effectively address these mechanisms.

8.3   TENSIONS IN INTEGRATING MULTIMODAL AIR JOURNEYS

Six system-level tensions were identified among stakeholders during the integration of air&rail journeys: no control over airport slots, conflicting priorities in train stop allocation, misaligned scheduling, different business models, fragmented booking systems and different passenger experiences. Furthermore, three collaboration-level tensions were observed: limited mutual understanding, embedding systems thinking in organizational processes, and different organizational momentum. The applied AR intervention not only generated practice-based insights but also demonstrated potential as a method for knowledge production in transport research.

8.4   KEY INSIGHTS ABOUT MULTIMODAL AIR TRAVEL INTEGRATION

Finally, the main learning of the thesis can be synthesized into one message, supported by five underlying conclusions:

Integrating transport modalities with aviation requires a fundamental redefinition of the airport as an MTH (1), where multi-level boundaries (2) and passenger experience and organizational collaboration (3) converge as interconnected focal points. Through orchestration (4) and viewing regulatory frameworks as adaptive (5), successful multimodal air transport can be created. This transformation emerges from reconfiguring existing elements through collaboration, design approaches, and iterative learning.

The five core conclusions are briefly described below and provide direction for the further integration of multimodal air journeys at airports. These insights tell us where designers, practitioners and researchers should focus on to enable that multiple modes of transportation at airports connect.

1) The airport as MTH

Although the airport is not a transport provider, it serves as a central hub where infrastructure, services, organizations, and passengers converge, and plays a crucial role in the development of multimodal transport. Transfers are often the most vulnerable and stressful points in a journey, especially when different modes of transport are involved, as passengers must actively switch between two different transport systems. Since the quality of transfers is a decisive factor in the success of multimodal air travel, airports must adopt a more integrated role that ensures seamless connections and facilitates smooth passenger transitions between modes.

Airports must evolve from being purely aviation-focused infrastructures to active, facilitating MTHs. This means they should invest in physical infrastructure for other modalities (such as stations, waiting areas, and hub design) and align the organizational and operational processes between different transport systems. They need to coordinate information and service integration, allowing travelers to transition seamlessly between transport modes (Figure 19). While airlines and rail operators often lead in developing multimodality, this thesis discusses how airports can gain a strategic advantage from multimodal collaboration by expanding their reach and reducing congestion.

This thesis argues that airport hubs should actively evolve into genuinely

passenger-oriented MTHs: strategic entities that enable integration across different organizational and operational processes, transport systems and services, and diverse stakeholders.
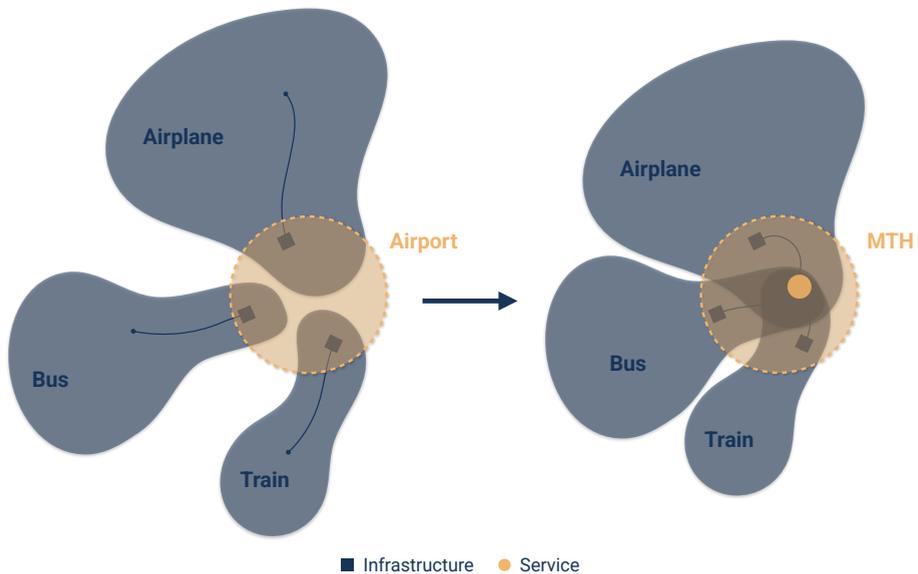

Figure 19. On the left the airport as the physical place where transport modalities connect, on the right an MTH that integrates whole transport systems including services

2) Multi-level boundaries

Boundaries are a recurring theme in this dissertation, influencing how multimodal air travel is integrated across different levels. Initially, I described transport systems as composed of subsystems based on modes of transport. However, the research revealed that the boundaries experienced by passengers are not solely defined by transport modalities. Boundaries also exist in inter-organizational collaboration, intra-modality systems, national systems, and regulatory frameworks (Figure 20).

For instance, the rail system contains internal boundaries between national networks, each with its own rules, infrastructure, and procedures. Transitions also occur between train operators; a delay with one provider can cause a passenger to miss a connecting train operated by another company, further fragmenting the travel experience.

These multi-level boundaries highlight the complexity of collaboration within and across transport systems. These boundaries intertwine and coexist, influencing one another in various ways and emphasizing their multi-faceted

nature. According to Meadows (2008), it is at the boundaries that the most significant difficulties occur, but also where creative potential can be found. To progress from partial reconfiguration to genuine transition, stakeholders must recognize and address these multi-level boundaries. Therefore, this thesis advocates for adopting a whole-system mindset in which transport subsystems are reshaped and interconnected through shared purposes, coordinated processes, and collaboration across organizational and travel modalities.
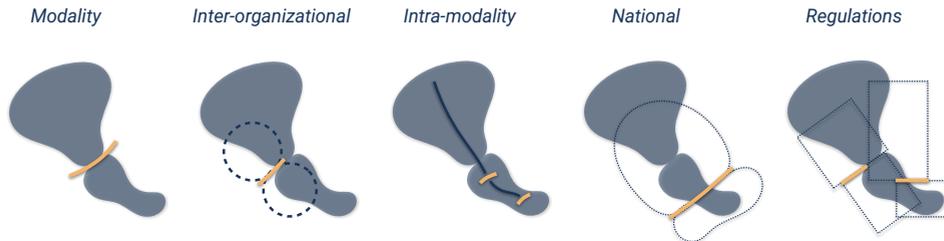
Figure 20. The intersection of system boundaries at the airport

3) Baseline modality in passenger experience and organizational collaboration

While multimodal air travel in theory focuses on the journey from departure node to arrival node, in practice, the mode of transport still plays a central role. This thesis captures this through the concept of baseline modality. According to practitioners, passengers tend to base their expectations on the dominant mode within the journey, which, in the case of multimodal air journeys, is almost always the flight segment (Figure 21).

This is partly because passengers may be unaware that they have booked a multimodal air journey, as the ticket is typically offered through an airline. Even when they are aware, their expectations are shaped by the booking channel, which directs their focus toward the air travel experience.

This concept was primarily found to influence these dimensions of the journey: 1) How passengers perceive service levels, such as catering and baggage handling; 2) How they evaluate disruption management, often expecting airline-level response standards; 3) How travel and waiting times are interpreted, which are frequently compared to the efficiency of traditional air-to-air transfers by both passengers and professionals.
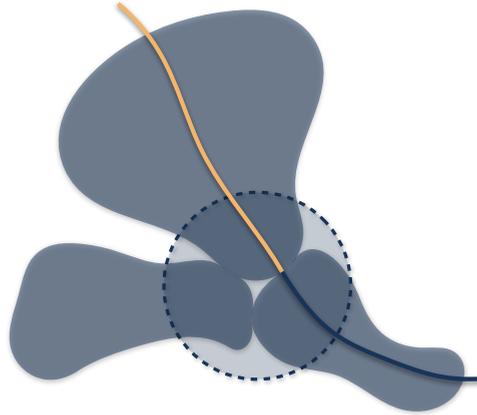
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Figure 21. The baseline modality that shapes the multimodal passenger experience

Although multimodal air journeys formally meet the established definition of multimodality in this thesis – characterized by a single contract and one responsible party – airlines often play a dominant role in the development (Figure 22). The rail segment is frequently treated as an extension of the air journey, shaped by aviation standards. This dominance influences cooperation among transport operators, as the baseline modality, typically the flight segment, sets expectations and guides how they collaborate to develop multimodal air journeys. Although this undermines collaboration with other actors on an equal footing, it benefits passengers on some parts, as it results in the passengers being offered disruption management.

Moreover, this raises the question of whether such developments truly represent modal integration or rather an expansion of the air transport system into the rail domain. This research argues that the specific form of multimodality, whether led by an airline or developed jointly by multiple operators, is less important than the ultimate goal of delivering a seamless passenger journey. However, without collaboration on equal footing, the dominant modality is likely to continue shaping the passenger experience. The findings indicate that actors pursue multimodality from their own system perspectives, focusing on the needs of their own passengers rather than the emerging multimodal traveler. If actors do not consider the multimodal passenger experience in the development process, it is likely that multimodal development will remain fragmented and organization-centric.
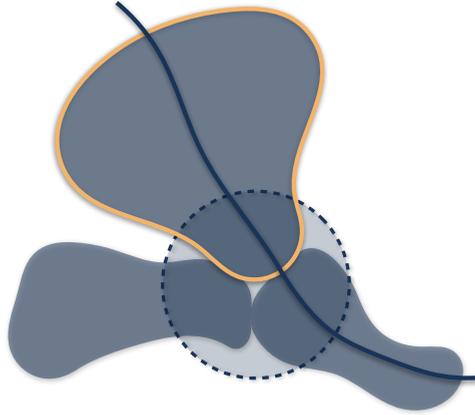
Figure 22. The baseline modality that influences multimodal collaboration

4) Orchestrating multimodality

Successful integration requires an orchestrating actor, a party that can coordinate collaboration and intervene as needed with decision-making power (Figure 23). This type of orchestrator is necessary for several reasons. First, to keep the passenger experience central. Second, to balance interests so that no party is structurally disadvantaged. This thesis shows stakeholders often try to maintain their power, leading to resistance. Third, orchestration drives change and should support decision-making that benefits the whole ecosystem. This coordination should not be limited to the national level; a European or global approach is necessary to establish shared standards and ambitions for multimodal air travel.
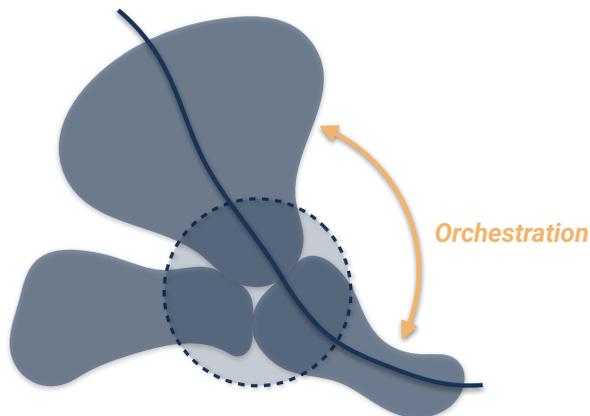

Figure 23. An orchestrator that drives multimodal decision-making and integration

5) Regulatory frameworks as variables

Real system change requires a new perspective on regulation (Figure 24). A key lesson from this research is that laws and rules should not be viewed as fixed constraints, but as variables that can be adjusted to enable innovation. Strict regulations in the aviation sector limit experimentation with new transport modes, and existing legal frameworks hinder the integration of multimodal air travel in pursuit of more sustainable mobility goals.

This underscores the notion that without the flexibility to revise existing rules, integration will stagnate. An innovative mindset, supported by design approaches, can advance multimodal air integration. To promote this, it is essential to review and adapt existing regulations to benefit multimodal transport.
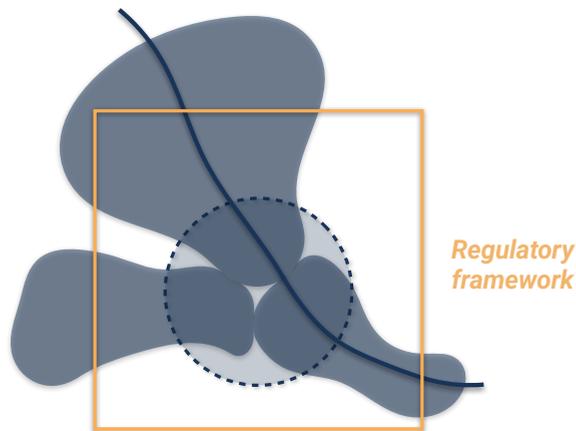
Regulatory framework

Figure 24. Regulatory and policy frameworks that enable multimodal air transport development

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Shopping at A

CHAPTER 9. TRAVEL REFLECTION

I would like to finish this dissertation with a personal reflection on (multimodal) travel, based on the experiences I have gained over the past four years. As I described in the discussion chapter, this research began with a first-person practice and gradually shifted to a third-person perspective. To conclude, I want to return to that first-person practice. I hope that by doing so, I can assist both myself and you, the reader, in making travel choices that lead to more passenger-oriented journeys in the future, whether those journeys are multimodal or not. Honestly, I also hope that this dissertation contributes, even in a small way, to making travel with less CO2 emissions a bit more accessible.

One of the reasons I felt this chapter was necessary is because I realized that I have flown more during my PhD than I did before I started. At the same time, I have become increasingly aware of the environmental impact of air travel. In the introduction, I mentioned that 10% of the global population is responsible for half of all CO_2 emissions from air travel. That statistic stayed with me, especially as I began to wonder whether I had now become part of that 10%.

My increased travel was largely due to the fieldwork I conducted during my PhD. The purpose of these journeys was to learn as much as possible to generate insights that could help improve these types of travel. I also traveled to academic conferences and to visit one of my supervisors in Sweden. The more I traveled, the more natural it became. I started to understand the systems better, including those in other countries, and I began to navigate them with increasing ease.

Simultaneously, I noticed that the ease of travel grew steadily also in my personal life. My phone became my most important travel companion. I remember standing in Paris once, overwhelmed by unclear signage, long queues at the ticket machines, and the pressure to be somewhere on time. Within minutes, I downloaded an app, bought a metro ticket and found my way. Digitalization has become embedded in my travel behavior as well.

Where possible, I started taking the train more often. I no longer focused on the distance in kilometers but rather on how easy it was to reach a destination. If a journey involved a maximum of one or two transfers, I was usually convinced. The duration mattered less to me as long as I could open my laptop and work along the way. The longest train journey I took was nearly 2,000 kilometers, and it was a pleasant experience. In contrast, one of my most frequent international train trips was just 400 kilometers, but far less enjoyable.

Travel is complex and never entirely predictable. Through both my personal

experiences and this research, I have learned that as a traveler you can make choices that enhance your journey. You may not be able to control every aspect of your trip, but you can influence how enjoyable, understandable, and perhaps even sustainable it will be. On the next pages, I share a few tips that may help you plan your own travel experience more thoughtfully.

General travel tips

Consider intermodality[i] spread over outbound and inbound journey

This approach allows you, for example, to take a multi-day train trip to your destination and fly back. It enables you to cut your CO_2 emissions almost in half while enjoying more of the journey. By taking your time (perhaps with one or two overnight stays), you experience far less stress and get to enjoy the trip more.

Stay informed during your journey.

Remember that stations and airports do not have your contact details, so it is up to you to check their apps and websites. Make sure your phone is charged, and you simcard allows for data roaming.

Always apply for compensation in case of delays or cancellations.

You can request this from the carrier or ticket vendor for trains, buses, or flights. If you booked directly with the operator, the process is usually more straightforward. Check your rights on the European Commission website[ii].

Train travel

Always check the terms and conditions of your train ticket.

In Germany, you are generally permitted to take the next available train in the event of a delay. Since seat reservations are not always included with the ticket, switching to a different route is relatively easy[iii]. In other countries or with different operators, tickets often include seat reservations, making it more challenging to continue your journey on an alternate train.

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i   As a reminder, this thesis follows the definition of intermodal transport as a journey that involves multiple transport modes without integration at the service level between those modes .

ii   https://europa.eu/youreurope/citizens/travel/passenger-rights/index_en.htm

iii   https://int.bahn.de/en/booking-information/passenger-rights/legal-regulations

Plan your train transfers wisely when traveling internationally.

Allow at least 30 minutes for transfers and schedule them early in your journey. The later the transfers occur in the travel itinerary, the more transfer time I tend to schedule. Booking websites sometimes suggest unrealistic connections, so consider planning your trip manually. Be aware that some websites schedule transfers between different stations; in such cases you'll need more than 30 minutes. Also note that train punctuality varies by country (for example, Germany and France differ significantly).

Preferably book your journey on the operator's website, not through a booking platform

This will keep you up to date with information and travel updates and makes rebooking or claiming a refund much easier.

Book a first-class seat, preferably one on its own.

It is often only slightly more expensive and offers peace, space, and comfort, making it ideal if you want to work. When selecting your seat, you can often see which direction the train is traveling, which is helpful if you're sensitive to motion or want to enjoy the view.

Flying

Always book a free time slot for security at Schiphol.

This helps you avoid unnecessary waiting and can be reserved via the Schiphol app or website.

Download the airport app

Download not only the airline app, but also the apps of the airports you'll be visiting. Familiarizing yourself with the airport layout and available services before departure or arrival can make your journey significantly smoother. Good preparation helps manage expectations, and most airports offer all essential information in advance.

Traveling with hand luggage is fast and flexible, but checked baggage can be more convenient.

At Schiphol, liquids can remain in your bag during security screening, but most other airports still require them to be removed. Checked baggage may take longer to retrieve, but using an AirTag allows you to track your suitcase, providing peace of mind and valuable information in case it gets lost.

9

BIBLIOGRAPHY

This list provides a complete overview of all references cited in this dissertation, including sources referenced within the papers.

Abenoza, R. F., Cats, O., & Susilo, Y. O. (2019). How does travel satisfaction sum up? An exploratory analysis in decomposing the door-to-door experience for multimodal trips. *Transportation, 46*(5), 1615–1642. https://doi.org/10.1007/s11116-018-9860-0

Adams, T. E., Ellis, C., & Jones, S. H. (2017). *Autoethnography.* In J. Matthes, C. S. Davis, & R. F. Potter (Eds.), The International Encyclopedia of Communication Research Methods (1st ed., pp. 1–11). Wiley. https://doi.org/10.1002/9781118901731.iecrm0011

Airports Council International Europe. (2022). *Airport industry connectivity report 2022.* https://www.aci-europe.org/downloads/resources/CONNECTIVITY%20REPORT%20 2022.pdf

Aleta, A., Meloni, S., & Moreno, Y. (2017). A multilayer perspective for the analysis of urban transportation systems. *Scientific Reports, 7*(1), 44359. https://doi.org/10.1038/ srep44359

Allard, R. F., & Moura, F. (2016). The Incorporation of Passenger Connectivity and Intermodal Considerations in Intercity Transport Planning. *Transport Reviews, 36*(2), 251–277. https://doi.org/10.1080/01441647.2015.1059379

Allen, J., Bellizzi, M. G., Eboli, L., Forciniti, C., & Mazzulla, G. (2020). Latent factors on the assessment of service quality in an Italian peripheral airport. *Transportation Research Procedia, 47*, 91–98. https://doi.org/10.1016/j.trpro.2020.03.083

Alyavina, E., Nikitas, A., & Njoya, E. T. (2022). Mobility as a service (MaaS): A thematic map of challenges and opportunities. R*esearch in Transportation Business & Management, 43*, 100783. https://doi.org/10.1016/j.rtbm.2022.100783

Anderson, K., Blanchard, S. D., Cheah, D., & Levitt, D. (2017). Incorporating equity and resiliency in municipal transportation planning: case study of mobility hubs in Oakland, California. *Transportation Research Record: Journal of the Transportation Research Board, 2653*(1), 65–74. https://doi.org/10.3141/2653-08

Ansell, C., & Gash, A. (2008). Collaborative Governance in Theory and Practice. *Journal of Public Administration Research and Theory, 18*(4), 543–571. https://doi.org/10.1093/ jopart/mum032

Ansell, C., & Torfing, J. (2021). Co-creation: The new kid on the block in public governance. *Policy & Politics, 49*(2), 211–230. https://doi.org/10.1332/030557321X16115951196045

Antwi, C. O., Fan, C., Ihnatushchenko, N., Aboagye, M. O., & Xu, H. (2020). Does the nature of airport terminal service activities matter? Processing and non-processing service quality, passenger affective image and satisfaction. *Journal of Air Transport Management, 89*, 101869. https://doi.org/10.1016/j.jairtraman.2020.101869

Araghi, Y., van Oort, N., & Hoogendoorn, S. (2022). Passengers' preferences for using emerging modes as first/last mile transport to and from a multimodal hub case study Delft Campus railway station. *case Studies on Transport Policy, 10*(1), 300-314. https://doi. org/10.1016/j.cstp.2021.12.011

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19–32. https://doi. org/10.1080/1364557032000119616

As'ad, N., Patrício, L., Koskela-Huotari, K., & Edvardsson, B. (2024). Understanding service ecosystem dynamics: A typology. *Journal of Service Management, 35*(6), 159–184. https://doi.org/10.1108/JOSM-07-2023-0322

Avogadro, N., Pels, E., & Redondi, R. (2023). Policy impacts on the propensity to travel by

HSR in the Amsterdam–London market. S*ocio-Economic Planning Sciences, 87*, 101585. https://doi.org/10.1016/j.seps.2023.101585

Babić, D., Colovic, A., Dožić, S., Kalić, M., Simić, T. K., Kukić, K., Ottomanelli, M., & Pilone, S. G. (2024). How to build a more sustainable passenger air transport system: Multimodal experience. *Transportation Engineering, 16*, 100245. https://doi.org/10.1016/j.treng.2024.100245

Babić, D., Kalić, M., Janić, M., Dožić, S., & Kukić, K. (2022). Integrated door-to-door transport services for air passengers: from intermodality to multimodality. *Sustainability, 14*(11), 6503. https://doi.org/10.3390/su14116503

Bagamanova, M., Mujica Mota, M., & Di Vito, V. (2022). Exploring the efficiency of future multimodal networks: a door-to-door case in Europe. *Sustainability, 14*(20), 13621. https://doi.org/10.3390/su142013621

Bairras, P., & Ardaiz, I. A. (2025). The slow and difficult implementation of high-speed rail interoperability in Europe: The case of the Atlantic Corridor. *Transportation Research Procedia, 82*, 2546–2558. https://doi.org/10.1016/j.trpro.2024.12.204

Banoun, A., Dufour, L., & Andiappan, M. (2016). Evolution of a service ecosystem: Longitudinal evidence from multiple shared services centers based on the economies of worth framework. *Journal of Business Research, 69*(8), 2990–2998. https://doi.org/10.1016/j.jbusres.2016.02.032

Bartunek, J.M. & Louis, M.R. (1996). *Insider/Outsider Team Research*, Sage.

Baumeister, S. (2019). Replacing short-haul flights with land-based transportation modes to reduce greenhouse gas emissions: The case of Finland. *Journal of Cleaner Production, 225*, 262–269. https://doi.org/10.1016/j.jclepro.2019.03.329

Bell, D. (2019). Intermodal mobility hubs and user needs. *Social Sciences, 8*(2), 65. https://doi.org/10.3390/socsci8020065

Benz, P. E. S. (2024). *Transforming railway stations and their surroundings into multimodal transportation hubs – bridging the gap through co-creation* [Doctoral dissertation, ETH Zürich].

Bergman, N. (2017). Stories of the future: Personal mobility innovation in the United Kingdom. *Energy research & social science, 31*, 184-193.

Berveling, J., Zijlstra, T., Knoope, M., & Huibregtse, O. (2020). *Op de groene tour. Kennisinstituut voor Mobiliteitsbeleid.*

Bitner, M. J., Ostrom, A. L., & Morgan, F. N. (2008). Service Blueprinting: A practical technique for service innovation. *California Management Review, 50*(3), 66–94. https://doi.org/10.2307/41166446

Blok, M., Vink, P., & Kamp, I. (2007). Comfortable flying: Comfort in aircraft interiors seen through the eyes of the passengers (in Dutch). *Tijdschrift Voor Ergonomie, 32*(4), 4–11.

Braun, V., & Clarke, V. (2006). Using Thematic Analysis in Psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), *APA handbook of research methods in psychology, Vol 2: Research designs: Quantitative, qualitative, neuropsychological, and biological.* (pp. 57–71). American Psychological Association. https://doi.org/10.1037/13620-004

Bremner, C., & Rodgers, P. (2013). Design without discipline. *Design Issues, 29*(3), 4–13. https://doi.org/10.1162/DESI_a_00217

Broman, E., & Eliasson, J. (2019). Welfare effects of open access competition on railway markets. *Transportation Research Part A: Policy and Practice, 129*, 72–91. https://doi.org/10.1016/j.tra.2019.07.005

Butler, L., Yigitcanlar, T., & Paz, A. (2020). Smart urban mobility innovations: a comprehensive review and evaluation. *IEEE Access, 8*, 196034–196049. https://doi.org/10.1109/ACCESS.2020.3034596

Calzada-Infante, L., Adenso-Díaz, B., & Carbajal, S. G. (2020). Analysis of the European international railway network and passenger transfers. *Chaos, Solitons & Fractals, 141*, 110357.

Camacho, T., Foth, M., Rakotonirainy, A., Rittenbruch, M., & Bunker, J. (2016). The role of passenger-centric innovation in the future of public transport. *Public Transport, 8*(3), 453–475. https://doi.org/10.1007/s12469-016-0148-5

Campos, J., & De Rus, G. (2009). Some stylized facts about high-speed rail: A review of HSR experiences around the world. *Transport Policy, 16*(1), 19–28. https://doi.org/10.1016/j.tranpol.2009.02.008

Canale, A., Tesoriere, G., & Campisi, T. (2019). The MAAS development as a mobility solution based on the individual needs of transport users. *Proceedings of the international conference of computational methods in sciences and engineering 2019* (ICCMSE-2019). https://doi.org/10.1063/1.5138073

Caridà, A., Colurcio, M., Edvardsson, B., & Pastore, A. (2022). Creating harmony through a plethora of interests, resources and actors: The challenging task of orchestrating the service ecosystem. *Journal of Service Theory and Practice, 32*(4), 477–504. https://doi.org/10.1108/JSTP-06-2021-0110

Cascajo, R., Lopez, E., Herrero, F., & Monzon, A. (2019). User perception of transfers in multimodal urban trips: A qualitative study. *International Journal of Sustainable Transportation, 13*(6), 393–406. https://doi.org/10.1080/15568318.2018.1476632

Ceder, A. (2021). Urban mobility and public transport: Future perspectives and review. *International Journal of Urban Sciences, 25*(4), 455–479. https://doi.org/10.1080/12265934.2020.1799846

Chakrabarti, A. (Ed.). (2019). *Research into design for a connected world: Proceedings of ICoRD 2019 Volume 2* (Vol. 135). Springer Singapore. https://doi.org/10.1007/978-981-13-5977-4

Chauhan, V., Gupta, A., & Parida, M. (2021). Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction of public transport. *Transport Policy, 102*, 47–60. https://doi.org/10.1016/j.tranpol.2021.01.004

Chesbrough, H. W. (2003). *Open innovation: The new imperative for creating and profiting from technology.* Harvard Business School Press.

Chesbrough, H. W., Vanhaverbeke, W., & West, J. (Eds.). (2006). *Open innovation: Researching a new paradigm.* Oxford University Press.

Chesbrough, H. W. (2017). The future of open innovation: The future of open innovation is more extensive, more collaborative, and more engaged with a wider variety of participants. *Research-Technology Management, 60*(1), 35–38. https://doi.org/10.1080/08956308.2017.1255054

Chesbrough, H. (2020). *Open innovation results: Going beyond the hype & getting down to business.* Oxford University Press.

Chesbrough, H. W., & Bogers, M. (2013). *Explicating open innovation: Clarifying an emerging paradigm for understanding innovation.* In H. W. Chesbrough, W. Vanhaverbeke, & J. West (Eds.), New frontiers in open innovation (pp. 3–28). Oxford University Press.

Chiambaretto, P., & Decker, C. (2012). Air–rail intermodal agreements: Balancing the competition and environmental effects. *Journal of Air Transport Management, 23*, 36–40. https://doi.org/10.1016/j.jairtraman.2012.01.012

Christensen Clayton, M. (1997). T*he innovator's dilemma: When new technologies cause great firms to fail.* Harvard Business School Press, Boston.

Chwiłkowska-Kubala, A., & Huderek-Glapska, S. (2020). The sources of barriers to airport development: A dynamic capabilities perspective. *Research in Transportation Business & Management, 3*7, 100587. https://doi.org/10.1016/j.rtbm.2020.100587

Coghlan, D. (2019). *Doing Action Research in Your Own Organization.* SAGE.

Cohen, A. P., Shaheen, S. A., & Farrar, E. M. (2021). Urban air mobility: History, ecosystem, market potential, and challenges. *IEEE Transactions on Intelligent Transportation Systems, 22*(9), 6074-6087.

Cooper, R. G., Easingwood, C. J., Edgett, S., Kleinschmidt, E. J., & Storey, C. (1994). What Distinguishes the Top Performing New Products in Financial Services. *Journal of Product Innovation Management, 11*(4), 281–299. https://doi.org/10.1111/1540-5885.1140281

Cornish, F., & Gillespie, A. (2009). A Pragmatist Approach to the Problem of Knowledge in Health Psychology. *Journal of Health Psychology, 14*(6), 800–809. https://doi.org/10.1177/1359105309338974

Corwin, S., Zarif, R., Berdichevskiy, A., & Pankratz, D. (2020). *The futures of mobility after COVID-19*. Deloitte Insights.

Coughlan, P., & Coghlan, D. (2002). Action research for operations management. *International Journal of Operations & Production Management, 22*(2), 220–240. https://doi.org/10.1108/01443570210417515

Council Regulation on Common Rules for the Allocation of Slots at Community Airports (No. Regulation 95/93). (1993). European Council.

Desmet, P. (2003). A Multilayered Model of Product Emotions. *The Design Journal, 6*(2), 4–13. https://doi.org/10.2752/146069203789355480

De Ruijter, P. *Scenario based strategy: Navigate the future.* (Routledge, 2014).

Detti, A., Tropea, G., Blefari Melazzi, N., Kjenstad, D., Bach, L., Christiansen, I., & Lisi, F. (2019). Federation and Orchestration: A Scalable Solution for EU Multimodal Travel Information Services. *Sustainability, 11*(7), 1888. https://doi.org/10.3390/su11071888

Dick, B. (2002). Postgraduate programs using action research. *The Learning Organization, 9*(4), 159–170. https://doi.org/10.1108/09696470210428886

Docherty, I., Marsden, G., & Anable, J. (2018). The governance of smart mobility. *Transportation Research Part A: Policy and Practice, 115*, 114–125. https://doi.org/10.1016/j.tra.2017.09.012

Donners, B. (2018). *Vergelijk vliegen met treinreizen voor korte afstanden: en hoe we vaker voor de trein kunnen kiezen.* Royal HaskoningDHV.

Doomernik, J. E. (2015). Performance and Efficiency of High-speed Rail Systems. *Transportation Research Procedia, 8*, 136–144. https://doi.org/10.1016/j.trpro.2015.06.049

Dooms, M., Verbeke, A., & Haezendonck, E. (2013). Stakeholder management and path dependence in large-scale transport infrastructure development: The port of Antwerp case (1960–2010). *Journal of Transport Geography, 27*, 14–25. https://doi.org/10.1016/j.jtrangeo.2012.06.002

Döringer, S. (2021). 'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge. *International Journal of Social Research Methodology, 24*(3), 265–278. https://doi.org/10.1080/13645579.2020.1766777

d.school. (2010). *An Introduction to Design Thinking: Process Guide.* Institute of Design at Stanford.

Durand, A., & Romijn, G. (2023). Substitutiemogelijkheden van luchtvaart naar spoor in 2030 en 2040. Kennisinstituut voor Mobiliteitsbeleid.

Eboli, L., & Mazzulla, G. (2015). Relationships between rail passengers' satisfaction and service quality: A framework for identifying key service factors. *Public Transport, 7*(2), 185–201. https://doi.org/10.1007/s12469-014-0096-x

Eccles, D. W., & Arsal, G. (2017). The think aloud method: What is it and how do I use it? *Qualitative Research in Sport, Exercise and Health, 9*(4), 514–531. https://doi.org/10.1080/2159676X.2017.1331501

Eckhardt, J., Nykänen, L., Aapaoja, A., & Niemi, P. (2018). MaaS in rural areas—case Finland. *Research in Transportation Business & Management, 27*, 75–83. https://doi.

org/10.1016/j.rtbm.2018.09.005

Eden, C. and Huxham, C. (1996), ``Action research for management research'', *British Journal of Management, Vol. 7*, pp. 75-86.

Edvardsson, B., & Olsson, J. (1996). Key Concepts for New Service Development. *The Service Industries Journal, 16*(2), 140–164. https://doi.org/10.1080/02642069600000019

Edvardsson, B., Kleinaltenkamp, M., Tronvoll, B., McHugh, P., & Windahl, C. (2014). Institutional logics matter when coordinating resource integration. *Marketing Theory, 14*(3), 291–309. https://doi.org/10.1177/1470593114534343

Edwards, B. (2011). *Sustainability and the Design of Transport Interchanges* (1st ed.). Routledge.

Eilstrup-Sangiovanni, M. (2022). Ordering global governance complexes: The evolution of the governance complex for international civil aviation. *The Review of International Organizations, 17*(2), 293–322. https://doi.org/10.1007/s11558-020-09411-z

Eisenhardt, K. M. (1989). Building Theories from case Study Research. *Academic Management Review, 14*, 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory Building From cases: Opportunities And Challenges. *Academy of Management Journal, 50*(1), 25–32. https://doi.org/10.5465/amj.2007.24160888

Emmerink, R., Burghouwt, G., & Boonekamp, T. (2024). *Verhoog belasting op langeafstandsvluchten.*

Eurocities. (2024). *Policy statement on prioritising fast and high-quality passenger train connection in Europe.* https://eurocities.eu/wp-content/uploads/2024/10/FINAL-Policy-Statement-on-Prioritising-fast-and-high-quality-passenger-train-connections-in-Europe.pdf

European Commission. (2011). *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (No. 144). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144

European Commission. (2020). *Sustainable and Smart Mobility Strategy—Putting European Transport on Track for the Future* (COM(2020) 789 final). https://eur lex.europa.eu/resource.html?uri=cellar:5e601657-3b06-11eb-b27b-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. (2021). *Sustainable & Smart Mobility Strategy—Putting European transport on track for the future.*

European Commission. (2024). *Multimodal digital mobility service: Report.* European Commission. https://data.europa.eu/doi/10.2832/0079219

European Environment Agency. (2021). *Transport and environment report 2020: Train or plane?* Publications Office. https://data.europa.eu/doi/10.2800/43379

European Parliament and of the Council. (2024). *Passenger rights in the context of multimodal journeys.* https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/767200/EPRS_BRI(2024)767200_EN.pdf

European Union Agency for Railways. (2024). *Rail environmental report.* Publications Office. https://doi.org/10.2821/243881

European Union. (2012). Consolidated version of the Treaty on the Functioning of the European Union (No. C 326). *Official Journal of the European Union.*

Faber, J., & van Wijngaarden, L. (2020). *Economische- en Duurzaamheidseffecten Vliegbelasting: Doorrekening nieuwe varianten.* CE Delft.

Farinloye, T., Mogaji, E., Aririguzoh, S., & Kieu, T. A. (2019). Qualitatively exploring the effect of change in the residential environment on travel behaviour. *Travel Behaviour and Society, 17*, 26–35. https://doi.org/10.1016/j.tbs.2019.06.001

Finger, M., Montero, J., & Serafimova, T. (2019). *Towards EU-Wide Multimodal Ticketing and Payment Systems.*

Flaherty, G. T., & Holmes, A. (2020). Will flight shaming influence the future of air travel?. *Journal of Travel Medicine, 27*(2), taz088.

Flaig, A., Guyader, H., & Ottosson, M. (2025). Design-Oriented stakeholder engagement in service ecosystems. *Journal of Business Research, 191*, 115255. https://doi.org/10.1016/j.jbusres.2025.115255

Friend, S. B., & Malshe, A. (2016). Key Skills for Crafting Customer Solutions Within an Ecosystem: A Theories-in-Use Perspective. *Journal of Service Research, 19*(2), 174–191. https://doi.org/10.1177/1094670515617154

Frow, P., McColl-Kennedy, J. R., Payne, A., & Govind, R. (2019). Service ecosystem well-being: Conceptualization and implications for theory and practice. *European Journal of Marketing, 53*(12), 2657–2691. https://doi.org/10.1108/EJM-07-2018-0465

Frow, P., Nenonen, S., Payne, A., & Storbacka, K. (2015). Managing Co-creation Design: A Strategic Approach to Innovation. *British Journal of Management, 26*(3), 463–483. https://doi.org/10.1111/1467-8551.12087

Fusch, P., & Ness, L. (2015). *Are We There Yet? Data Saturation in Qualitative Research.* Walden Faculty and Staff Publications, 455.

Garud, R., Tuertscher, P., & Van De Ven, A. H. (2013). Perspectives on Innovation Processes. *Academy of Management Annals, 7*(1), 775–819. https://doi.org/10.5465/19416520.2013.791066

Gebhardt, L., Krajzewicz, D., Oostendorp, R., Goletz, M., Greger, K., Klötzke, M., Wagner, P., & Heinrichs, D. (2016). Intermodal Urban Mobility: Users, Uses, and Use cases. *Transportation Research Procedia, 14*, 1183–1192. https://doi.org/10.1016/j.trpro.2016.05.189

Geertz, C. (1973). *Thick description: Toward an interpretive theory of culture.* In The interpretation of cultures: Selected essays (pp. 3–30). Basic Books.

Gemeente Amsterdam. (2021, December 15). *Hubsvisie Amsterdam.* https://www.amsterdam.nl/parkeren-verkeer/hubs/

Geng, Y., Yu, J., Lin, B., Wang, Z., & Huang, Y. (2017). Impact of individual IEQ factors on passengers' overall satisfaction in Chinese airport terminals. *Building and Environment, 112,* 241–249. https://doi.org/10.1016/j.buildenv.2016.11.040

Gerring, J. (2004). What Is a case Study and What Is It Good for? *American Political Science Review, 98*(2).

Geurs, K. T., La Paix, L., & Van Weperen, S. (2016). A multi-modal network approach to model public transport accessibility impacts of bicycle-train integration policies. *European Transport Research Review, 8*(4), 25. https://doi.org/10.1007/s12544-016-0212-x

Gil, N., Miozzo, M., & Massini, S. (2012). The innovation potential of new infrastructure development: An empirical study of Heathrow airport's T5 project. *Research Policy, 41*(2), 452-466.

Giorgi, A. P., & Giorgi, B. M. (2003). The descriptive phenomenological psychological method.

Givoni, M., & Banister, D. (2006). Airline and railway integration. *Transport Policy, 13*(5), 386–397. https://doi.org/10.1016/j.tranpol.2006.02.001

Goldstein, S. M., Johnston, R., Duffy, J., & Rao, J. (2002). The service concept: The missing link in service design research? *Journal of Operations Management, 20*(2), 121–134. https://doi.org/10.1016/S0272-6963(01)00090-0

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse education today, 24*(2), 105-112.

Greenwood, D. J., & Levin, M. (2007). *Introduction to Action Research* (2nd ed.). Sage Publications Inc. Haraway D. Situated knowledges: the science question in feminism and the privilege of partial perspective. In Haraway D. Simians, cyborgs, and women: the reinvention of nature. New York: Routledge, 1991: 183–201.

Greenwood, D. J., & Levin, M. (2007). I*ntroduction to action research: Social research for social change* (2nd ed). Sage Publications.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *ECTJ, 29*(2), 75. https://doi.org/10.1007/BF02766777

Guidon, S., Wicki, M., Bernauer, T., & Axhausen, K. (2020). Transportation service bundling – For whose benefit? Consumer valuation of pure bundling in the passenger transportation market. *Transportation Research Part A: Policy and Practice, 131*, 91–106. https://doi.org/10.1016/j.tra.2019.09.023

Guyader, H., Nansubuga, B., & Skill, K. (2021). Institutional Logics at Play in a Mobility-as-a-Service Ecosystem. *Sustainability, 13*(15), 8285. https://doi.org/10.3390/su13158285

Gössling, S., & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change, 65*, 102194. https://doi.org/10.1016/j.gloenvcha.2020.102194

Harper, J. C. (2003). *Improving links between tenant companies and higher education institutions: exploring emerging scenarios for Manchester Science Park*. PREST, University of Manchester, 8.

Heddebaut, O., & Palmer, D. (2014). *Multimodal city-hubs and their impact on local economy and land use.* In *Proceedings of the Transport Research Arena.* https://doi.org/10.13140/2.1.3845.3121

Henderson, R. M., & Clark, K. B. (1990). Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms. *Administrative science quarterly*, 9-30.

Henderson, R., & Clark, K. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly, 35*(1), 9. https://doi.org/10.2307/2393549

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine, 292,* 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Hensher, D. A. (2017). Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? *Transportation Research Part A: Policy and Practice, 98*, 86–96. https://doi.org/10.1016/j.tra.2017.02.006

Hensher, D. A. (2017). Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change?. *Transportation Research Part A: Policy and Practice, 98*, 86-96.

Hernandez Bueno, A. V. (2021). Becoming a passenger: Exploring the situational passenger experience and airport design in the Copenhagen Airport. *Mobilities, 16*(3), 440–459. https://doi.org/10.1080/17450101.2020.1864114

Hernandez, S., & Monzon, A. (2016). Key factors for defining an efficient urban transport inter-change: Users' perceptions. *Cities, 50,* 158–167. https://doi.org/10.1016/j.cities.2015.09.009

Herr, K., & Anderson, G. L. (2005). *The Action Research Dissertation A Guide for Students and Faculty.* Sage Publications, Inc.

Hickman, R., Chen, C.-L., Chow, A., & Saxena, S. (2015). Improving interchanges in China: The experiential phenomenon. *Journal of Transport Geography, 42*, 175–186. https://doi.org/10.1016/j.jtrangeo.2014.12.004

Huang, S., & Mu, D. (2018). Discussion on the Development Strategy of China's Multimodal Transport Stations. In 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018) (pp. 256-262). Atlantis Press.

Huang, S., & Mu, D. (2018). Discussion on the Development Strategy of China's Multimodal Transport Stations. Proceedings of the 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018). Proceedings

of the 2018 International Conference on Transportation & Logistics, Information & Communication, Smart City (TLICSC 2018), Chengdu City, China. https://doi.org/10.2991/tlicsc-18.2018.40

International Energy Agency (IEA). (2017). *CO2 emissions from fuel combustion*. International Enegery Agency (IEA).

International Union of Railways. (2022). *Customer experience by rail: State of the art and best practices with a vision 2030 case study.* UIC. https://uic.org/IMG/pdf/cemp-report-customer-experience-by-rail-state-of-the-art-and-best-practices-with-a-vision-2030-case-study.pdf

ISO. (2019). *ISO 9241-210 Ergonomics of human-system interaction.* Part 210: Human-centred design for interactive systems (No. ISO 9241-210).

Janic, M. (2011). Assessing some social and environmental effects of transforming an airport into a real multimodal transport node. *Transportation Research Part D: Transport and Environment, 16*(2), 137–149. https://doi.org/10.1016/j.trd.2010.10.002

Jeevan, J., Othman, M. R., Hasan, Z. R. A., Pham, T. Q. M., & Park, G. K. (2019). Exploring the development of Malaysian seaports as a hub for tourism activities. *Maritime Business Review.*

Jehn, M., & Rae, S. (2015). *Ski2LRT uses Systemic Design to transform winter community in Edmonton.* In: Relating Systems Thinking and Design (RSD4) 2015 Symposium.

Jiang, C., D'Alfonso, T., & Wan, Y. (2017). Air-rail cooperation: Partnership level, market structure and welfare implications. *Transportation Research Part B: Methodological, 104,* 461–482. https://doi.org/10.1016/j.trb.2017.01.006

Jiang, F., Wang, L., & Huang, S. (2022). Analysis of the Transfer Time and Influencing Factors of Air-Rail Integration Passengers: A case Study of Shijiazhuang Zhengding International Airport. *Sustainability, 14*(23), 16193. https://doi.org/10.3390/su142316193

Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M. J. A., & Narayan, J. (2017). Mobility as a Service: A Critical review of definitions, assessments of schemes, and key challenges. *Urban Planning, 2*(2), 13–25. https://doi.org/10.17645/up.v2i2.931

Johnson, S. P., Menor, L. J., Roth, A. V., & Chase, R. B. (2000). A critical evaluation of the new service development process. In *New Service Development* (pp. 1–32). Sage.

Jones, P. (2018). Contexts of Co-creation: Designing with System Stakeholders. In P. Jones & K. Kijima (Eds.), *Systemic Design* (Vol. 8, pp. 3–52). Springer Japan. https://doi.org/10.1007/978-4-431-55639-8_1

Jones, P. (2020). Systemic Design: Design for Complex, Social, and Sociotechnical Systems. *Handbook of Systems Sciences,* 1-25.

Jones, P., & Ael, V. K. (2022). Design Journeys through Complex Systems: Practice Tools for Systemic Design. BIS Publishers.

Jones, W., Kotiadis, K., Paola Scaparra, M., & O'Hanley, J. (2020). *Using simulation to improve the customer experience at Eurostar.* Impact, 2020(1), 7-11.

Joppien, J., Niermeijer, G., Niks, T., & Kuijk, J. (2013). *Exploring new possibilities for user-centred eticketing.* University of Technology.

Julagasigorn, P., Banomyong, R., Grant, D., & Varadejsatitwong, P. (2021). What encourages people to carpool? A conceptual framework of carpooling psychological factors and research propositions. *Transportation Research Interdisciplinary Perspectives, 12,* 100493. https://doi.org/10.1016/j.trip.2021.100493

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A Critical Review of New Mobility Services for Urban Transport. *Transportation Research Procedia, 14,* 3294–3303. https://doi.org/10.1016/j.trpro.2016.05.277

Kane, M., & Whitehead, J. (2017). How to ride transport disruption–a sustainable framework for future urban mobility. *Australian Planner, 54*(3), 177-185.

Karamychev, V., & van Reeven, P. (2011). Park-and-ride: Good for the city, good for the region?.

Regional Science and Urban Economics, 41(5), 455-464.

Kaufman, S. M., Gordon-Koven, L., Levenson, N., & Moss, M. L. (2015). *Citi Bike: the first two years.* Rudin Center for Transportation Policy and Management, New York University. https://wagner.nyu.edu/files/faculty/publications/Citi_Bike_First_Two_Years_RudinCenter.pdf

Khandkar, S. H. (2009). *Open coding.* University of Calgary, 23, 2009.

Kim, M. H., Park, J. W., & Choi, Y. J. (2020). A Study on the Effects of Waiting Time for Airport Security Screening Service on Passengers' Emotional Responses and Airport Image. *Sustainability, 12*(24), 10634. https://doi.org/10.3390/su122410634

Kirk, P., Popovic, V., Kraal, B., and Livingstone, A. (2012) Towards a Taxonomy of Airport Passenger Activities, in Israsena, P., Tangsantikul, J. and Durling, D. (eds.), *Research: Uncertainty Contradiction Value-DRS International Conf erence 2012 ,* 1-4 July, Bangkok, Thailand. https://dl.designresearchsociety.org/drs-conference-papers/drs2012/researchpapers/64

Kivela, M., Arenas, A., Barthelemy, M., Gleeson, J. P., Moreno, Y., & Porter, M. A. (2014). Multilayer networks. *Journal of Complex Networks, 2*(3), 203–271. https://doi.org/10.1093/comnet/cnu016

Kleinaltenkamp, M., Brodie, R. J., Frow, P., Hughes, T., Peters, L. D., & Woratschek, H. (2012). Resource integration. *Marketing Theory, 12*(2), 201–205. https://doi.org/10.1177/1470593111429512

Kochanowska, M., Gagliardi, W. R., & With Reference To Jonathan Ball. (2022). The Double Diamond Model: In Pursuit of Simplicity and Flexibility. In D. Raposo, J. Neves, & J. Silva (Eds.), *Perspectives on Design II* (Vol. 16, pp. 19–32). Springer International Publishing. https://doi.org/10.1007/978-3-030-79879-6_2

Koskela-Huotari, K., Edvardsson, B., Jonas, J. M., Sörhammar, D., & Witell, L. (2016). Innovation in service ecosystems—Breaking, making, and maintaining institutionalized rules of resource integration. *Journal of Business Research, 69*(8), 2964–2971. https://doi.org/10.1016/j.jbusres.2016.02.029

Kwasiborska, A., Skorupski, J., & Yatskiv, I. (2021). *Advances in Air Traffic Engineering.* 6th International Scientific Conference on Air Traffic Engineering, Warsaw. https://doi.org/10.1007/978-3-030-70924-2

Lai, W.-T., & Chen, C.-F. (2011). Behavioral intentions of public transit passengers—The roles of service quality, perceived value, satisfaction and involvement. *Transport Policy, 18*(2), 318–325. https://doi.org/10.1016/j.tranpol.2010.09.003

Lenz, B., & Heinrichs, D. (2017). What Can We Learn from Smart Urban Mobility Technologies? *IEEE Pervasive Computing, 16*(2), 84–86. https://doi.org/10.1109/MPRV.2017.27

Li, L., & Loo, B. P. Y. (2016). Towards people-centered integrated transport: A case study of Shanghai Hongqiao Comprehensive Transport Hub. *Cities, 58*, 50–58. https://doi.org/10.1016/j.cities.2016.05.003

Li, X., Jiang, C., Wang, K., & Ma, J. (2018). Determinants of partnership levels in air-rail cooperation. *Journal of Air Transport Management, 71*, 88–96. https://doi.org/10.1016/j.jairtraman.2018.06.002

Li, Z., & Xu, W. A. (2019). Path decision modelling for passengers in the urban rail transit hub un-der the guidance of traffic signs. J*ournal of Ambient Intelligence and Humanized Computing, 10*(1), 365–372. https://doi.org/10.1007/s12652-017-0544-y

Lincoln, Y.S. and Guba, E.G. (1985). *Naturalistic Inquiry.* Sage Publications, Newbury Park, CA.

Lindgren, B. M., Lundman, B., & Graneheim, U. H. (2020). Abstraction and interpretation during the qualitative content analysis process. *International journal of nursing studies, 108,* 103632.

Liu, Z. (2005). *Planning and Policy Coordination in China's Infrastructure Development* [Technical Report]. Lincoln Institute of Land Policy.

Lubbe, B., Douglas, A., & Zambellis, J. (2011). An application of the airport service quality

model in South Africa. *Journal of Air Transport Management, 17*(4), 224–227. https://doi.org/10.1016/j.jairtraman.2010.08.001

Lyons, G. (2018). Getting smart about urban mobility–aligning the paradigms of smart and sustainable. *Transportation Research Part A: Policy and Practice, 115,* 4-14

Lüscher, L. S., & Lewis, M. W. (2008). Organizational Change and Managerial Sensemaking: Working through Paradox. *Academy of Management Journal, 51*(2), 221-240.

Mager, B. (2009). *Service Design as an Emerging Field.* Designing Services with Innovative Methods, 1.

Magnani, G., & Gioia, D. (2023). Using the Gioia Methodology in international business and entrepreneurship research. *International Business Review, 32*(2), 102097. https://doi.org/10.1016/j.ibusrev.2022.102097

Malterud, K. (2001a). Qualitative research: Standards, challenges, and guidelines. *The Lancet, 358*(9280), 483–488. https://doi.org/10.1016/S0140-6736(01)05627-6

Malterud, K. (2001b). The art and science of clinical knowledge: Evidence beyond measures and numbers. *The Lancet, 358*(9279), 397–400. https://doi.org/10.1016/S0140-6736(01)05548-9

Marquez, V. (2019). *Landside/ Airside: Why Airports Are the Way They Are.* Springer.

Mascitelli, R. (2000). From Experience: Harnessing Tacit Knowledge to Achieve Breakthrough Innovation. *Journal of Product Innovation Management, 17*(3), 179–193. https://doi.org/10.1111/1540-5885.1730179

McColl-Kennedy, J. R., Cheung, L., & Coote, L. V. (2020). Tensions and trade-offs in multi-actor service ecosystems. *Journal of Business Research, 121,* 655–666. https://doi.org/10.1016/j.jbusres.2020.06.055

Meadows, D. H. (2008). *Thinking in Systems.* Chelsea Green Publishing.

Medvedev, A., Alomar, I., & Augustyn, S. (2017). *Innovation in airport design.* Aviation, 21(1), 23-28.

Mele, C., Nenonen, S., Pels, J., Storbacka, K., Nariswari, A., & Kaartemo, V. (2018). Shaping service ecosystems: Exploring the dark side of agency. *Journal of Service Management, 29*(4), 521–545. https://doi.org/10.1108/JOSM-02-2017-0026

METELKA, S., & JANOŠ, V. (2021, May). *Demand variation in regional transport.* In 2021 Smart City Symposium Prague (SCSP) (pp. 1-5). IEEE.

Meroni, A. (with Sangiorgi, D.). (2016). *Design for services.* Routledge.

Midor, K., Biały, W., & Ivanova, T. N. (2020). *Collective transport as a tool to reduce congestion – case study.* IOP Conference Series: Materials Science and Engineering, 971(5), 052063. https://doi.org/10.1088/1757-899X/971/5/052063

Miles, M., Huberman, M., & Saldaña, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook (3rd ed.).* Sage Publications.

Monzón, A., Hernández, S., & Di Ciommo, F. (2016). Efficient Urban Interchanges: The City-HUB Model. *Transportation Research Procedia, 14,* 1124–1133. https://doi.org/10.1016/j.trpro.2016.05.183

Morgan, D. L. (2007). Paradigms Lost and Pragmatism Regained: Methodological Implications of Combining Qualitative and Quantitative Methods. *Journal of Mixed Methods Research, 1*(1), 48–76. https://doi.org/10.1177/2345678906292462

Mujica Mota, M., Scala, P., Herranz, R., Schultz, M., & Jimenez, E. (2020). *Creating the future airport passenger experience: IMHOTEP.* Proceedings of the 32nd European Modeling & Simulation Symposium (EMSS 2020), 171–178. https://doi.org/10.46354/i3m.2020.emss.024

Mustak, M., & Plé, L. (2020). A critical analysis of service ecosystems re search: Rethinking its premises to move forward. *Journal of Services Marketing, 34*(3), 399–413. https://doi.org/10.1108/JSM-02-2019-0084

Nam, S., Ha, C., & Lee, H. C. (2018). Redesigning In-Flight Service with Service Blueprint Based

on Text Analysis. *Sustainability, 10*(12), 4492. https://doi.org/10.3390/su10124492

Nash, C. (2010). European rail reform and passenger services – the next steps. *Research in Transportation Economics, 29*(1), 204–211. https://doi.org/10.1016/j.retrec.2010.07.025

Nechyporuk, M., Pavlikov, V., & Kritskiy, D. (Eds.). (2022). *Integrated computer technologies in mechanical engineering – 2021: Synergetic engineering* (Vol. 367). Springer International Publishing. https://doi.org/10.1007/978-3-030-94259-5

Nielsen, O. A., Eltved, M., Anderson, M. K., & Prato, C. G. (2021). Relevance of detailed transfer attributes in large-scale multimodal route choice models for metropolitan public transport passengers. *Transportation Research Part A: Policy and Practice, 147,* 76–92. https://doi.org/10.1016/j.tra.2021.02.010

Nieuwborg, A., Hiemstra-van Mastrigt, S., Melles, M., Santema, S., & Zekveld, J. (2021). Designing for pandemic antifragility in multimodal transport hubs. *Proceedings of Relating Systems Thinking and Design, RSD10.* Article #056 (online-first number). https://rsdsymposium.org/designing-pandemic-antifragility-for-multimodal-transport-hubs/

Nikitas, A., Kougias, I., Alyavina, E., & Njoya Tchouamou, E. (2017). How can autonomous and connected vehicles, electromobility, BRT, hyperloop, shared use mobility and mobility-as-a-service shape transport futures for the context of smart cities?. *Urban Science, 1*(4), 36.

Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial Intelligence, Transport and the Smart City: Definitions and Dimensions of a New Mobility Era. *Sustainability, 12*(7), 2789. https://doi.org/10.3390/su12072789

Noussan, M., & Tagliapietra, S. (2020). The effect of digitalization in the energy consumption of passenger transport: An analysis of future scenarios for Europe. *Journal of Cleaner Production, 258,* 120926. https://doi.org/10.1016/j.jclepro.2020.120926

Ongkittikul, S., & Geerlings, H. (2006). Opportunities for innovation in public transport: Effects of regulatory reforms on innovative capabilities. *Transport Policy, 13*(4), 283–283. https://doi.org/10.1016/j.tranpol.2005.12.003

ORCHESTRA Project. (2022). *Initial use cases for multimodal traffic management* (EU H2020 Project Deliverable No. D3.1). Horizon 2020 / European Commission. https://orchestraproject.eu

Ostrom, A. L., Parasuraman, A., Bowen, D. E., Patrício, L., & Voss, C. A. (2015). Service Research Priorities in a Rapidly Changing Context. *Journal of Service Research, 18*(2), 127–159. https://doi.org/10.1177/1094670515576315

Papastathopoulou, P., & Hultink, E. J. (2012). New Service Development: An Analysis of 27 Years of Research. *Journal of Product Innovation Management, 29*(5), 705–714. https://doi.org/10.1111/j.1540-5885.2012.00944.x

Patton, M. Q. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (Fourth edition). SAGE.

Pels, E., Nijkamp, P., & Rietveld, P. (2003). Access to and competition between airports: A case study for the San Francisco Bay area. *Transportation Research Part A: Policy and Practice, 37*(1), 71–83. https://doi.org/10.1016/S0965-8564(02)00007-1

Pirie, G. (2016). *Geographies of air transport in Africa: aviation's 'last frontier'. In The Geographies of air transport* (pp. 263-282). Routledge.

Porter, B., Linse, M., & Barasz, Z. (2015). Six transportation trends that will change how we move. *Forbes.*

Portuguez-Castro, M. (2023). Exploring the Potential of Open Innovation for Co-Creation in Entrepreneurship: A Systematic Literature Review. *Administrative Sciences, 13*(9), 198. https://doi.org/10.3390/admsci13090198

Ramaswamy, V., & Ozcan, K. (2018). What is co-creation? An interactional creation framework and its implications for value creation. *Journal of Business Research, 84,* 196–205. https://

doi.org/10.1016/j.jbusres.2017.11.027

Rattanakijsuntorn, W., Suwannarat, B., Samittivate, N., & Nithikittiwat, C. (2024). Success Factors and Partnership Evaluation of Air–Rail Integration Development: A case of a High-Speed Rail Project Linking Three Airports in Thailand. *Infrastructures, 9*(7), 115. https://doi.org/10.3390/infrastructures9070115

Razmdoost, K., Alinaghian, L., Chandler, J. D., & Mele, C. (2023). Service ecosystem boundary and boundary work. *Journal of Business Research, 156,* 113489. https://doi.org/10.1016/j.jbusres.2022.113489

Reason, P., & Bradbury, H. (Eds.). (2008). *The Sage handbook of action research: Participative inquiry and practice (2nd ed).* SAGE Publications.

Reason, P., & Torbert, W. (2001). The action turn: Toward a transformational social science. *Concepts and Transformation, 6*(1), 1–37. https://doi.org/10.1075/cat.6.1.02rea

Reis, V., Fabian Meier, J., Pace, G., & Palacin, R. (2013). Rail and multi-modal transport. *Research in Transportation Economics, 41*(1), 17–30. https://doi.org/10.1016/j.retrec.2012.10.005

RLI. (2020). *Verzet de wissel: Naar beter internationaal reizigersvervoer per trein.* Raad voor de Leefomgeving en Infrastructuur (Rli).

Rodrigue, J.-P. (2024). *The Geography of Transport Systems* (6th ed.). Routledge.

Rogers, E. (2003). *Diffusion of Innovations* (5th edition). Simon and Schuster.

Román, C., & Martín, J. C. (2014). Integration of HSR and air transport: Understanding passengers' preferences. *Transportation Research Part E: Logistics and Transportation Review, 71,* 129–141. https://doi.org/10.1016/j.tre.2014.09.001

Rongen, T., Tillema, T., & Arts, J. (2020). A qualitative analysis of multimodal hub concepts in Dutch national transport and land-use policy.

Roozenburg, N., & Eekels, J. (1995). Product design: Fundamentals and methods (1st ed.). Wiley.

Rosenbaum, M. S., Otalora, M. L., & Ramírez, G. C. (2017). How to create a realistic customer journey map. *Business Horizons, 60*(1), 143–150. https://doi.org/10.1016/j.bushor.2016.09.010

Rothengatter, W. (2010). Competition between airlines and high-speed rail. In *Critical Issues in Air Transport Economics and Business* (1st ed.).

Roto, V., Law, E. C., Vermeeren, A. P., & Hoonhout, J. (Eds.)(2011). *User Experience White Paper: Bringing clarity to the concept of user experience.* Outcome of Dagstuhl Seminar 10373: Demarcating User Experience.

Sanders, E. B.-N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign, 4*(1), 5–18. https://doi.org/10.1080/15710880701875068

Sanders, E., & Stappers, P. (2012). *Convivial toolbox: Generative research for the front end of design.* BIS Publishers.

Sauter-Servaes, T., & Nash, A. (2009). Increasing Rail Demand by Improving Multimodal Information and Ticketing: Results of the Night & Flight case Study. *Transportation Research Record: Journal of the Transportation Research Board, 2117*(1), 7–13. https://doi.org/10.3141/2117-02

Schmitt, D., & Gollnick, V. (2016). *Air Transport System.* Springer Vienna. https://doi.org/10.1007/978-3-7091-1880-1

Schreier, H., Grimm, C., Kurz, U., Schwieger, B., Keßler, S., & Möser, G. (2018). *Analysis of the impacts of car-sharing in Bremen, Germany.* Retrieved from https://northsearegion.eu/ share-north/news/impact-analysis-of-car-sharing-in-bremen-english -report-published/ (Consulted on: 30-05-2022)

Schumpeter, J. A. (1934). *The theory of economic development. An inquiry into profits, capital, credit, interest, and the business cycle.* Harvard University Press.

Schäfer, A. W., Barrett, S. R., Doyme, K., Dray, L. M., Gnadt, A. R., Self, R., ... & Torija, A. J. (2019).

Technological, economic and environmental prospects of all-electric aircraft. *Nature Energy, 4*(2), 160-166.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22*(2), 63–75. https://doi.org/10.3233/EFI-2004-22201

Shostack, G. L. (1984). *Designing Services That Deliver.* Harvard Business Review, 84115.

Silverman, D. (2009). *Doing qualitative research* (3rd ed.). SAGE Publications.

Sklyar, A., Kowalkowski, C., Sörhammar, D., & Tronvoll, B. (2019). Resource integration through digitalisation: A service ecosystem perspective. *Journal of Marketing Management, 35*(11–12), 974–991. https://doi.org/10.1080/0267257X.2019.1600572

Snowden, D. J., & Boone, M. E. (2007). A leader's framework for decision making. *Harvard business review, 85*(11), 68.

Song, F., Hess, S., & Dekker, T. (2018). Accounting for the impact of variety-seeking: Theory and application to HSR-air intermodality in China. *Journal of Air Transport Management, 69,* 99–111. https://doi.org/10.1016/j.jairtraman.2018.02.008

Sprei, F. (2018). Disrupting mobility. *Energy Research & Social Science, 37,* 238–242. https://doi.org/10.1016/j.erss.2017.10.029

Stadler Benz, P., & Stauffacher, M. (2024). Co-creating multimodal transportation hubs in Switzerland: How to close the gap between actors across different scales, levels, and sectors. *Multimodal Transportation, 3*(4), 100168. https://doi.org/10.1016/j.multra.2024.100168

Sun, X., Zhang, Y., & Wandelt, S. (2017). Air Transport versus High-Speed Rail: An Overview and Research Agenda. *Journal of Advanced Transportation.*

Sune, A., & Gibb, J. (2015). Dynamic capabilities as patterns of organizational change: An empirical study on transforming a firm's resource base. *Journal of Organizational Change Management.*

Swann, C. (2002). Action Research and the Practice of Design. *Design Issues, 18*(1), 49–61. https://doi.org/10.1162/07479360252756287

Taillard, M., Peters, L. D., Pels, J., & Mele, C. (2016). The role of shared intentions in the emergence of service ecosystems. *Journal of Business Research, 69*(8), 2972–2980. https://doi.org/10.1016/j.jbusres.2016.02.030

This is Service Design Doing. (n.d.). *Autoethnography* [Method description]. https://www.thisisservicedesigndoing.com/methods/autoethnography

Timmer, S., Merfeld, K., & Henkel, S. (2023). Exploring motivations for multimodal commuting: A hierarchical means-end chain analysis. *Transportation Research Part A: Policy and Practice, 176,* 103831. https://doi.org/10.1016/j.tra.2023.103831

Toering, A., De Bruijne, M., & Veeneman, W. (2025). Exploring governance challenges of sustainable infrastructure development on the nexus between energy and mobility. *Npj Sustainable Mobility and Transport, 2*(1), 1. https://doi.org/10.1038/s44333-024-00018-0

Toet, A., Van Kuijk, J., Boersma, K., & Santema, S. (2023, October 9). *Themes for an airport hub in the transition towards a multimodal transport hub – an embedded researcher's perspective.* IASDR 2023: Life-Changing Design, Milan, Italy. https://doi.org/10.21606/iasdr.2023.272

Toet, A., van Kuijk, J., & Santema, S. (2022). *Transforming airport hubs into future-proof Multimodal Transport Hubs.* Relating Systems Thinking and Design (RSD11) Symposium: Possibilities and practices of systemic design, Brighton, UK.

Tripathi, M., Mandal, M., & Wadhwa, R. (2022). Air Taxis: A Technological Breakthrough to Beat the Traffic Woes. *Communications of the Association for Information Systems, 50*(1), 15.

UIC. (2024). *High-Speed Rail Atlas. International Union of Railways* (UIC).

Van De Ven, A. H., & Angle, H. (1989). *An introduction to the Minnesota innovation Research*

Program. In Research on the Management of Innovation (pp. 3–30). Oxford University Press.

Van Hagen, M., & Bron, P. (2014). Enhancing the Experience of the Train Journey: Changing the Focus from Satisfaction to Emotional Experience of Customers. *Transportation Research Procedia, 1*(1), 253–263. https://doi.org/10.1016/j.trpro.2014.07.025

Van Lierop, D., & El-Geneidy, A. (2016). Enjoying loyalty: The relationship between service quality, customer satisfaction, and behavioral intentions in public transit. *Research in Transportation Economics, 59,* 50–59. https://doi.org/10.1016/j.retrec.2016.04.001

Van Lierop, D., Badami, M. G., & El-Geneidy, A. M. (2018). What influences satisfaction and loyal-ty in public transport? A review of the literature. *Transport Reviews, 38*(1), 52–72. https://doi.org/10.1080/01441647.2017.1298683

Vargo, S. L., & Lusch, R. F. (2008a). Service-dominant logic: Continuing the evolution. *Journal of the Academy of Marketing Science, 36*(1), 1–10. https://doi.org/10.1007/s11747-007-0069-6

Vargo, S. L., & Lusch, R. F. (2008b). Why "service"? *Journal of the Academy of Marketing Science, 36*(1), 25–38. https://doi.org/10.1007/s11747-007-0068-7

Vargo, S. L., & Lusch, R. F. (2010). From Repeat Patronage to Value Co-creation in Service Ecosys-tems: A Transcending Conceptualization of Relationship. *Journal of Business Market Management, 4*(4), 169–179. https://doi.org/10.1007/s12087-010-0046-0

Vargo, S. L., & Lusch, R. F. (2016). Institutions and axioms: An extension and update of service-dominant logic. *Journal of the Academy of Marketing Science, 44*(1), 5–23. https://doi.org/10.1007/s11747-015-0456-3

Vargo, S. L., & Lusch, R. F. (2017). Service-dominant logic 2025. *International Journal of Research in Marketing, 34*(1), 46–67. https://doi.org/10.1016/j.ijresmar.2016.11.001

Vassallo, J. M., & Fagan, M. (2007). Nature or nurture: Why do railroads carry greater freight share in the United States than in Europe? *Transportation, 34*(2), 177–193. https://doi.org/10.1007/s11116-006-9103-7

Veeneman, W. (2023). Governance, COVID responses, and lessons on decision-making in uncertainty. *In Transportation Amid Pandemics (pp. 441–450).* Elsevier. https://doi.org/10.1016/B978-0-323-99770-6.00019-3

Veeneman, W. W., Van Kuijk, J. I., & Hiemstra-van Mastrigt, S. (2020). Dreaming of the Travelers' Experience in 2040: Exploring Governance Strategies and Their Consequences for Personal Mobility Systems. In B. Müller & G. Meyer (Eds.), *Towards User-Centric Transport in Europe 2 (pp. 225–239).* Springer International Publishing. https://doi.org/10.1007/978-3-030-38028-1_16

Vink, J., Koskela-Huotari, K., Tronvoll, B., Edvardsson, B., & Wetter-Edman, K. (2020). Service Ecosystem Design: Propositions, Process Model, and Future Research Agenda. *Journal of Service Research, 24*(2), 168–186. https://doi.org/10.1177/1094670520952537

Visser, F. S., Stappers, P. J., Van Der Lugt, R., & Sanders, E. B.-N. (2005). Context mapping: Experiences from practice. *CoDesign, 1*(2), 119–149. https://doi.org/10.1080/15710880500135987

Vuchic, V. R. (2007). Urban transit systems and technology. John Wiley & Sons.

Wall, S. (2006). An Autoethnography on Learning About Autoethnography. *International Journal of Qualitative Methods, 5*(2), 146–160. https://doi.org/10.1177/160940690600500205

Wan, Y., Ha, H.-K., Yoshida, Y., & Zhang, A. (2016). Airlines' reaction to high-speed rail entries: Empirical study of the Northeast Asian market. *Transportation Research Part A: Policy and Practice, 94,* 532–557. https://doi.org/10.1016/j.tra.2016.10.014

Wang, B., Loo, B., & Li, L. (2020). Situating High-Speed Railway Stations within Local Urban Contexts: Passenger Satisfaction with Intermodal Integration at the Hong Kong HSR Station. *Built Environment, 46*(3), 362–378. https://doi.org/10.2148/benv.46.3.362

Wang, B., Shen, G., Wang, X., Dong, Y., & Li, Z. (2024). Hub-and-Spoke Network Optimization with Flow Delay Cost: The case of Goods Delivery on Urban Logistics Networks in Eastern

China. *Mathematics, 12*(10), 1496. https://doi.org/10.3390/math12101496

Wang, Y., Yan, X., Zhou, Y., & Xue, Q. (2017). Influencing Mechanism of Potential Factors on Passengers' Long-Distance Travel Mode Choices Based on Structural Equation Modeling. *Sustainability, 9*(11), 1943. https://doi.org/10.3390/su9111943

Watkins, K. E., Ferris, B., Borning, A., Rutherford, G. S., & Layton, D. (2011). Where Is My Bus? Impact of mobile real-time information on the perceived and actual wait time of transit riders. *Transportation Research Part A: Policy and Practice, 45*(8), 839–848. https://doi.org/10.1016/j.tra.2011.06.010

Wattanacharoensil, W., Schuckert, M., & Graham, A. (2016). An Airport Experience Framework from a Tourism Perspective. *Transport Reviews, 36*(3), 318–340. https://doi.org/10.1080/01441647.2015.1077287

Wicks, D. (2017). The Coding Manual for Qualitative Researchers (3rd edition). *Qualitative Research in Organizations and Management: An International Journal, 12*(2), 169–170. https://doi.org/10.1108/qrom-08-2016-1408

Wohlin, C. (2014, May). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In P*roceedings of the 18th international conference on evaluation and assessment in software engineering* (pp. 1-10).

Wu, C., Vine, S. L., & Sivakumar, A. (2025). Assessment of the barriers in establishing passenger mobility-as-a-service (MaaS) systems: An analogy with multimodal freight transport. *case Studies on Transport Policy, 20,* 101433. https://doi.org/10.1016/j.cstp.2025.101433

Yang, H., & Zhang, A. (2012). Effects of high-speed rail and air transport competition on prices, profits and welfare. *Transportation Research Part B: Methodological, 46*(10), 1322–1333. https://doi.org/10.1016/j.trb.2012.09.001

Yatskiv, I., & Budilovich, E. (2017). A comprehensive analysis of the planned multimodal public transportation HUB. *Transportation Research Procedia, 24,* 50–57. https://doi.org/10.1016/j.trpro.2017.05.067

Yin, R. (2009). *case Study Research: Design and Methods (Fourth Edition)*. Sage Publications.

Yuan, Y., Yang, M., Feng, T., Rasouli, S., Li, D., & Ruan, X. (2021). Heterogeneity in passenger saisfaction with air-rail integration services: Results of a finite mixture partial least squares model. *Transportation Research Part A: Policy and Practice, 147,* 133–158. https://doi.org/10.1016/j.tra.2021.03.003

Zgodavova, Z., Rozenberg, R., & Szabo, S. (2018). *Analysis of Point-to-Point versus Hub-and-Spoke airline networks.* 2018 XIII International Scientific Conference - New Trends in Aviation Development (NTAD), 158–163. https://doi.org/10.1109/NTAD.2018.8551733.

Zhang, X. Q., Cui, Y. R., Li, Y., & Liang, X. F. (2018). Research on layout of multimodal transport center in Jinan City. In E3S Web of Conferences (Vol. 38, p. 01040). EDP Sciences.

Zhou, T., Tan, R., & Sedlin, T. (2018). Planning Modes for Major Transportation Infrastructure Projects (MTIPs): Comparing China and Germany. *Sustainability, 10*(10), 3401. https://doi.org/10.3390/su10103401

EPILOGUE

Where It Connects tells the story of how transport systems converge, collide and must adapt to move closer together. It specifically illustrates how these systems intersect at the airport and highlights the airport's crucial role in multimodal transport, even though it is not a provider or driver of multimodal air transport.

The story emerged from the combined efforts of one individual (the PhD candidate), supported by three supervisors, each bringing their own logic, structures, values, and goals. Together, they contributed their perspectives to this work. *Where It Connects* demonstrates how design approaches can assist professionals and organizations in pursuing multimodal transport systems. It also emphasizes the importance of having a clear goal and rationale in that pursuit while reminding us that striving for a good purpose does not always yield the best results in practice.

Where It Connects offers a new perspective on discourse in understanding how multimodal travel works, building on previous research and setting the stage for future endeavors. It calls for further exploration into upcoming developments and the technical execution of multimodal transport. Importantly, the outcomes of the thesis ask for serious changes in policy issues at both European and global levels.

Throughout this PhD, my aim was not only to study multimodality but also to contribute, step by step, to small changes in practice. Such changes are never guaranteed to last, yet I believe that the initiatives and motivations set in motion during this research can continue to grow. What gives me confidence is that the airport which supported this project has now offered me a position, marking the next step in my career. This opportunity allows me to remain connected to the field and to continue contributing in my own way, helping the first steps taken in this research to develop into lasting progress.

I hope this work will inspire not only researchers but, more importantly, practitioners, policy-makers, (large) organizations, and, above all, the travelers of the future. They must find the inspiration to make sustainable multimodal transport the standard.

ACKNOWLEDGEMENTS

Almost four and a half years ago, I got a call from my graduation professor asking if I had ever considered doing a PhD. My first reaction was something like, *"Yeah, right… no way."* Spending four years alone in an office doing research didn't sound that appealing to me.

Luckily, my professor managed to convince me otherwise. He explained that it wasn't really what I thought it was. I would be doing the research in collaboration with a company, spending most of my time working there, while still having all the freedom and space to explore and develop my own ideas.

My first heartfelt thanks go to that certain professor. Sicco, you have taught me a lot: that the answer is never "no." You placed great trust in me to find my own path, and you supported me wholeheartedly along the way. Your intentions were never self-serving; you always had my best interests at heart. You are honest and pragmatic, and I have deeply appreciated that. People often told me I had a "nice" PhD experience, but I am convinced that had little to do with the topic itself and everything to do with people like you who made it possible. Thank you for giving me this opportunity and for encouraging me to take it. I can say with almost absolute certainty that I never would have done it if you had not been my professor.

Jasper, I remember our first conversation. What was scheduled for one hour lasted almost twice as long. Later, I learned that this is more the rule than the exception with you. I truly admire your passion and the way you can become completely absorbed in so many topics. I find it impressive how quickly you can switch between topics and often immediately understand what I mean (something my impatient side really appreciates). When I told you in my final year that I was no longer enjoying working online, you immediately suggested we'd plan at least one in-person day every month. You always made time for the PhD and never delivered half-hearted work. Over the past four years, we've gotten to know each other, discovering both our commonalities and differences. I'm grateful for the open conversations we have had and the effort you've put into the work. No one can dive into the topic of multimodality with as much enthusiasm as we do, and I know very few who find it equally fascinating to analyze someone's travel itinerary in such detail.

Klaas, I have said it many times before, you have had a profound influence on my PhD journey. You approached my supervision not merely as part of your job, but as something you genuinely cared about and wanted to do. Over

the years, you dedicated yourself to this role, and even when circumstances changed, you made a great effort to remain involved. You stepped in at key moments to help coordinate the broader stakeholder dynamics, which made an enormous difference. Beyond your intellectual guidance, I am super grateful for the personal support you provided. We get along very well, and I cherish the many valuable moments and conversations we've had. I'm very happy that the end of this PhD does not signify a goodbye, instead, we will be colleagues!

Jan, you welcomed me to Schiphol at a time when I really had no idea what I was getting myself into. We share a love for innovation and for conceptual and theoretical ideas, which made our conversations always inspiring. Especially in the early years, when I occasionally found myself without direct supervision, you were the one who stepped in and made sure I wasn't left on my own. I'm very happy that I now get to take the next steps in my career with you at the Innovation Hub.

I am honored to present and defend my work before this committee: Peter, Wijnand, Margareta, Manuela and Guillaume. I sincerely appreciate the time and attention you have dedicated to reviewing my research, as well as the valuable insights I have gained from your work.

Garoa, you were both my colleague and my friend at Schiphol and TU Delft, so it felt only natural for me to ask you to be one of my paranymphs. We have shared so many wonderful experiences together: trips to Milan, Paris, and Boston, and of course our shared love for New York. Even though we often joke that you're my younger PhD sister, our bond genuinely feels close to me. You made my time at TU Delft much more enjoyable, and I love how we can endlessly talk about everything happening in our lives. Not only during coffee moments but also during many dinners, drinks, and voice memos. Very few people truly understand what the final stretch of my PhD was like, and I'm super grateful that you were one of them.

Katie, I know you're probably the last person who would ever want to stand in my shoes, which makes it all the more special that you're willing to share this moment with me. You've been a close friend ever since our student days. We bonded over creative ideas, and you were always there to help me with whatever project I had taken on (and you still are). You're one of the first people I turn to, and I'm thankful that I can always count on you (and your wardrobe, too). You never doubted that things would work out, and I'm very thankful to you for being my paranymph.

Many thanks to Schiphol, and especially the Innovation Hub and the Masterplanning team, for making my research possible, and to all the

wonderful colleagues I've had the pleasure of working with. I've experienced many great moments, learned a lot, met inspiring people, and built nice friendships.

Thanks to all my TU Delft colleagues who, in one way or another, were involved in my research. I'm proud to be part of an inspiring place doing important work. After all those years studying at Industrial Design Engineering, it took me a little while to get used to the idea of still being at TU Delft, but thanks to the people it felt welcoming again.

Alexander, when I started at Schiphol, you had paved the way. It was incredibly helpful to have someone guide me through what it actually means to do a PhD within a company, because honestly, I had no idea. It's been great to see everything you've achieved and to see your own research come to completion.

Bart, already during my studies, I was inspired by the way you look at mobility. We went through the final stretch of the PhD journey together, and it was comforting to have someone who understood exactly how that period felt.

Suzanne, thank you for all the lovely lunches we've shared. We could talk endlessly about baking, about mobility, but also about life in general. I'm grateful that you participated as a co-author on one of the papers and that you've always followed my research from the sidelines with genuine interest.

And a special thank you to Maike and Jesse; I'm lucky to have you both as PhD friends. I've thoroughly enjoyed all the great conversations, Aperol Spritzes, and trips we've made. And Maike, I can absolutely recommend doing a PhD alongside you; you always had great advice - both for PhD life and personal life - but of course mainly for the daily GIFs you send. :)

Many thanks to all the participants and organizations who contributed to this research. It was inspiring to learn from your work and to hear about the effort you put into creating better ways of traveling. Your participation was invaluable to my research.

Thanks also to the students who completed their graduation projects under my supervision; Berend, Zahra, Sarah, Samuel, Avi, and Meike. A special thanks to Ece, with whom I travelled across Europe exploring multimodal air journeys. I was very happy that you stayed on at Schiphol for a while afterwards.

Many thanks to all my dear friends. I'm sorry for all the times I canceled plans at the last minute because I had to write or my PhD demanded my attention once again. I'm incredibly grateful to have you all in my life, and I'm

very happy that I can now join you more often. A special thank you to Mau, Caro, Room, Floor, Ans, Cato, and Wan, for never forgetting about me. And Mau, for your invaluable service of breaking your leg, just so we could test the special assistance experience at the airport ;).

And of course, thank you to all my (in-law) family. I'm so happy that I finally get to share this day with you!

Papa, when I once doubted whether I should study in Delft – because I didn't have physics in my curriculum – you said: "*First decide what you want, then figure out how to get there.*" You've always had a knack for saying the right wise things, and I love that I inherited my passion for creating and innovating from you.

Mama, you are always there to listen, to think along, and to share everything, from choices and frustrations to the happy moments. Your warmth and involvement mean a lot to me.

Carlijn, Noor and Thomas, I'm so grateful for the close bond we have. Carlijn, you were one of the first to be proud of me when I decided to start my PhD, and thank you for always celebrating my wins with me. Noor, thank you for listening to my endless PhD stories, even when you had much more important things to share. You and Thomas have reminded me over the past months of what truly matters, with the arrival of Fien, the sweetest little niece there is.

And to Jacco and Marie-Louise, for opening your home to us over the past few months and for your kind support.

My deepest thanks go to Bob. I could ask you to do anything, from picking up packages in Delft, fixing flat tires, bringing me dry shoes, and repairing phone screens, to giving me countless foot massages. You also took on so much during the sale of our house and the purchase of our new place in Utrecht, which you also managed to renovate and oversee. The past year and a half have been intense for both of us; somehow, everything seemed to happen all at once. I genuinely mean it when I say I don't know how I would have done any of this without you. A thousand thanks for your unconditional support, the overload of compliments, and the way you always speak about me with such pride. Beyond being the best boyfriend I could imagine, you're also my favorite travel buddy, and I hope we'll share many more adventures together.

LIST OF PUBLICATIONS

Publications part of this thesis

- Toet, A., van Kuijk, J., & Santema, S. (2022). Transforming airport hubs into future-proof Multi-modal Transport Hubs. *Relating Systems Thinking and Design (RSD11) Symposium: Possibilities and practices of systemic design, Brighton, UK.*

- Toet, A., Van Kuijk, J., Boersma, K., & Santema, S. (2023, October 9). Themes for an airport hub in the transition towards a multimodal transport hub – an embedded researcher's perspective. *IASDR 2023: Life-Changing Design, Milan, Italy.* https://doi.org/10.21606/iasdr.2023.272

- Toet, A., van Kuijk, J., Boersma, K., & Hiemstra-van Mastrigt, S. (Accepted for publication). On the Move: Understanding Passenger Experience and Journey Integration in Multimodal Travel at Europe's Airports. *Transportation Research Interdisciplinary Perspectives,* Accepted for publication.

- Toet, A., van Kuijk, J., Boersma, K., & Santema, S. (Under review). Key Factors and Delivery Mechanisms for Passenger-Oriented Multimodal Air Journeys: A European Practitioners' Perspective. *Research in Transportation Business & Management,* Under review.

- Toet, A., van Kuijk, J., Boersma, K., & Santema, S. (Accepted for publication). Tensions in Air and Rail Integration Based on a European Longitudinal case Study with Stakeholders. *Journal of Sustainable Mobility and Transport,* Accepted for publication.

Other publications

- Toet, A., Boersma, K., & van Kuijk, J., 2025. Reimagining the role of hub airports as multimodal transport hubs in a sustainable future. *Journal of Airport Management*

Workshops

- Toet, A., Mouchrek, N., Ciliotta Chehade, E., 2024. Empowering travelers: how might we improve the airport experience? *DRS2024: Boston, 24-28 June, Boston, United States, Design Research Society.* (Workshop)

Presentations

- Toet, A., 2023. Transforming Airport Hubs into passenger-oriented

Multimodal Transport Hubs. *Week of International Rail, Railforum.* (Invited speaker).

- Toet, A., 2024. In the Blink of an Eye. *The Industrial Marketing and Purchasing Group (IMP) Conference 2024.* (Invited speaker).
- Toet, A., 2024. Flying through Europe by rail. *European Aerospace Science Network International Conference 2024* (Invited speaker).
- Toet, A., 2025. Improving passenger experiences in multimodal (air) travel. *Passenger Terminal Expo 2025* (Invited speaker).
- Toet, A., 2025. Working towards Air&Rail integration. Air-Rail integratie. *Railforum.* (Invited speaker).

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PROFILE

Designer and researcher with a background in innovation strategy and multimodal transport systems. Experienced in connecting academia and industry, focusing on designing frameworks, learning from complex environments, and collaborating with students. Driven by a systems perspective and a user-oriented mindset to create future-focused solutions. Energized by discovering new opportunities and addressing the urgent needs of society and the planet.

- -

WORK EXPERIENCE

Multimodal Hub PhD Candidate
Sep 2021 - Sep 2025

Delft University of Technology | Royal Schiphol Group

PhD research on improving the integration of transport modes at airport hubs, with a focus on designing passenger-oriented multimodal air journeys. The dissertation identified key barriers to integration, emphasized the need for a systems approach, and proposed five principles for enhancing the development and delivery of seamless multimodal travel experiences. The work provides actionable insights for researchers and practitioners.

•   Part of Schiphol's Master Planning team, Innovation Hub, and the faculty of Industrial Design Engineering (TU Delft).

• Led a 16-month Air&Rail strategy project with multimodal stakeholders

• Coached 26 student teams, and 8 master graduate students

Innovation Lead Multimodal Hub
Apr 2022 - Nov 2022

Royal Schiphol Group

Temporarily served as Innovation Lead for multimodal topics at Schiphol, focusing on the future of integrated and sustainable transport. Projects explored emerging technologies and the role of airport hubs as multimodal nodes in future mobility networks.

• Lead position within Innovation Hub for multimodal topics at Schiphol

• Led projects exploring electric aircraft, eVTOLs, hyperloop, and concepts for future transport hubs

• Coached summer interns who contributed to multimodal exploratory research

Graduate Internship
Sep 2020 - Feb 2021

KLM

Developed a concept framework to rapidly generate and structure innovation projects, while providing early insight into their potential value and strategic relevance.

• Positioned within KLM's Digital Studio, part of portfolio management team

• Tested a design-based framework with KLM employees to initiate and structure innovation projects in uncertain, real-world settings.

Extracurricular Activities

Supported local businesses in Tanzania with strategic business planning.   Sep 2017 - Feb 2018

- -

EDUCATION

2019 - 2021

MSc Strategic Product Design

(Cum Laude)

Delft University of Technology

2015 - 2018

BSc Industrial Design Engineering

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CERTIFICATES

- Public Speaking
- Human-centered Systems Thinking (IDEO)
- Data Visualization
- Creative Tools for Scientific Writing