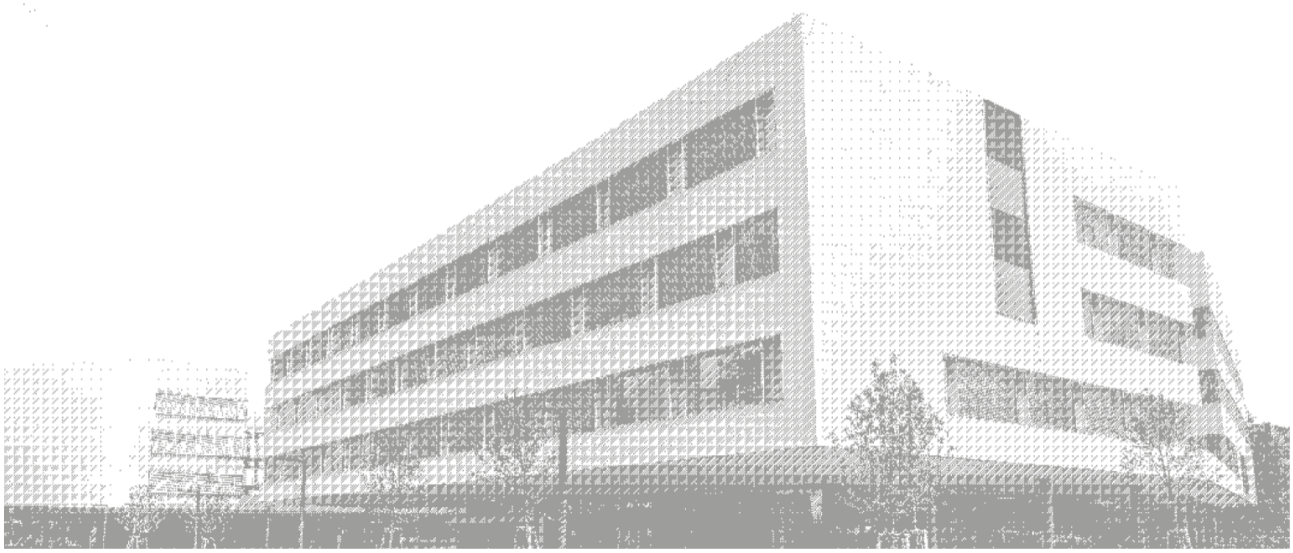

International Rail Ticketing

Future Perspectives on Competitive Booking Procedures for European Railways

Master Thesis
Summer Semester 2023

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Supervisor: Dipl.-Ing. Thomas Preslmayr

Preamble

This thesis was created between October 2022 and September 2023 in the course of my studies of Rail Technology and Management of Railway Systems at the St. Pölten University of Applied Sciences.
In 2019, while undertaking my Erasmus Internship, I had the opportunity to work at Eurail BV. in the Netherlands, a company that specializes in offering convenient travel options across 33 countries through the sale of Interrail and Eurail rail passes. While experiencing traveling internationally myself, some aspects like buying additional mandatory seat reservations, have been complex and frustrating in many cases. This issue is even more apparent when traveling without a rail pass, as to acquire a ticket in many cases multiple non-consistent booking sites need to be consulted. Therefore, I wondered how to improve the customer experience of rail ticketing.
Given my educational and professional background in computer science, gaining insight into the technical aspects of in-place systems and the environment needed to enable improvements fascinates me. I appreciate the opportunity to combine this personal interest with a research topic relevant to the success of the sector.

I would like to take this opportunity to thank …

... my supervisor Thomas Preslmayr, for providing professional and reliable support during the writing of this thesis. I am truly grateful for his constructive suggestions, guidance, and dedication throughout this academic journey.

... all interviewees for their precious time. This research could only be conducted reasonably based on their essential and inspiring insights.

... my friends for providing their help in the review process. Special thanks to Maximilian Zander and Joachim Meyer.

... my family for supporting me during all of my studies. Their encouragement has been fundamental in my academic journey, and I am truly grateful for their backing.

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David Prenninger
St. Pölten, September 2023

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Agreement for Publication

The author agrees that St. Pölten University of Applied Sciences is authorized to publish the present study in its original form in print or in PDF format by naming the author.

Affidavit

I hereby declare on oath that I have produced the present work myself. Ideas and thoughts derived from outside sources are identified as such. The work has never been submitted or published in the same or similar form.

David Prenninger
St. Pölten, September 2023

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Abstract

Rail is to play a more significant role in decarbonizing the mobility sector. This especially concerns international rail travel within Europe. Previous studies have revealed that, alongside infrastructure improvements and service enhancements, ticket distribution poses a significant obstacle for potential passengers.

Based on a qualitative user survey and a manual analysis, this thesis demonstrates that on selected routes, one out of every five bookings fails due to limited availability and poor user guidance. Additionally, the availability and bookability of international railway tickets, as well as the needs and expectations of customers during ticket acquisition, are evaluated.

To identify the underlying issues and potential measures for improving the current situation, the technical landscape of international rail ticketing systems has been analyzed. Current distribution systems are characterized by custom proprietary developments, restricting interoperability. The European Commission has launched initiatives aiming to reduce systemic fragmentation and facilitate improvements in international ticket sales within Europe. The creation of standardized interfaces allows components to be interchangeable and work interoperable between different systems.

The actual availability of tickets is not only limited by technical requirements but is also influenced by economic and political measures. Future regulations hold the potential to lay the groundwork for a One-Stop-Shop for international train travel in Europe. This requires an open exchange of data regarding schedules, fares, and real-time information, as well as rules for combining individual journeys, ensuring connections, and facilitating external distribution.

Overall, this thesis evaluates and lists the necessary improvements in ticket distribution to position the railway as a competitive mode of transportation for international travel within Europe.

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Zusammenfassung

Im Zuge der Dekarbonisierung des Mobilitätssektors soll der Eisenbahn eine bedeutendere Rolle bei internationalen Reisen innerhalb Europas zukommen. Vorangegangene Untersuchungen zeigen, dass dabei neben infrastrukturellen Maßnahmen und Angebotsverbesserungen vor allem der Fahrscheinvertrieb ein großes Hindernis für potenzielle Fahrgäste darstellt.

Diese Arbeit enthält eine Erhebung der Buchbarkeit mittels einer Probantenbefragung, welche zeigt, dass jede fünfte Buchung auf ausgewählten Relationen mangels limitierter Angebote und durch eine schlechte Nutzerführung scheitert. Des Weiteren wurden Verfügbarkeit und Buchbarkeit von internationalen Eisenbahnfahrscheinen, sowie die Bedürfnisse und Erwartungen von Kund*innen beim Fahrscheinerwerb erhoben.

Um die Hintergründe und mögliche Maßnahmen zur Verbesserung des Status-Quo identifizieren zu können, wurde die technische Systemlandschaft der internationalen Buchungssysteme analysiert. Während aktuelle Vertriebssysteme durch Eigenentwicklungen geprägt sind, existieren Bestrebungen auf europäischer Ebene, Standardisierung zu fördern, um die systemische Fragmentierung zu reduzieren und den internationalen Ticketvertrieb innerhalb Europas zu erleichtern. Um Komponenten zwischen verschiedenen Systemen interoperabel zu machen, werden einheitliche Schnittstellen geschaffen.

Die tatsächliche Verfügbarkeit von Fahrscheinen wird jedoch nicht nur durch technische Voraussetzungen begrenzt, sondern auch durch wirtschaftliche und politische Maßnahmen beeinflusst. Zukünftige Regulierungen bieten dabei das Potenzial, die Grundlagen für einen One-Stop-Shop für internationale Bahnfahrten in Europa zu schaffen. Dazu sind ein offener Datenaustausch von Fahrplänen, Tarifen und live Daten nötig, sowie Regeln zur Kombination einzelner Fahrten, Anschlusssicherung und Fremdvertrieb.

Insgesamt werden in dieser Arbeit Verbesserungen im Ticketvertrieb evaluiert und gelistet, die erforderlich sind, um die Bahn als konkurrenzfähiges Verkehrsmittel auf internationalen Relationen innerhalb Europas zu positionieren.

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1 Introduction

Emission reduction is required in all economic sectors to conform with the goals defined during the 2015 Convention on Climate Change (COP 21) in Paris. The decarbonization of transportation demands a reduction, electrification, and an increase in the efficiency of trips. Rail-based transportation offers low direct emissions and high energy efficiency. Therefore, a modal shift from individual fossil fuel-based modes of transportation to rail is aspired [77, p. 20].

The European Union stipulates the liberalization of the railway sector to generate internal competition and strengthen the sectoral appeal, supporting this transition. As a result, new business models have been created, and new competing railway companies were established. Meanwhile, the point of purchase for rail tickets is shifting from human agents towards online sales platforms [107]. Therefore, instead of approaching one station counter to buy a ticket, customers often need to navigate through multiple points of sale online. In this process, the availability and ease of purchase of tickets play a crucial role in letting passengers utilize the whole liberalized European railway network as one integrated transportation system and alternative attractive transportation mode for international journeys.

In 2021, Thomas Stütz [113] quantified the factual online availability as well as the accessibility of international tickets for Austrian passengers within his master thesis ”Schwachstellen im internationalen Ticketing” (en: ”Weak points of international ticketing”). The results of this evaluation show a high potential for improvements in the field of customer experience.

To follow up on the preceding analysis, the customer view on International Ticketing is reevaluated in this thesis to check for improvements promised in 2021 by railway companies, enabled through the introduction of the Open Sales and Distribution Model (OSDM). A geographically expanded view on the issue covering not only the Austrian public is needed to be able to assess upcoming proposals by the European Commission. Furthermore, European rail ticketing systems are influenced by additional new legislation like the recast on rail passenger’s rights and obligations (EU 2021/782, [45]) that has been put in place by the European Union. Moreover, several older directives have not been evaluated on their effects on rail ticketing (e.g., EU 2017/1926, [116]) and are considered in this revision.

To get an overview of already present booking systems, including the tech stack, interfaces, and service providers, a technical landscape of the system architecture is drawn. Finally, the legal and technical building blocks of a successful system for international rail ticketing in Europe are identified.

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1.1 Research Questions

The following research questions were picked as leading research questions for this work:

What is the customer experience when booking an international train ticket?

1.1 Did the bookability of former unbookable itineraries change since early 2021?
1.2 How does the booking duration differ between rail and air travel?
1.3 Which kind of added value offer mobility platforms?
1.4 What is the expectation of customers regarding international train ticketing?
1.5 How does the booking experience differ between nations within the investigation area?

What is the current technical framework for an international rail ticketing system?

2.1 How does the current system landscape look like from a technical perspective? Which systems are connected?
2.2 Which standards and interfaces are already used?
2.3 Why did former approaches to international ticketing platforms (like the Railteam-broker) fail?
2.4 Which standards and interfaces are drafted or tested?
2.5 Which technical challenges exist? What can be done to solve them?
2.6 How does the market of third-party software suppliers in the field of routing or ticketing look like? What is their role in international rail ticketing?
2.7 Which technical aspects should an international ticketing system ideally fulfill to improve the customer experience?

How does the economic and legal framework influence the development of international rail ticketing?

3.1 Which political and commercial interest groups exist? What are their goals and methods?
3.2 Which aims might contradict? Which commonalities or partnerships exist?
3.3 What are the main incentives and barriers for railway companies to implement inter carrier booking platforms?
3.4 Which legal requirements exist?
3.5 How could the legislative framework be changed to improve the customer experience of international ticketing?

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1.2 Methodology

Following the structure of the research questions, this thesis is split up into three parts, focusing on the customer, political, and commercial interests as well as technical solutions.

The first part of this thesis consists of a qualitative review of the bookability of international rail connections within Europe, followed by a quantitative customer survey (as a follow-up to the 2021 survey conducted by Thomas Stütz) to gather information about the customer experience. In Section 2.2.3, a detailed description of the survey's methodology is given.

The second part of the research is based on a technical analysis of the current international ticketing system landscape. To collect information about all underlying components, several booking systems have been reviewed based on their core technology, standards, interfaces, and interrelationships. This information is retrieved from customer-facing interfaces and expert interviews, while standard specifications and technical documentation serve as base material. As a result, exemplary systems are analyzed in greater detail. Further, graphical schematic representations of their technical architecture are created. Open questions and still unknown system aspects are highlighted and recorded for further research.

The last part, focusing on the legal and political framework, is based on explorative research as well as expert interviews. To get to know decision-makers and members of interest groups the sectoral job fair at the St. Pölten University of Applied Sciences[1], the anniversary celebration of the Austrian Klimaticket [2], and the 2022 symposium of the Austrian Schienen Control [3] have been visited to get in contact with decision-makers and interest groups. In succession, the following organizations have been directly contacted and interviewed about the topic: European Union Agency for Railways (ERA), EU Commission, HACON, Allrail, ÖBB, DB, Eurail, and Westbahn. Other organizations have been contacted but did not answer or did not show interest in the request for an interview, these include: Railteam, NS, TSGA, International Association of Railways (Union internationale des chemins de fer) (UIC), and Smart Ticketing Alliance.

[1] https://www.fhstp.ac.at/de/audiences/studierende/karriere-messen/firmenmesse-der-bahnbranche

[2] https://www.eventbrite.at/e/1-jahr-klimaticket-die-mobilitat-der-zukunft-wird-eins-tickets-406170897087

[3] https://schienencontrol.gv.at/en/splash-en.html

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The following experts have been interviewed as part of this thesis (cf. Appendix A.1):

- Klaus Kovar (Business Analyst - ÖV Ticketshop), Robert Prasnikar (System-Architect - ÖBB-Personenverkehr)
- Christian Pettauer (CIO - WESTbahn)
- Claus Fischer (Ticketing Software Developer - Dr. Claus Fischer)
- Hugo Knobbout (CIO - Eurail)
- Hans-Jürgen Freisinger (Project Manager - HACON)
- Alexander Mokros (Head of International Cooperations and Industry Partners - DB)
- Nick Brooks (Secretary General - Allrail)
- Stefan Jugelt (Project Manager - European Union Agency for Railways)
- Petra Söderqvist (Policy Officer - EU Commission, written answer)

Besides, CER and passenger associations (BEUC, EPF, Allianz Pro Schiene e.V., etc.) have not been contacted, due to the sufficient count of statements through public position papers.

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1.3 Definition of Terms

Several terms used within the following thesis need to be defined to establish a shared understanding and ensure clarity. The meaning of acronyms is listed in Section 5.3.

Bookability
In this thesis, bookability is used as a metric, describing the quality or degree of rail tickets being available for specific connections. It encompasses the seamless accessibility and absence of impediments associated with purchasing such tickets.

Combined-Journey
Multiple distinctive legs of a journey, operated by different companies, which are sold as one ticket package. Despite being displayed as one journey at the distribution platform, the included tickets are sold individually to the customer, resulting in no guarantee of transportation in case of disruption. With EU 2021/782 coming into force, the limitations of such offers need to be communicated with the customer pre-purchase.

Integrated Reservation Ticketing (IRT)
A ticketing strategy that treats tickets as directly assigned to a specific train and seat. This method is used on high-speed rail services across Europe. (e.g., France, Italy, Spain). An IRT ticket is limited to one rail connection. If a trip consists of multiple legs, the customer will receive one ticket for each service journey. As seat reservations or service upgrades are included in the ticket, IRT tickets are also referred to as global price tickets.

Interoperability
Within this thesis, Interoperability ”is [seen as] the ability of organizations to interact towards mutually beneficial goals, involving the sharing of information and knowledge between these organizations, through the business processes they support, by means of the exchange of data between their [information and communication technology] ICT systems.” [24, p.5]

Leg
In the context of this thesis, a ”leg” refers to a distinct segment or portion of a journey that encompasses travel between two specific points.

Mobility Platforms
In the following, a Mobility Platform is a third-party online travel agent or ticket aggregator page selling tickets from rail companies and/or letting customers compare offers and prices.

Non integrated Reservation Ticketing (NRT)
A ticketing strategy that allows more flexible tickets, which only include the right to travel on a specified route. Specific restrictions can be applied to the ticket, such as being limited to specific train categories or particular trains. Seat reservations are treated as an additional feature that can be added to the ticket. It is commonly used in regional transit systems. Examples of NRT ticketing utilized in high-speed rail or long-distance services can be found in

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Germany or Austria.

Service Endpoints
When offering digital services, the provider might define an Application Programming Interface (API), which provides access to different resources. These access points are within this thesis referred to as endpoints.

Service Journey
The full route a specific rail service is taking. A Passenger might use the service on only a subsection of this route.

State-Incumbents
Formerly state-owned and operated railway companies that dominate local markets.

Through-Ticket
A single ticket that covers multiple distinctive legs. It is also commonly referred to as integrated ticket. Each leg might be operated by a different Railway Undertaking (RU).

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1.4 Delimitation of the Area of Investigation

1.4.1 Time Delimitation

The writing of this thesis has been executed between October 2022 and September 2023. All results of the customer survey are based on the data collected between 15. December 2022 and 23. January 2023. Any development after the specified periods is therefore not reflected in this work.

1.4.2 Spatial Delimitation

The area of investigation includes all countries of the European Union except the Baltic States (Estonia, Latvia, Lithuania), Finland, Ireland, and Greece, as at the time of writing only very limited to no international rail services to these countries are operational. Additionally, Switzerland, the United Kingdom, and Norway have been added to the area of concern, as they are highly interconnected within the European rail network and voluntarily apply TSI regulations. [101, p. 10] This is not the case for the Balkan region, and no services directly connecting to the network of neighboring countries in 2023. The total area of investigation can be seen in Figure 1.

Figure 1: Spatial delimitation of the area of investigation, Source: own representation

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Additionally, only online sales channels have been evaluated, as those are accessible for all countries of the investigation area. While the study area is spatially limited, the empirical customer survey was open to everyone, regardless of origin.

1.4.3 Subject Delimitation

The evaluation conducted as part of this thesis focuses on specific aspects influencing the customer experience of acquiring an international rail ticket. As a comprehensive qualitative analysis of ticket prices would require knowledge of all potential time-dependent variations, a price-related analysis has been excluded.

While presenting general technical ideas of rail ticket distribution, this thesis focuses on aspects that influence international rail ticketing, not covering all local or national ticketing standards. Furthermore, to find out more about the technical evolution of international rail distribution, only domain-specific developments are highlighted, meaning that the general trends of software development are not directly addressed, but referenced if relevant.

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2 The Customer Perspective

This thesis approaches the issue of international rail ticketing from a customer point of view, to identify hurdles and needs of potential clients.

To get insights into the current state of international rail ticketing from a customer perspective, a qualitative analysis of the availability of bookable online tickets has been conducted. This review is accompanied by an empirical customer survey. Finally, the market, opportunities, and risks of mobility platforms are highlighted to evaluate this emerging market and its implications for customer experience.

2.1 Manual Availability Analysis

To gain ground truth data on the availability of international train tickets, online sales channels have been reviewed regarding their capabilities. To provide extensive data, automatic as well as manual testing methods to check the online availability of international rail tickets have been evaluated.

While providing better scalability and enabling a wider scope of the analysis, automatic testing demands that the success criteria and as many possible failure cases as possible are known. However, the first attempts to collect failure cases have shown no consistent behavior on some booking sites. As an example, a booking request on Trainline.com for one relation might return no train connections at all at one time, despite, after rerunning the search, all available connections are shown and bookable. Such unexpected behavior should be recognized and noted, while the relation should still be recorded as available and bookable during this analysis.
Therefore, to be able to fit a verification of the relations into the scope of this work, a manual approach has been chosen.

To create a general overview, all booking platforms of state incumbents inside the research area have been tested on their ability to sell tickets to other countries. This process involved conducting separate analyses of transportation routes connecting country A to the capital city of country B. This assessment was carried out for both Wednesdays and Saturdays, marking a shop as capable in case at least one connection has been bookable.

Gathering more detailed insight into specific relations, 56 city pairs have been chosen to be further investigated. The list of selected cities is based on the one chosen in 2021, while additional cities with over a hundred thousand inhabitants have been added to equalize the distribution within Europe. A Complete list of all relations can be found in Appendix A.2. All relations have been checked on their availability at five possible distribution channels, including the webshops of rail incumbents (or Eurostar) of the origin and destination country and three mobility platforms (Omio, Trainline, RailEurope). In case no ticket is bookable on a platform, even if connections are displayed, the journey has been classified as not avail-

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able. If a journey is required to be split up, so no through-ticket but both separate legs are bookable, the relation has also been categorized as not available. To improve the coverage of this analysis, each connection has been checked for every weekday two and four weeks up front. If an offer is available for at least one day, this is taken into account.

2.1.1 Results

Within the overall analysis of rail incumbent booking platforms, besides the far reach of central European distribution systems (e.g., SNCF-connect.com, nsinternational.com, bahn.de, oebb.at, b-europe.com, and sbb.ch) only limited cross-border capabilities have been observed. Figure 2 shows all incumbent ticket platforms selling international tickets in different colors. The ability of one site to offer a ticket to a specific country is indicated by a correspondingly colored circle. South-west and south-east European incumbents as well as National Rail did not offer international destinations at all.

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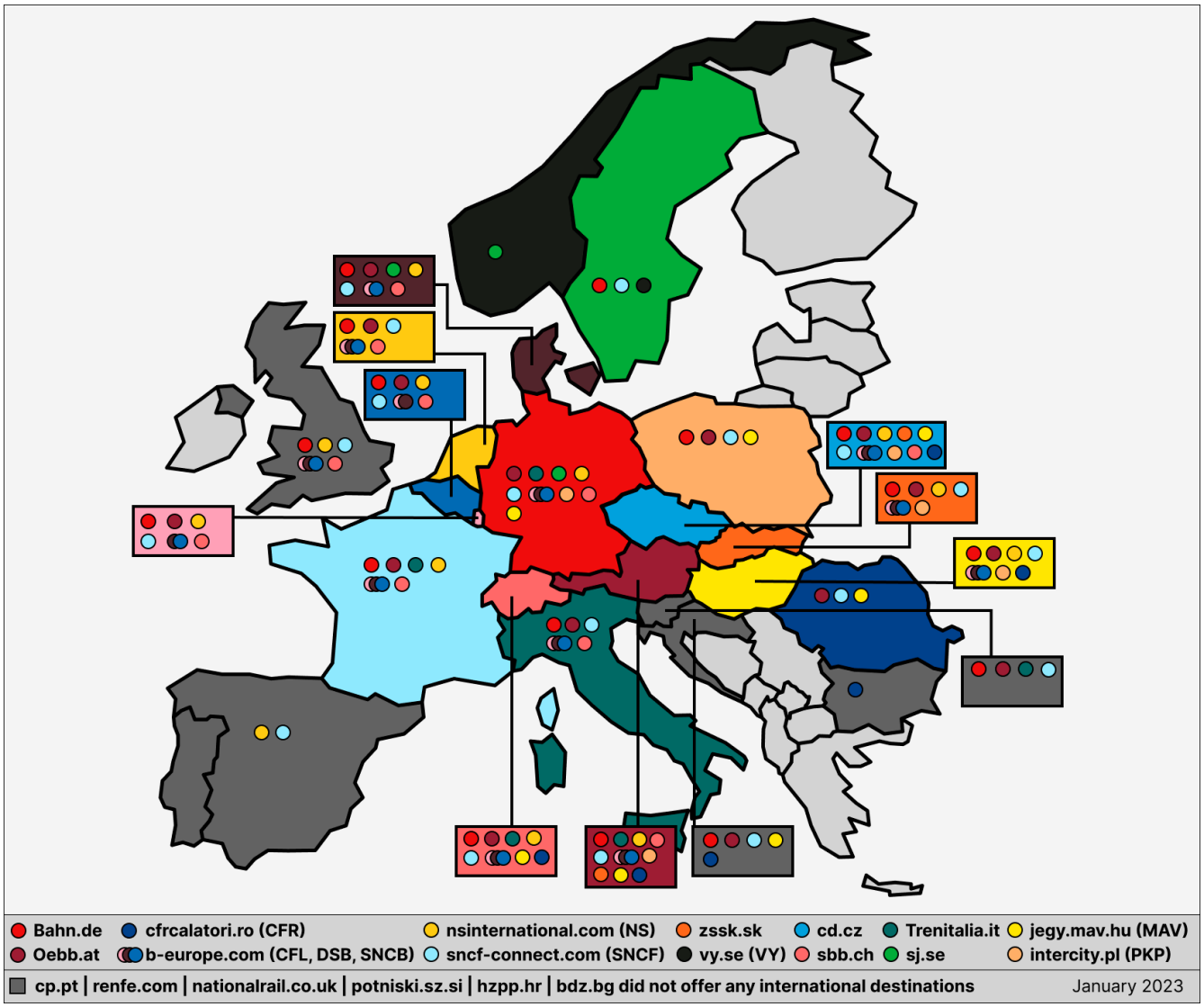

Figure 2: International ticketing capabilities of state incumbent ticket shops, Source: own research

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The first analysis of the selected relations has been conducted on 7. December 2022, leading up to the customer survey. This process has been repeated on 27. February 2023 to validate and include changes in the context of the recent timetable update. Between both iterations, the bookability of only one relation improved, as the shop of the Romanian carrier CFL stopped throwing an error when booking a train to Sofia.

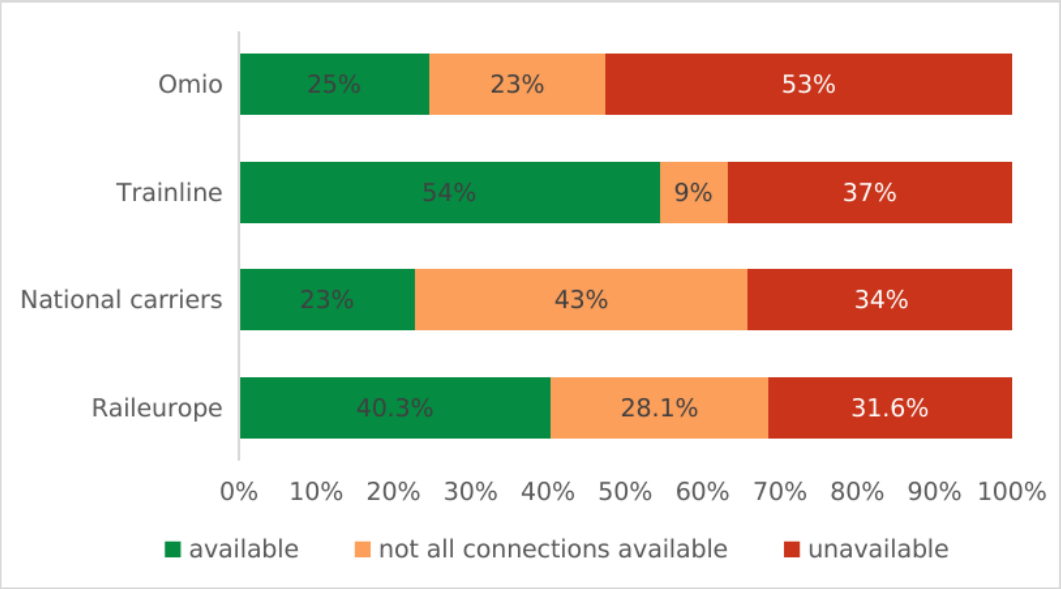

Figure 3: Availability of relations used in customer survey (full list in Appendix A.2) (n=56), Source: own research

In the case that only some of the present connections are bookable, the limitation has been documented, and the relation is classified as ”not all connections available” (orange, see Figure 3). If a wide selection of possible journeys is available, including all carriers offering service on legs of the trip, the relation is classified as ”available” (green, see Figure 3). In case no availability has been recorded at all, the platform has been marked as red.

Due to different internal recommendation mechanisms, varying results (route, stop-overs, price, etc.) still occurred.

While tickets for Paris ↔ London have been available on all tested booking platforms, out of 56 relations selected, five relations could not be booked on any website in both tests. These are:

- Madrid ↔ Porto
- Seville ↔ Lisbon
- Bratislava ↔ Cluj-Napoca
- Košice ↔ Sofia

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- Groningen ↔ Oslo

The complete list of all tests can be found in the Appendix A.2.

During this review, several booking pages, including the example of Trainline.com mentioned above, showed unanticipated behavior.

- The webpage of PKP Intercity only allows one tab to be opened simultaneously. If another tab is opened, an error message is shown after clicking the ”search” button, advising the user to close one tab again (cf. Appendix, Figure 49).
- Hungarian national railway MAV offers a wide selection of international journeys on their booking platform, however, no booking is possible, as long as not at least the start or destination is located inside Hungary (cf. Appendix, Figure 46).
- Tickets for specific connections from Poland to Austria can be booked online at oebb.at, but the website notifies the user, that the purchase as a ”print-at-home”-ticket is not possible. The same applies to tickets from Bucharest to Sofia and vice versa bought from CFR. Instead of receiving a digital ticket, customers are directed to retrieve a physical ticket at a vending machine or agent at the station of the home country of the railway (ÖBB - Austria / CFR - Romania).
- International SNCF services are not displayed when searching a route on sncf.fr. Again, no information about why this is the case is given to the customers, despite SNCF Connect delivering the desired results.
- Multiple pages (DB, CFL, ZSSK) promise to show or calculate prices in another step of the booking, but fail in many cases with different or no reason, without providing help or alternatives for the customer (cf. Appendix, Figure 47).
- Several national rail carriers (DB, SZ, DSB, NS, SNCB, CFR, CFL, Vy) redirect their customers, searching for international trains to pages, differing from their main booking platform. Depending on the carrier, the linking between these pages is integrated with the search of an international trip on their main page, separated as a button or link on the landing page, or not directly linked at all.
- In the case of Slovenske železnice (SZ), customers need to find a not highlighted link saying ”International transport”, which redirects them to the regular booking platform of DB (reiseauskunft.bahn.de) (cf. Appendix, Figure 48). Entering any connection from or to Slovenia will redirect the customer again to international-bahn.de, where the birthdate of travelers is required.

By February 2023, no incumbent displays private rail connections on the tested itineraries, and vice versa. As this review covered not all options for ticket purchase, no final conclusion can be drawn by this analysis, if a connection is generally bookable online. Nonetheless, the review covered the main entry points for customers on their search for tickets, as highlighted in Section 2.2.5.7.

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In contrast to the limited availability of train tickets, for all trips plane connections to the destination or close-by airports could be booked using a Global Distribution System (GDS) connected booking platform (e.g., Skyscanner, Google Flights, etc.).

2.1.2 Comparison to 2021

To answer the first research question ”Did the bookability of former unbookable itineraries change since early 2021?” (Question 1.1), five itineraries, that have not been bookable online in 2021 have been reevaluated.
As the previously reviewed 56 relations did not include Linz ↔ Oświęcim and Graz ↔ Split these have been checked additionally.

The result shows, that three out of five relations (Vienna ↔ Madrid, Warsaw ↔ Prague, Vienna ↔ Gdańsk [with Euronight]) are now available online (cf. Table 1) (marked green, orange if limitations apply). However, the relations Graz ↔ Split and Linz ↔ Oświęcim are still not bookable at the tested platforms online as through-ticket (red).

	2021*	2023				
		Trainline	Omio	Raileurope	Incument (out)	Incument (in)
Graz → Split				(1)	ÖBB, (1)	HZPP
Linz → Oświęcim					ÖBB, (1)	Koleje Śląskie
Vienna → Gdańsk				(1)	ÖBB, (2)	PKP-Intercity, (3)
Warsaw → Prague		(1)		(1)	PKP-Intercity, (1)	CD, (4)
Wien → Madrid					ÖBB, (1)	RENFE

(1) Timetable displayed, no ticket purchase possible
(2) Tickets need to be picked up in Austria
(3) Only direct connections are available
(4) Only some connections are bookable

Table 1: Qualitative availability test of routes not bookable in 2021, Source: [113, p. 151 ff.], own reasearch

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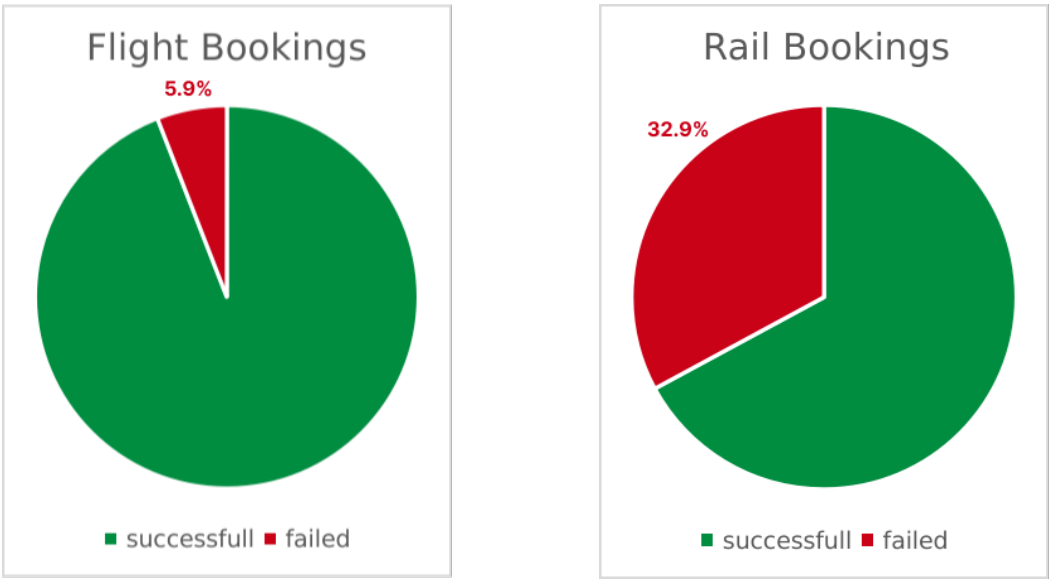
2.2 Empirical Customer Survey

To see how potential customers cope with the varying online availability of international rail tickets and how they progress in the booking process, a public survey has been undertaken as part of this thesis. In the following, the outcome of the former study by Thomas Stütz in 2021 (cf. [113]) is highlighted. In succession, the applied methodology of the survey 2023 is described, and the final results are presented. Concluding, summarized results from this iteration are shown.

2.2.1 Preceding Survey Results

The first iteration of this survey, directed by Thomas Stütz (cf. [113]), took place from 14. December 2020 until 10. January 2021. 76 respondents from Austria contributed by answering general questions and fulfilling two interactive scenarios. For each scenario, consisting of a relation (A ↔ B), a rail and a plane journey (one-way, 2. class / economy), including a seat reservation, should be booked by the participants. By manually assigning relations to probands, a minimal count of three probands per relation has been achieved. All participants have been advised to stop their efforts as soon as they would do in a real-world scenario. The booking has been counted as successfully finished, as soon as the payment step has been reached. After finishing the scenarios, the participants filled in an online survey, reporting on their experiences made during the booking process.

The result shows a highly different success rate between flight (94.1 %) and rail journey (67.1 %) online bookings.



(a) Success of flight bookings

(b) Success of rail bookings

Figure 4: Difference in booking success 2021, Source: [113, p.87])

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The following four out of 45 relations (44 city-pairs and one added as night and day trip separately) could not be booked by any participant:

- Wien - Pula
- Linz - Oświęcim
- Ljubljana - Zagreb
- Wien - Rom (by day)

16 others have been successfully booked by all probands. In comparison, all equivalent plane connections have been successfully booked by at least two participants. Thomas Stütz further stated that the purchase success rate of international train tickets declined significantly (-12,1 % on total success) with a lower education level of participants. Such an effect was not recordable when analyzing the equivalent flight bookings.

The mismatch between rail and air journey bookings has also been observed in the general customer satisfaction, measured using the statements made about the general booking procedure:

Transport mode	Positive	Undecided	Negative
Air	64%	18%	18%
Rail	39%	14%	47%

Table 2: Feedback on booking process (n=152),
Source: Analysis of raw data of 2021 (Thomas Stütz)

Strongly dependent on the chosen relation, the booking of a rail journey has been described by participants either to be fast and easy or problematic due to limited availability of combined or through-tickets. Besides successfully acquiring a ticket, 14 mentioned problems adding a seat reservation to their ticket / journey leg. Three comments have been made on a potential language barrier, as participants could not retrieve desired information in English nor German.

In the case of flight bookings, some participants have been confused or felt mislead. 17 felt irritated by additional offers shown by booking sites.
As the range of available direct international flight has been reduced in the winter 2020 due to the COVID-19 pandemic, offered flight connections have been irregularly complicated or longer, which affected the attractiveness of plane-connections for some connections.

At the end of the survey, participants were asked to give a rating of specific aspects of the booking. In general, the booking of train tickets has been perceived less positive compared to booking flights, mainly due to the lack of a One-Stop-Shop, ”simplicity”, ”intuitiveness”, and ”design” in the train booking process. However, train bookings were positively perceived in terms of ”price” and ”transparency” (cf. Figure 5).

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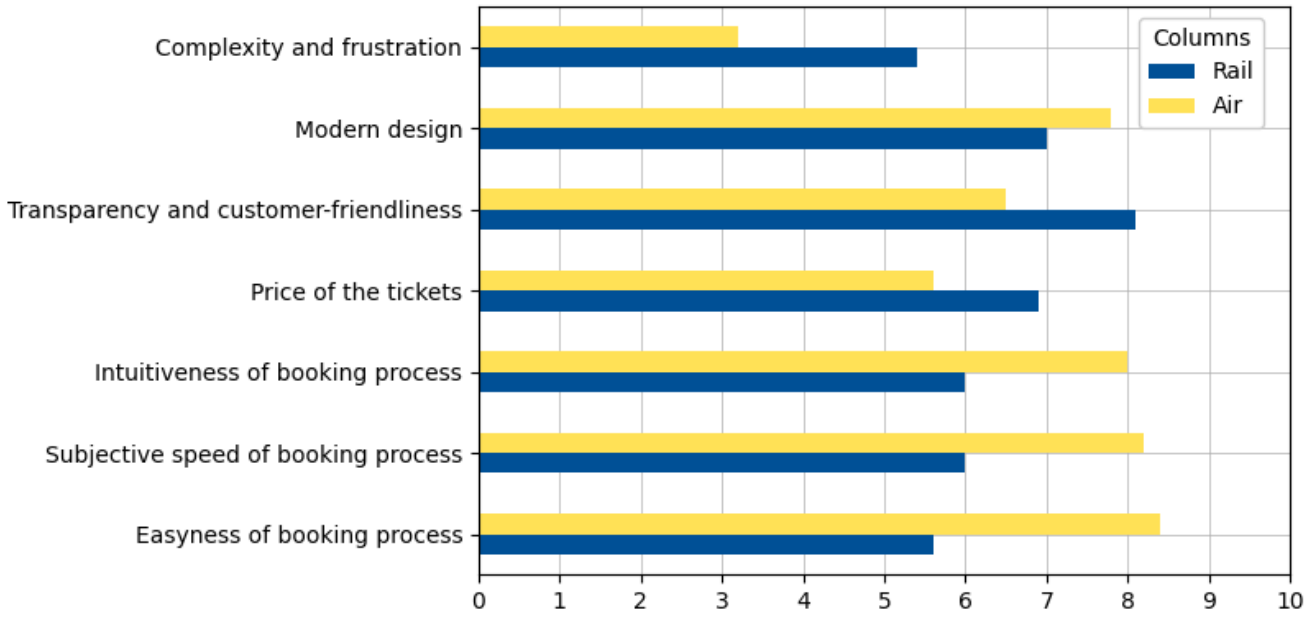

Figure 5: Quantitative rating of booking process (n=76), Source: [113, p. 96, p. 162-167]

To achieve an equilibrium of participating target groups for international rail travel, Stütz constructed personas, which have been used in the acquisition and selection process. Therefore, the survey cannot be seen as a generalized representative study, but covered certain customer groups. [113, p. 72ff.]

2.2.2 Goals of This Iteration

For the current iteration, the following three main objectives have been defined to be followed by the survey.

1. Record improvements and setbacks over time to enable an updated view on the issue. To make collected data comparable with the 2021 survey, the overall structure needs to be equal or similar in its fundaments. The general survey design, explained in detail in the following section, has been kept the same.
2. To validate the hypothesis of 2021, participants should be as diverse (in gender, age, and education) as possible. This will improve the comparability of the data with social demographics and allow specific analysis on these properties. The minimal participant count has been set to 86, to count at least three booking attempts per relation (similar to 2021), this time covering 56 instead of 44 city pairs.
3. As indicated in the underlying motivation of this work, to check if in the issue of international rail ticketing commonalities between Austria and other European countries exist, the area of investigation has been extended.

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2.2.3 Methodology

2.2.3.1 Technology and scalability improvements

To get as many participants from multiple countries in Europe to participate in the survey, the scalability of the survey needed to be improved compared to 2021. All sessions should be completed by the probands on their own. Furthermore, to improve the validation of inputs by the user and generate additional data, interactive booking scenarios, which are part of the survey, should be recorded. To fulfill these requirements, several technical changes have been made to the survey design.

In preparations of the 2022 / 2023 iteration, the tooling used 2021 (Google Forms) and alternative software (i.g. Limesurvey [4], Typeform [5], SurveyMonkey [6], etc.) have been checked on the capabilities for dynamic content presentation for customized relation assignment and session recording, as both has been identified as requirements. However, none of the available tools offered the required functionality. Therefore, a custom web-survey has been developed (see Figure 6) [7].

Based on JavaScript (Vue 3[8], Node.js[9]), this solution offers dynamic server side content generation, to evenly distribute relations and serve mission descriptions related to the previous user input.

[4] https://www.limesurvey.org/
[5] https://www.typeform.com
[6] https://de.surveymonkey.com/
[7] https://github.com/TheNewCivilian/Fahrgastbefragung
[8] https://vuejs.org/
[9] https://nodejs.org

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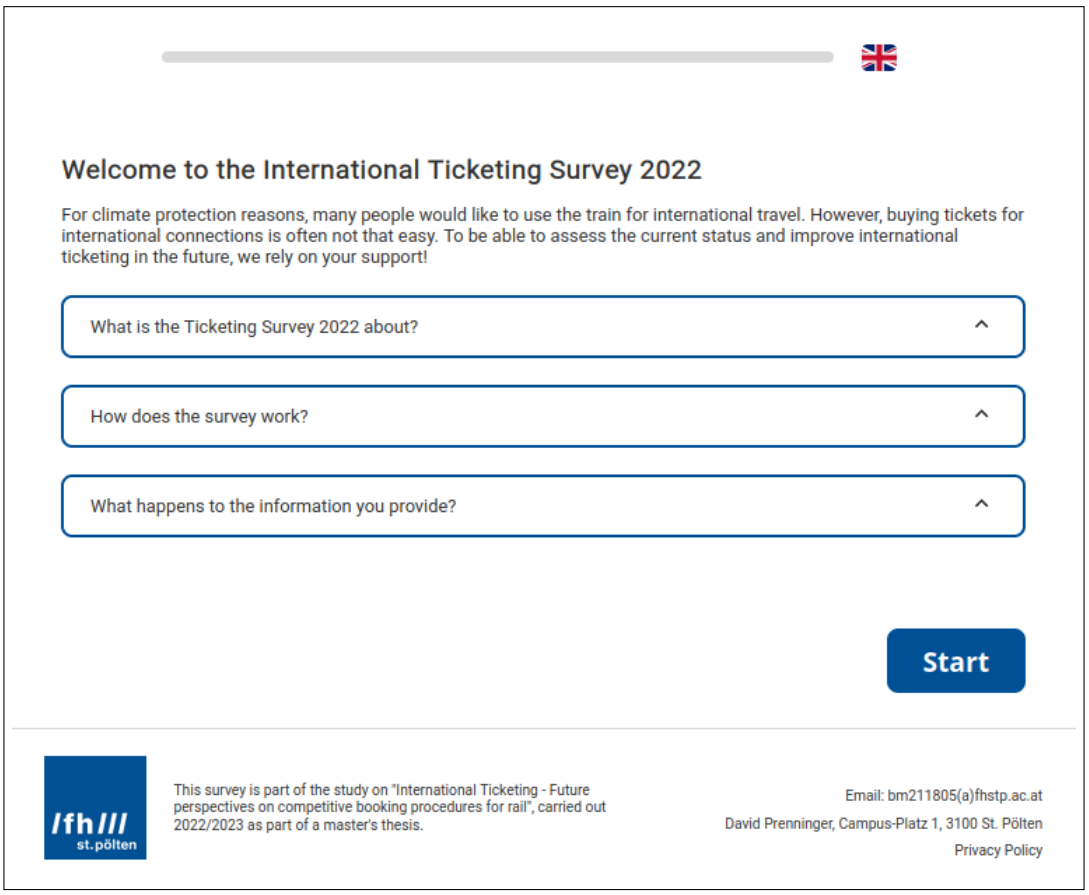

Figure 6: Screenshot of the survey tool landing page (All questions in Appendix A.2), Source: own representation

Participants have been presented an Opt-in option for recording their screen, while fulfilling interactive booking scenarios. During the development of this tooling, other methods of data gathering have been checked for viability, including the implementation of a Browser extension, to enable click-tracking on booking sites. As, during tests, those have been proven to be distracting and lead to a higher user drop-out, only screen recording has been included in the final version of the survey tool as an additional, monitoring option, requiring user interaction. All texts within the survey have been provided in English and German, by autodetecting the default browser language.

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2.2.3.2 Survey Structure

The fundamental content structure of the survey has been kept the same, consisting of general questions about the participant, two interactive booking scenarios followed by related questions and a final section about the general impression of railway vs. airline ticketing.

As some questions are only relevant for a selected group of people, the prompted questions differed between participants (e.g., Not questioning the duration of a booking, if it has been not successful). The overall structure of the survey can be seen in Figure 7.

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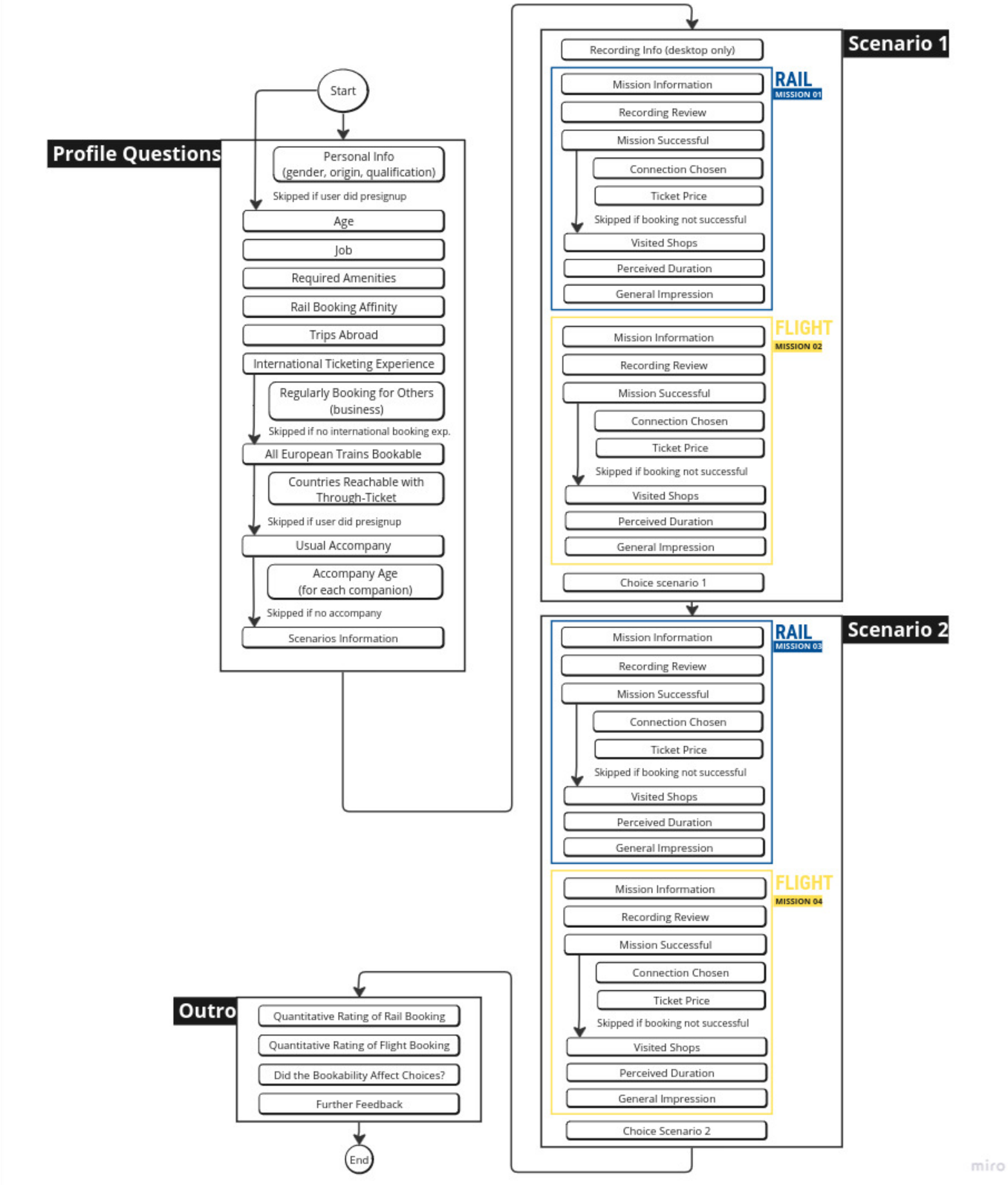

Figure 7: Schematic structure of the conducted survey (All questions in Appendix A.2), Source: own representation

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2.2.3.3 Relation Selection

The two interactive booking scenarios consisted of a user specific mission and a journey (A ↔ B), originating (if possible) from the home country of the participant. As mentioned in Section 2.1, the majority of these city-pairs has been carried forward from the last iteration. Relations involving cities with a population under 100,000 have been ruled out, and additional journeys have been added, to list at least two relations per investigated country. To see how customers work their way around not available online tickets, connections that could not be booked during the preceding availability analysis have been included.

The missions consist of a descriptive text including a possible reasoning behind the trip and the request to cover all aspects, that the participants would take into account in a real situation. All missions have been allocated to the users individually, matching the user's demographic characteristics and travel experience. The distribution of all six mission types can be seen in Figure 8. Additionally, a specific travel date has been defined by the mission by showing a date relative to the day of solving the scenario. (e.g., All business trips had to be booked only 14 from the day the participant filled in the survey) As an example, one mission description of the holiday mission looked like:

"Imagine you are going on **holiday with your friend/partner**. In this booking task, please find an offer on $[Date]$ by $[TransportMode]$ for **you and your accompany**."

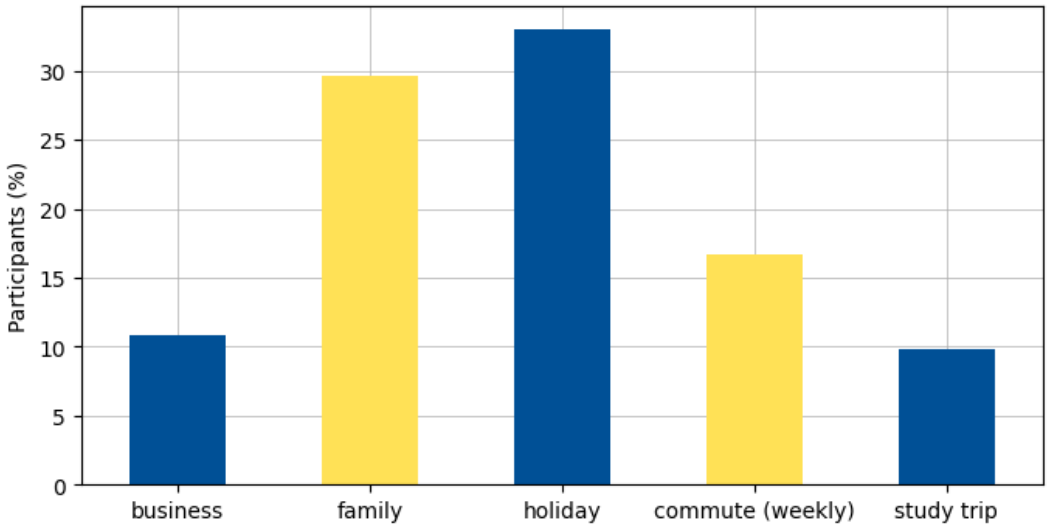

Figure 8: Distribution of scenario mission (n=324), Source: own research

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2.2.3.4 Participant Search

The sourcing of participants has been divided into three main pillars, which are the university, the E²udres³ network[10], and private acquisition.

As in 2021, students participating in the lecture ”Kundenorientierung im Schienenpersonenverkehr” at the St. Pölten University of Applied Sciences have been tasked to find three probands each for the survey. To find non-academic participants and escape the catchment area covering students and members of the university, a slightly adjusted set of exemplary Personas has been created as reference for the students (attached in Appendix A.2). In parallel, the department released a news article [90] about the findings of Thomas Stütz's master thesis, which included an invitation to take part in the second iteration of the survey.

Making use of the membership and lead position of the St. Pölten University of Applied Sciences in the Engaged and Entrepreneurial European University as Driver for European Smart and Sustainable Regions (E³UDRES²) network of European universities, internal calls to action have been distributed to all members. Besides the global invitation, private requests have been sent to members of the E³UDRES² program.

Finally, people have been invited via private channels and direct personal recommendations of participants to take part in the survey. To make sharing as simple as possible, the website has been served as a single-page-application and several sharing options have been presented to the participants at the end of the survey.

2.2.3.5 Timing

On 04.12.2022, a first pre-signup page was published, allowing individuals to fill in basic demographic information and get notified via E-mail as soon as the survey is released. Between 15. December 2022 and 23. January 2023 the online survey has been open for participation. The number of page visits per day can be seen in Figure 9.

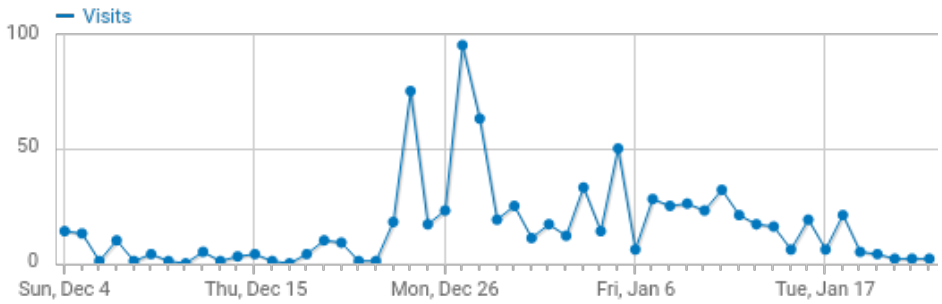

Figure 9: Number of page visits over time (n=816),
Source: matomo dashboard of the project

[10] https://www.eudres.eu/

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2.2.3.6 Post-processing

After the survey has been closed, all data points have been reviewed and checked on their individual validity based on the given input and the optional screen recordings. Seven submissions have been excluded from the analysis in the post-processing due to discrepancies in the data. The following analysis has been carried out using an automated Python script, documented in a Jupiter Notebook [11].

2.2.4 Demographic Context

All data collected during the empirical customer survey need to be viewed in relation to the demographic context of the respondents. A total of 168 people (92 male [54.8%], 70 female [41.7%], and 6 diverse [3.6%]) participated successfully in the survey (after post-processing), aged from 16 to 85 years. The majority of participants (57.1%) have been under 35, 35.7% between 35 and 60, and 7.1% over 60 years old.

The study aimed to recruit participants from non-German-speaking countries within the investigation area. However, 77.2% of all participants originated from Germany, Austria, or Switzerland. Around 3% each originated from Portugal, Sweden, and Belgium. The distribution of participants by country can be found in Figure 10.

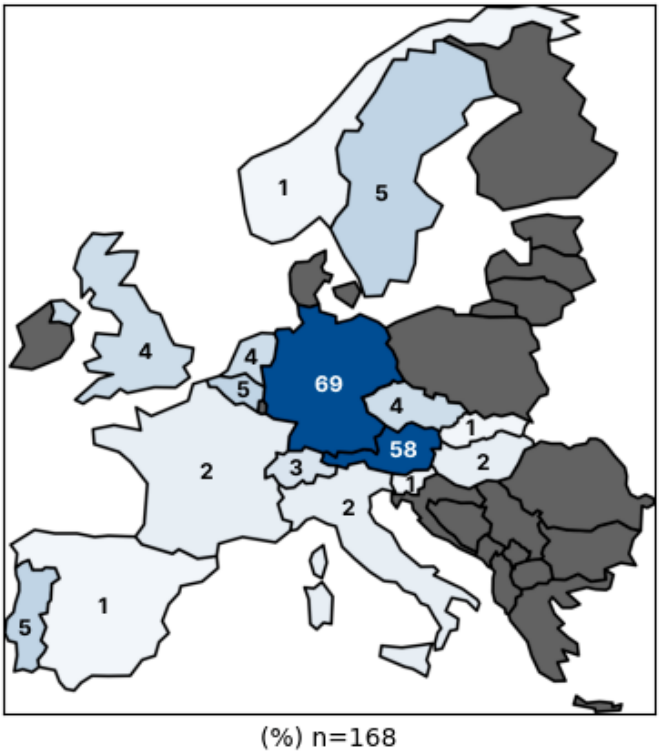

Figure 10: Map showing the origin of survey participants, Source: own representation

[11] https://gist.github.com/TheNewCivilian/10478363ec1d49a9eaf7b1b7baf14e0a

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Participants were asked to report their employment status (oriented towards Austrian employment types [44]), with the most prominent two groups forming with 56.0% reporting full-time or part-time employment and 27.61% stating to be student or enrolled in civil service (Summary in Figure 11).

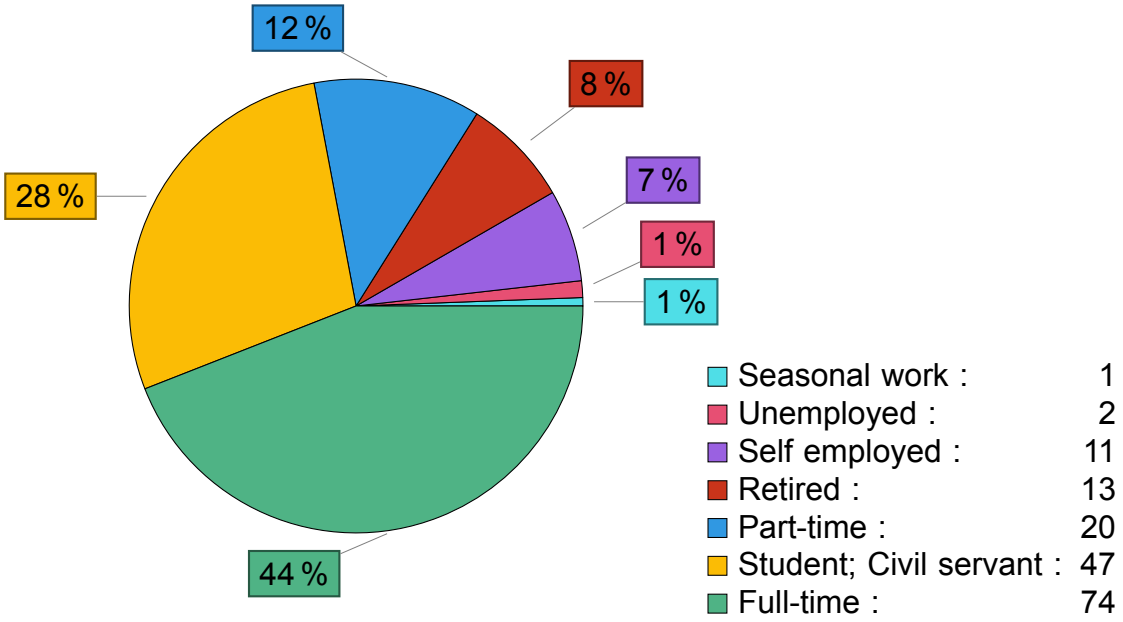

Figure 11: Employment by type (n=168), Source: own representation

To enable analysis based on the education level of participants, the highest qualification has been collected (see Table 3) As education systems vary within the European Union, similar employment types in different countries had to be mapped together.

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Employment type	Absolute	Relative
Without secondary education (Level 1) (< ISCED 2)		
without degree	0	0%
Secondary and post-secondary education (Level 2) (< ISCED 6)		
Compulsory school	4	2.4%
Professional training	14	8.3%
Secondary vocational school	4	2.4%
General higher education (A-Level / vocational diploma)	27	16.0%
Total	49	29.2%
Tertiary education (Level 3) (>= ISCED 6)		
University degree	119	70.8%

Table 3: Education level of participants, [54] (n=168), Source: own research

The sample of participants, represented in this study, shows a significant over-representation of individuals with higher education levels compared to the 2021 European average distribution of education levels. In that year, it consisted of 23.6% at level 1, 45.3% at level 2, and 31.1% at level 3. [53]. Travel behavior data from Austria suggests, that international travelers are on average higher educated, than the countries population (cf. Appendix 19).

Another parameter that has been identified to influence the behavior of individuals when booking rail tickets, is the previous booking experience. While 85.6% say to travel abroad at least once every year, only 73.2% have ever booked international rail tickets.

When it comes to rail ticketing in general (including national travel), 51.8 % of all interviewees purchase rail tickets on a yearly basis, 19.6% less frequently than that, and 28.6% at least monthly. 8.9% of all participants stated that their job requires them to book rail tickets for other people.

Due to the low sample size, the results of this survey can only be seen as a qualitative impression on the issue.

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2.2.5 Findings

This section presents the final survey results, including possible implications and fields of improvement for railway companies.

2.2.5.1 Customer Expectations

To collect information, about the customer's expectations regarding international rail ticketing (Question 1.4), participants have been asked whether they suspect the statement "All actual international rail connections, within the EU, can be booked online" to be true. As some connections (as shown in Section 2.1) are not bookable online, the statement is objectively incorrect, which 63.7% of all participants guessed correctly. The rest (36.3 %) assumed that they should be able to book tickets from their home country to anywhere in the EU. All individuals that disagreed have been asked to specify which countries they expect to reach using one online trough-ticket. The final results for German (a) Austrian (c), Protegees (b), and Swedish (d) participants can be seen in Figure 12. Those have been selected to be shown here as they covered the four highest numbers of participants, believing in limited ticket availability.

Wrong expectations can weaken the image of rail transportation, as potential customers who underestimate the bookability of tickets or even the availability of connections will divert to other modes of transportation. In the opposite case, one will get frustrated searching for a ticket or end up with handcrafted split-ticketing solutions, confronting the customer with unexpected risks while traveling.

Comments on the booking experience and choice of transportation mode underline this effect, containing responses like: "If booking sites are not set up to offer rail tickets in certain countries or between certain countries, they should make that clear when you try to search for tickets." or "[...] Although I have experience with train travel and know the route network in general, having some contextual knowledge about train travel, the bookings were quite tedious. The booking to Madrid was impossible, my anger and stress level was too high, and I therefore was forced to take the plane. [...][translated from German]"

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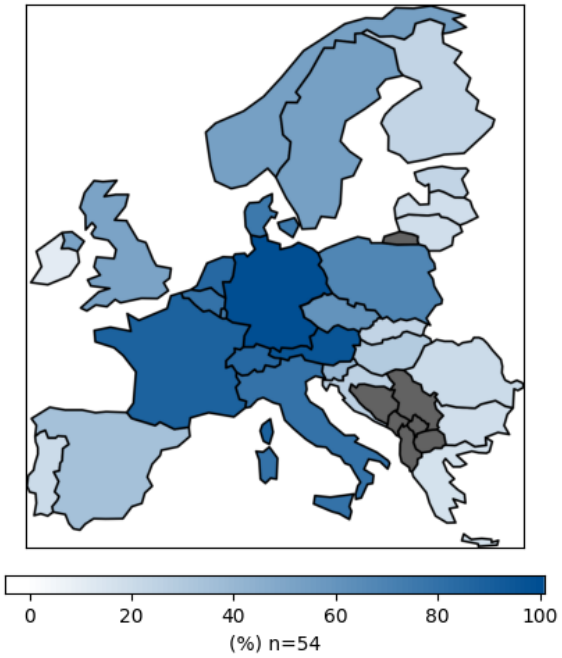
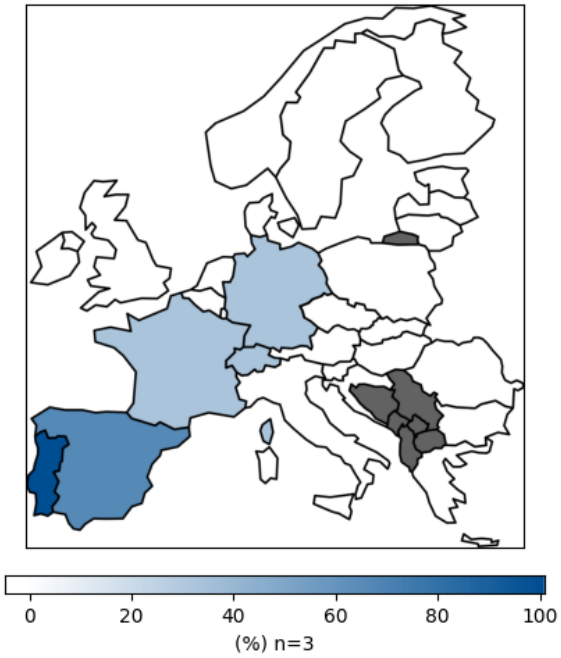
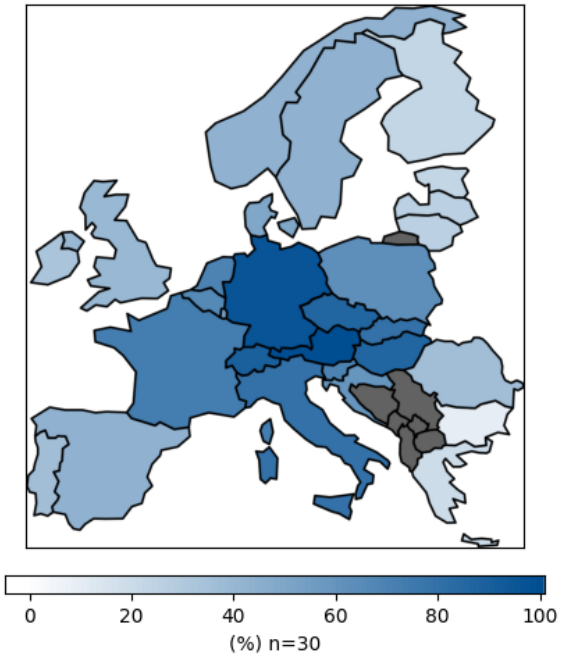


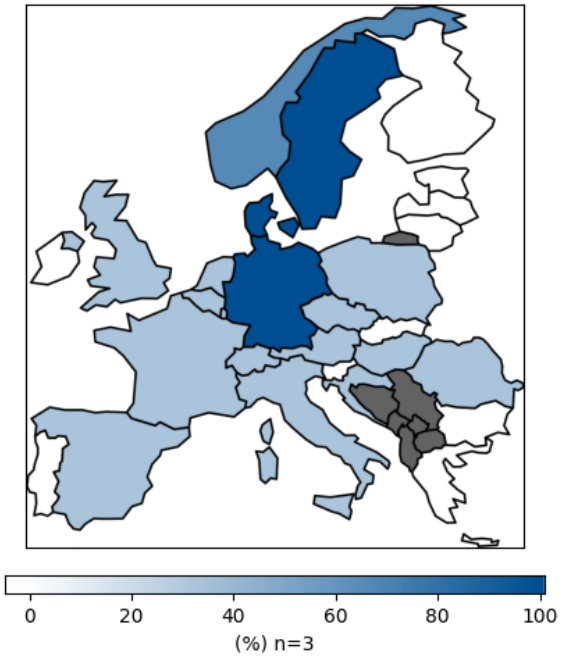
(a) Availability exp. German paticipants



(b) Availability exp. Portogeese paticipants



(c) Availability exp. Austrian paticipants



(d) Availability exp. Swedish paticipants

Figure 12: Ticket availability expectations by country, Source: own research

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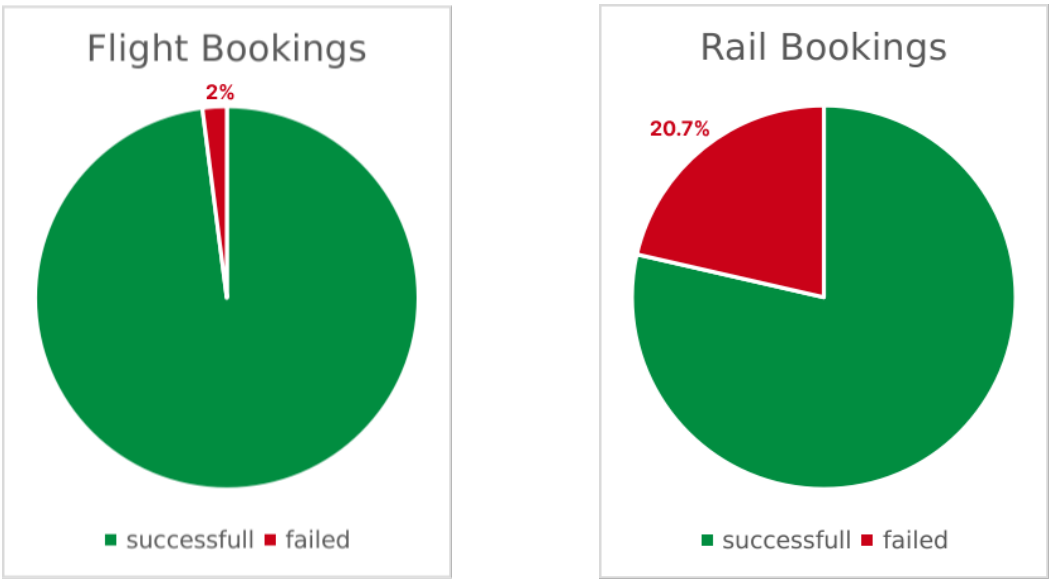
2.2.5.2 Success of Booking Scenarios

In the following scenarios, a total of 634 booking attempts have been undertaken by the participants. During post-processing, 21 flight and seven rail bookings have been excluded from further analysis, as the interviewees misunderstood the mission objective, decided not to proceed with booking due to a general lack of connections (e.g., flight time too long), or did not attempt a booking as required.

In total, 246 of 310 (79.3%) rail bookings have been successful, 150 (48.4%) without any issue caused by the booking process or the availability of tickets.



(a) Success of flight bookings

(b) Success of rail bookings

Figure 13: Difference in booking success 2023, Source: own research

While the percentage of failed bookings is lower than in 2021, the difference between flight and rail bookings is even more apparent. Rail bookings have been observed to fail ten times more likely than equivalent flight bookings, while in 2021, they were only five times more likely to be canceled.

64 (20.7%) booking processes have been canceled for various reasons that can be clustered in the categories seen in Table 4. Multiple problems could occur during a single booking.

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Reason of cancelation (n > 4)	Absolute	Relative to failed
The Booking site did not show a connection	26	40.6%
The booking site did only show the timetable	15	23.4%
A separate booking would have been necessary	15	23.4%
Participants felt misled, scammed, or confused	6	9.4%
Essential information was not provided	6	9.4%

Table 4: Reasons for abandoning rail booking process (number of total cancelations = 64), Source: own research

Based on this feedback, 16.7% of all bookings have been canceled due to the availability of tickets online and bookability of through-tickets, rendering it the main reason to fail in booking an international rail ticket. After attempting to use one or multiple booking pages, participants became frustrated due to the absence of a point-to-point ticket option. They canceled the process, even if, in theory, offers are present at some other booking platform. In Chapter 3 and 4 of this thesis, the technical and legal reasons behind the low ticket availability are investigated, and solutions are presented.

Out of the total number of bookings, 31.0% (96) were successful despite facing challenges during the process. These difficulties have been identified and classified into specific categories displayed in Table 5.

Difficulties encountered in booking process (n > 5)	Absolute	Relative (to successful)
Only separate tickets could be booked	26	10.5%
Bad user experience / accessibility	22	8.9%
Some booking site did only show the timetable	13	5.3%
Essential information was not provided	10	4.1%
Not all offers / legs have been bookable	8	3.3%
Complicated / No offer comparison	8	3.3%
Participants felt mislead, scammed, or confused	7	2.8%
The platform required personal data (age, login)	7	2.8%
The booking involved unknown / dubious pages	5	2.0%

Table 5: Difficulties encountered during booking process (n=246), Source: own research

One example of ”Bad user experience / accessibility” that confused multiple participants can be seen in the screenshot displayed in Figure 14. In this case, the customer entered the desired connection data on bahn.de and already has seen the possible connections with the note that ”The price is calculated in the next step”. While some customers dropped out at

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this point due to confusion with the similar-looking message ”Fares not available” and the absence of a price display, others continued by clicking the link and have been redirected to international.bahn.de.

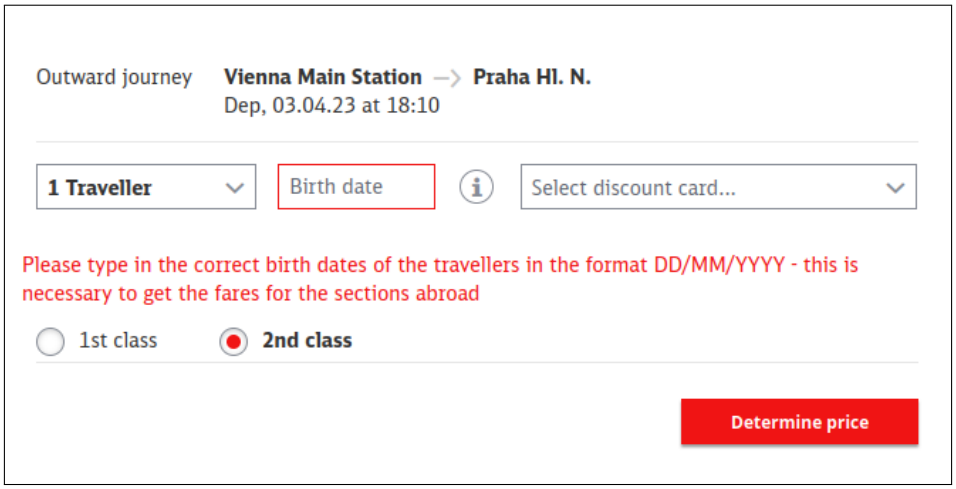

Figure 14: Screenshot of international.bahn.de after pressing determine price button

At this point, the previous search is already preselected, and the user needs to enter the birthdate, which is not highlighted or stated in any way. By pressing continue without providing a valid birthday, an error message is shown. In this example, the call to action (Birthday input not marked as mandatory, while the ”Determine Price” button is enabled) and the presentation of the error message, which is not spatially linked to the input, lead to confusion. Multiple individuals struggled to or could not resolve this, which led them to abandon their booking attempt at DB. As seen in the session recordings and feedback comments like:

- ”Difficulty with the user interface (I didn’t immediately recognize where to put the age of travelers).”
- ”Frustrating, as personal details had to be re-entered on the website and then no online booking possible via the DB site.”
- ”A difficulty arose once because I was asked to give my exact age and then did not understand how to continue”

As this did affect not only German customers or journeys with departure / destination in or route via Germany (as explained in Section 2.1), it’s a good example of how seemingly small user experience issues can cause customers to divert to other pages or modes of transportation.

In contrast to the high amount of participants canceling their rail ticketing attempt (20.6%), only six instances (2%) of failed flight bookings were recorded. Of these, three were attributable to the absence of direct connections between Vienna and Bern. Another two cancelations were linked to logistical challenges in accommodating special needs, such as

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wheelchair support or adding kids to the booking. The remaining instance of failure was caused by unforeseeable risks associated with a transfer that led a participant to cancel the booking.

In addition to evaluating the impression of each individual booking process, study participants were also prompted to choose between a flight and train travel for each finished scenario. In total 58.0% selected rail as a mode of transportation for the requested journey. The individual reasoning behind this choice, has been analyzed, and the primary decision factors for selecting a mode of transportation have been identified and summarized in Tables 6 and 7.

Reasoning (n > 10)	Absolute	Relative
More climate responsible transport	87	48.3%
Cheaper than flying	80	44.4%
Higher comfort / no security checks	57	31.7%
Less complicated changes / stop-overs	18	10.0%
Faster compared to flight alternative	18	10.0%

Table 6: Reason for choosing rail travel (n=180), Source: own research

Besides comfort and related quantifiable metrics like travel time and price, environmental consciousness has been identified as the main deciding factor for study probands to choose rail travel.

Reasoning (n > 10)	Absolute	Relative
Faster option	88	67.7%
Cheaper than rail travel	43	33.1%
Issues getting a train ticket	42	32.3%
Less complicated changes / stop-overs	17	13.1%

Table 7: Reason for choosing air travel (n=130), Source: own research

Similarly, quantifiable metrics (travel time, price, and the number of changes) play an important role in the decision to take the plane. Aside from this, the poor bookability of rail tickets for the journey has been related to nearly equally many decisions for air travel than an existing price difference.

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2.2.5.3 Success by Relation

The study design does not allow general quantified assumptions, based on the raw absolute comparison of rail and air bookability success, due to a high variance in bookability of train tickets by each relation and the selection of specific journeys, which did not follow volume or other normalization metrics. Therefore, Figure 15 shows the individual bookability of single relations by highlighting the success (green), difficulties (orange) and failures (red).

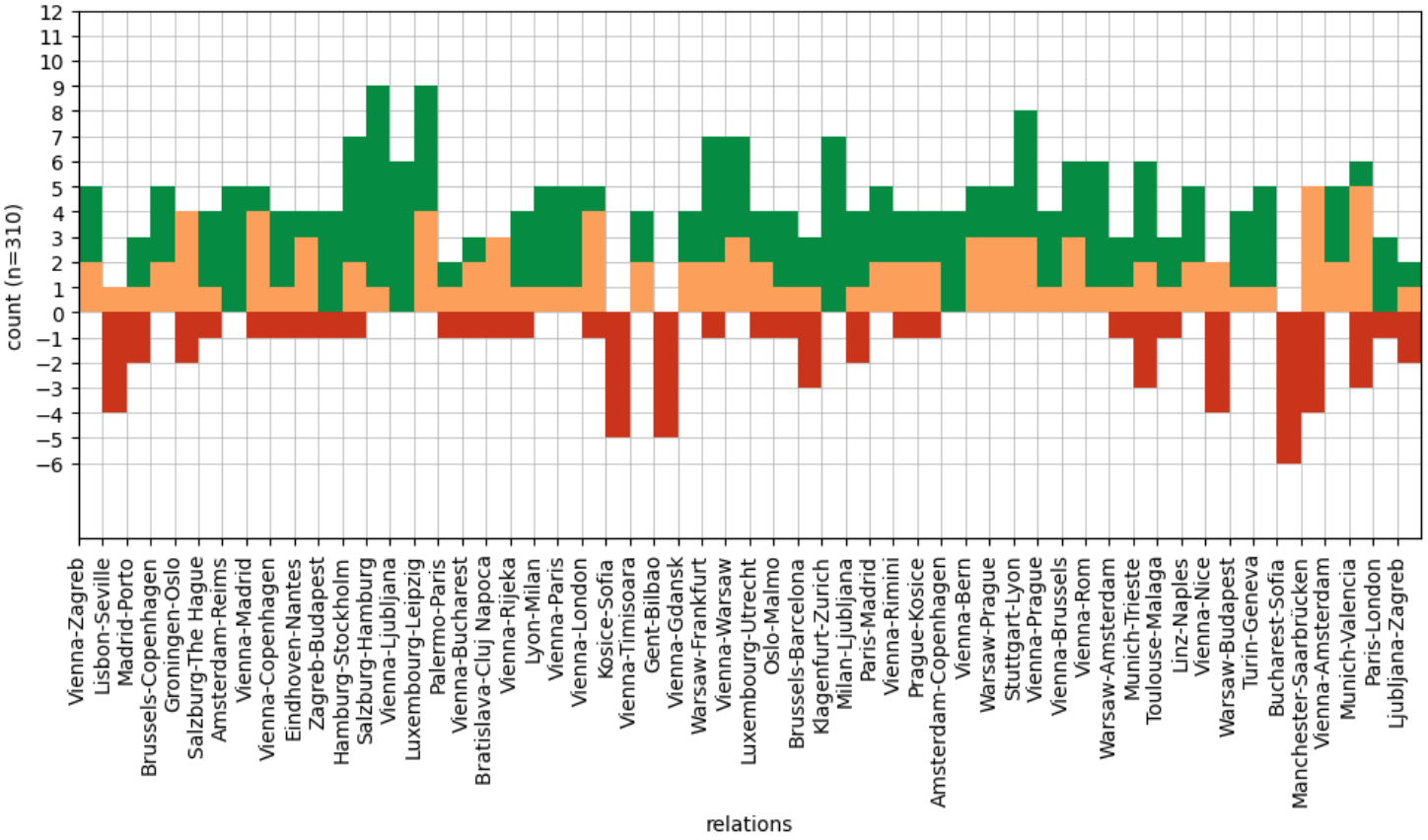

Figure 15: Success of rail booking attempts by relation, Source: own research

Four out of 56 relations have been booked without any difficulties (Vienna ↔ Ljubljana, Klagenfurt ↔ Zurich, Amsterdam ↔ Reims, Amsterdam ↔ Copenhagen). In contrast, for both routes involving Bulgaria and for the journey Gent ↔ Bilbao, no participant was able to book a train ticket. Reevaluating these findings with the results of the second round of the route availability verification (as outlined in Section 2.1), it has been found that the availability of online tickets for travel between Bucharest and Sofia has become possible through the Rumanian state incumbent CFR Călători. This leads to the assumption that subsequent enhancements in the availability of international travel tickets, originating from Bulgaria are possible in the near future.

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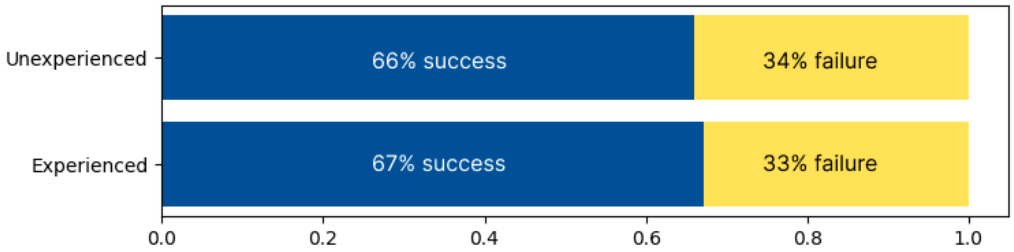
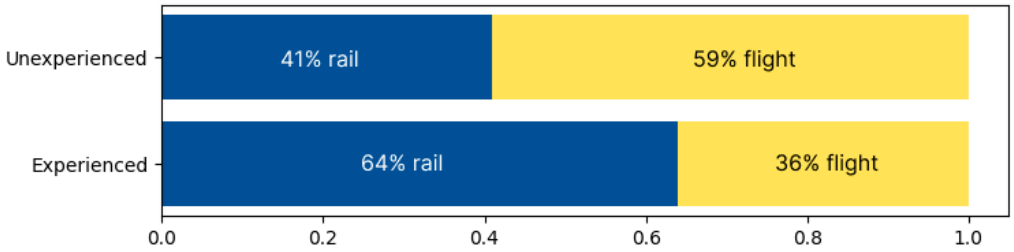
2.2.5.4 Success by Experience

Besides the success by relation, different user characteristics have been checked on their influence toward a successful booking. These include the participants' previous booking experience, age, and education.

As mentioned in the previous Section (2.2.4), more than two-thirds of all participants stated to have already collected experience booking international rail tickets. Comparing both groups by their likelihood of not succeeding in the booking process, no significant difference could be observed. Despite being similarly successful (cf. Figure 16 (a)), less experienced participants have been 34.7% less likely to choose rail transportation instead of flying when given a choice (cf. Figure 16 (b)).



(a) Success by experience



(b) Choice by experience

Figure 16: Disparity of success and choice depending on booking experience (n=[88, 222]), Source: own research

"High-familiarity customers, therefore, seem to utilize broader intervals of postpurchase continua." [106, p. 872], a phenomenon already investigated on a conceptual level by Söderlund. This is similarly reflected in 14.9% of participants stating that knowing the booking platform helped them find a ticket and set expectations.

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2.2.5.5 Influence of Education Level

In 2021, Stütz suggested that the education level of participants could play a crucial role in the successful acquisition of international rail tickets. However, this assertion was not evident in the present iteration. Although the absolute count of non-academic participants was similar to that of the previous iteration (48 - 2021 / 49 - 2023 [< lower than tertiary education], 27 - 2021 / 22 - 2023 [< lower than higher secondary education]), their number was too low to allow a rebuttal with statistical significance.

2.2.5.6 Accessibility

The topic of accessibility has not only been visited concerning different education levels as part of this study. The topic has been brought up by study participants in several individual comments. Two individuals described how, as wheelchair users, taking a train or plane sometimes requires special reservations or treatment, which must be notable in the booking.

One person stated: ”I don’t just need a ticket, I need a ticket, a reservation for a special space (which can never seem to be booked online, and I have no idea why!) and also a reservation for someone to bring a ramp to the train.”

Currently, some rail companies (e.g., ÖBB [83], DB [29]) require that individuals who need assistance of any kind register prior to their journey on a separate platform. This needs to be done on the day before departure. Regarding international journeys, DB even recommends registration 48h before the day of travel. With (EU) 2021/782 being in force since 7. June 2023, the minimum notification time upfront has been reduced to 24 hours (cf. Article 24, [45]). Besides this added complexity, affected persons face the issue of standard booking or journey information systems not providing essential accessibility information, as this person notes: ”I am not informed during the booking process whether the connection is barrier-free for wheelchair users.”

Despite all these hurdles, in some cases, depending on individual needs and limitations, rail travel can be the only viable option for long-haul travel, as flying might not be possible. Therefore, barrier-free access and accessibility needs to be included in the planning of future international ticketing systems, standards, and design of platforms.

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2.2.5.7 Discovered Booking Behavior

To answer the question ”How does the booking duration differ between rail and air travel?” (Question 1.2), all provided video recordings (n=216) have been analyzed on their duration. As Figure 17 shows, the average duration of the booking process, differed between Rail and Air transportation bookings. While plane tickets could be found and booked in 4 minutes and 39 seconds on average, doing the same for a train trip took 1.7 times as long, necessitating 8 minutes. The standard deviation shows substantial variations in the duration of rail bookings ($\sigma = 7min\ 53s$) while being only $\sigma = 4min\ 39s$ in the case of air travel. In extreme cases, around one hour has been spent actively finding a combination of train tickets for a journey.

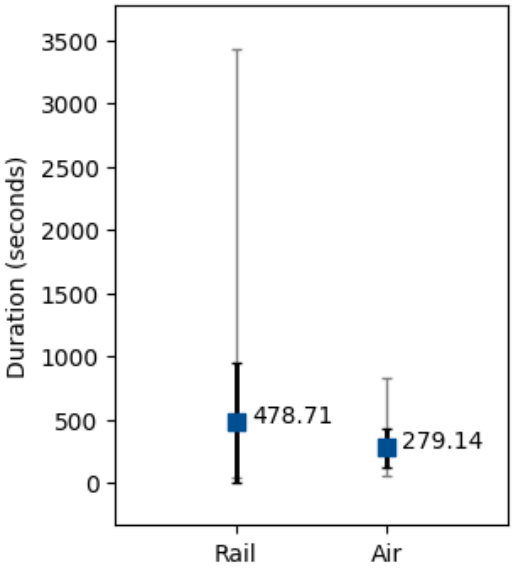

Figure 17: Booking time by transportation mode (n=102, 114), Source: own research

In addition to the empirical analysis, participants have been asked to estimate the duration of each booking, of which the results can be seen in Figure 18, compared to the actual time spent. It has been determined that the total time spent was overestimated. In reality, many rail bookings took less time than expected.

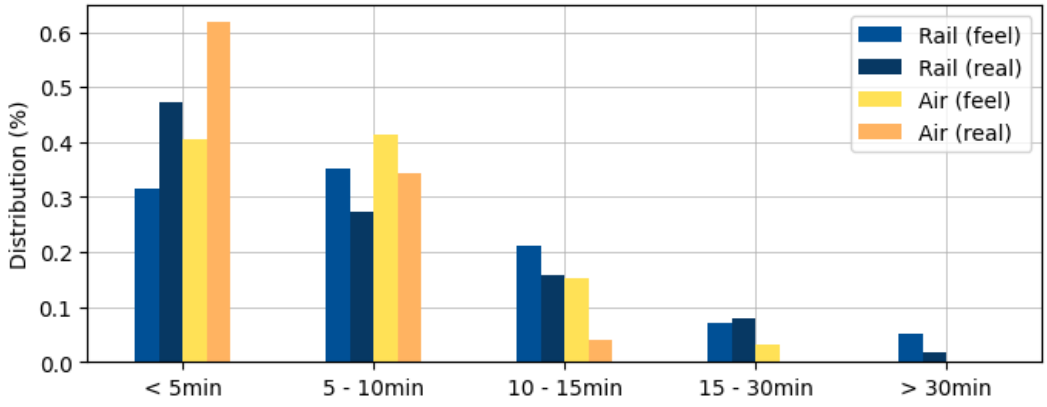

Figure 18: Comparison of perceived and actual time spent on bookings (n=168), Source: own research

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The type of booking platform consulted during each scenario varied significantly between rail and flight bookings. In the case of rail booking, participants mostly turned to the booking platforms of the carriers, as indicated by the highlighted blue in Figures 19, 20. In total, out of 42 sites visited, 14 (33%) have been non-carrier platforms, highlighted in yellow in Figures 19, 20. Besides the generally low number of third-party choices, the mobility platforms Trainline, Omio, and RailEurope have been within the top 10 most utilized booking sites.

Regarding air travel, ticket distribution mainly occurs through booking platforms. However, the sites of national carriers and Ryanair as the market leader have, in some cases, been accessed directly. Of 63 used booking platforms, 46 (73%) have been mobility platforms.

It is evident that the number of existing mobility platforms differs between these two sectors. Still, the importance of such a platform for rail ticketing is clearly stated by the high access count recorded.

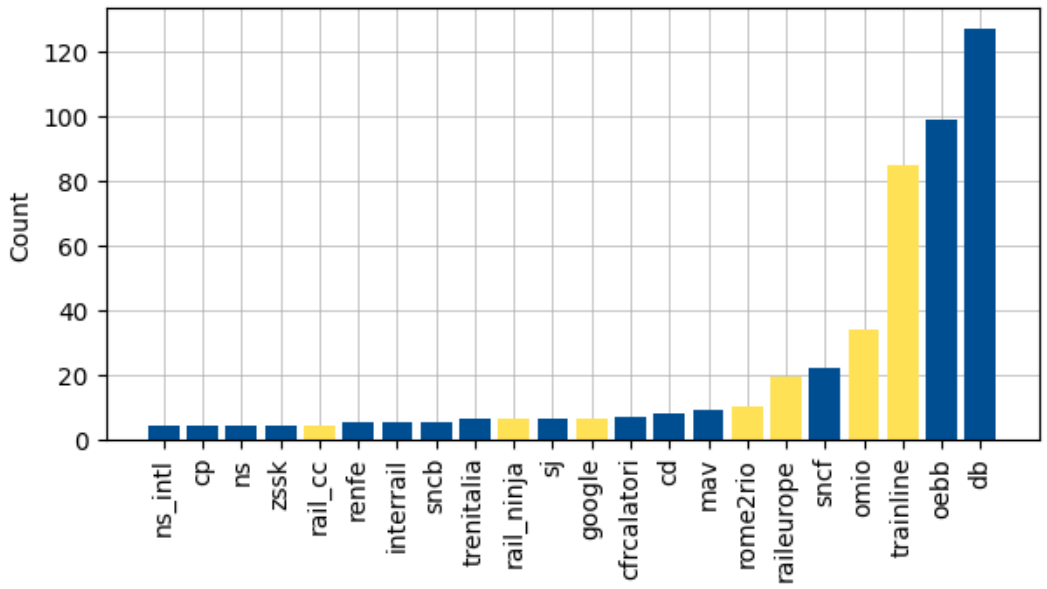

Figure 19: Shops used by participants during the rail booking missions (number of booking platforms mentioned = 506, n>3), Source: own research

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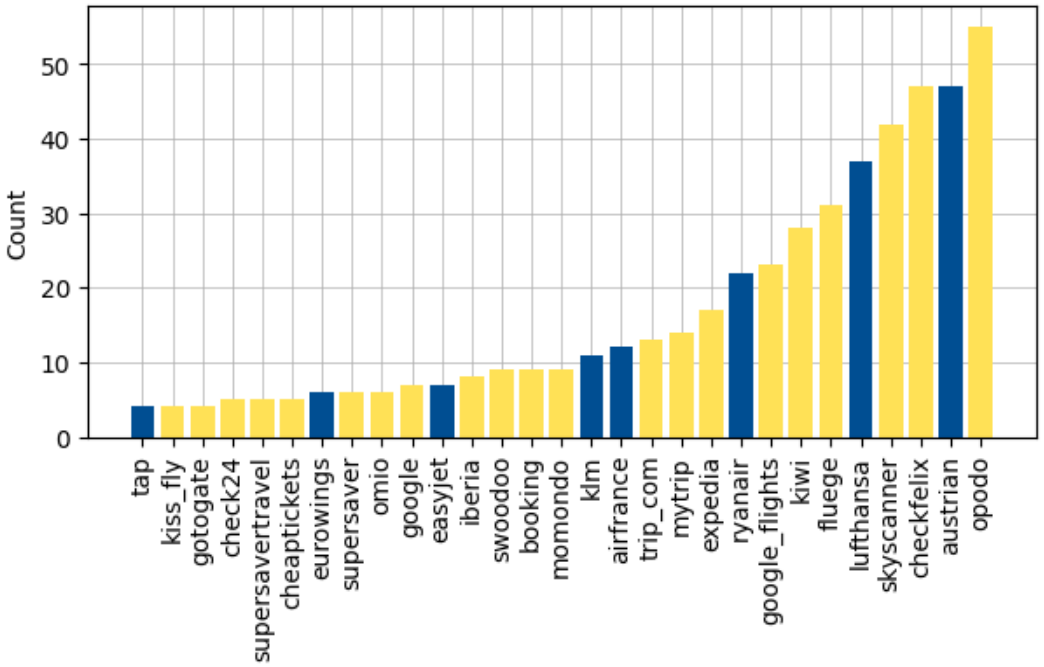

Figure 20: Shops used by participants during the flight booking missions (number of booking platforms mentioned = 552, n>3), Source: own research

To get further insights into the behavior of potential customers and the role of mobility platforms for each sector, the customer journey has been analyzed. Figure 21 illustrates the initial and final booking sites a participant utilized within their rail and flight missions, respectively. At first glance, the significant difference in the amount of singularly used carrier / mobility platforms is apparent. Furthermore, the customer movement between these types can be seen in the center of each chart. While in the case of rail ticketing, mobility platforms have been used for the final booking in 37% of their total views after a carrier has been visited, in 21% of cases, the customer, starting at a mobility platform, turned away or has been redirected to a carrier page to finalize the booking. After starting at a carrier page, only 19% visited a mobility platform and finalized their booking there. A similar distribution has been observed in flight bookings, where the distribution is turned around, as the initial visit of mobility platforms can be seen in the majority of cases.

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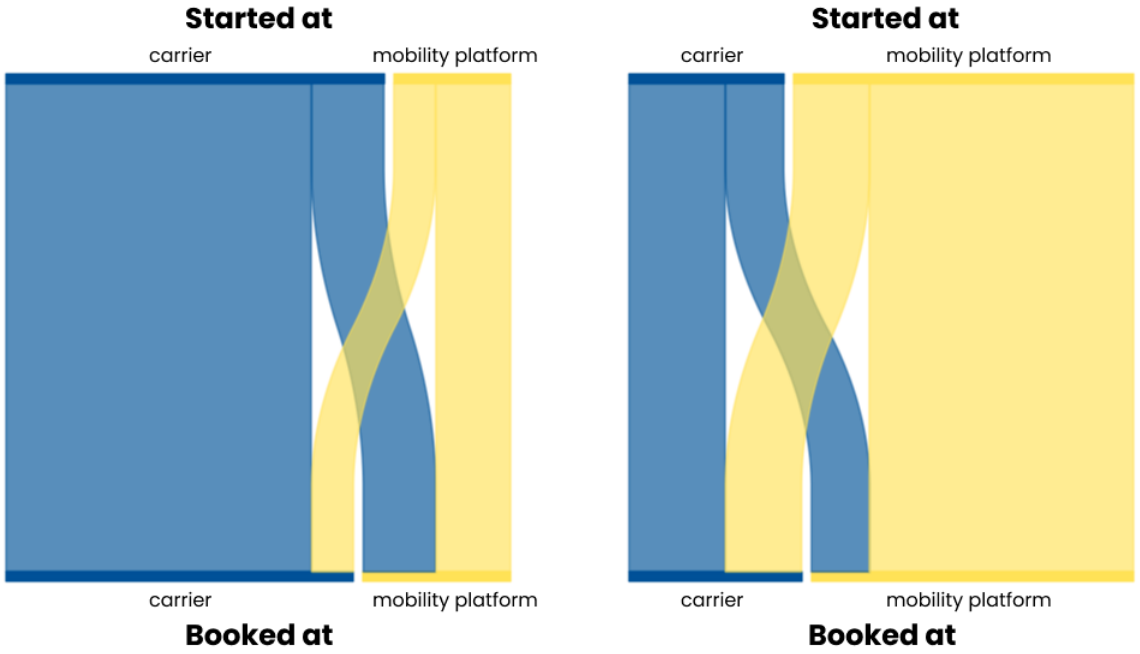

(a) Rail ticketing customer journey (n = 310) (b) Flight ticketing customer journey (n = 294)

Figure 21: Customer journey within the booking process, Source: own research

2.2.5.8 Quantitative Rating

Similar to the quantitative rating of the 2021 survey, probands have been asked to rate their experience of booking a ticket by sector and feature on a scale from 1 to 10 after finishing all booking scenarios, where a high rating corresponds with positive reception. The survey asked participants about each transport mode (rail/flight) separately without directly comparing the two. This approach allowed participants to provide their intuitive image of each sector without being influenced by a direct line-to-line comparison. The results are displayed in Figure 22.

The evaluation shows that compared to 2021, the gap in the modernity perception of design between rail- and air-travel portals, continues to exist, while both lose 1 point compared to the result of the last survey. The survey also revealed that while rail tickets were perceived as slightly cheaper in 2021, this could not be observed in the current survey.

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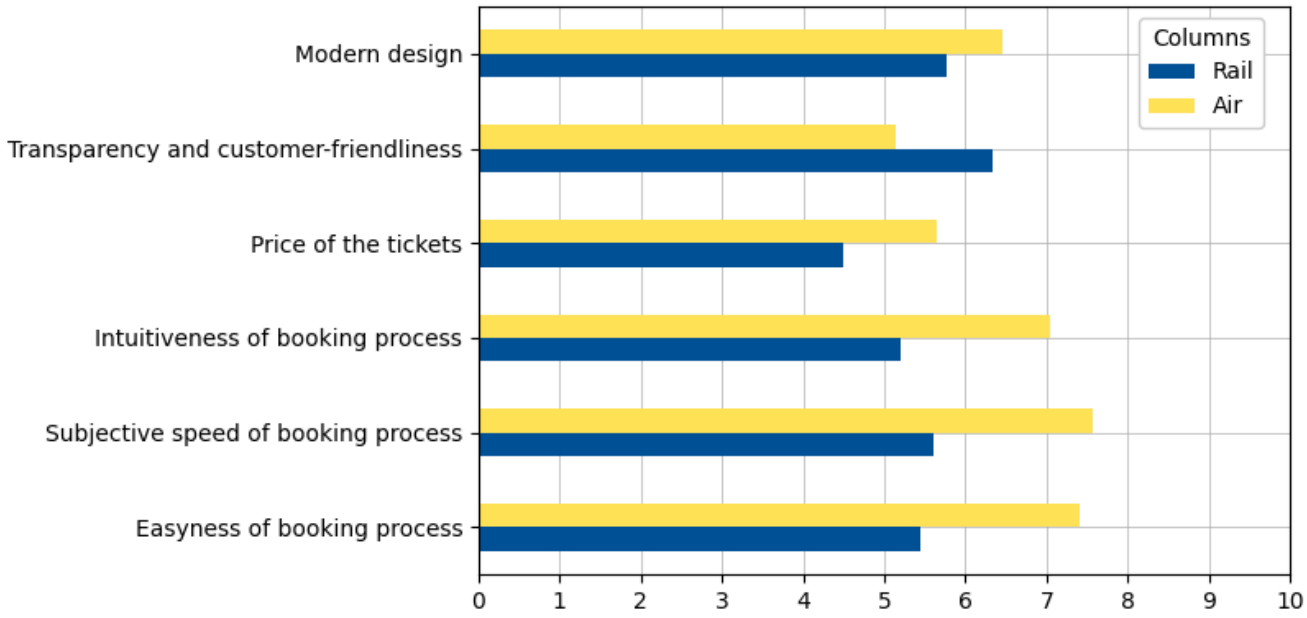

Figure 22: Quantitative rating of booking process 2023 (n=168), Source: own research

Furthermore, rail ticketing was rated worse than flight ticketing in categories such as intuitiveness, perceived speed of booking, and ease of use by 1.8 to 2.0 points on average. However, rail travel portals were given 1.2 points more than air travel portals in terms of transparency and customer friendliness, providing a noteworthy exception where rail surpassed air travel portals in the survey. In summary, these findings suggest that there is a need for improvement in the design and user experience of rail travel portals to enhance their competitiveness and meet the expectations of their customers.

As the actual price difference and the resulting perception is strongly influenced by the selected relations and differences in mission description, a comparison to the last edition of this survey might differ due to a missing commonality in its data basis. Nonetheless, reviewing all achieved prices revealed that only 31.7% of all bookable rail tickets have been more expensive than an equivalent flight. This does contradict the price rating of both transport modes, where rail travel is on average rated one point lower than air travel, despite being equally or less expensive in over two thirds of all bookings.

2.2.5.9 National Differences

While searching for national differences in the booking experience, (Question 1.5) more commonalities, than disparity, have been observed in the feedback of the survey participants.

As shown in Table 4, availability and accessibility of international railway tickets have been identified as the main pain points throughout all collected booking experiences. The overall success of booking one relation could not be generally related to one specific country or

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carrier. However, in some cases (e.g., Connections between Austria and Switzerland), due to partnerships between incumbents, international connections are more widely available, leading to a higher booking success rate (cf. Figure 15, Klagenfurt ↔ Zurich, Vienna ↔ Bern). The opposite effect has been observed for international travel to Bulgaria, for which at the time of the customer survey, no international tickets have been available online via the national carrier BDZ. Correspondingly, no successful bookings have been recorded (cf. Figure 15, Kosice ↔ Sofia, Bucharest ↔ Sofia).

In some cases, incumbents do separate international ticket purchase from their main platform (e.g., nsinternational.com, travel.b-europe.com, etc.), leading to increased awareness about the limitations of the main carrier platform, which does not serve international journeys. This is the case for the main platforms of the national incumbents in the Netherlands, Belgium, and Slovenia. All participants (n=10) from these countries seem to be aware of this limitation and have intentionally avoided the main page.

Aside from differences in the national booking platforms of incumbents, websites of private operators have only rarely been visited, as none offers tickets of other carriers forming a network, and no tested relation has been offered as a direct connection.

International mobility platforms like Omio, Trainline or RailEurope create a unified customer experience throughout the countries they support, reaching most participants when searching using a search machine. Still, specific countries or combinations are not sold on these platforms, resulting in limited offerings to Norway, Great Britain (except London), or Romania. At the same time, digital tickets are available for these countries.

2.2.6 Further Improvements

During the course of setting up and maintaining the survey, as well as analyzing the data, different potential improvements and followup research questions have been identified for the next iteration.

Analyzing answers provided via an open text field, requires a labor-intensive post-processing. For future iterations, the collected categories should be used to already give a predefined set of options, while still offering the option to add custom answers in an optional text-field. Scale rating should not be quantified scaling from 1-10, but include relative metrics. When these adjustments are applied, a more uniform data collection and faster analysis would be possible.

To be able to make quantified statement about the revenue lost, due to poor online ticket bookability, the transport volume of a route should be reviewed and considered on relation selection. Investigating the revenue lost per rail company should be another research topic, as it would create a new data basis for decision makers.

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Furthermore, revisiting the topic of accessibility of ticket acquisition for people with reduced mobility, could provide valuable insights into the shortfalls of the current platforms. From a technical perspective, this topic are further analyzed in Section 3.3.5.

As detailed aspects that could influence the customer experience per country, like the number of supported languages, specific usability issues or differing booking behavior, could not be observed in this iteration of the customer survey, a more targeted survey is needed to collect this data.

2.3 Mobility Platforms

As the results of the customer survey show, mobility platforms play different roles in the searches for rail or flight tickets (cf. Section 2.2.5.7). Therefore, this section is dedicated to giving an overview of of the market analyzing risks as well as benefits for customers and their role in international rail ticketing.

2.3.1 Market Development

The survey revealed that mainly four mobility platforms - Trainline, RailEurope, Omio, and Rail.Ninja - have been visited by participants (cf. Figure 19).

RailEurope
The platform established the earliest dates back to the foundation of a European travel agency aiming at the American market in the 1930s by European carriers. In 1991, RailEurope has been reinstutionated as Rail Europe Group, offering rail passes and tickets. This effort also included the first search and purchase option for international tickets online [91]. 2022 the company split off e.Voyageurs SNCF and SBB now represent a private entity, making it a semi-indipendent third-party mobility platform operator [38].

Trainline
The history of the private mobility platform Trainline started in 1997 as Virgin Trains Ticketing, focusing on the British rail and bus market, which has been accessible for private entries in the field of ticket distribution due to early liberalization (coach: 1980 [56, p. 117], rail: 1997 [68, p. 39]) of the transportation market [121]. In 2016, the company bought the Paris-based Startup Captain Train, which was founded in 2009 after French regulators fined SNCF for treating competing distributors fair. Captain Train has been selling tickets for multiple private and state-owned railway carriers across Europe since 2012 publicly [13]. Today, Trainline offers Rail and Bus tickets across the continent while being the most visited mobility platform in the customer survey (cf. Figure 19), offering the most of the selected relations (cf. Figure 3).

Omio
The Berlin based mobility platform was founded in 2013, as GoEuro Corp. (Registered in

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Delaware, USA, nr. 4973690). The company rebranded its booking platform to Omio in 2019 and acquired the door-to-door routing service Rome2Rio [123]. In 2023 Omio offers rail, bus, and flight tickets for Europe as well as North America. To show aggregated rail ticket offers, Omio relies on a service offered by the company Silverrail Technologies Inc. [104]. In 2022, Trainline as well as Omio stated in their reporting to experience rising booking numbers compared to pre-pandemic (2019) levels.

Rail.Ninja
Searching for specific rail connections in Europe via a search engine, the platform Rail.Ninja[12] has been approached by many participants within the empirical customer survey. Founded in 2017, the platform is operated by Arsia Limited, listed in Malta [6]. Multiple cases of potential customer fraud have been recorded within the online travel community [13][27]. As no proof of the validity of the service offered on the Rail.Ninja platform could be found during this research, the service has been excluded from all further investigations. Other brands related to the company are: travelbetter.com[14], koreantrain.com [15] and russiantrains.com [16].

2.3.2 Potentials

To answer the research question: ”Which kind of added value offer mobility platforms?” (Question 1.3) several potential benefits that mobility platforms can offer are listed based on the results of the previous market research, customer survey and expert interviews.

As third parties, mobility platforms are not restrained by inter-carrier competition to show offers of private as well as state owned RUs at the same time and even offer combined tickets. Subsequently, customers might experience improved comparability and bookability of multi-carrier offers. As an example, Trainline is offering tickets and combined tickets from both Italo and Trenitalia in Italy.

Another advantage the service of mobility platforms can bring is an improved accessibility of offers for a wider market segment. This includes customer groups with specific needs which are not big enough within the home market of a railway company to justify the implementation of these requirements. Accessibility aspects that could be affected are language support, a special quality or type of information, and additional services (e.g., wheelchair registration, etc.). As an example, DB offers eight main languages, while offers presented by Omio can be shown in 21 different According to Alexander Mokros Head of International Cooperations and Industry Partner at DB, the company is mainly focusing its efforts towards the German market (cf. Appendix A.1.1).
Furthermore, some mobility platforms (e.g., Trainline, RailEurope) offer one single contact

[12] https://rail.ninja/
[13] https://de.trustpilot.com/review/rail.ninja
[14] https://www.travelbetter.com/
[15] https://www.koreantrain.com/
[16] https://www.russiantrains.com/

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point for customer support to guide or relieve the customers from contacting all related transport companies on their own. As EU passenger rights, distinguishes in the responsibility of RUs and platform operators between delay refunds [45, Article 18] and reimbursements for missed rail connections in custom through-ticketing [45, Article 12], to prevent confusion mobility platforms act proactive and provide additional services that benefit the customer experience.

2.3.3 Risks and Challenges

Besides the value mobility platforms can provide, the introduction of such services also comes with several challenges and risks.

The lack of available online tickets causes passengers to use any available source, as seen in many examples during the customer survey. Mobility platforms could take advantage of this void, filling it with fraudulent offers, unreasonable prices (e.g., Rail.Ninja) or charging unexpected fees, as done for some routes at the end of the checkout by all three major providers.

Secondly, beyond the sensation of an improved offer comparability by customers, mobility platforms might not show the cheapest price. This can be caused by additional service fees, technical limitations (e.g., ability to combine offers), lack of special offer integration, or missing market incentives due to lower expected revenue (either through lower prices or distribution commissions). Comparing the cheapest offers of Omio, Trainline, and Raileurope for a randomly selected trip (e.g., Vienna → Berlin) returned three different results.

When actively connecting two separate rail services on their own, customers are not eligible for journey continuation in case a connection is missed due to a delayed service on a previous leg. In the context of mobility platforms, this aspect holds particular significance due to the potential application of nullity rules within and between specific RUs (cf. Section 4.2.3). With EU 2021/782 [45, Article 12 (4)] coming into force on 7th of June 2023, such combined ticketing that is not agreed on with the carriers in a partnership contract (as such the risk is covered by the carriers) must be clearly marked. [70, p.7 - 15.] Giving customers a clear sense of the monetary risk involved in the purchase.

Lastly, rail incumbents fear an emerging dominance of mobility platforms, opposing the risk of opening the market for ”well-funded tech giants (often non-European actors), with limited investments”, according to CER [22]. Nick Brooks, head of Allrail, and former Trainline employee, calls the fear of incumbents a smokescreen, which is meant to distract from the fact that the market situation is the opposite of the described scenario, third-party platforms only accounting for around 3% of the total market (Brooks, cf. Appendix A.1.2).

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2.4 Summary

When reviewing the customer perspective on international rail ticketing, several aspects were identified, which are essential when defining the requirements of new rail ticket distribution systems.

Oriented to the 2021 customer survey designed by Thomas Stütz, a new edition in the form of a highly automated survey has been conducted that involved participants originating from a wide range of European countries. The survey revealed that the expectations towards the bookability of rail journeys differ from the available offers.

Furthermore, it has been found that the booking behavior is characterized by the trust of customers in familiar pages, which reflects in booking pages of incumbents to be the first point of contact. This strongly differs from the reality in air travel, where the opposite behavior could be observed. National differences in the customer experience (as shown in Section 2.1 and 2.2.5.9) therefore mainly relate to the structure and partnerships of the national incumbents booking platform. While in contrast to 2021, no significant influence of the education level of participants on the success of finalizing a booking could be recorded, a generally lower success rate (78.9% vs 98%, cf. Section 2.2.5.2) and longer total execution time (7min 53s vs 4min 39s on average, cf. Section 2.2.5.7) has been observed when compared to equivalent flight bookings.

The low accessibility of platforms has been observed as problematic throughout all booking sites (e.g., lack of language support, user experience, special accessibility features, etc.). This issue, in combination with the need for additional services, has been shown to be a vital problem for people with reduced mobility. (cf. Section 2.2.5.6). While mobility platforms show potential for improvements in different aspects of accessibility. The high demand and low availability of international rail tickets generate risks for customers. These span from unexpected costs due to limited rights in journey continuation, unexpected booking fees, and even fraud.

All aspects of the customer perspective are influenced by legal framework and technical standards, that define the system. These are reviewed in the following chapters to finally define requirements for future international ticket distribution systems.

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3 Technical Background and Solutions

The second part of this work investigates the technical background and solutions for the limited availability of international train tickets, identifies challenges, and highlights opportunities. It creates the basis to reflect on future regulatory measures and the perspective of different interest groups in Chapter 4 of this thesis.

Besides a hands-on review of existing systems and literature research, eight interviews with experts from different parties have been conducted to get insights into the structure of multiple booking systems.

The following sections review the underlying process structure, standards, and system components currently part of the architecture used to sell international rail tickets. This includes specific examples that show the base architecture of distribution systems of a state incumbent, a private rail company, and a third-party ticket vendor.

Furthermore, technical standards for international rail ticket distribution throughout all EU member states currently proposed by the ERA and evaluated by the EU Commission are introduced. Finally, all results are summarized, presenting a set of challenges and opportunities that arise from the technical framework discovered.

3.1 Process Structure

To understand the technical needs of a distribution system, all tasks that need to be completed to sell a ticket to a customer have been analyzed. The process flow in Figure 23 shows the generalized process used in different in-production distribution systems. It has been based on the process overview of the European Union Agency for Railways (ERA) [52, p. 7], the vision of a subgroup of European ministers of transportation [89] and the Ticketing Roadmap of the CER [26, p. 3]. The general structure follows the customer journey from getting information about the available offers to physically arriving at the desired destination.

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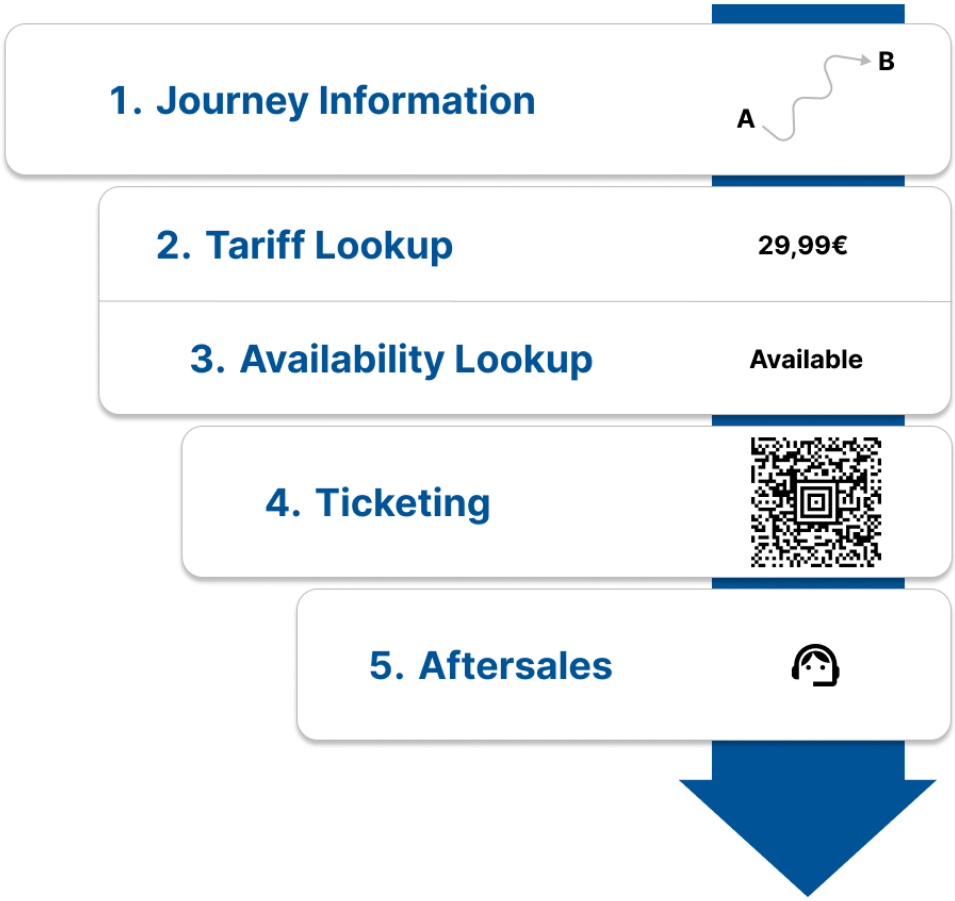

Figure 23: Generalized rail ticketing process, Source: own representation

3.1.1 Journey Information

The first step towards selling a rail ticket consists of the customer querying trips available in the underlying timetable. To do so, the current timetable data has to be available. Depending on the complexity of the rail network served, a routing algorithm needs to decide which journeys to show to the customer based on the available data. In addition to informing the passenger about possible connections in the timetable, this sub-process provides more detailed metadata about the trip (e.g., accessibility of used stations, vehicle type, average delay, etc.).

For international trips to be advertised, the required data must either be available to the specific system or another interoperable journey information system must be connected. For this reason, the majority of backends for journey information systems of state incumbents are split into a data-providing global database (cf. Section 3.2.1.2, 3.2.1.3) and a routing engine.

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3.1.2 Tariff and Availability Lookup

The next step is calculating the selected journey's available offers and prices. The underlying process differs depending on which ticketing strategy is applied.

For tickets sold following a fixed-price tariff system (e.g., suburban- / flexi-tickets), this information can be directly retrieved from a static dataset. Fixed-price Non integrated Reservation Ticketing (NRT) (e.g., suburban- / flexi-tickets) can be sold without checking the availability and, therefore, can be distributed by third parties without directly connecting to the carrier's systems. However, without a shared infrastructure, carriers might lack information about which tickets have been issued [80, p. 8].

Dynamic pricing systems require the availability lookup to be executed to determine which offers are available, to allow RUs to adjust prices according to capacity utilization accomplishing Yield-Management. This also applies to all Integrated Reservation Ticketings (IRTs) (fixed and dynamically priced) as well as standalone reservations to allow seats to be reserved. Systems that manage ticket availability are commonly known as Inventory Systems [49, p. 16]. To enable third parties to distribute tickets reflected in these systems, access via an Application Programming Interface (API) must be granted.

If all available offers are collected, they are shown to the customer for them to choose an option.

3.1.3 Ticketing

After the customer selects a specific offer, the actual ticketing takes place. This includes the payment process, creation of a ticket, storage of the generated information, and providing verification capabilities. A ticket hereby ensures that the passenger holds the right to travel on a specific route. To accomplish this task, several general strategies exist that define the system's requirements. These differ in the method to ensure ticket integrity to allow ticket verification and prevent fraud. [146, p. 28]

3.1.3.1 Security in Paper

The first and earliest method relies on security features integrated into the paper the ticket is printed on. Therefore, all information on the ticket is assumed to be legitimate and can be checked by a conductor by visually inspecting the ticket. After inspection, the ticket can be stamped to mark this event on the ticket.

The formats used for international rail ticketing within Europe using paper tickets are designed by the Ticket Layout Group, a subgroup of the UIC Ticketing Action Group. IRS 90918.2 covers different formats, including the Rail Combined Ticket 2 (RCT2), which is most commonly used for international ticketing [131, p. 10][33, p. 7].

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Starting from 1. January 2023, UIC members agreed only to accept the International Rail Transport Committee (Comité international des transports ferroviaires) (CIT) 2012 security background, which defines the security mechanism integrated into the value paper (shown in Figure 24) [135].

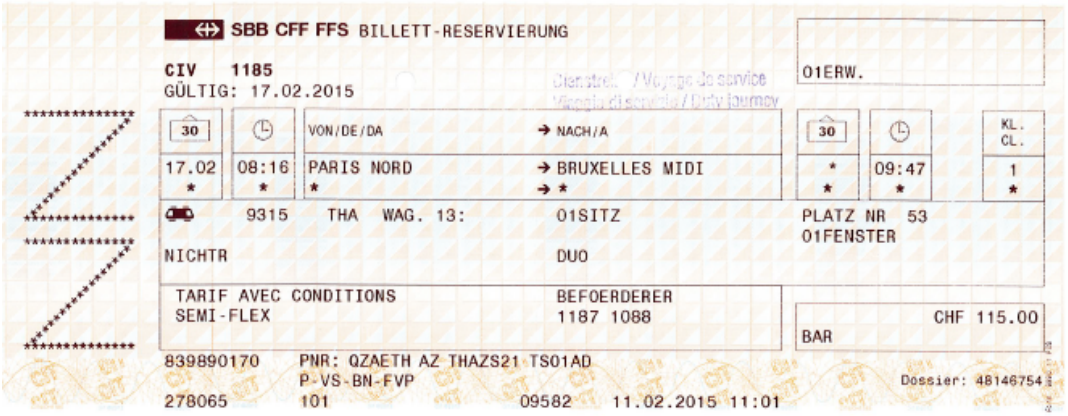

Figure 24: Example of an international IRT ticket printed on ticket paper with the CIT 2012 security background, Source: [135]

3.1.3.2 Security in Data

A new method had to be found to ensure ticket integrity and overcome the limitations introduced by the dependence of Security in Paper (SiP) systems to allow customers to buy and print tickets at home. For this purpose, UIC developed a set of barcode formats (specified in IRS 918-2, 918-3), that inherit the information previously printed on the ticket and a digital seal securing the information integrity. Figure 25 shows a decision tree that contains all data formats and barcode types used in the TAP-TSI.

Aztec (ISO/IEC 24778:2008) is the preferred barcode type for home printing, as it allows for error corrections and is more flexible in data size. PDF417 (ISO 15438) is an alternative to support older Automated Ticket & Boarding Pass (ATB) printers that do not support Aztec. While listed as an alternative barcode type in the TAP-TSI, QR-Codes (ISO/IEC 18004:2015) ERA claims that they are not used for international (cross-carrier) ticketing in [51, p. 10].

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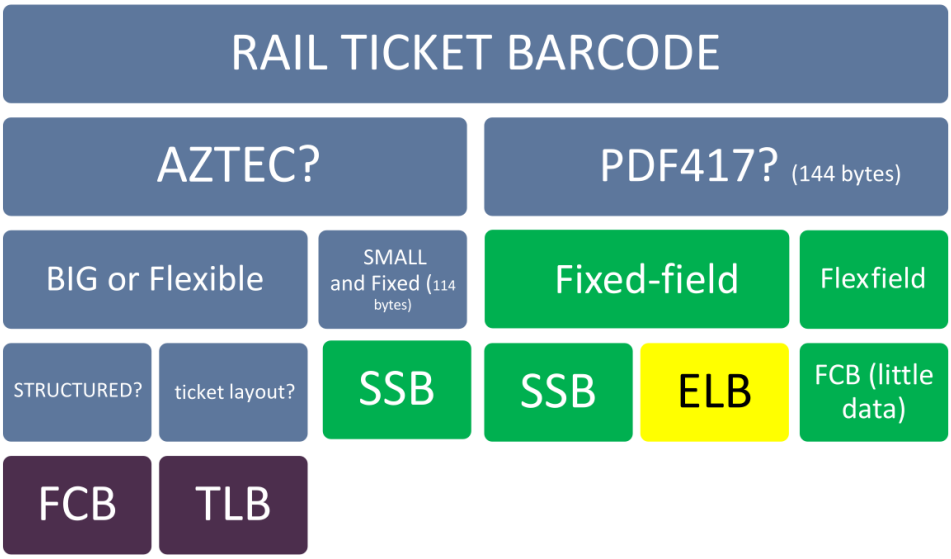

Figure 25: Decision tree to barcode layouts referenced in Annex 12 of the TAP TSI, Source: [51]

Out of the four available data formats, one is chosen in respect to the content requirements and size limitations that apply.

- The **Small Structured Barcode (SSB)** is a limited ticket data format, which forgoes data tagging to reduce the space needed to a minimum. With this limitation to 114 Bytes, printing the SBB data in a 6-layer AZTEC or a PDF417 barcode is possible. [51, p. 21-30]
- The **Ticket Layout Barcode (TLB)** represents, as the name suggests, a generic digital representation of a physical ticket layout that data is laid over. This allows the RCT2 ticket layout to be fully represented in the format. All data, including the added barcode header, is compressed using the Deflate algorithm [17]. [51, p. 36-46]
- The **Flexible Content Barcode (FCB)** is the newest addition to the list of barcode data formats. It originates from the need to store fields with different encodings to make them more readable by computers (by providing ID instead of alphanumeric text) or allow data translation. For example, to display the ticket information in all national languages of countries the international ticket is valid in. Furthermore, additional services can be linked (e.g., opening the platform doors at Eurostar terminals), resulting in an unspecified flexible barcode length. This flexibility even allows using the barcode in Security in System (SiS), storing only a reference to a virtual account in the barcode. [140] To ensure seal security in the future, the barcode needs to be additionally signed time-dependent. Therefore, a dynamic header has been defined as an extension to FCB, called DOSIPAS.

[17] https://www.rfc-editor.org/rfc/rfc1951

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- The **Element List Barcode (ELB)** is a data format used by the SNCF, which does not provide a security seal and therefore is not recommended for further implementations by the ERA.

The content of SSB, TLB, and FCB barcodes is hashed (i.e., using SHA-224), ensuring the integrity of the data stored in the code. Furthermore, the resulting hash is encrypted with a DSA or ECDSA algorithm using a private key pair of the distributor, forming a seal that can later be used to confirm the authenticity of the code. To decrypt the seal, a public key is used that is published by the UIC online [18].

To support both Security in Data (SiD) and SiP, combined versions with barcodes being printed on value paper are possible. [51, p. 45]

3.1.3.3 Security in System

While SiD allows the ticket information to be independent of the display medium, it is limited in its capabilities to record events, altering its validity. To fix this issue, the SiS concept introduces a digital representation of the ticket which is stored on a centralized system. This mechanism is referred to as Account Based Ticketing (ABT), named after the virtual shadow account created. [72] This SiS concept follows the idea of storing all information related to the ticket in this single account while handing out only a reference code to the client. As soon as the ticket is checked, refunded, or invalidated, this is recorded on the virtual account. Moreover, this dynamic ticket state allows ABT to enable alternative ticketing models like GPS-Ticketing or Mobility-as-a-Service (MaaS) application [5].

Account-Based Ticketing only requires the customer to present a reference to the virtual ticket. Any identifying document can replace this reference (e.g., credit card, driver's license). If this is the case, the system can also be referred to as Identification Based Ticketing System (ID-Based-Tickting). Norway created such a system on a national level, obligating all transport operators to make use of it. [98]

3.1.4 Aftersales

After the customer finishes their purchase, the ticketing system still provides several services that need to be considered when designing such systems. As required by the passenger rights regulation EU 2021/782, this includes the process of coordinating refunds or delay compensations. Other services like the in-journey information of the customer about delays can be considered part of the aftersale process as well as classic customer support. [89, p. 17]

[18] https://railpublickey.uic.org/

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3.2 Current System Landscape

To later be able to analyze how an ideal implementation of the ticketing process could look like to allow interoperability and enable international rail ticketing, this section is dedicated to the evaluation of the current system landscape (Question 2.1). In addition, some legacy systems, that influence future implementations, are covered.

The evaluation includes a review of operational standards that have been implemented to facilitate cross-carrier ticketing and various deployed architectures that serve specific use cases. Finally, this analysis discloses the weaknesses and strengths of current distribution architectures and provides an overview of the ticketing landscape.

3.2.1 Technical Standards for International Ticketing Architectures

Since the railway industry started using digital tools to automate their operation in the mid-60s, several standards have been developed to standardize communication between railways and coordinate distribution processes. To better understand why it is still complicated or impossible to buy international trough-tickets for some journeys and comprehend the decisions made in future developments (highlighted in Section 3.3), this section is presenting several standards and interfaces aiming to improve international rail travel (Question 2.2). Starting with a former approach to distribution standardization, timetable, and tariff databases, as well as common booking and networking interfaces are highlighted.

3.2.1.1 Railteam Broker

As one of the first initiatives, the 2007 newly founded Railteam alliance (highlighted in Section 4.2.3.3), was pursuing the goal of creating a digital One-Stop-Shop to provide passengers easy access to their high-speed rail network. To achieve this goal, a new GDS system should have been built, uniting all present reservation systems and allowing through-tickets to be sold. At the end of 2007, the IT development department of SBB was awarded the contract to implement the system. After the estimated cost reached more than double the originally planned 30 million Euros, the project was canceled without replacement [81].

The Railteam Broker (RTB) resembles an early failed digital effort to improve international rail ticketing (Question 2.3). Alexander Mokros (DB) states that Railteam might have been 'ahead of its time' and that the Railteam broker failed due to the approach of 'multiple rail companies creating and operating solutions simultaneously [, which] has proven to be not ideal.' (Mokros, cf. Appendix A.1.1). Other reasons mentioned by sector experts (cf. Appendix A.1.1, A.1.2, A.1.8), why similar former undertakings have not been successful or carried out are:

- Low market pressure
- Missing standards / late standard development
- Limited resources / high cost of custom developments

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Besides the failure of the Railteam broker, the alliance managed to create an internal exchange of real-time traffic data, which is still in use today (Knoubbout, cf. Appendix A.1.3). Furthermore, 'as a result of the Railteam project, two early participants in the market of international rail ticketing emerged. These are the SBB and Benerail (SNCB / NS), still being one of the main partners when it comes to international tickets.' (Mokros, cf. Appendix A.1.1).

3.2.1.2 MERITS

As a basis for international rail ticket distribution, the journey information requires an aggregation and integration of the timetable data of individual RUs. For this purpose, the UIC created the Multiple East-West Railways Integrated Timetable Storage (MERITS) in 2014, integrating the data of "a few hundred" RUs in 2019 [129]. The resulting base dataset is aimed at all participating RUs and is open to third parties to create journey-information-systems for passengers.

'MERITS combines data of all operators involved in the service journey to cover the trip, keeping the data of the respective entity for its part of the journey. This might lead to parts of the journey flagged differently or divert from the data of just one operator.' (Freisinger, cf. Appendix A.1.4). In other cases, one information provider is used as the source of truth for the whole service journey. The decision is made by the software based on the input of MERITS's users [55, p. 15-19]. The actual integration is managed by the HACON tool TPS.Integrate [59].

All data exported and imported to MERITS follow either the Schedule Update (SKDUPD)[19] or Timetable Static Data Update (TSDUPD)[20] UN/EDIFACT message type (Jugelt, cf. Appendix A.1.8)(cf. Figure 26).

[19] https://service.unece.org/trade/untdid/latest/timd/skdupd_c.htm
[20] https://service.unece.org/trade/untdid/d21a/timd/tsdupd_c.htm

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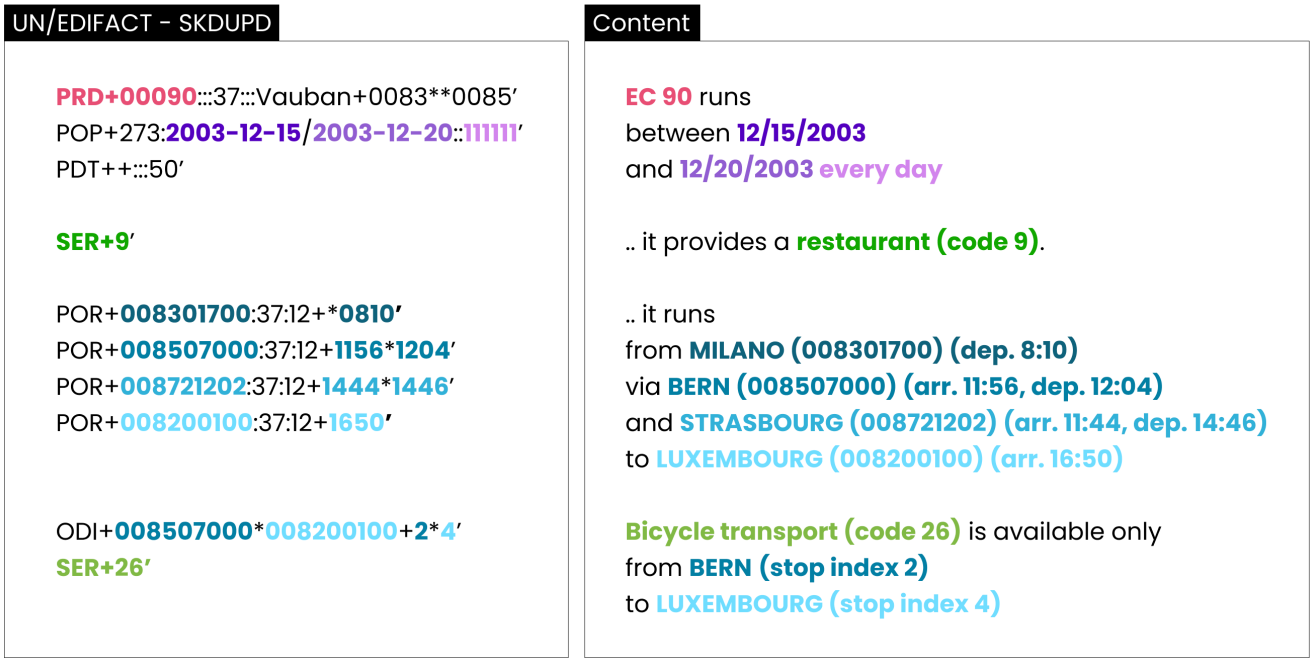

Figure 26: Example of a timetable data in UN/EDIFACT-SKDUPD format, Source: [52, p. 11], own representation

3.2.1.3 EFZ

Besides MERITS, Deutsche Bahn set up the European Timetable Center (Europäisches Fahrplanzentrum) (EFZ), which integrates the database following a different strategy, as it keeps the data of the most trusted source. Again, the HACON tool TPS.Integrate is used as a database manipulation toolkit. Access to the timetable database is provided through the journey-information-system EVAplus (also known as EuroEVA) [2]. Besides other individual data sources, the MERITS dataset is also integrated. (Freisinger, cf. Appendix A.1.4) The export of data used by the HAFAS journey-information-system backend is delivered in the Hafas Rohdaten Format (Hafas Raw Data Format) (HRDF), which represents a multi-file database export [114]. EFZ data is used by many European RUs, including the ÖBB Scotty application.

3.2.1.4 EPA

To allow seat reservations to be managed electronically, Deutsche Bahn launched their first Electronic Seat Reservation System (Elektronische Platzbuchungsanlage) (EPA) in February 1971, called EPA70 [103, p. 98]. Right from its start, several partnering RUs (ÖBB, SNCB, CFL, DSB) adopted the system, which allowed them to not only manage their own seat capacities but also sell seat reservations for TEE and night-train services [1, p. 39]. In 1983, EPA80 was introduced and later became an integral part of the DB ticketing system KURS 90. In 2005, KURS 90 was replaced with the new distribution system DB Neues Vertriebssystem (NVS), still using EPA as its reservation service. The system established itself as a centralized reservation system, in which many state incumbents aligned their systems

to indirectly or directly use the service provided in Frankfurt (DB, ÖBB, SBB, MAV, CFL, NS, SNCB) [31, p. 50f].

3.2.1.5 SABRE

To be able to sell IRT-tickets for its TGV service, which EPA does not support, SNCF licensed the SABRE global distribution system of American Airlines in 1989, replacing its original RESA reservation system built in the early 1980s with Résarail 2000 [69]. In doing so, many issues arose due to the higher complexity and data volume of rail networks compared to the requirements of international air travel. [82]

Today, SABRE GDS provides tickets of SNCF, Trenitalia, Amtrak, RZD, RENFE, SJ as well as connecting to the GDS service of Rail International NV [97] and Trainline, which utilizes Résarail itself to sell SNCF tickets [96]. Besides the SABRE system, other GDS providers like Amadeus and Travelport offer similar services, distributing IRT tickets.

3.2.1.6 Hermes

To allow railways to exchange messages digitally, UIC designed the original version of the Hermes system from 1974 to 1976 [95, p. 142]. Today, the system forms the backbone for communication, creating a virtual private network (VPN) between 60 RUs across 28 countries in Europe [64].

While the first versions of HERMES consisted of an X.25 network, which is one of the oldest packet-switching communication protocols developed in 1976 [74], since 1999 HERMES offers its services based on an IP calling it the Hermes Open Systems Architecture (HOSA) [60, p. 8].

Only a specific set of messages are exchanged using the network, for passenger related services these include [7]:

- Seat reservations along UIC 918-1
- Seat reservations using the EPA reservation system
- Accounting related to international passenger traffic along UIC 301-1
- Seat reservation / combined services accounting along UIC 301-1

Similar to the German EPA system, Résarail by SNCF has been part of HERMES [8]. Until the end of 2023 Résarail will be replaced with S3 Passenger from Sqills, which will still be reachable through HERMES [75].

3.2.1.7 PriFIS

The Price and Fare Information Storage (PriFIS) has been created in 2004 to serve pricing

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information about NRT and IRT tariffs of 36 RUs [133]. The data exchanged follows the format defined in UIC 108-1 [136] and UIC 108-2 [137]. [138]

From 2019 to 2020, the PriFIS database has been restructured, as it reached its end of life in 2020 [144], and is now maintained by Hit Rail B.V. [67]. With this migration, PriFIS is the first central component of the offline part of the Open Sales and Distribution Model (OSDM), which is further explained in Section 3.3.3.

3.2.2 Ticketing Architectures by Example

Depending on the requirements to serve the intended customer target group, the system structure employed differs between various rail ticket distribution systems. For this reason the architectural design and process mechanisms of three different businesses are presented in the following subsections, covering:

- a **private rail company**, with a limited network,
- a **state incumbent** operating a naturally grown distribution infrastructure,
- and a **third party**, that sells international rail passes.

3.2.2.1 WESTBahn

WESTbahn is a private operator founded in 2008, running a long-distance rail service from Vienna to Salzburg, with extensions to Munich or Innsbruck. As of the time of writing, the company's fleet is completely homogeneous, consisting entirely out of Stadler Kiss 3 railcars offering three different travel categories (Standard, Comfort, First) [145].

The following system description is based on the information provided during interviews with WESTBahn CIO Christian Pettauer (cf. Appendix A.1.5) and system developer Dr. Claus Fischer (cf. Appendix A.1.6). To better visualize the WESTbahn distribution system, a generalized architecture model has been created, which is shown in Figure 27.

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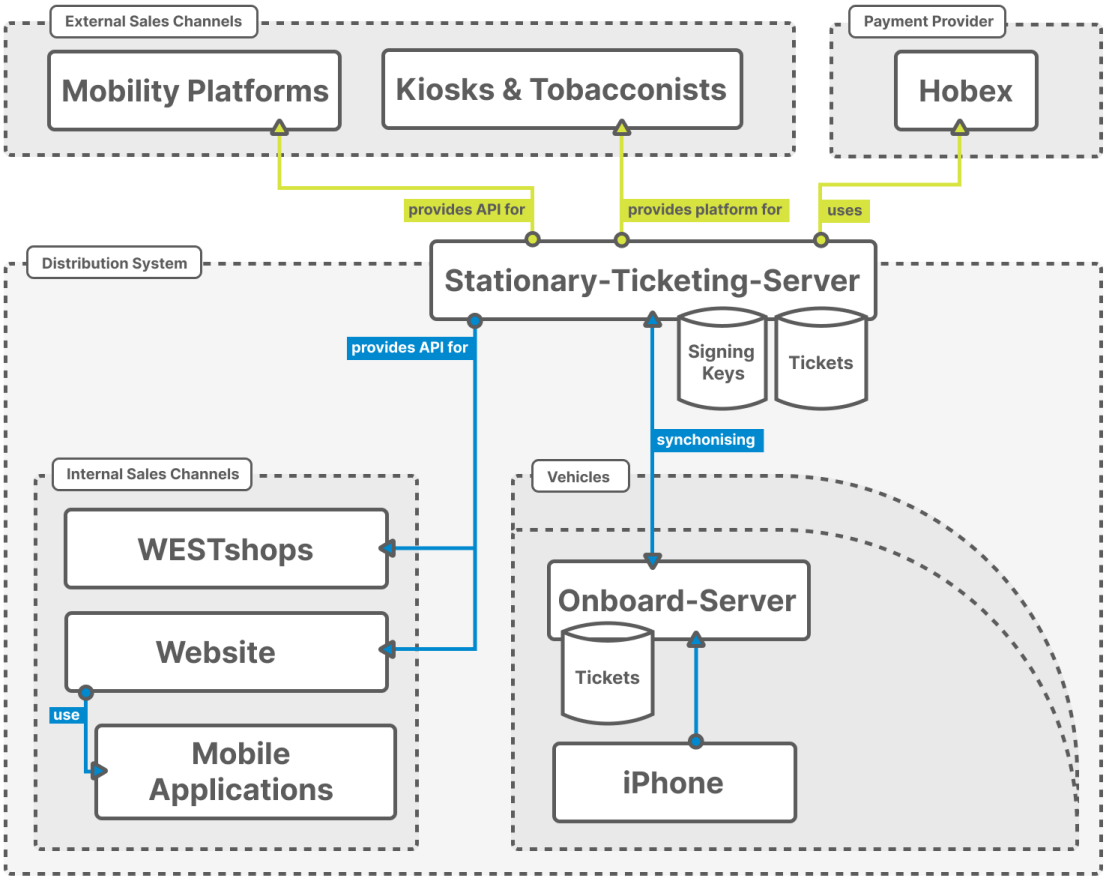

Figure 27: Generalized architecture of the WESTbahn distribution system, Source: own representation

The design of the WESTbahn rail ticket distribution system follows the Account Based Ticketing concept. Initial journey information is provided to customers on the company's webpage[21] or mobile applications, as well as the journey-information-systems of the state incumbents (e.g., ÖBB Scotty, DB Navigator). To be represented in these third-party systems, WESTbahn delivers every timetable update to the UIC MERITS timetable database, the Austrian infrastructure manager (ÖBB-Infrastructure AG), and the German European Timetable Center (EFZ). Besides the connection being shown in the respective applications, no direct link to the offers available for the displayed relations is provided, requiring customers to perform another search to acquire a ticket. For other mobility applications offering journey information, WESTbahn offers a static timetable dataset in the General Transit Feed Specification (GTFS) format[22]. According to Christian Pettauer, 'besides its existence, until this point not a lot of use has been made from this data' (Pettauer, cf. Appendix A.1.5).

[21] https://westbahn.at/
[22] https://gtfs.westbahn.at

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The pricing system of WESTbahn can be categorized in three segments:

- The static standard price ticket, which is constantly available and can even be bought at crew members during the journey.
- A static discounted price ticket is available to holders of any rail loyalty card (e.g., DB BahnCard, ÖBB Vorteilscard).
- And lastly, a yield-controlled discounted price ticket with limited availability.

While designed as NRT-system, complimentary seat reservations can be attached to WESTbahn tickets in Standard class. The upgrade to a higher travel category (Comfort, First) is realized as an additional seat reservation surcharge. As this method does not require class-specific tickets to be sold, the right to travel is separated from the right of a specific seat in a specific travel class.

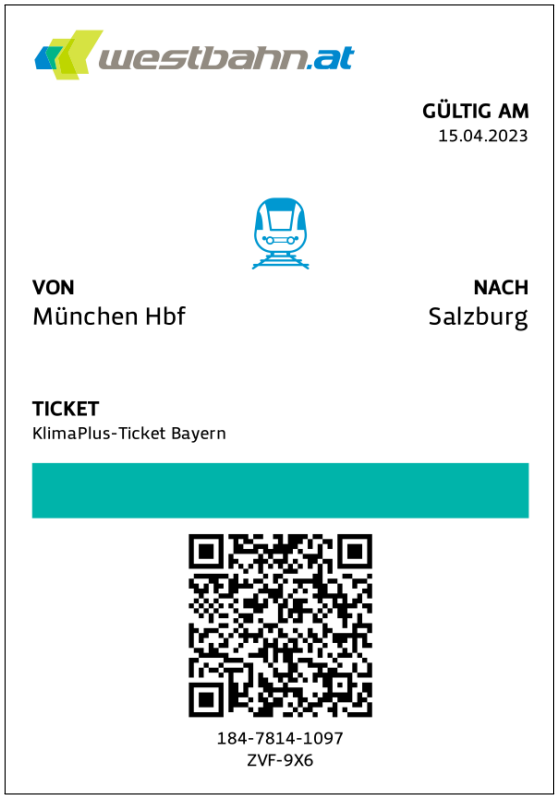

Figure 28: WESTbahn ticket with QR-Code leading to the ticket overview

As a ticket, the customer receives a QR code (as seen in Figure 28) that contains the link to the ticket's account in the system. According to Claus Fischer, QR codes have been deliberately chosen to allow customers to check their ticket's status by scanning the code.

WESTbahn tickets are sold via various outlets, which include the company's website, mobile application, and counters, as well as private kiosks and small shop tobacconists along the route. Additionally, WESTbahn provides mobility platforms an interface to connect to, leading to WESTbahn tickets being available at Trainline and Omio. To allow all conductors (WESTbahn crew members) on the train to sell tickets during the trip, a special system architecture is required that allows the distribution of up to one ticket every 12 seconds on the most frequented parts of the line that mainly runs through tunnels (i.e., Wienderwaldtunnel) (Fischer, cf. Appendix A.1.6). As the mobile network might not allow a constant stable connection during the trip, all conductor terminals (iPhones) are paired with a separate internal network that contains two onboard servers (as seen in Figure 27). These servers hold a copy of all valid tickets. They constantly synchronize changes with a stationary ticketing server

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using data streams over UDP as soon as the network is available. Overall, the architecture of the core system can be described as a distributed database application shaped in a star configuration, with a static server forming the center and an in-vehicle server the elements outside. The whole data coordination is handled by a shared C-library provided by the private company of Claus Fischer.

As the ticket validity is dynamic and state information can be added, customers can use WESTbahn's ”Relax Check-in” function, binding their ticket to a specific seat by scanning another QR code printed at each seat. This allows the digital reservation signs of the railcar to be automatically updated and ticket inspection to be sped up. To prevent fraud, each ticket is signed with a private key of the issuing device or party. If a device gets stolen, all related tickets can be invalidated based on the public key exchange within the system and the timestamp of the ticket.

For aftersales, WESTbahn integrated the ability to add refunds and compensation, which is provided to the customer as a travel voucher directly into the ticket. This allows passengers to keep the ”ticket” as its shadow account now contains a voucher instead of the right to travel. To provide real-time information to the customer, delays occurring during the journey are prompted on the Passenger Information System of the railcar as well as in third-party applications (e.g., Scotty), which retrieve the traffic information directly from the infrastructure manager.

Altogether, the rail ticketing system employed by WESTbahn is a system made to fit the company's requirements, consisting of a single ticketing service that is distributed to ensure a high quality of service. According to Mr. Fischer, the total cost of the system development amounts to 2.5 million Euros. Because no transit connection is offered, no routing service is part of the system, which further reduces the complexity of the system. While multiple distribution channels are served by the company, only a single ticket format is served in the form of a QR-Code delivered either digitally or printed on recipe paper. Despite its simplified structure, Claus Fischer claims that the way digital tickets are handled in the WESTbahn system it can be scaled up to the size of a medium-sized incumbent like ÖBB, even if the database currently stored on the in-vehicle servers is brought to the handheld iPhones directly.

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3.2.2.2 ÖBB

Besides the larger operational scale of incumbents like the Österreichische Bundesbahnen (ÖBB) compared to the linear operation of WESTbahn, the longer-lasting history of ticket distribution and greater international network are generating a more complex legacy environment in which such a ticketing system needs to run. In 2022, ÖBB transported 252.5 million passengers by rail [85, p. 332] of which 14.7 million traveled internationally, selling a total of 50.6 million tickets [84, p.4 + 7]. To better understand the practice applied in such a scenario, Klaus Kovar, Business Analyst at ÖV-Ticketshop GmbH and Robert Prasnikar, System-Architect at ÖBB Personenverkehr AG have been interviewed (Kovar, Prasnikar, cf. Appendix A.1.7).

From 2005 to 2018, the basis of the current ticketing system (”Ticketshop 2.0”) has been developed to harmonize the previous split-up system architecture, which included the first digital ticket shop of the ÖBB and separate subsystems (KISS, EURIS, Vlex) serving all other distribution channels [142, p. 8]. In 2020, the until-then-used DB EPA seat reservation system was replaced with a custom system developed by the development department of the Czech incumbent CD (”České dráhy IKT”), which is similar to the Automatický rezervační systém (Automatic reservation system) (ARES) system [28] [87]. The resulting system architecture, which is constantly evolving, can be seen in Figure 29.

The journey-information-system ÖBB Scotty is not displayed here, as it is entirely developed and operated by the HACON Ingenieurgesellschaft mbH[23]. However, the underlying routing engine HAFAS is used in both cases (Scotty and ÖBB Ticketshop), running on data provided by the European Timetable Center (EFZ), that coordinates and integrates timetable data of multiple European carriers (Freisinger, cf. Appendix A.1.4).

[23] https://www.hacon.de/

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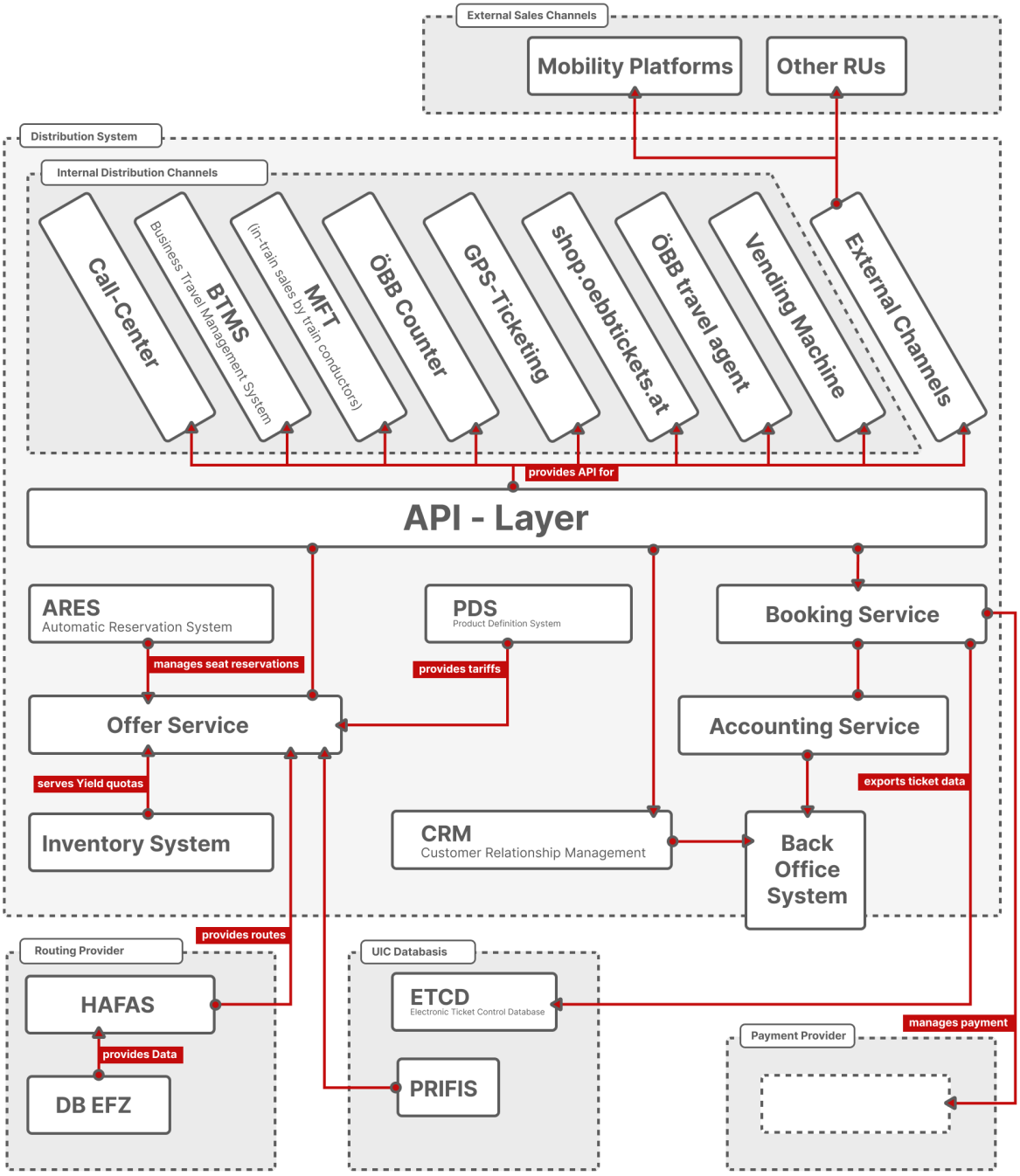

Figure 29: Generalized architecture of the ÖBB distribution system (cf. A.1.7, [142, p. 10]), Source: own representation

After a user specifies a specific route and a desired departure / arrival time, possible journeys are retrieved from HAFAS. By automatically comparing the metadata of all journey legs and

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mapping them to routes known in the ÖBB Product Definition System (PDS), possible offers are retrieved. This includes the comparison of tariffs of ÖBB, local transport federations, or other (foreign) partnering carriers. The PDS also determines, via which of the nine possible distribution platforms offers are available (cf. Figure 29). Until this point, all components are part of the design time system, that operates on static data.

Before showing the offers to the customer, specific runtime components are executed, which include an availability lookup of yield-managed relation-specific offers. The availability of international tickets mostly depends on the integration of individual interfaces to the respective companies, 'as nearly every railway company is building its own ticketing and reservation system' (Kovar, Prasnikar, cf. Appendix A.1.7). Hence, the current standard implementation varies. In 2021 Thomas Stütz observed that no day trips through Italy have been bookable via the ÖBB Ticketshop. Mr. Kovar explained how since 2022 these relations have been bookable via the ÖBB Ticketshop, due to additional interfaces of the Italian incumbent Trenitalia being connected.

Differing from the purely SiS based approach used by WESTbahn, ÖBB uses all ticketing strategies (SiP, SiD, SiS) to cover different use cases. All international tickets sold by ÖBB contain a barcode, being one of the first to implement the FCB format. While it is unclear to what extent the implementation of SiS has progressed at ÖBB, the company claims to connect to the UIC ticket storage electronic Ticket Control Database (eTCD) [134]. Furthermore, it has implemented the OSDM interface to allow resellers to connect to the distribution system (Kovar, Prasnikar, cf. Appendix A.1.7).

According to the Austrian Court of Audit, the development of the base for the ÖBB's "Ticketshop 2.0" cost around 131 million Euros [94].

3.2.2.3 Eurail

As issuer of the Interrail and Eurail rail passes, that enable passengers to travel across 33 countries[24], Eurail BV provides a rail ticket valid for most services across Europe. In 2022, over 600,000 Interrail rail passes have been sold by the company [115]. As core business processes, Eurail provides three main services to customers:

- Provide passengers with journey information for their trips across Europe.
- Sell and provide customer support for Interrail / Eurail rail passes.
- Provide a One-Stop-Shop for seat reservations, to allow taking trips, that would otherwise sell as IRT-tickets.

To get to know the system architecture that is enabling these services, the CIO of the company, Hugo Knobbout, has been interviewed (cf. A.1.3). Figure 30 shows the different systems employed for each business process.

[24] https://www.eurail.com/en/eurail-passes

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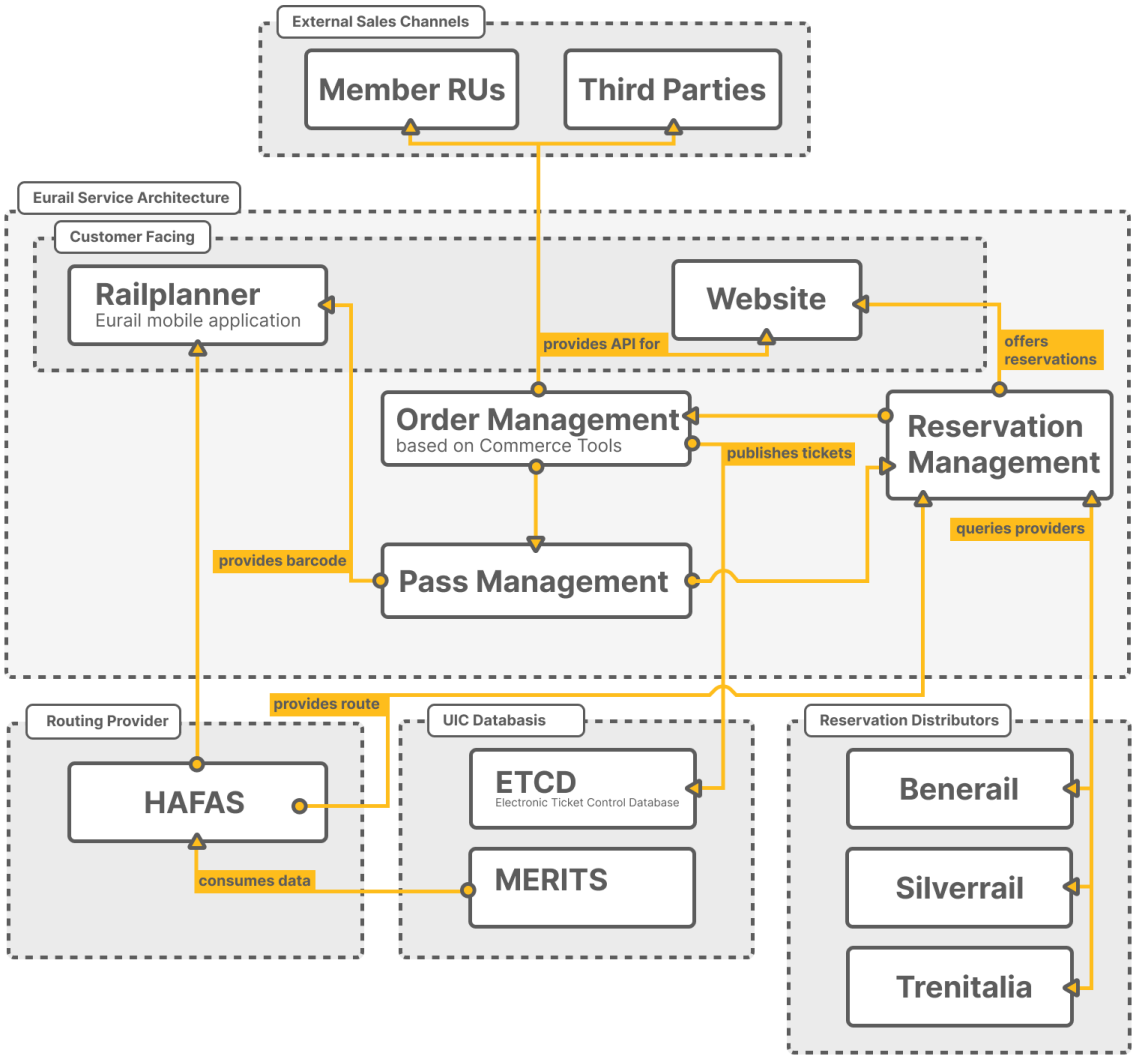

Figure 30: Generalized architecture of the Eurail distribution system (cf. A.1.3), Source: own representation

The first service of Eurail, supplying information about all rail services across Europe, is provided to passengers as part of the Railplanner mobile App [25] or the website of the company[26]. Both services rely on the MERITS dataset using the HACON Fahrplan-Auskunfts-System (HACON Timetable Information System) (HAFAS) journey planner to calculate routes. While MERITS includes most connections, that the rail passes are valid for, the dataset misses some connections or contains inaccurate data. As the main product of the company is a rail pass allowing for unlimited travel without being bound to a specific connection, route planning continues to be of interest for customers, throughout the journey. However, journey

[25] https://www.interrail.eu/de/plan-your-trip/tips-and-tricks/rail-planner-app
[26] https://www.eurail.com/en/plan-your-trip/eurail-timetable/

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information is limited to static timetable data, as Eurail does not yet provide real-time traffic information. According to Hugo Knobbout, the company is working together with UIC members on solutions for a new common real-time timetable exchange format.

As a second service and main product, Eurail is selling different rail passes. Until 2020 these followed the SiP strategy, consisting of a physical RCT2 format ticket printed on value paper and stapled together with a travel diary. During the travel, customers had to fill in each trip manually before boarding any service [37]. Only the combination of a valid ticket and a filled travel diary provided the right to travel on the specified journey. To later payout partner RUs, pass holders were incentivized to send in the rail pass after they returned home to calculate the share of each company.

In 2020, Eurail released the digital rail pass, getting rid of the physical ticket and integrating the digitalized travel diary into the Rail Planner mobile application. Besides the barcode shown in the application following SiP security measures, Eurail has integrated the pass into eTCD and is controlling the access to the ticket using an Account Based Ticketing strategy. As no availability limitation applies and passes are sold for a fixed price, there is no need for dynamic offer calculation or operation dependency, simplifying the process. This allows the company to use Commercetools [23], a from-the-shelf shop system, as the retail backend.

As passengers using a rail pass need to purchase additional seat reservations to use any services utilizing IRT-ticketing (e.g., TGV, Thalys, Frecciarossa services), Eurail aims to provide a common platform for this task. These are Bene Rail International NV[27], SilverRail Technologies Inc.[28] and Trenitalia. Software developed by Eurail matches the routes contained in the planned journey with the available services of the reservation providers. In some cases, divergence in data leads to missing results either in the journey planning or matching of reservation offers, even if a service is running. According to Knobbout, 'this example shows, how the implementation of international distribution services would benefit from a unified timetable format'.

In the interview, Hugo Knobbout stated, that the company is also working on new services targeting smaller RUs, to make use of Eurail's position as a global partner to provide software for standardized ticketing solutions (Knobbout, cf. Appendix A.1.3).

3.2.3 Overview

While multiple attempts to harmonize international ticket distribution have been undertaken in the fields of reservation and timetable systems, none has evolved to cover all services present. As IRT ticketing gained popularity in many south- and north-European countries, central- and east-Europe stuck with NRT tickets, resulting in a systemic divide. The architectural landscape of the international rail ticket distribution system in Europe is therefore

[27] https://benerail.com/
[28] https://www.silverrailtech.com/

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characterized by fragmentation (Question 2.1). Figure 31 shows different integral components of its technical landscape which are:

- **RU distribution system core** - The railway-specific core business logic coordinating the national ticketing process.
- **Journey-Information-System** - Providing routing and live traffic information capabilities.
- **Reservation Systems** - National or foreign reservation and inventory systems
- **GDS Provider** - Aggregating, integrating, and distributing offer information to sales frontends and travel agents.
- **Mobility Platforms** - Aggregating, integrating, and distributing offer information directly to customers.
- **Centralized Databases (Timetable, Fares, Ticket data)** - Provide and integrating shared data to all participants
- **Integration Tooling** - Manipulating and integrating timetable data.
- **Interface and Networking Standards** - Connect network components and provide common interfaces (e.i., Hermes VPN / OSDM)

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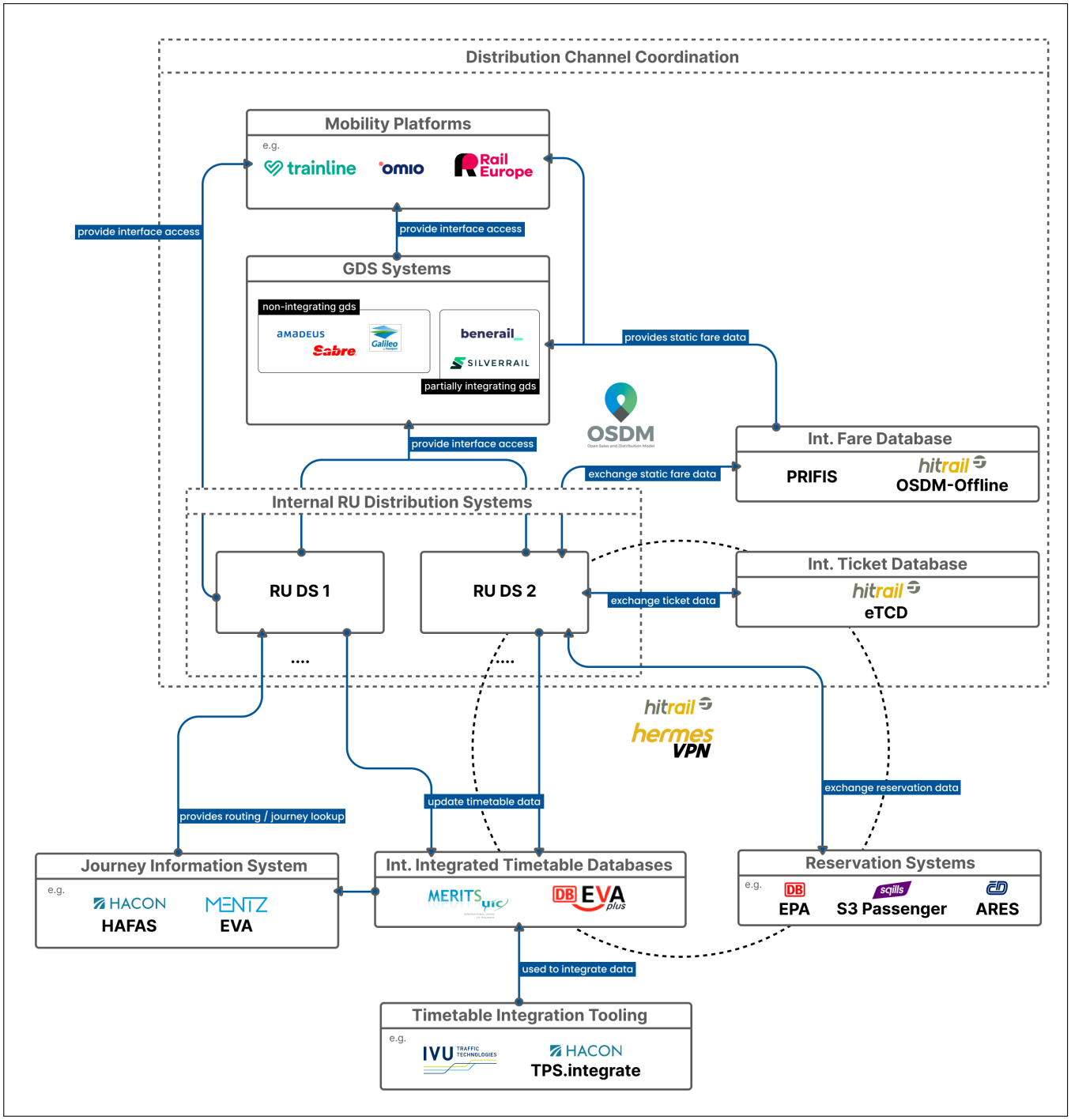

Figure 31: System overview of elements and exemplary entities involved in international rail ticketing, Source: own research

As RUs in some cases decide to not provide such services on their own, third parties are consulted to supply certain components. In addition, standardization facilitates the development of uniform products that can be utilized by multiple entities. To get insight into the

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role third parties play in the development of international rail ticketing solutions, the market of involved supplier companies has been investigated as part of this thesis (Question 2.6).

Following the system architecture above, provided services can be categorized into four groups, shown in Table 8 together with the main actors in the international market.

Data exchange / storage: e.g., Hitrail
Data integration: e.g., HACON, IVU Traffic Technolgies
Services (Inventory / Journey-Information-Systems): e.g., Squills, HACON, MENTZ
Distribution: e.g., Silverrail, Benerail, Sabre, Amadeus, Travelport

Table 8: Market segmentation of third party software suppliers, Source: own research

The companies listed have been identified to directly supply components utilized in international ticketing. By clustering them by their respective founding dates, two main groups emerge: the first group comprises companies established during the 1970s and early 1980s (HACON, MENTZ, IVU), while the second group consists of newly founded entities (Squills, Silverrail, Benerail, Travelport) that have been established between the years 2000 and 2010. The outlier to this scheme is the 1990-founded Hitrail, which has been set up by multiple state rail incumbents as a supplier for centralized system components [65].

In addition to the companies already mentioned, further software suppliers populate the field of national public transport ticketing and related activities. The company Lylco conducted market research, identifying 196 companies working in the field of multimodal transport solutions (cf. Appendix, Figure 50). These are of particular interest, as the EU regulation aspires to integrate international offers into such Mobility-as-a-Service (MaaS) applications, as highlighted in Section 4.2.2.

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3.3 Future technical developments

To harmonize systems and improve interoperability, the European Commission, together with the European Union Agency for Railways (ERA) have released a ”technical specification for interoperability relating to the subsystem ‘telematics applications for passenger services’ of the trans-European rail system” (TAP-TSI) [119]. This regulation defines European procedures and interfaces for all parties in rail ticket distribution. The future of international rail ticketing will be shaped by the obligated technical specifications. To get further insights about the development of the TAP-TSI, the ERA expert Stefan Jugelt has been interviewed to answer the research question: What standards and interfaces are drafted or tested? (Question 2.4). The following subsections introduce the current standards and ideas that are part of the regulation, as well as additions discussed for its recast.

3.3.1 TAP-TSI Overview

The first release of TAP-TSI (EU) 454/2011 consists of 8 Articles [119]. To structure its implementation three phases have been determined, starting with the definition of detailed IT specifications (phase one), its development (phase two), and concluding with the deployment of the final data exchange systems (phase three).

In addition to the core content, the regulation consists of three annexes, that contain further descriptions about the obligations on timetable and tariff data exchange, open points, and referenced technical specifications. The latter can be seen in Table 9. In 2016, the TAP-TSI amendment (EU) 2016/527 updated all references of the original document [117] (blue). Amendment (EU) 1273/2013 added further documents defined as part of implementation phase one (orange) [118]. Additionally, three new specifications (green) will be adapting OSDM, eTCD, which are highlighted in the following sections. Furthermore, these will specify an accessibility data exchange based on NeTEx to address the need for such in (EU) 1300/2014. [32]

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B.1	Computer generation and exchange of tariff data meant for international or foreign sales – NRT tickets
B.2	Computer generation and exchange of tariff data meant for international and foreign sales – Integrated Reservation Tickets (IRT)
B.3	Computer generation and exchange of data meant for international or foreign sales – Special offers
B.4	Implementation guide for EDIFACT messages covering timetable data exchange
B.5	Electronic reservation of seats/berths and electronic production of travel documents — Exchange of messages
B.6	Electronic seat/berth reservation and electronic production of transport documents (RCT2 standards)
B.7	International rail ticket for home printing
B.8	Standard numerical coding for railway undertakings, infrastructure managers and other companies involved in rail-transport chains
B.9	Standard numerical coding of locations
B.10	Electronic reservation of assistance for persons with reduced mobility — Exchange of messages
B.11	Layout for electronically issued rail passenger tickets
B.12	Digital security elements for rail passenger ticketing
B.13	Open Sales and Distribution Model (OSDM)
B.14	e-Ticket Exchange for Control
B.15	European Passenger Information Railway Station Accessibility Profile
B.30	Schema — messages/datasets catalog needed for the RU/IM communication of TAP TSI'
B.50	Timetable Application Guide
B.51	Tariff Application Guide
B.52	Reservation Application Guide
B.53	Direct Fulfilment Application Guide
B.54	Indirect Fulfilment Application Guide
B.55	PRM Assistance Application Guide
B.56	RU/IM communication Application Guide
B.60	TAP Retail Architecture
B.61	TAP Governance
B.62	TAP Master Plan

Table 9: List of TAP-TSI documents referenced as Annex,
Source: [119, p. 65], [32, p. 16f, 36]

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Figure 32 shows an overview of the development history of standards in relation to TAP-TSI, which are referenced in the following sections.

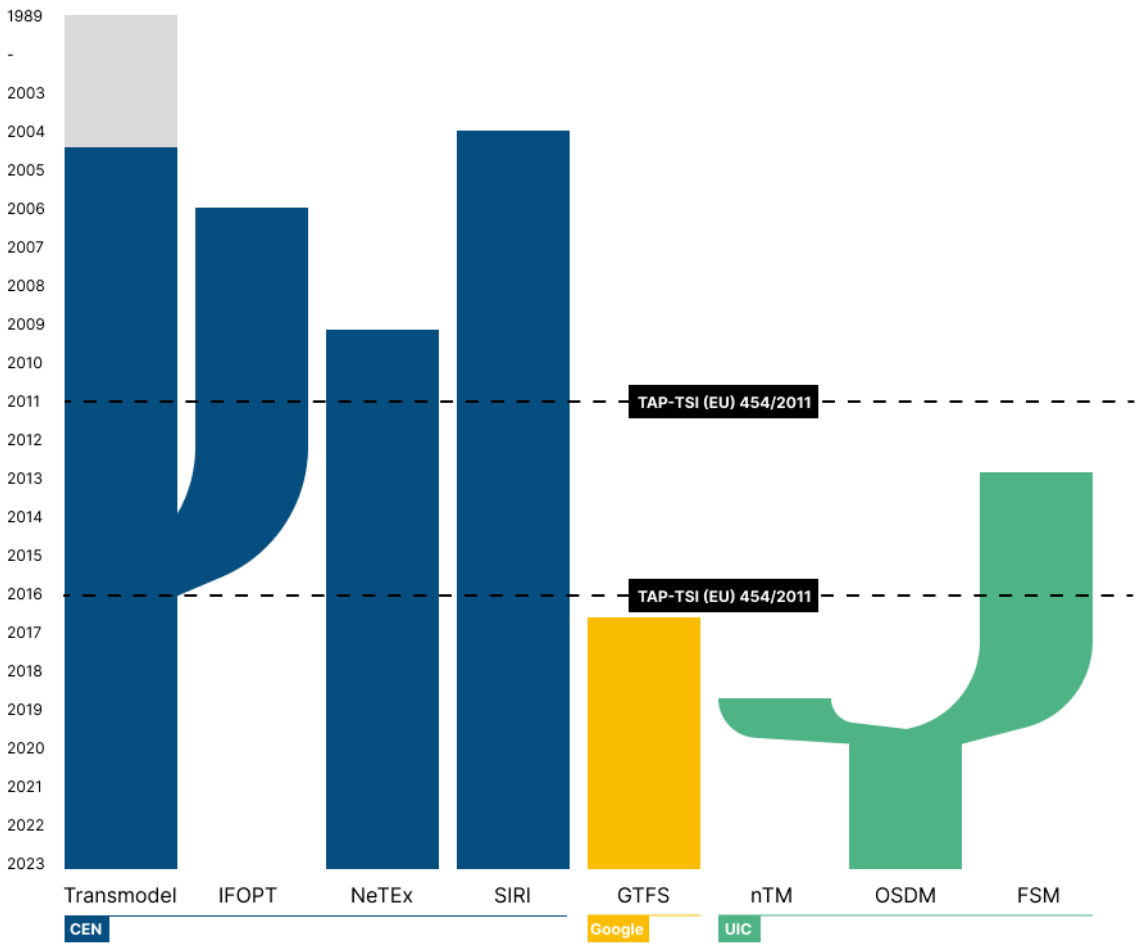

Figure 32: Timeline of standard development,
Source: custom adaptation of [120]

3.3.2 Transmodel

One of the standards forming the basis for the development of a common systematic is the Transmodel effort developed by the Community of European Railway and Infrastructure Companies (Communauté européenne du rail) (CER). It aims to improve the reusability, flexibility, and comparability of systems by enabling multiple sub-standards to form for specific use cases. The idea of this ambition was born out of multiple predecessor projects, the first of which dates back to 1989 [14].

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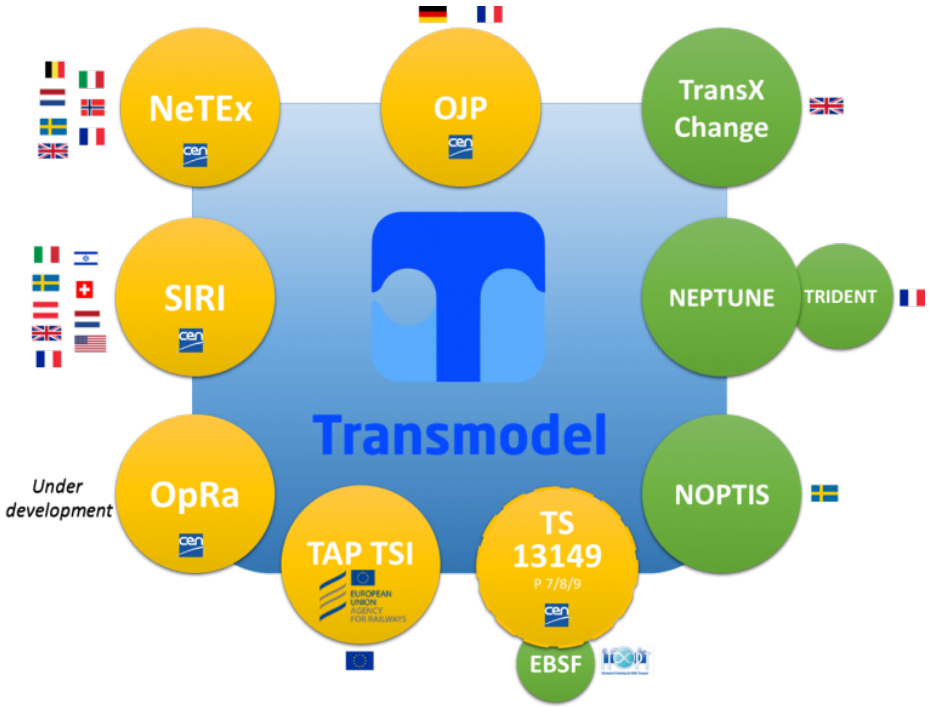

Figure 33: Overview of the Transmodel ecosystem, showing related standards, Source: CEN[15]

The Transmodel v6 (EN 12896) provides a common language and relational understanding for the following 9 parts, mostly presented in UML models and XML format descriptions.

- **Part 1 - Common Concepts** - describes grouping, validation and versioning of standards
- **Part 2 - Public Transport Network Topology** - provides formats for line elements (integration of the Identification of Fixed Objects in Public Transport (IFOPT) model in 2016)
- **Part 3 - Timing Information and Vehicle Scheduling** - includes timetables and time related information exchange
- **Part 4 - Operations Monitoring and Control**
- **Part 5 - Fare Management** - describing the exchange of fare data
- **Part 6 - Passenger Information**
- **Part 7 - Driver Management** - for the standardized coordination of shift plans
- **Part 8 - Management Information and Statistics**
- **Part 10 - Alternative Modes** - integrates alternative modes of transportation (especially shared mobility)

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In Annex I, section 4.2.22 of (EU) 454/2011, Transmodel is directly referenced for the exchange of timetable data, including station elements and real-time information. In the following subsections, related Standards (as seen in Figure 33) that are part of EU regulation and are essential to processes of international rail ticketing are presented.

3.3.2.1 NeTEx

The Network Timetable Exchange (NeTEx) standard (CEN/TS 16614) is an extension to the Transmodel, that "is intended to be a general purpose XML format designed for the efficient, updatable exchange of complex transport data among distributed systems"[29].

While it is not directly mentioned in the TAP-Technical Specifications for Interoperability (TSI) and technical documents, NeTEx is referenced in the regulation with regard to the provision of EU-wide travel information services (MMTIS) (EU) 2017/1926 [116]. To conform with this legislation, NeTEx aside from General Transit Feed Specification (GTFS) — a similar purpose open standard developed by Google[30] — is commonly used as publication format for National Access Points (NAPs), that should provide a collection of all transport services of an EU member country.

Mappings from the EDIFACT, UIC 108-1, and UIC 108-2 standard formats exist [35], enabling the use of NeTEx in the context of the TAP-TSI. One example of such mapping is shown in Figure 45 in the Appendix, displaying the semantic connections between Annex B.1 of the TAP-TSI and NeTEx.

Nick Brooks, the head of Allrail (Alliance of private European RUs) believes that NeTEx could be used as the backbone to coordinate international timetables and fare data exchange to enable a common distribution of railway tickets in Europe, that can be extended to serve dynamic fare prices (cf. A.1.2).

As of 2023, it consists out of five parts, extending

- Part 2 - Network Topology (CEN/TS 16614-1:2014),
- Part 3 - Scheduled Timetables (CEN/TS 16614-2:2014),
- Part 5 - Fare information (CEN/TS 16614-3:2015),
- Part 6 - Passenger Information Profile (CEN/TS 16614-4:2017),
- Part 10 - Alternative modes exchange formats (CEN/TS 16614-5:2021),

of the Transmodel.

[29] https://www.netex-cen.eu/
[30] https://developers.google.com/transit/gtfs

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Additionally, a European Passenger Information Accessibility Profile (EPIAP) is currently defined. Besides this general structure, the implementation of NeTEx varies as multiple national dialects exist.

3.3.2.2 SIRI

The Service Interface for Real time Information (SIRI) (CEN/TS 15531-4/-5 and EN 15531-1/-2/-3) is another standard extending the Transmodel established in 2006, which is directly referenced in Annex I, section 4.2.22. of the TAP-TSI. It acts as a natural complement to NeTEx, covering the transmission of real-time traffic updates. As the interface description is published as Open Source on GitHub[31], anyone can submit change requests to SIRI.
Similar to NeTEx, multiple mobility providers already use SIRI to exchange real-time information. One example is the Île-de-France mobility networks, which publish their SIRI endpoint on the NAP of France [32].

A similar noteworthy open standard is General Transit Feed Specification Realtime (GTFS-RT), which is similarly often used to exchange real-time traffic information.

3.3.2.3 OJP

In addition to the models mentioned above, the Open API for Distributed Journey Planning (OJP) (also referred to as Open Journey Planner) is another project of the Transmodel standardization effort, that makes use of common concepts, inheriting call structures of SIRI and object descriptions from IFOPT. It is originally based on the German TRIAS (VDV 431) and consists of the definition of multiple API endpoints, that are related to public transport rout planning. Similar to NeTEx, it is not part of the Telematic Applications for Passengers (TAP)-TSI directly, but referenced as it is part of the converging MMTIS (EU) 2017/1926.

The API model consists out of six services, which are:

- A **Location Information Service** providing geocoding functionality, including location identification, object information, geographical context and coordinate to address capabilities
- A **Stop Event Service** serving arrival and departure information of a stop
- A **Trip Info Service** providing information about one service journey and if requested real time information
- A **Trip Service** allowing to find a trip from A to B
- A **Multi-Point-Trip Service** allowing to find a trip with stopovers (e.g., A→B→C)
- A **Fare Service** providing fare lookup capabilities for all available fares or fares applying to the service journey or trip [16]

[31] https://github.com/SIRI-CEN/SIRI
[32] https://transport.data.gouv.fr/datasets/reseau-urbain-et-interurbain-dile-de-france-mobilites

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3.3.3 OSDM

The Open Sales and Distribution Model (OSDM) has been created by the UIC, European Technology and Travel Services Association (ETTSA)[33], and the European Travel Agents' and Tour Operators' Association (ECTAA)[34] to harmonize the distribution of rail tickets and subsequently bring down cost for system components and simplify the booking process for customers.

The development of the standard originates from two projects:

1. The **Full Service Model (FSM)**, which was created in 2014 by a committee of DB, NS, PKP Intercity, Renfe, SJ, SNCB, SNCF, and Trenitalia together with Amadeus, Sabre, SilverRail, Trainline and Travelport, later joined by ÖBB, SBB, DSB (2017), and ČD (2018). The project members acknowledged the fact that rail distribution systems are mostly based on proprietary IT-distribution systems (as seen in 3.2) and an "Open-IT-framework that can be integrated in already existing IT-distributions systems"[122] is needed. Furthermore, due to the split into NRT and IRT tickets, a business-neutral implementation, that can serve both ticketing strategies was defined as a requirement. Out of this motivation, a process structure was created, that includes commonly defined data formats and system-to-system messages.
2. The **new Tariff Model (nTM)** created in 2019 by the UIC as successor to the PriFIS tariff database, that reached the end of life 2020.

In October 2020, nTM and FSM efforts merged into a joined effort, creating OSDM. As early as December 2020, the first release of OSDM V1.0 / FSM 2.0 happened. In 2023, OSDM offline is operational after the PriFIS database has been migrated into the new infrastructure, aligned to the model in the summer of 2021. A proof of concept implementation of the whole system has been undertaken by the Czech coach ticket distributor Bileto[35] [88].

From a technical perspective, the standard makes use of several industry web standards, following a RESTful API and event structure, implementing OAuth2 authentication and returning HTTP Error Codes (RFC7807) for error handling. To comply with European initiatives, the modeling of places and trips is aligned to the Transmodel Open Journey Planner (OJP) model [20]. As the standard is developed as a fully Open Source project under Apache License 2.0, any party can view the documents and contribute to its development. All final results are integrated and released in the UIC IRS 90918-10.

According to the standard definition V.3.0.2 (visualized in Figure 34), the process of selling a ticket is handled by three core parties:

[33] https://eutraveltech.eu/members/
[34] https://www.ectaa.org/en
[35] https://www.bileto.com/en

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- **Fare Providers**, who define the offers available for service journeys, provide fulfillment parts and manage accounting and complaints related to their services. This role can be filled by the carriers themselves or local transport authorities.
- **Distributors** (called ”Allocator” in earlier versions) collect all partial offers, combine them into new offers for the complete journeys, make them available to Retailers, and manage the lifecycle of all products. The latter consists of selling and providing tickets as well as verification options.
- **Retailers** (called ”Distributors” in earlier versions) provide customer-facing services, handle initial customer payments, and aggregate offers provided by distributors. If Distributors provide a ruleset on how offers can be combined, the Retailer can be in charge of combining offer parts based on these rules.

As these roles only split process ownership, in real-world scenarios, one entity might fulfill multiple roles at once. Following the OSDM specification, different endpoints are provided by fare providers and distributors and can be called by distributors and retailers. While all resources are accessible to distributors and retailers, the user mode (Distributor Mode / Retailer Mode) defines if fares are served within the response, as seen in Figure 34.

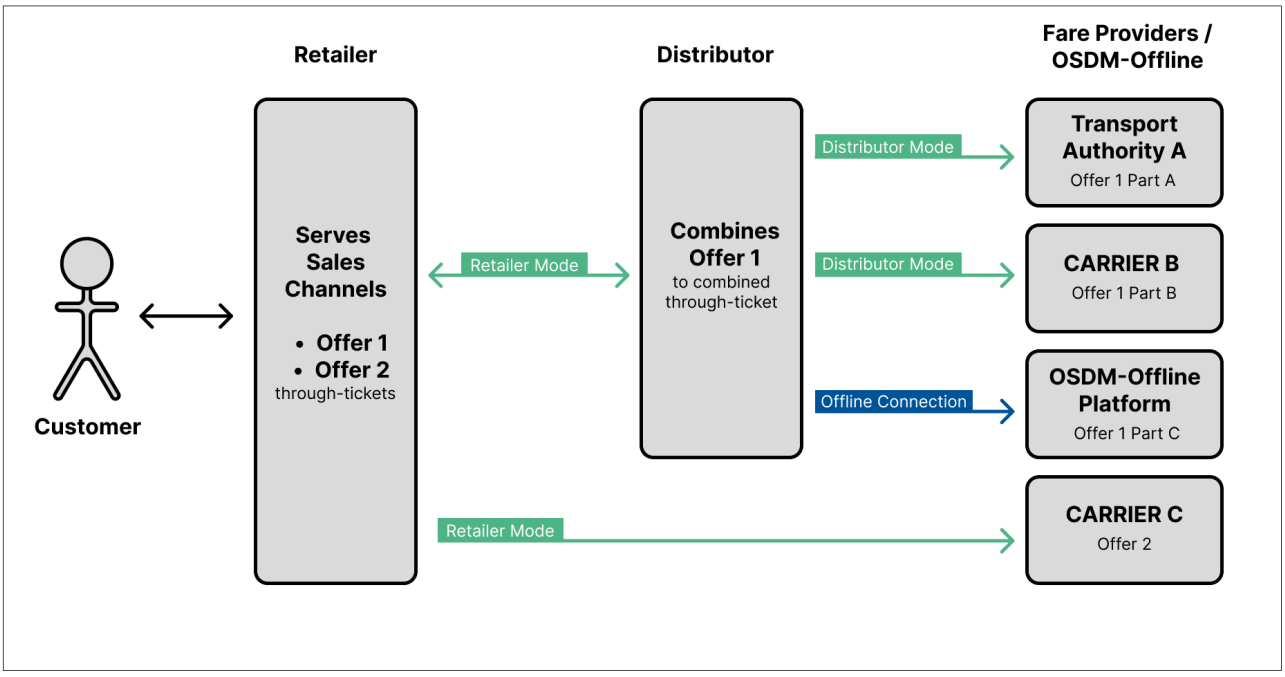

Figure 34: Offer composition and roles in OSDM, Source: cf. [130], own representation

Finally, only one distributor site should be needed to access all possible offers of carriers from the user’s perspective.

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The components of OSDM are split up by online or offline functionality, serving either static fares or dynamic ones. The following subsections highlight each functional system fraction.

3.3.3.1 OSDM-Offline

OSDM-Offline aims to replace the former PriFIS database concept. While doing so, the new structure aims to fully integrate reservation services, allowing new tariff models that can come with different conditions for tickets to be communicated while using modern technologies as its basis. Its name reveals the general concept, as the created fare database being served as Software as a Service (SaaS) database application can be cached and stored offline, resulting in no requirement of a network connection. The actual implementation of a database used by UIC members has been handed to Hitrail, which developed the Database for Rail Tariffs and Fares (DRTF) in response [62].

To exchange fare data in a structured way that enables a more frequent update of fares, a custom data model has been defined. The JavaScript Object Notation (JSON) has been chosen as a universal file format. The Swiss Open Government Data portal provides one example of such fare data [100], of which one fare entry is displayed in Figure 35.
According to Stefan Jugelt from ERA, OSDM-Offline aligns with the specifications of the TAP-TSI.

3.3.3.2 OSDM-Online

In addition to the standardized exchange of static fare data with OSDM-Offline, all processes handling dynamic data are combined in the OSDM-Online part of the model. This aims to reduce unnecessary message conversions within current systems, support real-time timetable updates, align the refund processes with fulfillment, and create common interfaces that can be used to support existing or upcoming systems in their development by lowering the initial investment cost.

From a technical perspective, OSDM-Online is defined by a set of API endpoints that cover the lookup of offers, management of bookings, and ticket fulfillment, including ticket validation. The API specification in OpenAPI[36] format can be found in the project's GitHub repository [130]. By design, systems proposed by the model are structured and split up to serve as SaaS services, which can be run in a cloud system architecture.

A demo application has been developed based on the standard documentation in seven days [102]. Multiple companies like Sqills [76] or Benerail [126] have already invested in multiple products supporting the OSDM-Online model. According to Stefan Jugelt (ERA), the adoption of OSDM-Online into the TAP-TSI is still under discussion, as non-discriminatory access of all parties needs to be investigated.

[36] https://www.openapis.org/

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```
{
  "id": "_0CnoOBXuEeyS_doyWEEzIA",
  "bundleRef": "1185_1_S__1",
  |-> referencing: several constraints
      (e.g., ticket sold 182 - 1 days before dep.)
  "fareType": "ADMISSION",
  "nameRef": "Normaler Fahrpreis",
  "priceRef": "1185_2_I__1",
  |-> referencing: 71.00 EUR
  "regionalConstraintRef": "1185_2_K__8"
  |-> referencing: From 8774549 Annemasse, FR
      to 8014431, Wolfegg/Kr Ravensbg, Zürnen Abzw., DE
  "carrierConstraintRef": "1185_2_C__2",
  |-> referencing: 1185 SBB Passengers
  "regulatoryConditions": ["CIV"],
  "serviceClassRef": "BASIC",
  "passengerConstraintRef": "1185_1_G__1",
  |-> referencing: Adult 16-150
  "legacyAccountingIdentifier": {...},
  "legacyConversion": "YES",
  "individualContracts": false
}
```

Figure 35: Annotated fare published in SBB OSDM-Offline dataset, Source: [100], own representation

Figure 36 shows an example process using OSDM-Online endpoints to create a booking based on a previously queried offer.

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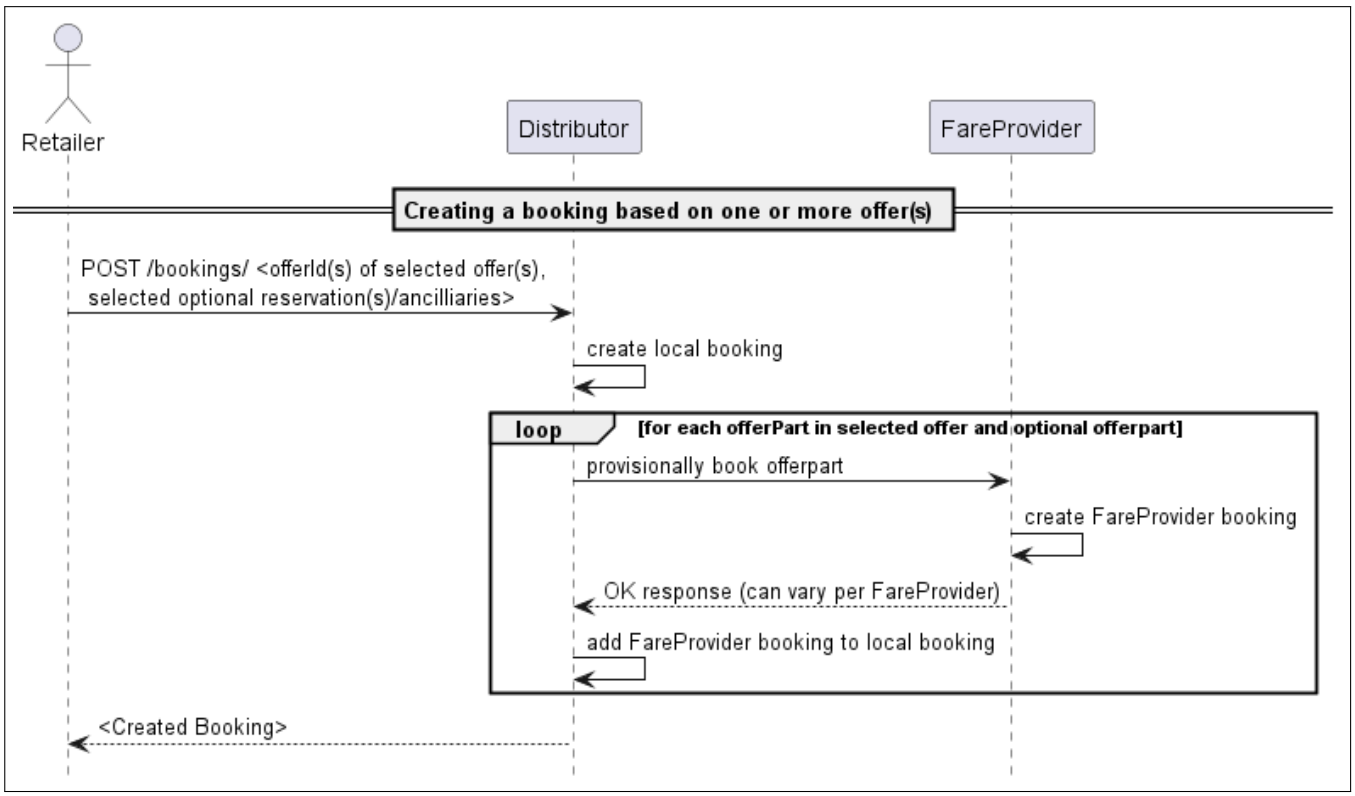

Figure 36: Process of booking an offer in OSDM, Source: cf. [86]

3.3.4 eTCD

Following the transition of validation techniques from SiP to SiD and SiS, the UIC initiated the creation of an electronic Ticket Control Database (eTCD) (IRS) 90918-4. This intends to allow RUs to store and annotate ticket data to prevent fraud, enable international customer service (e.g., allowing foreign ticket offices to refund tickets), and provide more data about the validation process. [66]

In the 2023 amendment to the TAP-TSI, the eTCD JSON format to exchange ticket information and validation events is expected to be included as technical specification defined in Annex B.14 [34].

Figure 37 shows an example of possible ticket annotations during a disrupted journey. With eTCD a continuous validation of the ticket is made possible across multiple carriers and countries.

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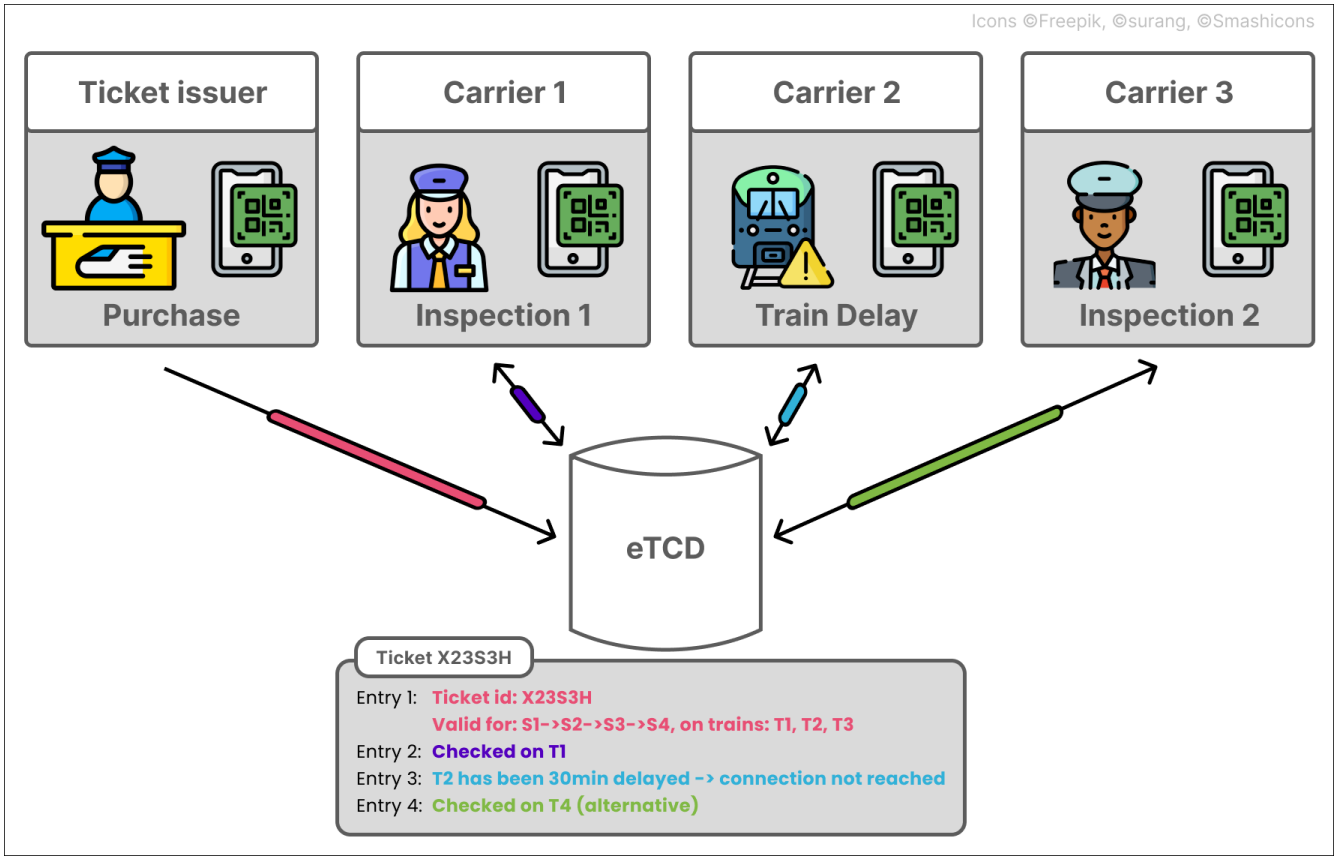

Figure 37: Exemplary customer journey utilizing eTCD, Source: cf. [63], own representation

3.3.5 Accessibility

As the empirical customer survey revealed a lack of access for people with reduced mobility (PRM), the TAP-TSI has been checked on requirements for distribution systems. Section 4.2.6 of the TAP-TSI discusses ”Handling of information concerning carriage and assistance of persons with reduced mobility”, specifying different kinds of information (e.g., train/line numbers where PRM facilities are available) that need to be available to the customer, as well as an interface that needs to be provided for interaction.

Annex B.10 of the TAP-TSI specifically describes the underlying processes to provide a common way to access rail tickets and assistance services for people concerned. While this specification describes an integration of PRM services synchronous to the ticket distributed system, it acknowledges that in many cases, assistance request handling is still a manual and distributed (between RUs) process and delivers process structures for such systems. [48]

Apart from the TAP-TSI the topic of accessibility has been primarily covered by TSI PRM (EU) 1300/2014 [42]. While this regulation hands over the implementation of accessibility aspects reflected in telematics applications to the TAP-TSI, its amendment (EU) 300/2014

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specifies that as long as the architecture intended by TAP-TSI is not fully implemented a separate European Railway Stations Accessibility Database (ERSAD) should be maintained. [41] This database requires a set of parameters to be known about the station accessibility (e.g. if the station facilitates a wheelchair-accessible ticket vending counter). All stations in the database are referenced to NeTEx ”access space/entrance”-points by specifying them as ”Station Reference point”. [47]

As of 2023, the UIC provides a PRM Assistance Booking Tool (specified in (IRS) 90918-6) allowing for the reservation of assistance services for multiple European carriers [132]. However, this only covers the assistance services and provides no ticketing for customers.

3.4 Discussion

Reviewing current technical standards and systems in place to enable international rail ticketing, several difficulties, and possible solutions can be identified, answering the research questions: Which technical challenges exist? What can be done to solve them? (Question 2.5).

The following key aspects have been identified, that are the main challenges and possible solutions of current ticketing systems:

1. The technical landscape of the rail distribution system is fragmented and many custom-made solutions exist, that are not interoperable by design. This requires mappings between data formats to be carried out, which does not add business value and might reduce the number of connected systems.

   One example of this situation can be seen in the wide variety of timetable data exchange formats. While four formats have been mentioned in this chapter (i.e. NeTEx, GTFS, SIRI and EDIFACT), many more proprietary formats exist (e.g. NTFS, NOPTIS).

   To reduce the amount of necessary data mappings, already defined standards need to find wider adoption. This might require further development of the standard while aligning to more general frameworks like the Transmodel. National dialects of existing standards (cf. NeTEx) need to be aligned to provide real interoperability.

2. While migrating from paper-based tickets, the former physical process of ticket validation needs to be replaced with a digital one to ensure system integrity. Current solutions do not align in this aspect, as modern Account-/Id-Based ticketing solutions are implemented individually and optimized to the needs of the RU. This complicates mutual ticket recognition between carriers and reduces the availability of international rail tickets.

   For example, to avoid connected complications and keep costs low, WESTbahn opted for the implementation of their own SiS solution that provides additional functionality

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(e.g., ”Relax-Check-In”) to the customer but does not provide options to directly integrate with existing standards (e.g., through visualizing a FCB barcode).

This issue will be addressed by the introduction of eTCD, which will become part of the TAP-TSI, standardizing ticket data exchange.

3. As standards defined by state incumbents aim for centralization of systems (e.g., OSDM-offline, eTCD, MERITS) and no legal enforcement to use them is in place, distribution systems of private operators tend to get isolated, as implementation cost and competitive thinking shape decision-making.

   For example, the Italian private high-speed rail operator Italo[37] does not contribute to the MERITS timetable database, rendering the service invisible for customers using applications that solely rely on this database.

   Until this point RUs did not solve this problem as incentives to share data are missing.

Besides these challenges, the introduction of OSDM promises to harmonize the ticketing process between carriers. While it provides modern and standardized interfaces for ticket distribution, it is unclear, if the standard implementation will result in a level playing field for all carriers. The role of ticket combination is mainly served by the Distributor role, that following current EU legislation is controlled by the individual fare providers. As each RU can choose which foreign services can be combined with their offers, larger operators benefit from their market position. The ERA is currently still investigating if and to what extent OSDM-online could be included in further amendments to the TAP-TSI. The current version of OSDM introduced significant changes in the naming convention (as seen in Section 3.3.3), which raises the question of how stable the standard currently is and if delaying the implementation would reduce cost for further adaption to new releases.

Concluding the findings of this review, an ideal international ticketing system has to fulfill several technical aspects to ensure seamless connectivity, interoperability, and efficient service delivery (Question 2.7). The following four domain-specific aspects have been identified through the preceding review:

- **Common Language and Interfaces** - An ideal system must follow the concepts and standards that are part of the TSIs and related documents. Aside from ensuring compliance by implementing mandatory features, applying currently optional standards can be beneficial in the future, as stronger regulation of the distribution can be anticipated (e.g., through the adaptation of OSDM / eTCD into TAP-TSI). Furthermore, the ideal system should follow global standardization approaches (e.g., Transmodel) and support modern data formats for efficient data exchange, reducing the number of data mappings. Altogether, a common language and standardized interfaces create the basis for data exchange that forms the foundation to make international tickets available.

[37] https://www.italotreno.it/en

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- **Common validation mechanisms** - To be able to take advantage of the exchange of data and interface access to provide added value to the customer, the whole ticket process needs to be interoperable. This includes ticket validation, which itself requires common mechanisms to be employed to allow seamless integration into corresponding systems. In the physical world, such standards exist in the form of paper ticket formats (e.g., RCT2). Similarly, the use of FCB barcodes and the centralized eTCD ticket storage can provide interoperability but need to be considered in the design of a rail ticket distribution system.

- **Share system components** - If the first two aspects are fulfilled, the decision to build, rent, or buy should be reevaluated to take advantage of the interoperability of components. Split responsibilities and standardized interfaces enable the development of third-party components that can be used as off-the-shelf software, lowering implementation costs and removing qualification requirements to operate a custom system. This also includes the use of cloud computing to reduce operational overhead and improve service security, as certain aspects are outsourced to domain experts [58]. More recent standard development supports this transition, as they rely on concepts (e.g., RESTful design of OSDM) enabling the implementation of structures well-suited to be deployed as cloud service.

- **Include Services for PRM** The system should provide interoperable services for People with Reduced Mobility (PRM). The use of a centralized service or open access to crucial interfaces must be obligated to cover the SERA. This should include the data required for accessible ticket purchases and individual assistance requests to ensure inclusivity and equal access to mobility. Direct integration of such services into a booking platform must be favored above-separated solutions that only cover subaspects.

Besides these domain-specific aspects, when developing a new rail ticket distribution system, modern implementation organization and software technology should be considered, leading to better maintainable and sustainable systems. For further reads on possible strategies to employ, see [112], [79] and [61], that highlight agile, cloud, and mobile-first concepts.

While the highlighted elements answer the question ”Which technical aspects should an international ticketing system ideally fulfill?”, the implementation of such a system is highly dependent on the legal and economic framework, which are highlighted in the following chapter.

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4 Economic and political environment

Like Hans-Jürgen Freisinger from HACON, who states that 'from a technical perspective, any solution is possible and implementable, but action needs to be taken' (cf. Appendix A.1.4), many interviewed experts identified decision-making as the main factor limiting the availability of cross-border through-tickets.

To further investigate the reasons for poor customer experience observed in international rail ticketing, the contributing legal framework and economic decision-making factors are analyzed in this chapter.

Key interest groups are presented to approach this topic, and fields of concern are discussed in the following subsections. Finally, obstacles that prevent the implementation of enhancements are identified, and future measures to counteract them are proposed to improve the customer experience in international rail ticketing.

4.1 EU Interest Groups

To answer the question: Which political and commercial interest groups exist? What are their goals and methods? (Question 3.1), the main interest groups that influence decision-making have been identified. Figure 38 shows these actors, their related industries, and overlapping member pools (e.g., WESTbahn being UIC and Allrail member).

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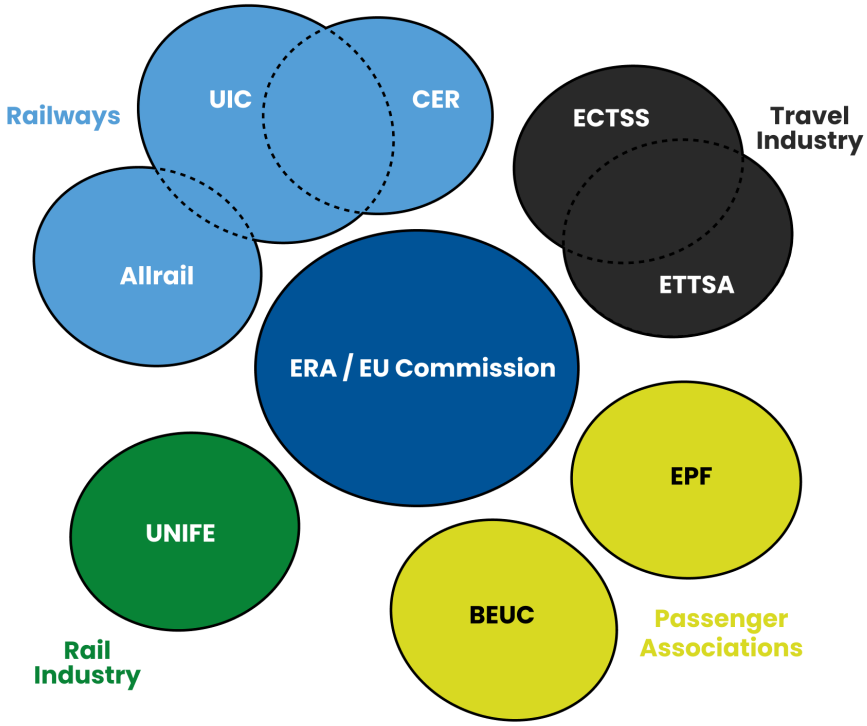

Figure 38: Main interest groups shaping international rail ticketing on EU level, Source: own research

In the following, each organization and its agenda are presented to see which of their aims might contradict and which commonalities or partnerships exist (Question 3.2). To structure the gathered information, public statements of all parties have been analyzed on their agreement / disagreement to the following statements:

1. All public transport **data**, including static (timetable, tariff data, etc.) and dynamic data (real-time delays, time-dependent fare availability, etc.), should be **open accessible** to third parties.

2. Full integration of tickets should be made mandatory for all combinations of services operated by **any carrier** resulting in available **through-tickets**, following common rules (e.g., min-transfer time) (e.g., WESTbahn Vienna → Munich, DB Munich → Berlin integrated into one ticket).

3. The implementation of **OSDM** should be fully included in TAP-TSI to standardize the ticket distribution process.

4. **Third parties** (e.g., Trainline) should get non-discriminatory access to **sell rail tickets**.

A summary of all parties' positions towards the statements is presented in Section 4.3.

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Aside from the differing individual positions, all entities have released a joined sectoral statement [4]. Accordingly, to create a Single European Railway Area (SERA), the rail sector commits to

- close cooperation with other transport modes to create a multimodal transport system,
- support innovation,
- implement OSDM,
- ”create a level playing field between Railway Undertakings and third-party vendors or MaaS services’ providers”[4, p. 3],
- improve the booking horizon,
- and improve passenger information and rights

4.1.1 UIC

The first organization shaping the future of international rail ticketing in Europe is the International Association of Railways (Union internationale des chemins de fer) (UIC) founded in 1922. It has been formed to create international cooperation between railways and strengthen their development and market position. This also includes the creation of industry standards.

As of 2023, many technical norms used in the field across Europe have been the outcome of UIC standardization efforts. Within over 700 published leaflets / IRSs maintained by 118 working groups, several standards, touching the area of rail ticketing and distribution, have been developed [124](cf. Table 10).

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IRS 108-1	Computer generation and exchange of tariff information
IRS 108-2	Computer generation of global prices and exchange of fare information on computer medium
IRS 130	Commercial framework for the international distribution of rail products
IRS 120	Auditing cross-distribution and accounting processes of tickets in passenger transport
IRS 914	Technical security standards for electronic sales and distribution systems
IRS 90918-0	Electronic seat/berth reservation and electronic production of travel documents — General regulations
IRS 90918-1	Electronic reservation of seats/berths and electronic production of travel documents — Exchange of messages
IRS 90918-4	e-Ticket Exchange for Control
IRS 90918-6	Electronic reservation of assistance for persons with reduced mobility - Exchange of messages
IRS 90918-8	Layout for electronically issued rail passenger tickets
IRS 90918-9	Digital Security Elements for Rail Passenger Ticketing
IRS 90918-10	Open Sales and Distribution Model OSDM

Table 10: Selection of in-force International Rail Solutions (IRS) related to international rail ticketing

To develop new standards and maintain existing ones, the UIC organizes several working groups related to passenger services, as shown in Figure 39. One of them is in charge of developing the Open Sales and Distribution Model (OSDM), that UIC aims to integrate into the TAP-TSI [125, p. 4].

Besides all state incumbents of the research area, several private operators are affiliate or associate members of the UIC including Italo, WESTbahn, and the Student Agency (running RegioJet) [139]. In comparison to the active memberships mainly held by bigger state incumbents (e.g. SNCF, DB, ÖBB), access to the inner organizational UIC management is limited, but working group participation as well as access to standards is granted [128].

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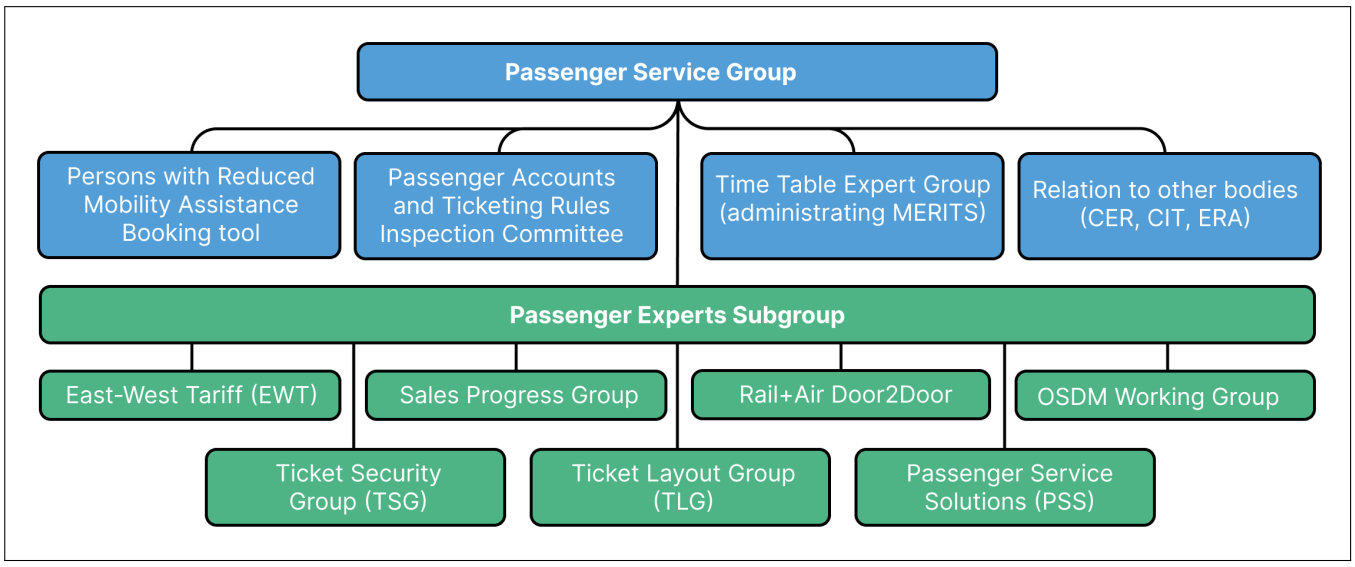

Figure 39: Structure of UIC user groups, working on topics related to rail ticketing, Source: [141, p. 12, 17], own representation

For its future, the UIC formulated a clear self understanding of being a Standards Setting Organization (SSO) that supports the creation of the Single European Railway Area (SERA) for the Railway Operating Community (ROC). The organization sees itself in line with the normation institutes CEN, CENELEC and ETSI (despite UIC not being an official European standards body), focusing on ”standardization of the processes for operation and maintenance” following the guidelines of European TSIs. [127] As this is the case, the UIC did not publish any position papers on data availability, ticket integration obligations, or third party access to ticketing. Putting the UIC as an organization in a neutral position towards these topics (as seen in Table 11). While no demands towards providing access to third party ticket vendors are made, their interests are represented within working groups and standard definitions.

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
UIC	~	~	✓	~

Table 11: Analysis of UIC position towards reference statements

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4.1.2 CER

The Community of European Railway and Infrastructure Companies (Communauté européenne du rail) (CER) embodies the interest group of state rail incumbents, including their infrastructure as well as passenger and freight subdivisions, on European level, joined by national associations. In total, CER claims that their members ”represent 73% of the rail network length, 76% of the rail freight business and about 92% of rail passenger operations” [26, p. 9].

In 2021, the group published a roadmap towards improved international rail ticketing, that outlines the main standpoints and future objectives. These have been split into concrete actions, that should be taken until 2025 and a long-term plan that should be executed until 2030 (cf. Figure 40).

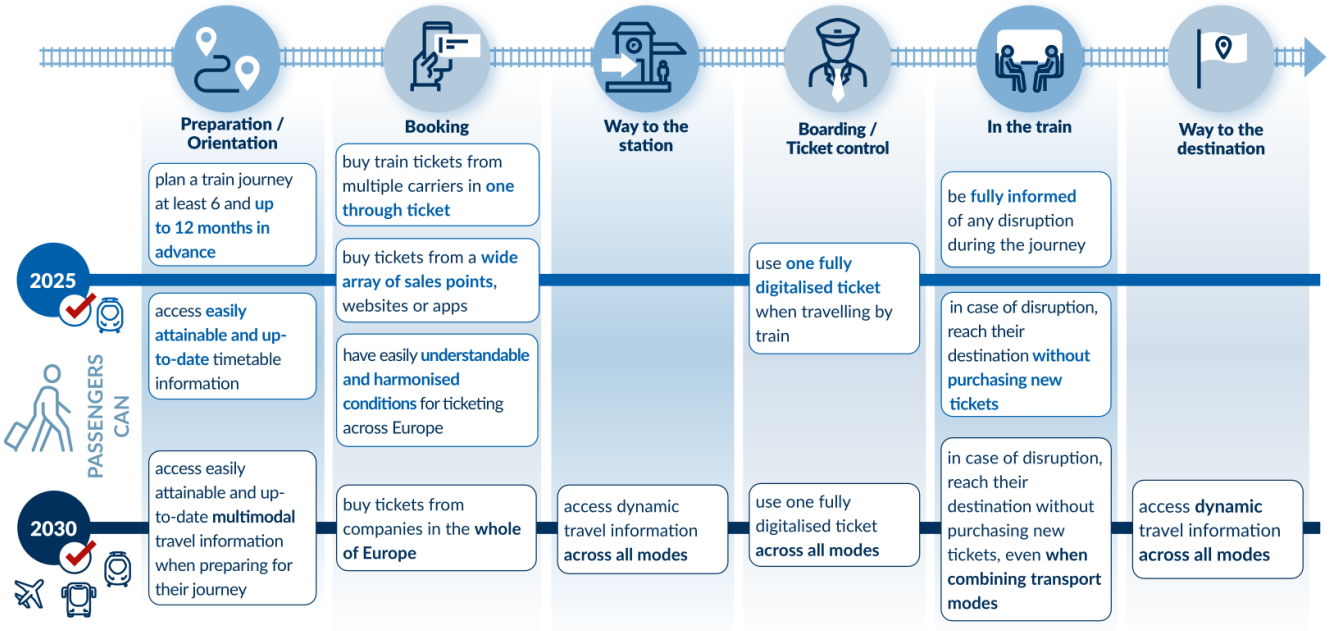

Figure 40: CER Ticketing Roadmap, Source: [17]

As CER shares most of its members with the UIC, the adoption of OSDM, MERITS, and eTCD into EU regulation is aspired by CER to achieve key elements of the roadmap. Furthermore, the expansion of agreements to simplify journey continuation in case of occurring delays are anticipated, referencing the Agreement on Journey Continuation (AJC) and HOTNAT, that is further discussed in Section 4.2.3.

Stating that ”the decision to share real-time information [...] should remain up to individual transport operators.” [19, p. 3] and suggesting to remove ”the obligation to share observed data on delays, passing times and cancellations”[19, p. 1], from a drafted amendment to (EU) 2017/1926, CER tries to limit the availability of open data. ”CER would like to caution against any changes in the current provisions on through-tickets” [18, p. 1], when comment-

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ing on new passenger rights regulations, defending the status quo of unregulated cross carrier ticket integration and through-ticketing. Furthermore, the organization claims that ”each railway undertaking shall only make available its tariffs to railway undertakings and third parties to which it grants authorization to sell”[19, p. 3], restricting the access of third-party ticket vendors.

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
CER	✗	✗	✓	✗

Table 12: Analysis of CERs position towards reference statements

4.1.3 Allrail

Counteracting the state incumbent-dominated lobbying efforts of CER on the European level, the official EU representative body of private rail undertakings Allrail was established in 2017. In 2023, the alliance has 17 members, including three ticket vendors and one coach operator.

According to Nick Brooks, Secretary General of Allrail, ’standards for ticketing must be created by an EU agency at the European level, not by private interest groups, otherwise, there is an obvious conflict of interest.’. This includes the use and further development of CEN NeTEx instead of the UIC OSDM model, as NeTEx ’is sufficient, and fulfills a lot of requirements’, while being ’more transparent’ (Brooks, cf. Appendix A.1.2).

To really improve rail ticketing, Brooks asks, ’of what use is a common standard such as OSDM if through-tickets are only available between state-owned incumbents?’ (Brooks, cf. Appendix A.1.2), suggesting that mutual ticket recognition and journey continuation as a basic passenger right would be the most effective measure to establish a level playing field for all parties. [3] Else, he states, ’the inherited network of the state incumbents will be used as a competitive advantage over new entrants’.

In ticket distribution, Allrail supports open data exchange, market liberalization (i.e., third-party booking platforms), and efforts to establish more multi-modal offerings. (Brooks, cf. Appendix A.1.2).

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
Allrail	✓	✓	✗	✓

Table 13: Analysis of Allrails position towards reference statements

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4.1.4 EPF / BEUC

Representing the customers, the European Passengers Federation (EPF) (est. 2002) and the European Consumer Organisation (Bureau Européen des Unions de Consommateurs) (BEUC) (est. 1962) unite national passenger and consumer organizations on the European level.

Both support efforts to create multimodal ticketing solutions, that can cover international trips within Europe [4], while following a user-centric approach [89, p. 29]. To exert pressure on legislators, clearly state the organizations' views, and influence the future of public transport ticketing in general, both EPF[38] and BEUC[39] publish position papers on a regular basis and take part in related projects and hearings. In the field of international rail ticketing, the organizations focus on passenger rights, improving customer access to the rail network, and public information [46] [11].

The organizations state that there is a "lack of sufficient legal obligations to share static and dynamic data" and call on the EU Commission to "oblige rail operators to share a minimum set of static and real-time/dynamic data."[89, p. 25] This should promote the "efficient distribution by third-party ticket vendors"[89, p. 25]. In addition to EPF being members of the FSM Sounding Board [57, p. 22], the BEUC claims that new initiatives (like MDMS, cf. Section 4.2.2) "should promote the development of these standards [(OSDM)] and their swift implementation by all actors"[10, p. 11]. Moreover, "new legislative proposals to make mandatory offers of through-tickets, including international travel, should be considered."[89, p. 25]

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
EPF / BEUC	✓	✓	✓	✓

Table 14: Analysis of EPFs and BEUCs position towards reference statements

4.1.5 ECTAA / ETTSA

United in the European Travel Agents' and Tour Operators' Association (ECTAA) (est. 1961) and European Technology and Travel Services Association (ETTSA) (est. 2009), travel agents, GDS providers, and rail mobility platforms promote their collective business interests on the European level.

Both organizations have been advisors for the Full Service Model [57, p. 22] and have further been part of the creation of OSDM. Within the implementation of the TAP-TSI, ECTAA and ETTSA are responsible for reporting retail parameters provided by their member ticket

[38] https://www.epf.eu/wp/position-papers/
[39] https://www.beuc.eu/position-papers

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vendors to ERA [30, p. 9]. ETTSA recommends ”regulated access to all transport operators’ data for mobility platforms” as part of their position paper on the new MDMS regulation [36, p. 6].

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
ECTSS / ETTSA	✓	~	✓	✓

Table 15: Analysis of ECTAAs and ETTSAs position towards reference statements

4.1.6 UNIFE

Representing the voice of suppliers, European Rail Supply Industry Association (Union des Industries Ferroviaires Européennes) (UNIFE) (est. 1991) leads the it2Rail project, which has been part of the EU initiative shift2rail (later renamed into Europe’s Rail) [39], aiming to provide an interoperable framework for including ticket distribution [73]. In its March 2022 report UNIFE underlines the importance of dynamic data (e.g., real-time data) to support multimodal travel, which includes international rail ticketing [143, p. 11ff.].

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
UNIFE	✓	~	~	~

Table 16: Analysis of UNIFEs position towards reference statements

4.1.7 European Commission / ERA

As the executive-legislative body, the European Commission is in charge of submitting new legislation to regulate passenger rail and initialize the European legislative procedure. To provide technical expertise, Chapter 1, Article 2 of (EU) 2016/796 states that ”the Agency [(ERA)] shall contribute, on technical matters, to the implementation of Union legislation by developing a common approach to safety on the Union rail system and by enhancing the level of interoperability on the Union rail system.” [50, p. 8] Several regulations are in force for the design of international rail ticket distribution systems that regulate data exchange, mandatory services, and passenger rights. The main legal texts covering these topics are:

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(EU) 454/2011 (EU) 2016/527	Telematics applications for passenger services (TAP-TSI) Amending TAP-TSI with updated technical references
(EU) 2010/40 (EU) 2017/1926	framework for the deployment of Intelligent Transport Systems Provision of EU-wide multimodal travel information services (MMTIS) (Supplement to (EU) 2010/40)
(EU) 2021/782	Rail passengers rights and obligations (also referred to as Passenger Rights Regulation (PRR))
2012/34/EU	Establishing a single European railway area

Table 17: List of EU legislation directly concerning international rail ticketing

Future ambitions of ERA include the recast of the TAP-TSI, that will include eTCD and OSDM (cf. Section 3.3.1). Parts of the model are still subject to assessment, as the access conditions of OSDM-online are not clear to be non-discriminatory (cf. Appendix A.1.8, A.1.9). Furthermore, an amendment to the MMTIS (highlighted in 4.2.2) regulation is discussed, enforcing the access to real-time and occupation data. According to (EU) 454/2011 (TAP-TSI), third parties get access to tariff data if they have been authorized to sell by the operator. As this information is essential for ticket distribution, this contradicts non-discriminatory access for third-party ticket vendors.

	Open data access	All Carrier through-ticketing	OSDM	Third-party ticketsales
Current EU legislation	✓	~	✓ ~	~

Table 18: Analysis of EU regulation in relation to reference statements

4.2 Fields of Concern

This section explores four topics that serve as obstacles or potential advancements in the field of international rail ticketing. They have been derived from the concerns and trends identified by experts in the field of international rail ticketing. These main hurdles and emerging developments include:

- Enhancing **access and availability of through-tickets** (highlighted by Brooks, cf. Appendix A.1.2)
- Implementing **modern standardized distribution systems** (suggested by Mokros, Brooks, and Fischer, cf. Appendix A.1.1, A.1.2, A.1.6)
- Embracing distribution as **Mobility-as-a-Service** (mentioned by Freisinger and Prasnikar, cf. Appendix A.1.4, A.1.7)

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- Ensuring **non-discriminatory access for smaller carriers** (spotlighted by Brooks, cf. Appendix A.1.2)

To encompass these issues, this thesis focuses on four overarching topics: interoperability, multimodal ticketing, journey continuation, and economic market conditions. These topics have been identified as critical areas that encapsulate the challenges and advancements in international rail ticketing. The pertaining legal aspects are examined in order to address the research question: Which legal requirements exist? (Question 3.3).

4.2.1 Interoperability

To efficiently exchange all information needed to sell international rail tickets in a single customer-facing platform, common data formats, and interfaces are required, as highlighted in the previous chapter. Claus Fischer states that 'standardization is the essential key towards success in the interoperability of distribution systems' (Fischer, cf. Appendix A.1.6). Besides technical aspects, commercial standards are equally important, reducing incompatibilities and complexity.

In addition to technical aspects, the significance of commercial standards should not be overlooked, as they are equally important to mitigate incompatibilities and reduce complexity. When a distribution system is required to handle diverse national standards for ticket formats and rules concerning through-ticketing, the complexity level becomes unreasonably high, reducing its likelihood of implementation.

4.2.1.1 Legal Foundation

The first standards for international rail ticketing were introduced with the Convention concerning International Carriage by Rail (Convention relative aux transports internationaux ferroviaires) (COTIF) in 1980. This international agreement, coordinated by the intergovernmental organization Convention concerning International Carriage by Rail (Organisation intergouvernementale pour les transports internationaux ferroviaires) (OTIF), includes the International Convention for the transportation of Passengers (Convention Internationale pour le transport des Voyageurs) (CIV), which defines the legal base for international passenger rail travel. CIV Article 7 § 5 describes the possibility of digital ticketing but only specifies that the ticket content must still be convertible to text and contain the prescribed information (CIV Article 7 §2).

Based on this framework, the European Commission, in cooperation with ERA, designed TSIs that should further improve interoperability.

4.2.1.2 Common Distribution Guidlines

Aside from covering technical interfaces for data exchange, the TSIs lack a framework for revenue sharing and rules for offer combination (cf. Appendix A.1.4) [43, p. 2]. This means that no interoperability between individual offers is achieved even if the distribution system

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complies with all regulations, leaving customers with no option to buy a through-ticket that includes both offers. As a result, any ticket vendor selling through-tickets needs to arrange individual agreements with operators or combine individual tickets on its initiative. The latter opposes an unpresentable financial risk to the vendor, as article 12 §4 (EU) 2021/782 would require a 175% repayment of the passenger if a connection is missed [45, p. 17].

To provide the required common guidelines, the regional public transport authorities of Sweden founded the joint undertaking Samtrafiken. Since its launch in 1993, the company has created unified standards and offers, like the Resplus ticket, that can combine service journeys of multiple carriers into a single ticket [99]. Agreements on transfer times were centrally collected and are available online [40], which allows ticket distributors to combine tickets into through-tickets without additional bilateral agreements.

In 2021, a report on ”Long-distance cross-border passenger rail services” commissioned by the EU Commission suggested the implementation of similar practices on a European level [110, p. 69].

4.2.1.3 System Access

Another issue, that dampens the effect of connecting interoperable systems, is created by restrictive access policies, blocking communication and data exchange between parties. This can facilitate in access to real-time data being denied by rail companies or low commission payouts that make further integration an unprofitable undertaking.

The industry acknowledges that Fair, Reasonable And Non-Discriminatory (FRAND) principles need to be deployed to use the full potential of digitalization efforts [4]. The cooperation between European Air travel platforms and carriers already implemented such a framework, regulated in 2009/80/E.

In 2023, two cartel rulings enforce the mitigation of protectionist restrictions of DB [12] and RENFE [40], holding back real-time data and employing non-FRAND practices.

4.2.2 Multimodal Ticketing

To create an efficient public transport infrastructure that users can utilize via a One-Stop-Shop, different services (e.g., serving rail, bus, or shared mobility services) need to be connected. The resulting Mobility-as-a-Service (MaaS) application would serve one price for a transport task from A to B, potentially involving multiple transport modes and operators. For short-distance mobility needs, such an initiative focuses on integrating last-mile solutions. However, international rail ticketing must be present with integrated and competitive offers to enable rail to substitute air travel on long distances (up to 800km). A report of the Independet Regulators Group - Rail (IRG-Rail) reveals that in 2021, no international MaaS offerings have been recorded (cf. Figure 41).

[40] https://brm.samtrafiken.se/showtimes

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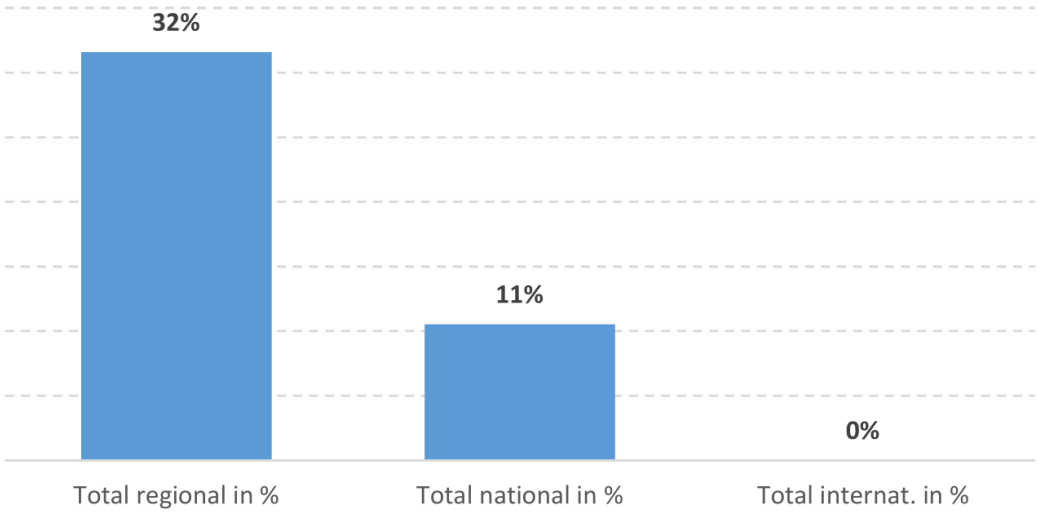

Figure 41: Availability of Mobility-as-a-Service (MaaS) (number of participating states = 19), Source: [70, p. 11]

4.2.2.1 Legal Foundation

The EU Commission released the MMTIS regulation (EU) 2017/1926 to address the need for multimodal traffic information systems. As a result, each EU member state should collect and share rail timetable data using NeTEx on a National Access Point (NAP) in addition to information about other transport modes. Optionally, dynamic data can be provided using the SIRI format.

As the regulation does not cover payment and booking of multimodal services, the EU Commission is preparing a new regulation on Multimodal digital mobility services (MDMS) that follows three specific objectives [43, p. 3]:

1. ”Provide certainty and transparency for business-to-business commercial agreements for services re-selling mobility products for land-based modes, waterborne and maritime transport, as well as for agreements on journey continuation.” The latter is highlighted in Section 4.2.3.

2. ”Prevent harmful market effects which may arise from discriminatory behavior of MDMS against operators, and ensure that the deployment of MDMS is not hampered by discriminatory practices”.

3. ”Ensure that MDMS enhance the efficiency and sustainability of the transport system”.

As there is currently no obligation of FRAND agreements between rail operators and ticket vendors, a MDMS regulation providing this addition could improve the availability of international rail ticketing. Furthermore, the revision of the MMTIS ”planned for adoption during autumn 2023 [...] [is] [...] strengthening the importance of cooperation amongst ITS stakeholders” (Söderqvist, c.f. Appendix A.1.9). The aligned EU project NAPCORE[41] ”aims to

[41] https://napcore.eu/

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improve the cooperation amongst national access points in the Member States" (Söderqvist, c.f. Appendix A.1.9). A common European Mobility Data Space (EMDS) to simplify the pooling and sharing of mobility data is envisioned by the EU Commission (c.f. Appendix A.1.9).

4.2.2.2 Ticket Integration

Different stages of ticket integration can be identified to categorize the progress in developing a MaaS applications. The topological model (shown in Figure 42) is split into four levels.

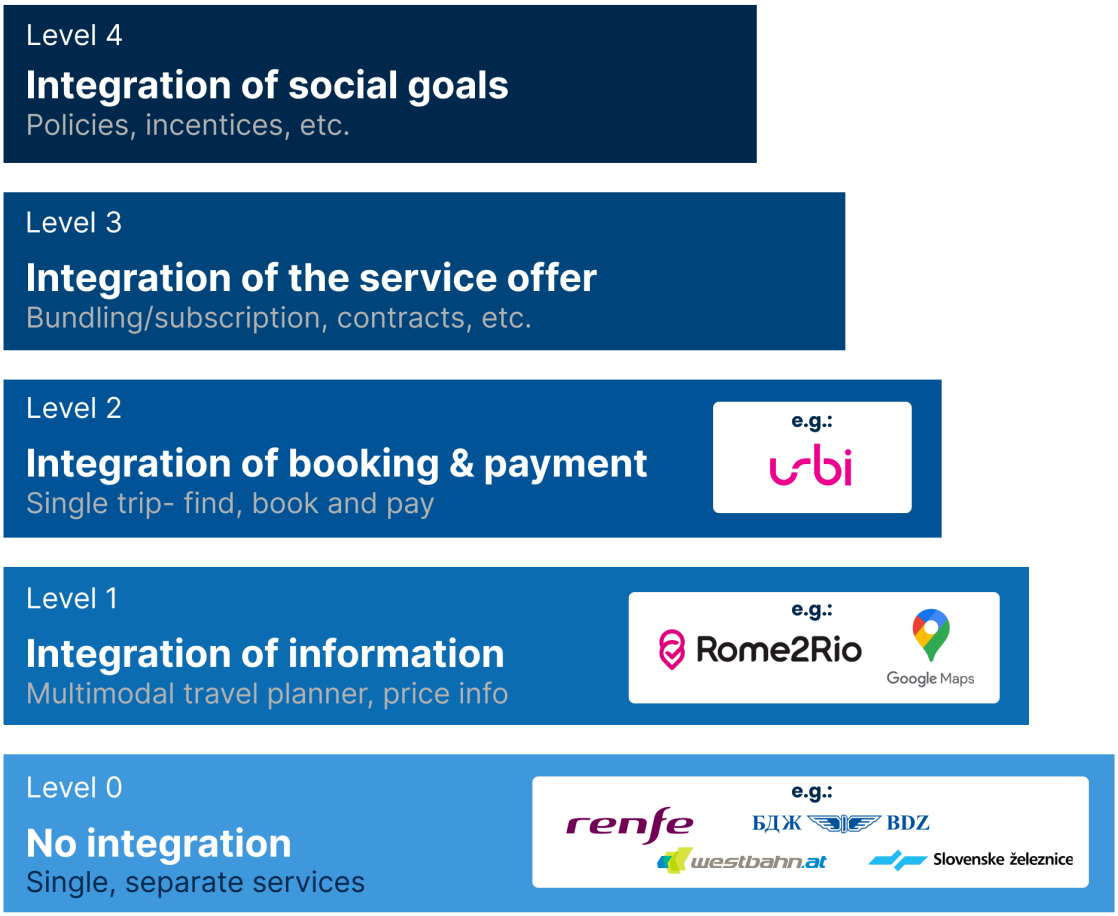

Figure 42: MaaS implementation levels and multimodal examples that include rail services, Source: [105], [70, p.4-9], own representation

- **Level 1**: Integration of Information - Multimodal travel planner that might present prices but does not allow booking of tickets on the platform.
- **Level 2**: Integration of booking & payment (i.e., partial integration) - Single trips are bookable. Journeys involving multiple carriers are sold as a combined ticket.

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- **Level 3**: Integration of the service offer (i.e., full integration) - Through-tickets are available for trips involving multiple carriers. A mobility subscription might be offered.
- **Level 4**: Integration of societal goals - Regulation implied optimizations are applied to the offer selection.

The organizational structure of a MaaS application can be broken into three distinctive roles. These are the mobility service provider, MaaS integrator, and MaaS Operator. By stratifying these roles (OSDM: Fare Provider, Distributor, Retailer), the Open Sales and Distribution Model (OSDM) can act as the backbone of distribution platforms to achieve higher integration levels.

The current legal framework requires the Integrator (OSDM: Distributor) to take the entire commercial risk if not agreed otherwise with mobility service providers (cf. Article 12 §4 (EU) 2021/782). Therefore, to achieve higher integration levels to offer MaaS services utilizing international rail, operators need to be encouraged to agree on common integration guidelines (as highlighted in Section 4.2.1.2).

4.2.3 Journey continuation

To enable through-ticketing, one key aspect that needs to be agreed on concerns handling passengers in case of service delays and cancellations. The current EU MDMS "initiative looks at ensuring journey-continuation and protection in case of missed connections for passengers traveling on combined separate tickets" (Söderqvist, c.f. Appendix A.1.9). To later identify possible improvements regarding this issue, the current legislative framework and private initiatives are highlighted in the following subsections.

4.2.3.1 Legal Foundation

As part of the CIV attachment of the 1999 COTIF agreement, Article 32 specified the RUs responsibilities in case a connection is missed. In 2007, the EU Commission stated, "The current international arrangements, based on an international convention (CIV10), are inadequate." [25, p. 8] defining European passenger rights and obligations in 1371/2007/EG. Its recast (EU) 2021/782 specifies the circumstances in greater detail in Articles 18, 19 and 20. According to the regulation, passengers stranded due to a missed connection are entitled to choose between:

1. getting reimbursed for the missing part of the transport contract
2. getting re-routed
3. continue their journey at a later date at the passenger's convenience

In case a third party sells a combined journey, it is required to reimburse 100% of the ticket price and pay 75% of the price as compensation. This is not the case if the ticket vendor informed the customer and the ticket specifies that it represents separate transport contracts.

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In addition to European and national law, bilateral agreements are highlighted in the following sections.

4.2.3.2 AJC

The Agreement on Journey Continuation (AJC) has been signed by 16 carries (BLS, CD, CFL, DB, DSB, MAV-START, NS, ÖBB, Renfe, SBB/CFF, SJ, SNCB/NMBS, SNCF, SZ, Trenitalia, ZSSK) providing a ”commercial gesture to stranded passengers” [21]. Specifically designed for international connecting passengers, the agreement enables passengers to continue their combined journey, even if they do not possess a through-ticket. To do so, the customer might be required to present a confirmation of delay that should be made available in case (obligated as part of CIV Article 11). Continuing their journey, passengers might board the next train of the original carrier at no extra cost. The agreement states that the described service is a gesture of goodwill, as ”this solution does not provide rights to passengers”[21].

Stefan Jugelt (ERA) states that an integration of an obligation to a similar agreement is currently ’discussed as part of the MDMS initiative’ (Jugelt, cf. Appendix A.1.8).

As the AJC is not the only agreement concerning the continuation of travel, the contract states explicitly that other agreements might also be applicable.

4.2.3.3 Railteam

To strengthen European high-speed rail and improve interoperability, Railteam was founded in 2007. All stakeholders of the alliance (DB, SNCF [each 20%], SNCB, Eurostar, NS International, ÖBB, SBB, and Thalys [10%][92]) commit themselves to provide a selection of services to all passengers on their high-speed rail network. Besides trying to establish a One-Stop-Shop (as highlighted in Section 3.2.1.1), these are [93]:

- **Information points** in stations
- **Multilingual personnel**, to assist travelers at the station and on the trains
- Mutual **recognition of frequent traveler cards** (i.e. in frequent traveler Lounges)
- Agreement on **extended passenger rights**

The latter includes the agreement to allow passengers to ”hop on the next available train” (HOTNAT). As the name suggests, it allows passengers of member high-speed services to take the next train in case a connection is missed. Between carriers, the agreement does not include any act of reimbursement. From the point of view of Nick Brooks (Allrail), a similar model should be obligated by the European Commission.

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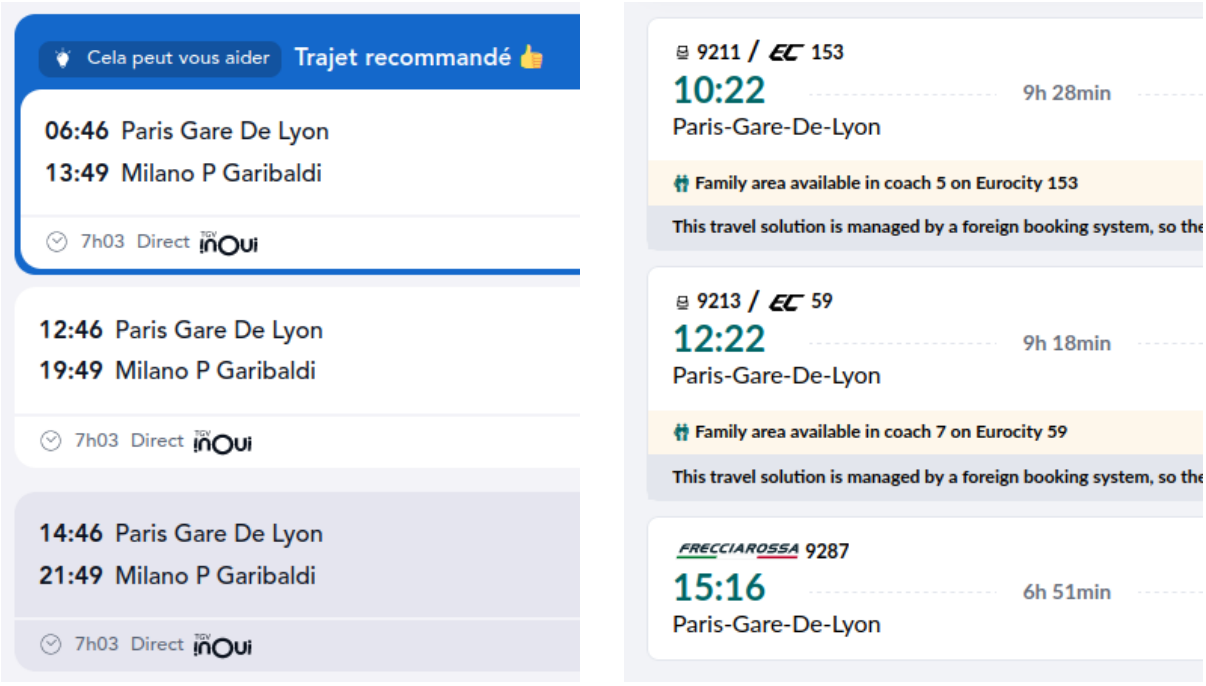
4.2.4 Economic conditions

The last aspect influencing the future developments of international rail ticketing concerns the economic conditions a RU needs to consider. Internal (RU vs. RU) and external (rail vs. plane, coach, car) competition influences investment and partnership decisions. Alexander Mokros (DB) states that 'connecting non-standardized distribution systems comes at a significant cost, which is hindering some efforts' (Mokros, cf. Appendix A.1.1). Known prices for the implementation of modern distribution systems range from 2.5 (WESTbahn, cf. Appendix A.1.6) to 234 million Euro (Renfe, [71]). Therefore, to support RUs in implementing interoperable standards and connecting distribution systems.

4.2.4.1 Market competition

With the third railway package coming into force in 2010, open access following FRAND rules was granted to new entrants in the private passenger rail segment (cf. Directive 2007/58/EG, and recast 2012/34/EU). While this measure stipulates competition, it requires partnerships between RUs to be strategically beneficial. As soon as this is not the case, the variety of available through-tickets is affected. For example, while mutually distributing tickets for other national relations, SNCF and Trenitalia only show their own connections when searching for direct connections between Paris and Milan (cf. Figure 43).



(a) SNCF-Connect offering only inOui services

(b) Trenitalia not showing direct trains by SNCF

Figure 43: Direct comparison of offers shown by SNCF and Trenitalia. Source: SNCF-Connect.fr, trenitalia.it

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Similarly, WESTbahn stopped its partnership with Bavarian carrier Meridian, allowing passengers to travel between Vienna and Munich with one ticket (utilizing WESTbahn), after expanding its service [9].

To remove competition as a decision-making factor and improve their own visibility, private RUs demand a regulation for mandatory contraction in ticket sales (Pettauer, cf. Appendix A.1.5).

4.2.4.2 Funding

The implementation of interoperable booking systems might differ from the individual financially ideal system. Christian Pettauer (WESTbahn) underlines this, stating, 'OSDM [...] is complex and cost-intensive to implement' (Pettauer, cf. Appendix A.1.5).

To support the technical implementation of interoperable booking systems financially, the European Climate, Infrastructure and Environment Executive Agency (CINEA) provides the Connecting Europe Facility (CEF) funding program covering transition and innovation projects (Jugelt, cf. Appendix A.1.8). However, no projects directly related to international ticketing have been listed in July 2023.

Aside from investments dedicated to the adaption or expansion of systems in use, the application of standardized interfaces will reduce the cost of new implementations. This is due to the modularity and reusability of software being improved. Thus, third parties will be able to provide standardized modules as off-the-shelf products to RUs. One example of such a new business model is the OSDM-compliant S3 Passenger inventory and reservation system developed by Sqills [75]. Further supporting this trend, the CIO of Eurail, Hugo Knobbout, notes that in the future, 'Eurail could be a trusted partner to provide standardized applications for ticket inspection and distribution' (Knobbout, cf. Appendix A.1.3).

4.3 Summary

The analysis of the legal and economic framework for international rail ticketing has shown that in 2023, bilateral agreements between railways define the bookability of cross-carrier tickets, as EU legislation currently does not obligate FRAND access to ticket distribution.

The main incentive of railways to enable international ticket sales has been identified to be the increase of market reach (Question 3.3). However, significant barriers, including the high cost associated with adapting systems to enable cross-carrier distribution, limit the offers available to the customer. Additionally, RUs express concerns about the potential loss of customer sales data and market share, further complicating bilateral agreements on reciprocal sales and journey continuation.

This has also been observed reviewing standpoints of interest groups on the European level.

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Figure 44 shows the position of all identified parties towards the analyzed statements (cf. statements in 4.1).

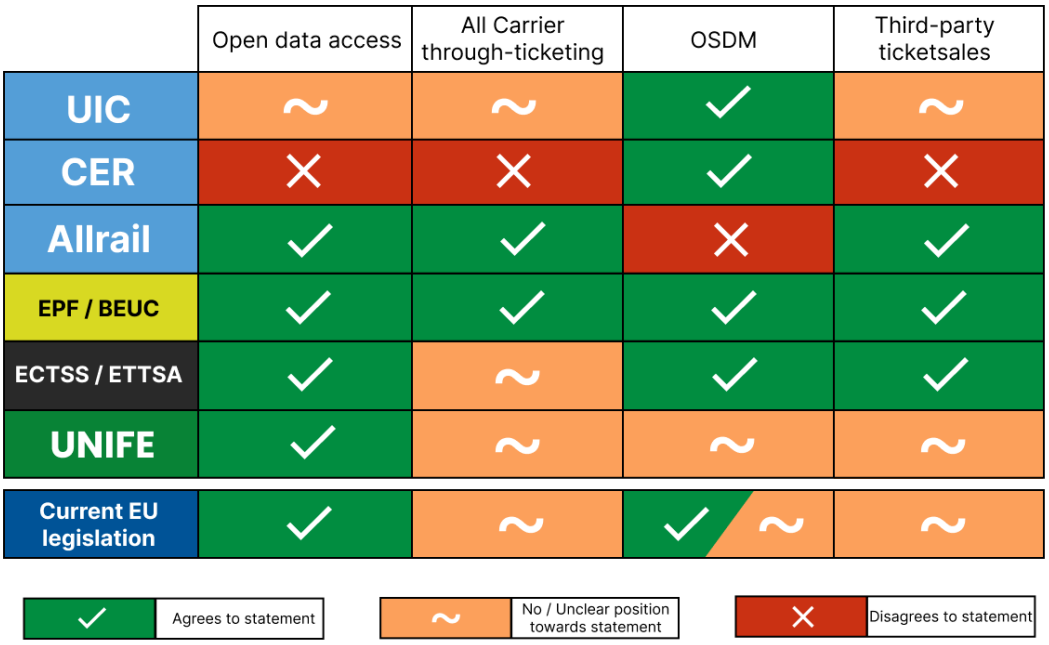

Figure 44: Summary of position analysis towards reference statements, Source: own research

As these measures can be anticipated to improve the customer experience, all statements are supported by passenger rights associations. At the same time, contradicting aims of rail incumbents represented by CER and private rail represented by Allrail are notable.

A future legislation should aim to improve the customer experience of international ticketing by implementing the following (Question 3.5):

- **Common distribution guidelines**, that allow the redistribution and combination of any service journeys.
- Obligatory **exchange of dynamic data** (e.g., real-time timetable, Yield-managed fares)
- The use of **centralized distribution infrastructure** to lower cost and reduce data government concerns.
- Do not let the RUs make the decision on whether a third-party vendor can offer tickets. Instead, have an **independent third party** make the decision.

Future changes to EU legislation — like the MDMS regulation — might include a subset of these possible improvements. Petra Söderqvist states that ”to achieve this, we [EU Commission] are considering obligations for transport operators (including airlines) and MDMS

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platforms, which should be obliged to enter into commercial agreements based on FRAND (fair, reasonable, and non-discriminatory) principles for re-linking or for re-sell." (Söderqvist, c.f. Appendix A.1.9) The revision of the MMTIS regulation will strengthen the importance of NAPs. A common European Mobility Data Space (EMDS) is envisioned. Additionally to changes in legislation, market supervision is counteracting protectionists and unfair competition, resulting in a more open market environment. All taken measures will increase the availability and bookability of international rail tickets, benefiting the customer experience.

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5 Conclusion

This thesis provides an overview of the current customer experience, technical landscape, and economic and political framework of international rail ticketing. Identifying key issues and solutions and providing data about customer perception enables the further observation of technical and legal additions affecting the field.

5.1 Identified Issues

To assess the status quo, this thesis surveyed customers' expectations, experience, and needs. Ticket availability (Issue 1), aside from comparability (Issue 2) and accessibility of offers (Issue 3), have been identified as the main reasons for bad user experience. Furthermore, if tickets are available, booking sites are often not user-friendly or misleading customers (Issue 4). Due to limited journey continuation requirements, customers might get stranded when buying combined tickets from multiple carriers. This exposes them to significant financial risks in case of service disruptions (Issue 5).

As former non-digital international ticketing utilized security mechanisms within the paper ticket and, therefore, did not rely on common interfaces between technical systems, many legacy distribution systems are stand-alone custom developments that are not digitally interoperable by design (Issue 6). Additionally, multiple distinctive standards for data exchange and booking interfaces exist (Issue 7). These require extra resources for data conversions or adoptions of in-place systems. To still be able to sell international rail tickets, centralized systems to exchange timetables and fares have been established. However, previous efforts to create a One-Stop-Shop selling all available trips around Europe have failed due to decentralized organization and a lack of funding (Issue 8). Due to its design, the Open Sales and Distribution Model (OSDM) is the subject of ongoing debates, as new entrants fear being discriminated by inherent access restricting mechanisms and incumbent-dominated centralized architectures slowing down its adoption (Issue 9).

To solve technical challenges, the European Union is mandating TSIs, covering different data formats and regulating data exchange. However, current legislation lacks provisions for combining offers (Issue 10). It does not require inter-carrier through-tickets to be made available (Issue 11). The competitive environment and commercial interests of rail incumbents and new entrants inhibit partnerships from forming (Issue 12).

In conclusion, the review of international rail ticketing showed that railways optimized their systems to fit the local markets while neglecting interoperability. Restrictive data exchange policies and technical limitations result in low ticket availability, negatively impacting the customer experience of purchasing an international rail ticket.

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5.2 Identified Solutions

To find solutions to the issues listed above, the technical process of ticketing, former and present system components, future standards, and regulations have been reviewed as part of this thesis.

As a result, the following actions have been identified as potential measures to improve international ticketing:

1. Technical improvements
    - New standards must utilize the common domain language Transmodel to reduce systemic confusion (Addresses issue 6).
    - Modular components should be shared within and between carriers to reduce required development and maintenance resources, thus reducing cost (addresses issue 8).
    - Common interfaces (e.g., OSDM) need to find wider adoption, creating an interoperable system landscape (addresses issue 7).
    - PRM-services should be integrated into the main distribution channels to reduce barriers and overhead of current processes (addresses issue 3).
    - A centralized validation mechanism and ticket data exchange must be provided to enable third-party sales and validation while allowing RUs to govern customer data (addresses issues 1, 2).
    - Ticketing platforms have to be modernized, and usability issues that irritate and turn away customers need to be fixed by following common best practices (addresses issue 4).
2. Legal actions
    - Mandate the provision of dynamic data to third parties (i.e., other RUs and mobility platforms) (addresses issue 2).
    - Reevaluate the governance of centralized system components, considering ERA involvement to ensure non-discriminatory access for all market participants (addresses issues 9, 12).
    - Provide common guidelines for ticket combination (addresses issue 10).
    - Require inter-carrier through-tickets to be made available for distribution (addresses issue 11).
    - Establish transparent rules for open journey combinations by customers to not expose them to financial risk when traveling with multiple rail companies (addresses issue 5).

Many of the solutions mentioned are in the process of being discussed or implemented. The new European initiative for Multimodal digital mobility services (MDMS) might provide Fair,

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Reasonable And Non-Discriminatory (FRAND) market conditions for third-party resale and stipulate data exchange.

Overall, modern international rail ticketing requires cooperation between actors. For this to happen, regulation is needed to make all services of the European rail network available via One-Stop-Shop platforms. Efficient technical solutions have been developed, while continued attention needs to be paid to ensure access following the FRAND principle. The sector should be encouraged to establish competition in ticket distribution to improve ticket availability and customer experience.

5.3 Next Steps

Due to its broad scope, this work could not cover all subsystems in detail and leaves further research questions to be answered. Possible follow-up topics worth investigating could be:

- Conducting a more in-depth analysis to quantify the potential increase in yield achievable by improving ticket availability and enhancing the usability of booking platforms.
- Investigating the development of commission rates for ticket distribution in other sectors in comparison to the rail market.
- Reviewing and comparing the usage and versatility of current data exchange formats, such as NeTEx.
- Analyzing different options of journey continuation agreements and investigating user expectations concerning compensation in the event of service disruptions.

Additionally, the MDMS regulation and TAP-TSI recast need to be reviewed in their final version, as at the time of writing, only drafts or statements of intent have been available.

Reducing the amount of failing international rail ticket booking attempts will be essential to make cross-border rail travel more attractive and support the required modal shift towards rail. Staying updated on these regulatory developments will allow research to be conducted on their effects and propose further improvements to reduce the number of failing booking processes.

Ultimately, improving the process of international rail ticketing is essential to make cross-border rail travel more attractive and to support the necessary modal shift toward more sustainable transportation options. The implementation of enhancements proposed in this work can play a key role in achieving these objectives and further advancing the common international rail ticketing standards.

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List of Acronyms

ABT Account Based Ticketing 51

AJC Agreement on Journey Continuation 88

API Application Programming Interface 6

ARES Automatický rezervační systém (Automatic reservation system) 60

ATB Automated Ticket & Boarding Pass 49

BEUC European Consumer Organisation (Bureau Européen des Unions de Consommateurs) 90

BoB Biljett- och Betal-standard (Swedish National Ticket Standard)

CEF Connecting Europe Facility 100

CEN European Committee for Standardization (Comité Européen de Normalisation)

CER Community of European Railway and Infrastructure Companies (Communauté européenne du rail) 70

CINEA European Climate, Infrastructure and Environment Executive Agency . 100

CIT International Rail Transport Committee (Comité international des transports ferroviaires) 49

CIV International Convention for the transportation of Passengers (Convention Internationale pour le transport des Voyageurs) 93

COTIF Convention concerning International Carriage by Rail (Convention relative aux transports internationaux ferroviaires) 93

DB Deutsche Bahn 142

DRTF Database for Rail Tariffs and Fares 76

DSA Digital Signature Algorithm

ECDSA Elliptic Curve Digital Signature Algorithm

ECTAA European Travel Agents' and Tour Operators' Association 74

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EFZ	European Timetable Center (Europäisches Fahrplanzentrum)	54
ELB	Element List Barcode	51
EMDS	European Mobility Data Space	96
EPA	Electronic Seat Reservation System (Elektronische Platzbuchungsanlage)	54
EPF	European Passengers Federation	90
EPIAP	European Passenger Information Accessibility Profile	73
ERA	European Union Agency for Railways	3
ERSAD	European Railway Stations Accessibility Database	80
ETTSA	European Technology and Travel Services Association	74
E³UDRES²	Engaged and Entrepreneurial European University as Driver for European Smart and Sustainable Regions	23
FCB	Flexible Content Barcode	50
FRAND	Fair, Reasonable And Non-Discriminatory	94
FSM	Full Service Model	74
GDS	Global Distribution System	14
GTFS	General Transit Feed Specification	57
GTFS-RT	General Transit Feed Specification Realtime	73
HAFAS	HACON Fahrplan-Auskunfts-System (HACON Timetable Information System)	63
HOSA	Hermes Open Systems Architecture	55
HOTNAT	”Hop on the next train available”-Agreement	
HRDF	Hafas Rohdaten Format (Hafas Raw Data Format)	54
HTTP	Hypertext Transfer Protocol	

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IFOPT	Identification of Fixed Objects in Public Transport	71
IP	Internet Protocol	
IRG-Rail	Independet Regulators Group - Rail	94
IRS	International Railway Solution	
IRT	Integrated Reservation Ticketing	5
ISCED	International Standard Classification of Education	
JSON	JavaScript Object Notation	76
MDMS	Multimodal digital mobility services	95
MERITS	Multiple East-West Railways Integrated Timetable Storage	53
MMTIS	Multimodal Travel Information Services	
MaaS	Mobility-as-a-Service	51
NAP	National Access Point	72
NFC	Near Field Communication	125
NOPTIS	Nordic Public Transport Interface Standard	
NRT	Non integrated Reservation Ticketing	5
NTFS	Navitia Transit Feed Specification	
NeTEx	Network Timetable Exchange	72
OJP	Open API for Distributed Journey Planning	73
OSDM	Open Sales and Distribution Model	1
OSJD	Organization for Cooperation of Railways	159
OTIF	Convention concerning International Carriage by Rail (Organisation intergouvernementale pour les transports internationaux ferroviaires)	93
PDS	Product Definition System	154

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PRM	Person with reduced mobility	
PRR	Passenger Rights Regulation	92
PSO	Public Service Obligation	129
PriFIS	Price and Fare Information Storage	55
RCT2	Rail Combined Ticket 2	48
REST	Representational State Transfer	
ROC	Railway Operating Community	87
RTB	Railteam Broker	52
RU	Railway Undertaking	6
SERA	Single European Railway Area	85
SIRI	Service Interface for Real time Information	73
SSB	Small Structured Barcode	50
SSMS	Smart and Sustainable Mobility Strategy	162
SSO	Standards Setting Organization	87
SaaS	Software as a Service	76
SiD	Security in Data	51
SiP	Security in Paper	49
SiS	Security in System	50
TAF	Telematic Applications for Freight	
TAP	Telematic Applications for Passengers	73
TLB	Ticket Layout Barcode	50
TPS	Train Planning System	143

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TRIAS	Travellers Realtime Information and Advisory Standard
TSGA	TAP TSI Services Governance Association
TSI	Technical Specifications for Interoperability 72
UDP	User Datagram Protocol
UIC	International Association of Railways (Union internationale des chemins de fer) 3
UML	Unified Modelling Language
UN/EDIFACT	United Nations / Electronic Data Interchange for Administration, Commerce and Transport
UNIFE	European Rail Supply Industry Association (Union des Industries Ferroviaires Européennes) 91
eTCD	electronic Ticket Control Database 62
nTM	new Tariff Model 74

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A Appendix

A.1 Expert interviews

The following interview summaries have been created by transcription notes taken during the interviews. These have been verified in their final version by the interviewee. The answers therefore do not represent direct quotes, but summarize the answer given. Direct quotes are marked with quotation marks (”).

A.1.1 Alexander Mokros - Deutsche Bahn

This interview took place on 15. March 2023.

Alexander Mokros has been involved in the railway industry for more than 15 years and has been a member of Deutsche Bahn since 2010. In the following interview, he shares his personal perspective on the subject. As part of his work, he has been focusing on international relations and finance and has been involved in projects like the Brenner-EuroCity or setting up an ICE link to London. Since 2019, he has been a member of the Eurail Group GIE Board, and since December 2021, also chairman of the Eurail BV supervisory board and has been involved in partnerships with different retail platforms.

As Head of international cooperation of one of the major railway companies in Europe, he has been identified as an expert of the industry.

How do the relationships with third-party sales platforms look like? How are these organized?

Former state railways, like DB, are considered to be locally market-dominant. Therefore, specific rules are applicable. As an example, Deutsche Bahn needs to conform to national and international rules, ensuring equal treatment and providing data. Currently, legislation is undergoing significant changes. One example of an essential piece in the ticketing framework is the new amendment to the European Passenger Rights Regulation (PRR). A new regulation for ”multi-modality” is discussed right now [42].

In general, sales via third parties are additives to the main sales channels (Website, App) - accounting for over 90% - which are still operated by the rail carriers themselves. This strongly differs from other transport modes (e.g., air travel) or hotels, where tickets are sold mainly by third parties.

From a strategic perspective, mobility platforms are perceived as growth partners in complementary environments and use cases, like comparing and combining multiple modes of

[42] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13133-Multimodale-digitale-Mobilitatsdienste_de

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transportation and tickets or presenting offers to an international (non-German / English-speaking) audience.

On big travel portals like Booking or Expedia, rail is not yet present, but efforts are undertaken to get offers displayed as alternatives to flights. Currently, these platforms earn their main profit by selling accommodation or plane tickets. Therefore rail needs to compete as only one of multiple business opportunities.

New platforms reach out to DB regularly and get access.

What role does GDS play in these partnerships?

Depending on the network structure and organizational framework of each railway, the integration differs in complexity. For centralized systems, like the TGV network or Eurostar, where Integrated Reservation Tickets (IRT) are sold, it is more accessible to provide compatible imports to GDS, as these are similar to conventional airline tickets.

In Germany, a country with a polycentric settlement structure, the rail network is characterized by multiple intermediate stops and Non Reservation Ticketing (NRT). Therefore, DB, like in other NRT systems, steers the occupancy of their trains (peak/off-peak times) in order to offer the best possible service to users and make the best of its rolling stock. In such a case, it is extremely difficult and expensive to map tickets into a flight GDS understood format. This also leads to lower customer adoption.

Currently, because of these reasons, only selected routes are offered via GDS, while observing higher adoption in direct partnerships, like the Rail&Fly program or Express Rail in cooperation with Lufthansa.

Why did former approaches to international ticketing platforms (like the Railteam Broker) fail?

The initiative has been ahead of its time. A similar case happened, when DB tried to introduce Check-in-Check-out travel at DB 2007 (Touch and travel), where there have not even been many Near Field Communication (NFC) compatible phones. Today, such a system has been introduced by third parties, still using the same core technology.

For Railteam, the general approach of having multiple rail companies creating and operating solutions simultaneously has proven to be not ideal. This differs from the way Products like Interrail / Eurail have been offered and operated by a central external organization (Eurail BV[43]).

As a result of the Railteam project, two early participants in the market of international rail

[43] https://www.eurail.com

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ticketing emerged. These are the SBB and Benerail[44] (SNCB / NS), still being one of the main partners when it comes to international tickets.

Currently, the industry is counting on standardization - mainly through the Open Sales and Distribution Model (OSDM) - to allow all members to integrate international ticketing seamlessly into their own system. Technical colleagues describe the introduction of the currently discussed solutions as 'Quantum Leap', as it will reform the current systems, which are mainly based on the technical development of the early 2000s or even earlier.

Speaking of OSDM, what is the current status of its implementation at DB?

DB has been involved since the emergence of OSDM and is providing the chair or vice-chair and technical experts of the undertaking. Influencing strongly the design and steering the standard.

As members of CER, DB is committed to introducing OSDM till 2025 on the customer-facing site. Several internal studies have been conducted on what is needed to upgrade current systems to support the standard. Currently, it is known what needs to be done and how much it will cost. In the near future, workarounds, like the separated international-bahn.de[45] page, will be integrated into a single site.

Till end of this year, the whole Swedish market will be running OSDM. Multiple railway companies and service providers (including SBB, SNCF and Benerail) are proclaiming that they started the implementation. It seems, that the big transition will start as soon as DB and SNCF will start using OSDM, as they are the key players - especially geographically - when it comes to international European travel.

What is the reasoning behind the existence of the separated sites reiseauskunft.bahn.de and international-bahn.de?

The separation has mainly been caused, by budgetary reasons and resource limitations. At the time of its development, Deutsche Bahn exited the night-train segment and needed a new system to sell IRT tickets from external carriers. Simultaneously, SNCF already announced, that they will withdraw from legacy systems. This also included Hermes[46], which has been used to exchange reservations among carriers. Refactoring works towards a new system had already begun. Some backend components from the old system originate back to the 70th / 80th, with the core frontend dating back to the early 2000. Therefore, no extra resources could be freed to directly integrate the needed functionality into reiseauskunft.bahn.de[47] and

[44] https://benerail.com
[45] https://www.international-bahn.de
[46] https://web.archive.org/web/20160306181310/http://hermes-project.net/
[47] https://reiseauskunft.bahn.de

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international-bahn.de was born. The project has been carried out together with Amadeus[48], which is responsible for the technical provisioning of the system.

As this split has always been constructed as a temporary solution, the new systems will supersede this construct in the future with the rollout of next.bahn.de[49] and its extension to be able to sell OSDM-based offers in 2025.

What kind of regulation do you expect from the European Union?

Right now, connecting non-standardized distribution systems comes at a significant cost, which is hindering some efforts.

Regulation often tries to solve multiple issues at the same time, combining the ideas of different interest groups. From DB's perspective, low technical barriers for ticket distribution are important, while keeping control of certain commercial aspects. Regulation shall provide a level playing field by maintaining commercial freedom, for instance for markets like cross-border rail, based on the open access principle, where ticketing is the only revenue source (no subsidies, no compensation) for rail operators.

The current standard NeTEx, originally introduced for local public transport, does not fulfill the need for long-distance / high-speed rail. Using NeTEx the implementation of dynamic pricing is not feasible, which is why OSDM is needed, which allows live and flexible pricing. Besides that, NeTEx does not even support real-time routing data. Some parties on the European level are open to integrating OSDM into the TAP-TSI, including ERA. Others do not want to understand the necessity and the enabling nature of OSDM. The introduction of OSDM should not become the plaything of any lobby organization. Currently, the whole Swedish railway market is implementing OSDM, including private operators like Snalltaget[50] or MTR[51].

How do you assess the central role of UIC in OSDM?

In general, the Open Sales and Distribution Model (OSDM) is as its name suggests organized as an open source project, being accessible through a dedicated website[52]. Not even its main information page is directly on the UIC domain [53]. Still, someone needs to take ownership and provide central infrastructure. In the executive committee, the rail operators and ticket vendors make decisions unanimously.

In the future, anyone can implement OSDM. Maybe, if the EU enforces OSDM, there will

[48] https://amadeus.com
[49] https://next.bahn.de
[50] https://www.snalltaget.se/en
[51] https://mtrx.travel/en
[52] https://osdm.io/
[53] https://osdm.io/

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be the possibility to get certified as OSDM compliant, but this will not be mandatory. The IT providers Sqills [54] already offered to build a test tool based on Postman[55] to verify OSDM the compliance of an endpoint.

Other railways do reference DB ticket shop for international tickets. Are you aware of this situation and if so, how do partnerships look like?

Yes, DB is aware of this. The case of the Slovenian SZ is especially interesting, as they actually have direct access to the internal sales interfaces, which they apparently only make use of at their station counters. Direct linking represents a stopgap solution and is not ideal.

Are there any developments you are especially excited about in the near future?

Without standardization, the digitization of ticketing in Europe leads to a patchwork of different, drifting-apart systems.

One example, being launched as part of next.bahn.de and that will be rolled out to all users of bahn.de until the end of this year, will be the distribution of digital tickets to Poland. In the past, due to a lack of the technical ability to verify tickets, this has not been possible before. Now, the Electronic Ticket Control Database (eTCD) enables real-time control of passenger tickets.

[54] https://www.sqills.com/
[55] https://www.postman.com/

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A.1.2 Nick Brooks - Allrail

This interview took place on 24. March 2023.

Since 2018, Nick Brooks is secretary general of Allrail, the European interest group of private rail companies (including WESTbahn, Flixtrain, Leo Express, RegioJet, and many others). Before his pursuits at Allrail, he was head of Business Development at the German long-distance operator Hamburg-Köln-Express (HKX) and Head of EU Affairs at Trainline, collecting first-hand experience with the state of international rail ticketing in Europe.
Given his extensive experience and leadership roles in the transportation industry, Nick Brooks has been recognized as a knowledgeable expert for this thesis.

UIC standards - like OSDM - are referenced in the Impact Assessment 2022 for TAP-TSI. Do you expect that these will be made mandatory in the future?

The UIC is a private members group and represents a subset of the industry, a solution like OSDM is therefore inherently not applicable to all parties. UIC standards are often imperfect. OSDM itself is technically flawed, for example with an untransparent algorithm that suppresses both some slower trains and some cross-border rail connections that could still be very interesting for passengers. Standards for ticketing must be created by an EU agency at the European level, not by private interest groups, otherwise, there is an obvious conflict of interest. The UIC's claim to create standards for the entire industry contrasts to other transport sector. There is no comparable institution in the airline industry, for example. The role that the UIC would like to fulfill in the area of standardization should be taken over by the ERA as the EU Agency for Railways and/or CEN and CENELEC, the EU Agency that makes standards for Europe.

The full implementation of the 4th railway package over the next 11 years will lead to an increase in the market share of private passenger railways. Similar to the freight market, where private companies already hold up to 50% of the market, the share should increase significantly, currently, it is still below 10% in passenger transport.

State railways gain large amounts of lobby money through their large market share and direct awarding of Public Service Obligations (PSOs). There is no non-discriminatory access to lobby money and representation on European level. Therefore, it is possible that the lobby for UIC standards will be cross financed and will also prevail, but this would be detrimental to competition.

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Is there an alternative to OSDM?

The European Standard Argentur (CEN) has developed the Transmodel NeTEx standard, which is sufficient, and fulfills a lot of requirements. The only thing missing was the final booking process, and this is all that was necessary to have a truly interoperable standard across all ground transport modes, from local bus through to high-speed rail. Instead, state incumbents and their suppliers in the value chain (e.g., reservation system providers) saw this as the opportunity to develop an entire new duplicate standard instead that is under their political influence. From the perspective of Allrail's alliance members, there is no need for OSDM. OSDM came into existence as a power play so that state incumbents could control the interoperability of ticketing for decades to come. Instead of a new standard, further development should be invested into the booking process of Transmodel NeTEx.

The expert, Alexander Mokros from Deutsche Bahn, questioned the applicability of NeTEx for modern, yield controlled distribution systems. How do you assess this?

NeTEx can be utilized for the distribution of dynamically priced long-distance tickets. Any allegation against this fact, is a deliberate misstatement to frame NeTEx as being inadequate and promote DB's preferred system. DB should have shown more responsibility and simply helped finish off the job to help further develop the booking piece of Transmodel NeTEx. Deutsche Bahn and its acolytes has manipulated OSDM so that it is not truly impartial, which is why we trust the much more transparent Transmodel NeTEx instead.

How do you view the existence of UIC's MERITS, the current de facto standard of a pan-European timetable information / distribution system?

Such a system should not be hosted by UIC, it should be moved to the neutral independent EU Agency of Railways. The current structure allows UIC to charge high fees for access to this dataset. It is an anomaly that we have UIC as a private members body carrying out a crucial sector function, and we worry that those who have long been UIC members and helped develop this (i.e., incumbents) will pay lower fees while newcomers to the sector will be subsidisingit ex-poste. Instead, no operator should have been involved in the development; independent technical experts should have done this instead. Then special interests would not be at play, and all operators would face a level playing field. The general idea behind MERITS is not bad, collecting timetable data at a centralized institution, but it should not be the UIC to do so. Some Allrail members are represented in MERITS, others are not, depending on business judgement. Some do not agree with the role of a private members body to carry out this role and do not want to or cannot spend so much money on it.

What is your view on standardization efforts for rail ticketing in general?

Common technical standards are a very good thing across transport modes, and "we fully support multi-modality". Through-tickets are best made mandatory, i.e., from door-to-door,

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including First and Last mile (municipal scheduled transport), with rail as the backbone of long distance journeys. This is the only way to rival the convenience of our sector's biggest competitor, the private individual motor car (reminder: Passenger Rail has a market share of just 8% in domestic travel and 4% in cross-border, despite billions of taxpayers subsidy each year). The current Status Quo simply does not work; more of the same as before will change little. There is currently no network of private railways across the EU or even in any one country, and the routes of private carriers only rarely directly connect with each other. Contrast this to the situation with state incumbents who unfairly inherited national networks from their position as subsidized historical operators without needing to make any effort. In air transport, there is a choice between several airlines on most routes, while the largest provider (Ryanair) has a market share of only 17%. So, unlike the railways, there are competing networks in this industry.

Above all, mutual ticket recognition would benefit the consumer.

In the current state of the European rail network, there is a need for one or more stop-overs, even on important corridors. This is much more prevalent than in all other transport sectors (car, aviation, bus where point-to-point services across Europe are much more common). Examples are: Paris ↔ Madrid or Paris ↔ Rome. As long, as mandatory through-ticketing is not in place, the inherited network of the state incumbents will be used as a competitive advantage over new entrants, because unlike, say, in aviation, they will be the only type of operators benefiting from a network advantage. With at least 30% of rail passengers changing trains, this is a hugely unfair advantage in what is meant to be a competitive market in the future (i.e., the emergency of the Single European Rail Area (SERA))

Here is a concrete example: it can be observed on the route between Cologne (DE) and Lille (FR), which covers a total distance of approximately 320 km and offers 27 daily connections with various trains. This is exactly the kind of distance (not too long) where there are high expectations that most travelers should be taking the train within the next few decades. Right now, there are around 50 reasonable connecting rail journeys each day in each direction. However, passengers are always required to change trains in one or two times because there is no direct service. Alas, in the very best scenario at one specific rail ticket vendor, only 43% of the cross-border connecting rail journeys between Cologne and Lille that are actually operating can be booked online as one through-ticket in a single transaction at the same 'One-Stop-Shop' ticket vendor. Most rail ticket vendors show even less. OSDM would not be a solution to this issue, as its opaque technical algorithm would only serve to strengthen such opaqueness It should also be noted that the Cologne to Lille example almost exclusively involves state-owned rail incumbents. Only a very small segment of the trip (between Cologne and Aachen) is one of the five available rail operators actually independently owned – otherwise nowhere. To put it simply, the state incumbents cannot even solve ticketing obstacles like Cologne-Lille, even if they operate all the trains.

Booking the connecting trains between Cologne and Lille separately in advance can result in

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a favorable price as low as 40€, due to yield management systems of some of the operators that serve this whole route. However, if the passenger misses the connecting train in Brussels due to a delay, they would have to purchase the onward journey at full price. Otherwise, if using slower trains, there can be a competitive fare even on the day of travel - if it were to be shown and sold. All in all, the existing passenger rail services could be an attractive alternative to long distance buses and the private individual motor car.

Furthermore, starting from 6th June 2023 a mandatory warning message will appear when booking separate rail tickets in the same booking transaction (because a through-ticket is denied by the incumbent operator as part of the same travel chain with an independent operator), informing customers of the risks associated with their chosen route due to the fact that there will not be passenger rights coverage from the beginning until the end of entire one-way journey – because the whole thing is not a through-ticket or single transport contract. The warning message will seriously harm the overall system and deter customers from a myriad of reasonable cross-border rail options. In principle, it is similar to a cigarette packet warning. As a result, this can be seen as a ”warning message against the railway industry” (”Warnhinweis gegen die Bahnbranche”) – “DON’T TAKE THE TRAIN!”. Following efforts by various interest groups, including Allrail, the EU Commission and Parliament were initially against the warning message and in favor of making all reasonable rail connections into mandatory through-tickets with passenger rights coverage from the beginning until the end of the entire one-way journey. Still, this new warning was successfully lobbied for by the state incumbents, which maintain a strong influence on the EU Council due to their close relationship with member countries, and it was successfully approved by legislators. The incumbents wanted to ensure that they decide who to join in the creation of through-tickets, and in reality this will happen only with other state incumbents. For any other combination of rail operators in the travel chain, they lobbied for a warning, in order to protect their inherited networks

If progress is not made in the near future, like achieving more than 10-15% market share for rail by 2030, other less environmental modes of transportation will probably innovate by then. They are currently trying to rectify poor climate credentials (e.g., electric cars, sustainable aviation fuels, hydrogen-powered aircraft). Once other transport modes become more climate friendly, political stakeholders will wonder why they spend so much on rail when it is cheaper to help other transport modes financially, but reaching the same results. Currently, the rail industry only holds 4% market share for cross-border travel (8% for national travel). If this trend continues, policymakers will undoubtedly reconsider subsidies for the industry.

”Of what use is a common standard such as OSDM if through-tickets are only available between state-owned incumbent?” Therefore, only through-tickets are the solution. Regardless of which solution is used, whether it be NeTEx or OSDM, without a commitment to mandatory through-tickets, then the problem of international ticketing simply will not be solved.

”The distribution [of rail tickets] is [currently] not impartial or transparent.” The dominant rail

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ticket distribution channels with over 95% market share are subsidiaries of state-owned rail incumbents, and they naturally exclude other railway companies. In 2005, Deutsche Bahn was forced by a court ruling to display the timetables of other companies. However, when searching for a connection, only the fastest connections are displayed by a deliberate default mechanism that passengers otherwise have to opt out of (and most do not realize that this is possible), meaning that most often between the major cities it is the faster ICE trains of Deutsche Bahn – no other operator in Germany has high-speed trains after all. Consequently, the slower conventional long distance and regional connections are often not shown at all, with the notable exception of DB's in-house slower conventional trains (the Intercitys and Eurocitys). Privately-owned competing rail operators are therefore in reality rarely displayed. However, even the timetable information is not sufficient as long as customers are deliberately not told the fare on the competing operator. In reality, they are deterred by the additional effort of researching fares elsewhere and having to swap to different Apps and website in order to do this.

Last year, for example, the DB and ÖBB did not sell the Alpen-Sylt-Express (night train)[56] in their in-house ticket vendors which are market dominant in Germany and Austria respectively. The Alpen-Sylt-Express was neither displayed nor directly sold at all, contrary to the alleged love of incumbents for the climate hero night train. Due to lack of exposure, the Alpen-Sylt-Express failed.

By contrast in Finland and the UK, impartial transparent distribution of train tickets has been a reality for two decades, and these countries have never once witnessed 100% subsidiary operators of EU incumbents (e.g., NS's Abellio, DB's Grand Central, Trenitalia's C2C) complaining about it in public at all – because in the UK they are in the new entrant operators, and they know that impartial retail makes their trains in the UK more accessible and bookable – quite a double standard.

Should this problem be solved by adjusting passenger rights?

Yes, that is the way to true through-tickets. However, some conditions, such as a reasonable minimum transfer time (measured by people with mobility impairments), need to be defined first.

Currently, there are even examples among the state railways themselves with too short transfer times (example Brussels North only 5min between Intercity from Namur and final ICE of the day departing for Cologne) Even if the 1st train is on time, then it is still hard for less agile people to make the final connection of the day at such a large station, and it is often missed. By contrast in Italy, utopian long transfer times were present (up to 2 hours), in order to reduce any risk of a missed connection to virtually zero. However, this made the total travel time by train artificially long, meaning Rail is less competitive versus other transport modes. Both approaches are wrong.

[56] https://www.nachtexpress.de/

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In passenger rights, it should be regulated that if the connection is missed without being the passenger's fault, a continuation to the destination without extra charge is possible.

Compensating for delays might be too complex to be carried out. Nevertheless, similar circumstances have already been implemented in Great Britain, where passengers have the right to continue their journey in case of a missed connection, through-tickets are mandatory, and compensation for delays is provided.

Infrastructure companies should also be made liable for delays resulting from the delays that they cause: such a performance driven system would motivate all stakeholders in the process to improve.

You worked for Trainline yourself. What role do mobility platforms play in your point of view, and how do they solve current problems?

Trainline (not part of the Allrail association), which evolved from Capitan Train [57], has developed a good technology for making connections even in those cases where incumbents refuse to do through-tickets with independent operators. It links individual separate tickets and sells them, if that is not possible as a through-ticket, a package of individual tickets is sold as combined-journey. This means that the company and all mobility platforms that practice this are affected by the aforementioned warning notice if they show combined one-way rail journeys and offer them for sale, even if the option concerned is the cheapest fastest or even the only rail option between the two stations concerned.

Would an insurance model on the part of the mobility platforms be conceivable in order to assume the risk of the passengers?

68% of passenger rail in the EU is co-financed by Public Service Obligation (PSO) subsidies – i.e. the taxpayer is co-subsidising the service, as it could allegedly not be done in a commercially driven manner. In addition, 100% of infrastructure is co-funded by the taxpayer, except for two private infrastructure operators in France and the UK and thus it is in the public interest that all available passenger rail options between any two places are accessible and bookable for the public, even on slower trains (which can still have an attractive price at the last minute, even if the passenger needs to change trains).

Price-conscious passengers are the ones that need to be incentivized to switch from the motor car, long distance buses and low-cost airlines to rail. For those, adding insurance premiums to the journey in order to combine different rail tickets of different rail operators into the same reasonable one-way journey (i.e., a combined journey) – even if just a few euros – can make the difference between choosing rail or a different cheaper transport mode. Such would also be a competitive disadvantage for combined journeys involving independent rail

[57] https://www.linkedin.com/company/capitaine-train/about/

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operators, as there would be no additional insurance charges for through-tickets exclusively when changing trains between state incumbents, as they cover this risk themselves. It would also be immoral to let the insurance companies earn from the failure of the railways.

Why did former approaches to international ticketing (like the Railteam Alliance) fail?

There has never really been a sustained approach. Railteam was probably just a PR measure. Around 2013 or 2014 there was a working group, of which it is not known if it still exists, but the website does. It is basically a mutual Missed Connection Protection. The model also has problems, for example it is difficult for consumers to understand that IC connections in Germany are not part of the network, but ICE connections are, even if both types of trains are part of the same operator DB Fernverkehr (the DB Long Distance Train subsidy) and even have the same livery.

What is good about this idea, however, is the principle behind it. If the connecting train is missed, even if the delayed 2nd connecting is served by another RU (and not the one originally booked), the customer can continue his journey at no extra cost, rather than having to wait for the next available service on the same operator as originally booked. This is better for the passenger, as she or he gets to her or his final destination sooner. In addition, as far as I know, no payments are made between different operators involved, as there is the assumption that they will all be equally delayed over the course of a calendar year and “it will all come out in the wash” This is exemplary, but the state railways refuse to introduce such a principle together as part of combined journeys with independent operators.

The bureaucratic effort to pay fees to each other if there are delayed passengers from other operators on board with each other would hardly be worthwhile, as the number of delays is probably basically similar for all transport operators over the course of a year. Such a bureaucracy would probably end up with each operator paying each other the same amount ultimately. A simple non-financial solution, such as the Railteam, is therefore to be favored.

A similar project was started in Switzerland with the secret Agreement on Journey Continuation (AJC) which was 5-6 years ago. This required conductors to enable a continuation of the journey, even if the passenger combines separate tickets in a one-way journey, even, without knowing about a minimum connection time (in other words, when the passenger booked two separate tickets separately her- or hisself. Under the AJC, there is no money flowing between different operators i.e. when the 2nd operator, but the passenger is bound to stay on the same operator for the 2nd journey (as originally booked) and not board any operator in order to get to her or his final destination (if there is one). In general, such solutions are to be welcomed, but they resemble a patchwork – because the AJC is voluntary and not mandatory across the EU. This is not a real solution to the problem. Furthermore, in the near future, the EU’s ‘cigarette packet warning’ “DON’T TAKE THE TRAIN” warning against lack of passenger rights coverage separate booking would still be visible even in the cases of AJC.

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The EU Commission intends to propose a similar principle (like AJC) in September 2023 as part of its upcoming Multi-Modal-Digital Services MDMS Proposal, with a more formalized and mandatory form of the AJC. We welcome this but still prefer the Railteam model (which clearly can be done, as several incumbent operators signed up to the Railteam), proving that it is possible.

What are the main incentives and barriers for railway operators to implement impartial and transparent booking platforms?

Currently, cartel-like structures exist. A larger market share in overall transport could be developed by the railways if through-tickets were available to all. However, incumbents see non-discriminatory access a loss to their inherited national networks (and being the only operator that can offer a network) as a risk and therefore oppose it.

How could the legislative framework be changed to support international ticketing?

An obligation to offer through-tickets and impartial distribution is needed. In both respects, Austria is in a better position than other countries. Impartial distribution could soon become a reality in some EU Member States, such as in Austria, where measures such like the Klimaticket[58] have already been implemented here on a non-discriminatory basis. In general, the smaller state incumbents tend to be more open to impartial retail, as they themselves run the risk of falling victim to the closed nature of other large incumbents for international journeys.

For example, Swedish state incumbent SJ Euro Night train between Stockholm and Berlin - SJ is not an international brand that can garner global direct sales in the same way as DB can. Hence, SJ is – just like independent operators that are members of Allrail – deeply unhappy that their train is not being sold on DB's market dominant in-house retail channels, bemoaning the lack of exposure.

The ticketing should be separated from the market dominating companies. Ticketing should be viewed as part of the infrastructure and hence neutral. Distribution discrimination is the silent killer of market liberalization.

Why does the national regulator not intervene in such a case?

Regulatory action is bound to legislation, which does not currently cover online ticket distribution. Besides that, some regulators are trying to impose requirements on their own. France can be seen as a particularly strong example of that. Other regulators, such as in Poland, are strongly linked to the state incumbent and are not an independent authority.

The German Federal Cartel Office in Bonn has started an investigation into Deutsche Bahn's manipulation of the downstream distribution market, a press release was published in April

[58] https://www.klimaticket.at/

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2022 [59]. They will make a ruling soon, should Deutsche Bahn not submit a sufficient offer. In March 2022, DB's dominant in-house ticket vendor (96% market share, as proven by the German Monopolies Commission) Vertrieb was integrated into DB Fernverkehr to create fait accompli, so that there is no longer even a formal separation of the distribution division. If this is implemented successfully in Germany by DB, it may have repercussions for other incumbents in Europe. This is the completely opposite measure of what will open up the distribution market.

Then one year later, in April 2023, the EU Commission opened an investigation into possible anticompetitive practices by Spanish state-owned rail incumbent Renfe in online rail ticketing. The EU Commission said it had concerns that Renfe may have restricted competition by refusing to provide independent ticketing platforms with full content concerning its range of tickets, discounts and features, and real time data on its services. If proven, this may breach EU competition rules, which prohibit the abuse of a dominant position [60].

Then in May 2023 French Competition Authority (Autorité de la Concurrence) carried out "unannounced inspections" in the passenger rail transport, travel agency services, products distribution, and digital mobility sectors two weeks ago. These inspections were based upon grounds of suspected "anticompetitive practices" vis-à-vis independent ticket vendors [61].

Although the French Competition Authority did not disclose the identity of the companies in question, France's leading newspapers, Le Figaro, revealed that it was the state-owned rail incumbent SNCF that was targeted by these inspections [62].

The French Competition Authority's announcement is very similar to other recent developments across Europe, noticing a distinct pattern: the increasing number of rail incumbents being investigated for alleged abuse of dominant market position whereas, at the same time, their representatives seek to distract from this fact by making the baseless claim that independent rail ticket vendors might become market dominant (similar to Booking.com / Amazon). It is a smokescreen, which is meant to distract from the fact that exactly such a situation exists in reverse, where the incumbent reigns over the market. There is no evidence for this - the dynamics of the passenger rail are different to other sectors. Trainline, as the largest third party provider, only has a market share of about 3%. It is a classic example of do as I say, not as I do.

CER claims third-party portals have large margins, which does not correspond to reality. Mobility platforms have no market power and low margins. Renfe, for example, pays only 0.5% commissions to 3rd party ticket vendors but a lot more to its in-house sales unit – prob-

[59] https://www.bundeskartellamt.de/SharedDocs/Meldung/DE/Meldungen%20News%20Karussell/2022/20_04_2022_Bahn.html;jsessionid=D7B50DB34C55C67D95733BFFCD6148F1.1_cid362

[60] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2448

[61] https://www.autoritedelaconcurrence.fr/en/press-release/general-rapporteur-autorite-de-la-concurrence-indicates-unannounced-inspections-were

[62] https://www.lefigaro.fr/societes/l-autorite-de-la-concurrence-enquete-sur-la-sncf-20230512

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ably one of the reasons it is currently being investigated.

Any wishes or fears towards the future of rail ticketing?

Important would be to use multimodal standards (transmodel NeTEx) and enable multimodal transport through a true one-stop-shop. State railways have had time since the establishment of the internet to build such a portal and they have failed to do so. ”Where was the UIC 20 years ago?” (”Wo war die UIC vor 20 Jahren?”) The goal must be a liberalized distribution market with multiple platforms competing with each other and serving the ground transport collectively.

For this, the mentioned legal framework for through-tickets is needed.

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A.1.3 Hugo Knobbout - Eurail

This interview took place on 1. February 2023.

As Chief Information Officer of Eurail BV., Hugo Knobbout is responsible for overseeing the company's technological strategy and implementing innovative solutions to enhance the customer experience around ticketing and traveling with Interrail / Eurail rail passes.

What is Eurail's current role with regard to international rail ticketing?

Eurail is in a very active role, taking part in many initiatives shaping the future of international ticketing.

As an example, Eurail is participating in the introduction of the so-called Flexible Content Barcode (FCB) and its dynamic header DOSiPAS (IRS 90918-9). This should replace the currently used Ticket Layout Barcode (TLB), which mainly represents a digitalized version of printed rail tickets, specified in UIC 918.3.

Eurail also has been one of the first to implement eTCD, allowing any associated railway company to scan and check the validity of tickets. Fraud protection is even further enhanced, as plausibility checks can be performed using this centralized ticket storage, which allows tickets to be further annotated by conductors.

To support smaller railways, without in-house IT-development resources, in the introduction of such technology, Eurail could be a partner on a European level, serving solutions. One project of the company to facilitate this effort is the development of a barcode check app, that allows ticket inspectors to validate tickets with a smartphone (FCB + DOSiPAS).

Another project, following Eurail's vision, is the implementation of a new European real-time timetable. In this manner, members of the Railteam already have a custom solution, but this needs to be refined to be usable as a global solution. To support this effort, Eurail is working together with DB, PKP, NS, and Trenitalia on the specification of the integral parts of this undertaking, as part of a UIC working group

OSDM provides a solution, that is set up with a global mindset, to streamline the distribution processes. Eurail is investigating how it can use the OSDM model in the future.

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How can third parties participate in the UIC working groups you mentioned?

The main goal of these efforts is to create global and open standards. This also implies that anybody can join the specific working groups. Participants do not need to be a member of the UIC to join for example the FCB undertaking.

As some rail services are operated utilizing IRT ticketing, Eurail sells reservations for these services to make them accessible for pass-holders. What does the architecture and process of this service look like?

On the customer-facing side, Eurail offers the Rail-planner app, this mobile application lets customers search rail connections. The base functionality is powered by the HaCon Journey Planner, which Eurail integrated into the application. All used and presented data originates from the UIC MERITS database.

To sell reservations, the selected journey needs to be checked on availability and bookability at associated suppliers Bene, Silverrail, and Trenitalia. On an architectural level, the matching process is currently executed in a middleware developed by Eurail As journey details of supplier systems might differ, this process is key to being able to offer a connection. If the divergence in data is too extreme, no matching can be established, rendering no reservation bookable.

This example shows, how the implementation of international distribution services would benefit from a unified timetable format. Furthermore, ”Planned data” could be used not only for customer-facing applications and services but would also benefit railway operations, as delays could be communicated using standardized European formats.

What is the timeline for implementing the real-time timetable? Are existing standards taken into consideration?

Currently, it is expected, that the finalization of the standard will take three more months (August 2023). After this milestone is achieved, a tender will be opened for submission to build a running system. A proof of concept implementation of the real-time timetable could be implemented as soon as summer 2024. The current specifications are ”Pretty well-designed”.

GTFS-RT is in consideration, but also a new open standard could be the outcome. In the end, UIC tries to make it available to all RUs.

How will the current implementation of the customer information and reservation system have to change with this new format?

Currently, the timetable data is downloaded to the mobile device of the customer with an app update. How this process could be adapted to make use of live timetable information is

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currently evaluated. Talks with HaCon are ongoing.

Could you share how a joined effort like the Interrail pass, which is recognized by the major RUs across Europe and many smaller railways, is coordinated?

Twice a year, appointed railway representatives of each member country are invited to participate in the Eurail Full Assembly. With this meetup, the company aims to establish closer connections with its shareholders, the railway carriers, to operate in a customer-centric and agile way. Private RU can join the network under transparent and fair conditions, which directly lets them join revenue sharing of pass sales by line usage.

What are your future plans to strengthen the position of Eurail in the European ticketing market?

Eurail wants to support the implementation of global standards and ticketing processes. Especially smaller carriers and eastern European railways, without their own in-house development, will be confronted with a high need of resources for technical implementation. Here, Eurail could be a trusted partner to provide standardized applications for ticket inspection and distribution.

In general, the European Union should approach the issue from a customer perspective, focusing on sustainability and practicality. In the past, each individual country optimized to a local optimum, therefore no globally applicable open standards have been created. Now UIC is creating these missing solutions and Eurail will be part of the realization.

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A.1.4 Dr. Hans-Jürgen Freisinger - HaCon

This interview took place on 1. March 2023.

As project manager at the HACON Ingenieurgesellschaft mbH, Dr. Freisinger sits at the heart of the largest software house for timetable tooling, routing applications and many more mobility related products. Besides his PhD in Mathematics, his fascination for railways enables him to provide insights into the area of concern and discuss solutions for the future of digital services for rail.
To get insights into the workings of a supplier of essential services, needed for a transformation of international rail ticketing, Dr. Freisinger has been recommended as expert by Hugo Knobbout from Eurail.

What is the role and objective of HACON in the field of rail transportation?

Mainly HACON offers a Train Planning System (TPS)[63], which consists of different tools and systems, the most known of which is the HACON Fahrplan-Auskunfts-System (HAFAS)[64], that provides the foundation for many routing and ticketing platforms in Europe (i.g. DB-Navigator, ÖBB Scotty). Besides its main use case to find the best route on multiple criteria, it can be extended to also serve static prices (e.g. Tickets of the transport associations in Germany).

Currently, the company is shifting its focus towards creating software for Mobility as a Service (MaaS) Platforms, allowing multiple transport modes to be connected. Connecting multiple operators and serving a single price for a trip to a customer raises similar problems as the implementation of international rail ticketing. HACON has identified MaaS as an important future development and set it as the company's main vision. Still, the company will only provide software as a service and will not act as a mobility service operator.

Does HACON, as the biggest provider of routing solutions, manage its own timetable database? What sources for timetable data exist?

No, HACON does not own any timetable data. The company only supplies the digital tooling for timetable data enrichment and distribution, but the customers are in charge of actually providing and managing the data processed by it.

Timetable aggregation is done by two parties in Europe. These are the UIC with their MERITS system and Deutsche Bahn (DB), operating the European Timetable Center (Europäisches Fahrplanzentrum) (EFZ) using EVAplus (also known as Euro EVA) from HACON. EFZ is among extra sources is integrating data from the MERITS database.

[63] https://www.hacon.de/en/portfolio/timetable-construction-disposition/
[64] https://www.hacon.de/fileadmin/user_upload/Portfolio/Factsheets/HAFAS/HAFAS.engine_german.pdf

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Both aggregators follow different integration paradigms, where integration means the creation of a single dataset from multiple data sources. In both cases, the HACON tool Train Planning System (TPS).Integrate is harnessed for this job. MERITS combines data of all operators involved in the service journey to cover the trip, keeping the data of the respective entity for its part of the journey. This might lead to parts of the journey being flagged differently or diverted from the data of just one operator. The EFZ on the other hand, identifies a single source of trust for each trip, avoiding data convergence. Different customers of HACON use different base data for their systems. (e.g., ÖBB, SBB use EFZ data, Eurail uses MERITS directly)

One difficulty of integrating data is matching stations of different datasets and connecting adjacent stations with transit points. While both systems have their means to harmonize existing stations, MERITS does not necessarily include interchange relations. DB moreover calculates and creates footpaths between adjacent stops for this purpose, allowing more connections to be possible in EVAplus.

The HACON TPS.Integrate is a database solution, which provides capabilities to enrich, adapt and harmonize the data. The data belongs to each RU, but is collected by DB or MERITS, before being processed by TPS. HACON does not own any of this data.

In general, railway companies should be inherently interested in integrating international timetables. ”The more information a railway can provide, the more tickets it sells.” (”Je mehr eine Bahn beauskunften kann, je mehr Tickets verkauft Sie.”) Therefore, ”if you want to sell tickets, you need good data”. (”Wenn du Tickets verkaufen willst, brauchst du gute Daten.”)

What are the competitors of HACON in the field of timetable integration and routing applications?

Two competitors in the same field are the IVU Traffic Technologies AG [65] with their products IVU.pool and IVU.timetable and the MENTZ GmbH [66]. As timetable integration is a complex task, central entities working towards providing such service, have naturally been larger RUs, like the DB, that HACON considers to be the main customers for TPS.Integrate. Other solutions HACON offers (i.e., HAFAS journey information system) are deployed by any size of the operator or transport authority.

On the HACON website, an inventory system solution is advertised. Can you explain what role these systems play in rail ticketing?

The company Sqills [67] has been bought by Simens and therefore is now in the same business unit HACON also belongs to. Actually, inventory systems are a completely different subject,

[65] https://www.ivu.com/
[66] https://www.mentz.net/
[67] https://www.sqills.com/

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dealing with the questions: Which trainset is used? What is their capacity? What is the amount of which price category? etc. Such systems provide Yield-management capabilities for railways, allowing for a more targeted pricing strategy. In general, common dependencies between these systems exist, but no direct link is made between these systems.

How does HACON take action in shaping the future of international rail ticketing?

First and foremost, HACON is a software and service supplier that is a trusted partner in the industry. In their projects, the company is partnering up with their customers to help them create innovative solutions. While some of their projects are directly won through a public tender, HACON has built up a large customer base, including companies from all around Europe. Within these projects, the implementation of new trends is directly shaped by HACON together with business partners.

Besides the company's core business, HACON members are taking part in many standardization working groups. This includes among others the UIC's Timetable Expert Group where the MERITS members meet bi-annually, as well as a working group for real-time timetable data or a standardization effort for disruption information. Besides global standards, internal ones are also being used outside HACON products. As an example, timetable data in Switzerland is available online in the HAFAS raw data format (HRDF)[68].

What is the process of selling a ticket based on the routing result? How are the specific systems linked?

The process starts with a customer entering the desired start and end point of a journey. This information is used by a journey information system like HAFAS to calculate the best route. Finally, this information is handed over to another system that matches the routing results to available tariffs and returns prices for each journey, which are then presented to the customer. The matching between those two systems is established using the core parameters of the trip. There is no common ID, which relates the trip to the inventory or distribution system.

One issue from the user side could be, that customers might not know the name of the closest station. A journey information system therefore should let the customer enter their current location and guide them to the starting point of their rail journey. Such situations need to be taken into account when designing a journey information system to enable ticket distribution based on it.

What are the main issues from your perspective for international rail ticketing to be deployed successfully?

Each RU does want to have a direct customer relationship, this is why companies tend to be

[68] https://opentransportdata.swiss/de/cookbook/hafas-rohdaten-format-hrdf/

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closed up when it comes to third-party distribution channels. Furthermore, revenue sharing on international, multi-operator routes is complex and adds additional overhead to the operation. Finally, standards need to be defined, that specify, which connections are ensured and can be sold together (including e.g., the standard for transfer time). On a national level, Sweden implemented such standards, creating Samtrafiken [69] and its National Ticket Standard (BoB).

Who should create such global standards (e.g., for transit time)?

The example of Sweden shows, that while being challenging, national regulation can be effective and quick to implement. If all nations solve the issue first internally, cross-border traffic will be solved or easy to cover by additional bilateral or European agreements.

Even within Germany, the lack of such standards leads to inconsistencies, and it is not clear which organization should step in. Currently, DB claims to provide the guidelines, instead of a neutral market entity. Even multiple ideas of how a standard could be implemented are possible, including a fixed maximum duration, operator-specific transit times - as these organizations know best about delays or possible waiting margins - or even the agent selling the ticket.

Compared to air travel, the complexity level of selling rail tickets is much higher. In the railway sector, a lot of protectionist RU, dominating their own market, create their own tariffs and rules. To fix this, it is even conceivable, that the EU Commission creates a fixed tariff structure, similar to the one in Sweden, that structures the ticket market into: not cancellable, rebookable, or flexible tickets. On the other hand, important non-EU parties, like Switzerland might not conform with such a regulation, which would create confusion again. Therefore, it is not clear if implementing such regulation, to organize recourse payments, solely on the European level is feasible.

From a technical perspective, any solution is possible and implementable, but action needs to be taken.

How do mobility platforms like Trainline integrate into the market?

For an informed decision, the full context and all offers need to be shown and compared. Right now as a customer, special knowledge is still important as this problem has not been solved by mobility platforms yet. But, as long as there is no mandatory mutual ticket recognition and distribution, such platforms are more suited for this task than competing RUs. In general, it is an interesting question of how to add this knowledge to these systems.

Actually, Trainline is a customer of HACON. While it shows more options to the customers, it is still not necessary to show the best price. For example, when booking the journey from

[69] https://samtrafiken.se/

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Naples to Karlsruhe, Trainline presents options including the private operator Italo, but fails to show the ”Sparpreis” offered by DB until the Swiss-Italian border. As Trainline splits the journey into segments to calculate the fare, it only splits on transfers, not on intermediate stops, leading to some offers not being presented to the customer.

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A.1.5 Christian Pettauer - CIO WESTbahn

This interview took place on 24. January 2023.

As the CIO of Westbahn, Christian Pettauer leads the charge in developing and executing the company's technological vision, ensuring that the latest innovations are employed to improve the customer experience. With a keen focus on ticketing innovation, the company collects the most detailed capacity utilization data of its services industry-wide.

To see how an international ticketing solution could benefit from this solution and what challenges WESTbahn faces, when it comes to the deployment of a global standard, this interview has been requested.

How did Westbahn implement its digital ticket distribution from scratch?

First of all, several key features have been identified to be key for a successful ticketing system. These are:

- No personalization requirement of the ticket
- Straight forward and immediate refundability
- Immediate validity checking

Even large RU like the ÖBB are not able to implement all these key features. To create a system, that checks all requirements, and be cost-effective, Westbahn decided to employ their own custom system architecture.

The external software development firm of Dr. Fischer [70], therefore created a system, that is now maintained by the GEKKO it-solutions GmbH [71].

How does cooperation with Allrail and influencing take place at EU level?

Currently, Allrail is still too small to create its own regulation, like the UIC is doing it.

This leads to legislation being heavily influenced by the ideas and to the profit of former state railways. OSDM is a good example of that, which is complex and cost intensive to implement. Furthermore, it does not require an obligation to contract ("Kontrahierungszwang"), that would allow through-ticketing and the creation of a cross-carrier booking platform. Especially for smaller carriers, OSDM is therefore a not really practical solution. By making such regulation mandatory, former state railways increase pressure on smaller carriers, while not endangering their own market advantage.

[70] http://clausfischer.com/
[71] https://www.gekko.at/

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In the airline industry, GDS has been proven to be a working a non-discriminatory standard. Unfortunately, GDS cannot cope with the complexity and volume of a European rail network. As en example, the data quantity currently represented within a GDS system is approximately the size of the Bavarian rail network.

One part of acquiring a ticket certainly is getting basic availability and routing information about a journey. How does Westbahn integrate its data into systems like Scotty?

In general, the timetable data is provided to the ÖBB-Infrastructure AG, which does integrate this base data and any delay information into Scotty. Besides this process working more or less flawlessly, no link is given to guide the customer to a distribution page, so they are left alone and need to search and find the WESTbahn page on their own.

In Germany, private railways had to take legal action to force DB to show and also link to the webpage of the carrier. Still, supplying data is a tedious process, in which the updated timetable is sent to the European-timetable-center for each timetable change.

Can you give a rough overview of the general ticketing infrastructure of Westbahn?

Besides the Frontend, customers experience on our website [72] and mobile application, the system consists of a Backbone, which utilizes a microservice Backend architecture. This Backbone is also in charge of communicating with partner distributors, like Trainline. Besides this centralized core system, each train houses its own copy of the system, allowing ticket validation using staff IPhones and relax-check-in without constant internet connection.

During the special service ordered by the Austrian government (”Notvergabe” [73]) from March 2020 to April 2021, mutual ticket recognition has been mandated. In this timeframe to prevent fraud by using a ticket on both carriers, a technical partnership with ÖBB has been set up, that allowed a nightly data exchange of both carriers.

To incentivize OpenData development, WESTbahn offers access to the current version of the static timetable data [74]. Besides its existence, until this point not a lot of use has been made from this data.

How will the future of ticketing look like at WESTbahn?

In 2024 the Klimaticket will be available as solely digital ticket. This will be a big leap forward, as it means that digital checks of the ticket will need to be introduced at all points,

[72] https://westbahn.at/
[73] https://www.derstandard.at/story/2000125172506/oebb-und-westbahn-erhielten-vom-bund-83-5-millionen-euro
[74] https://gtfs.westbahn.at

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where currently ticket validation is done manually. (e.g., regional buses) Currently, the public transport associations are in discussions about the technical details to make this possible.

If OSDM is mandated by the EU Commission, WESTbahn will deliver it, while demanding an obligation to contract. Technical gaps in the standard need to be closed, allowing the company to facilitate WESTbahn specific tariffs, like Comfort 2+.

When investigating solutions, WESTbahn is always checking for the best approach for the general public.

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A.1.6 Dr. Claus Fischer

This interview took place on 31. January 2023.

Dr. Fischer studied electronic engineering with a focus on early computer science. Leading his own company, focused on custom software and distributed database solutions, he has been developing countless projects, including a mountain rescue management tool or simulating the customer flow of a new airport terminal in Vienna. In 2012 his company has been employed to set up the ticket distribution system for WESTbahn.

Dr. Fischer has been recommended as technical expert by Christian Pettauer.

What is the general architecture of the WESTbahn ticketing system?

When WESTbahn started in 2009, Dr. Fischer reached out to offer his companies distributed ticketing solution.

In 2011, the first year of operation certain requirements have been specified, that a new distribution system needed to fulfill. The vision of WESTbahn at that time was to have no need for vending machines and ticket offices, as anyone should be able to buy a ticket online or in the train. Furthermore, each system should be traceable, collecting valuable information about the exact capacity utilization, while preventing fraud. At the time of the introduction of the new system, the onboard WESTbahn Crew sold one ticket against cash every 12 seconds on the most frequented parts of the line (Wienerwaldtunnel between Wien-Hütteldorf and St. Pölten). Additionally, EU 1371/2007 requires, that the ticketing system is capable of a simple method to redeem vouchers.

To create a system that is compliant with these requirements, the general architecture consists of a distributed database solution in which each trainset holds two servers, that mirror the ticket database. All activities on the train - ticket sales and verifications - are executed using IOS based handhelds that are directly connected to the onboard servers. As soon as the train can establish a network connection, database updates are pushed and pulled to the central, physically stable servers. For these transmissions and passenger WLAN, the train connects to the networks of three different mobile network providers at the same time using 12 antennas (6 purely dedicated to IP transmissions, 6 purely dedicated to telephony).

From a software perspective, the base of all these systems is a custom-made c-library, that manages the distributed ticket database.

Which other carrier could serve the system showcased at WESTbahn?

The system presented at WESTbahn could be implemented at any small rail operator fast. Depending on the scenario and type of operation, smaller adjustments would be made. For example, to make the deployment of such system possible on wagon based trainsets, the

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handhelds directly can be utilized as database mirrors instead of dedicated onboard servers to eliminate the need for complex modifications of the rolling stock. A newer version of the distribution system already supports this functionality, letting companies keep 20 to 40 million tickets up to date on conductor edge devices.

For larger deployments like a scenario of the size of ÖBB (around 40 million sold tickets per year [75]) the base system could still handle all currently active tickets. While creating a system like this from scratch for such a large scale is technically possible, challenges might arise when a high amount of additional legacy interfaces of other systems need to be integrated.

Could this system be connected to distribution systems of former state railways?

Definitely yes. This already happened, when WESTbahn and ÖBB have received a special contract to continue operations during the low demand phases of the COVID-19 pandemic. During this phase, both companies have been forced to mutually recognize tickets, leading to ÖBB tickets being used on WESTbahn and vice versa. To prevent fraud, extensive data exchange of both companies had to occur.

To prove a ticket is valid on the selected journey, both systems work totally different. At WESTbahn, customers are entitled and encouraged to just simply check their ticket status on their own, as the code printed on the ticket is a standard QR-Code leading to a website. The ticket information itself is stored on the WESTbahn servers. Most former state railways still use the old UIC ticket format (c.f. UIC 108.2), which simply represents the data previously printed onto the ticket together with an added signature (DSA-hash), which can be used to validate the ticket data. While the ticket data can be checked by any staff member with a device capable of reading and deciphering the Asctec-Code, only systems which are connected to the specific keystore can actually prove the validity of the specific ticket. As validation is ensured locally, this system can be harder to maintain for international tickets on a global (European) scale, as all public keys of signing parties need to be known. A centralized keystore would be needed.

The system used at WESTbahn does not require any keys to validate a ticket. Still, to create a new ticket, local private keys are used on the edge devices. To prevent fraud by stolen devices being used to generate new tickets, the system already provides a device management, that allows to report a device stolen and revoke all tickets created by a single device.

In general, validation systems need to be capable of the following key features:

- prove validity of document (on sight, or remote)
- detect double use of the same ticket

[75] https://konzern.oebb.at/de/ueber-den-konzern/fakten/subventionen

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- detect post travel refunds
- provide current data (real time)

”The information needs to be faster than the passenger” (translated from German: ”Die Information muss schneller sein als der Fahrgast”) Transparency can help to implement reliable and secure systems. Any additional offer, that is bound to the ticket, should not be separate tickets by itself. Signing the ticket information should only be a stopgap solution to the problem.

Which party should be in charge of implementing centralized components for an international rail ticketing system?

The EU Commission should regulate the steps towards a global standard. As long as interoperability and non-discriminating access is granted to any party, that wants to actively participate, even the UIC could lead such working groups. System integrators like Hacon could implement a branch wide solution. In the end, standardization is the essential key towards success in the interoperability of distribution systems.

How could the future of railway ticketing be shaped in general? Which developments should a new distribution system already support?

Currently, multiple initiatives try to implement measures to lowering the access barrier towards rail transportation. This includes programs like the 9€-Ticket or the Klimaticket, that dramatically lower the price of public transportation. As these succeed and show their intended effect, measures to balance the new loads might need to be implemented. It is possible, that reducing the price of single trip tickets could prove to be the better option. For long distance trains, utilization based pricing will find even further adoption. Furthermore, the ability to combine mobility services will gain more importance, especially as autonomous driving is entering the market. Currently, there is no UIC initiative to create open standards for a multimodal transportation system.

Besides that, other non-railway specific trends also need to be taken into account, like the shortage of qualified employees. As an example, human customer service could be outsourced to local shops, as WESTbahn did this, by allowing newsstand and tobacconist’s to sell tickets, creating a win-win-situation for local suppliers and the RU.

What is the role of the GEKKO it-solutions GmbH ?

As a result of changes in the financing, WESTbahn decided to let Gekko taken over maintenance of the distribution System. In the last years the company integrated smaller changes into the system (e.g., change of credit card payment, integration of local transport association tickets). While WESTbahn spend 2.5 million Euro on its distribution system, ÖBB spent

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24 million, employing Wirecard for this job [76].

The website and shop frontend has always been maintained by the Ovos Media GmbH [77]

Are there any certifications needed to implement a distribution system like the one showcased at WESTbahn?

All parts essential for train operation need a certification, this also includes the servers, used for ticket verification and the customer WLAN. For example, the inner communication is managed by a Standing-tree protocol using a circle of communication lines throughout the train. The WIFI is distributed by 4 routers, including a private network for all crew members and access to the onboard servers. The servers themselves need to be modified to comply with all regulations, including screw mounted cabling. A GPS antenna is mounted on the roof, to geolocate the train and estimate its journey progress.

Besides these hardware certification requirements, payment processes are another issue, when designing a secure distribution system. , especially when requiring offline payments. In the case of WESTbahn, the company switched payment provider (Verifone[78] to Hobex[79]) to deliver offline payment. Still, only credit card payments are possible.

[76] https://orf.at/stories/3204136/
[77] https://ovos.at/de/
[78] https://www.verifone.com/de/de
[79] https://www.hobex.at/

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A.1.7 Klaus Kovar, Robert Prasnikar - ÖBB Ticketshop

This interview took place on 1. December 2022.

As Business Analyst at ÖV-Ticketshop GmbH, a subsidiary of ÖBB, Dipl.-Ing. Klaus Kovar is actively shaping the future of international rail ticketing. Being a contributor to the OSDM, he can provide valuable insights into the most recent developments of the standard. Mag. Robert Prasnikar is a system architect at the ÖBB-Personenverkehr AG, actively designing and implementing new ticketing solutions.

Getting to know the ideas and systems in place for international rail ticketing at the Austrian incumbent has been identified as essential to this thesis.

From an organizational and technical perspective, how is the task of ticket distribution structured at ÖBB?

At ÖBB the development and maintenance of its ticketing system is executed by its subsidiary ÖV-Ticketshop GmbH. This separation is purely organizational, as strong cooperation and linkage of both parties exist.

From a technical perspective, the systems used for ticket distribution strongly differ across Europe. Different national ticketing strategies like NRT and IRT ticketing resulted in divergent underlying system architectures. Currently, custom-made solutions make up the majority of the market, as nearly every railway company is building its own ticketing and reservation system.

The distribution system at ÖBB is structured in two lifecycle phases, the design time and runtime phase. Starting with the design time phase, all static data is preprocessed, including, for example, timetable, tariffs, and train composition. In the runtime phase, the customer's virtual shopping cart is managed and relation-specific offers, are returned by the internal yield management system.

Which steps are carried out, when a customer purchases a ticket?

It all starts with the customer searching for a trip. This request is handled by HAFAS, a timetable information system developed and maintained by the external partner HaCon. After selecting a journey, the specific details are used to look up the train in the distribution system. At this point, the available fairs are retrieved from the Product Definition System (PDS), determining which of the nine possible distribution channels are eligible for each tariff. If a mobility platform is used, it would also connect to the ÖBB Backend via a proprietary interface in the background, providing the necessary information to match a trip. Usually, the lookup of fairs is done pre-travel, which is not the case when using ÖBB's smart journey system,

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SimplyGo! [80] developed by the company Fairtiq[81].

In 2021 ÖBB promised that OSDM would improve bookability of international rail tickets. What is the current implementation status of OSDM at ÖBB?

As promised, OSDM is already productive at ÖBB providing information to partners, however, it is not currently used by the ÖBB distribution system.

The Czech ticketing platforms Bileto [82] or OneTicket [83] already showcase working implementations of OSDM. In Sweden, Samtrafiken[84] has already introduced OSDM to connect service operators and vendors within the country. For the further implementation of OSDM at ÖBB, there is currently no timeline set, but "OSDM must come to live" - (translated from German: "OSDM muss zum fliegen kommen") as for ÖBB international ticketing it is not only important to allow customers in Austria to travel further by rail, but also to let foreign customers discover the service.

ÖBB has implemented the Rail-Team-Broker before, but this approach has not proven to establish itself as a working solution. Currently, all DB connections to Germany are sold via Hermes, a message exchange system.

Why are there so many custom-made solutions and no consolidation?

To decide whether to rent, buy, or build a product, a company needs to weigh different parameters. For example, in the case of reservation systems, the high need for customization and the low number of potential suppliers leads to a high introduction price of systems.

As OSDM contains some centralized components, these will be handled by external suppliers. For example, the management of offline tariff data will be done by the company Hitrail[85]. In the future, the ideal scenario would be a global standard, that all ticket shops and operators support. To achieve this vision OSDM plays a key role.

How does the distribution system architecture look like?

As mentioned, as a customer, you are experiencing the sales frontend, which can be one of nine different channels. All channels retrieve their information from an API Layer, that acts as middleware, to weight limit and load balance the requests. This is currently written in node.js[86]. The actual Backend consists of multiple microservices, written in Java Spring-

[80] https://www.oebb.at/de/tickets-kundenkarten/online-mobile-ticketing/oebb-app/simplygo
[81] https://fairtiq.com/de/
[82] https://www.bileto.com
[83] https://oneticket.cz/home
[84] https://samtrafiken.se/
[85] https://www.hitrail.com/
[86] https://nodejs.org/en

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Boot[87] running on an Azure[88] hosted Kubernetes [89] cluster. This architecture allows for a fast and flexible scalability of the system. A separation of services is done by following the user flow. An external provider handles the payment. As database technology, ÖBB is now using Postgresql[90] and mongo.db[91] for some applications after migrating from Oracle [92].

How many people are employed for this service? How does the company develop?

As the products developed in-house usually have a specific predefined feature list, work is carried out following mostly a Kanban, sometimes a waterfall system. Around 200 people are employed in this job.

The team follows a release cycle of two weeks. Every cycle concludes with the testing of all changes that were implemented during that period through automated integration and regression tests, followed by their deployment. But not only code changes require testing. Every change of timetable or tariff data - which are applied twice a week - requires automatic tests as well, to ensure no error fares show up.

What is the ideal future from ÖBB perspective

Currently, the industry is experiencing fast development, which is not limited to ÖBB. In the future, the task of ticket distribution will be shared among multiple operators, and equally, the customer base will be shared, expanding the reach of every participant. The connection of other mobility services (within a MaaS platform), will not be limited to the integration of timetable data but will play a key role in the distribution of tickets. ÖBB will continue to focus its efforts on the Austrian market.

[87] https://spring.io/projects/spring-boot
[88] https://azure.microsoft.com/en-us
[89] https://kubernetes.io/
[90] https://www.postgresql.org/
[91] https://www.mongodb.com/
[92] https://www.oracle.com/database/enterprise/

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A.1.8 Stefan Jugelt - ERA

Besides the here transcribed interview, Stefan Jugelt started the meeting with a short presentation of the basic structure and ideas behind the TAP-TSI (cf. [52]).

This interview took place on 9. June 2023.

After his studies in mechatronics and automation technology, Stefan Jugelt collected valuable experience as a software developer working for a software and automation provider. Being an active member of different rail passenger associations, he has been a board member of Pro Bahn[93] from 2001 to 2010. At the European Union Agency for Railways (ERA), he is working as a project manager on the novelization of European regulations for telematics applications and interoperability of data exchange since 2009.
As a knowledgeable expert on timetable and booking interfaces, Stefan Jugelt has been recommended as an interview partner by Josef Doppelbauer.

Will there be an ERA-managed timetable database, similar to MERITS, following the idea of the value provided by National Access Points (NAP)?

The timetable database MERITS is perceived by the ERA as a product of a private company. The data available via NAPs is often limited to trip segments that are operated by national carriers (trips might be separated if the operator changes at the border). Furthermore, this data is not necessarily further integrated between providers as MERITS does it. This leads to not only trips within the timetable data not having a common identifier, but also station identification might differ between domestic and MERITS datasets. To address this issue, a common reference code to further harmonize the data and improve cross-integration has to be used, as defined as a mandatory location code within the TAP-TSI.
Besides the regulation (EU) 2017/1926 (MMTIS) mandated the usage of NeTEx, TAP TSI technical document B.4 (EDIFACT) and companies complaining about the high integration cost of standardization, the data provided via the NAPs is surprisingly mostly provided in NeTEx or GTFS format, but not following the EDIFACT standard specified in the TAP-TSI and created by most of the railway undertakings to feed MERITS.

[93] http://probahn.de

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You mentioned, that the use of equivalent standardized data formats is generally possible. Could GTFS be a drop-in replacement for the timetable capabilities of NeTEx?

GTFS is a very limited, slowly developing format, that can be applicable for especially local transit. Representing Intercity services in this format might be more problematic, as it does not allow for example the representation of train separations (e.g., through coach services) or the specification of more specific service classes. For some limited use cases in railways, it might still be used.

Talking with representatives of private rail companies, compulsory contracting ticket sales was demanded several times. Will there be any regulation mandating such reciprocal ticket sales?

Currently, this is discussed as part of the MDMS initiative. The current passenger rights agreement includes an obligation of through-ticketing within the offerings of one carrier and its subsidiaries. Currently, private agreements like Advanced-Journey-Continuation (AJC) or HOTNAT ("Hop on the next available train") exist between operators, but are either not known by the passengers or are not well implemented.
From a technical perspective, a new standard called Universal Rail Ticket is currently in preparation for publication as an ERA technical document (Expected for the end of 2023). It includes a general ticket specification, including all legs of the trip and, informing the passenger which legs are combined as a through-ticket. Starting with the new passenger rights regulation (EU) 2021/782, railway undertakings and ticket vendors need to inform the customer if a ticket is defined as a combined (not through) ticket, and therefore no claims for reimbursement can be made.

In your presentation, the user journey did not include ticket validation. Currently, this seems to be a hurdle towards standardized international ticketing. Does ERA aim to regulate and standardize elements of this subprocess?

A document specifying the structure of ticket validation data is currently drafted as ERA technical document B.14 and recommended to be accepted by the EU Commission. The content and format of barcodes printed on a paper ticket are already standardized, but the exchange of validation events isn't. Therefore, for third parties (e.g., foreign RUs) following the current TAP-TSI, it is not possible to truly verify the validity of the ticket. In the future, there will be a standardized exchange of validation events, that might be adapted to better suit specific local needs.

In the end, the stored information about validation events could enable different use cases - not only in international travel but also locally (e.g., simplify revenue distribution).

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How does ERA's relationship with the UIC look like?

In 2009 ERA bought several UIC leaflets (IRS) that are incorporated as technical documents in the TAP TSI. These documents are now publicly available and maintained by ERA. A specific change management group meets twice a year in May and November. Still, most of the change requests originate from UIC, but all recognized organizations are welcome to submit change requests. In the railroad sector, national concerns still strongly influence regulations, hindering generalized international efforts.

What is the current status of the MDMS initiative?

MDMS is currently discussed within the EU Commission. ERA is accompanying this effort by bringing railway standards to the table. Not much output of the initiative is currently finalized and public.

How is the EU supporting smaller rail companies in the introduction of distribution systems following the new standard?

The EU has set up the Connecting Europe Facility (CEF) [94] funding program at the European Climate, Infrastructure and Environment Executive Agency (CINEA) [95], which supports the introduction costs of efforts to implement TAF- / TAP-TSI standards. Currently, mostly TAF related projects are calling up the funds (mostly for projects regarding the communication between RU and railway infrastructure managers). Examples for TAP related projects implementing the ticket distribution can be found in Slovakia and Greece.
In general, the sector still seems to prefer privately developed solutions. OSDM for example originally has been created as a parallel effort to the creation of NeTEx fare exchange.

Does ERA sustain relationships to other countries / organizations outside of Europe?

Absolutely, ERA maintained strong relations with the Organization for Cooperation of Railways (OSJD) [96] (some EU members are part of OSJD), till February 2022, since when all communications have been on hold due to the Russian invasion in Ukraine. In the last ten years, a project outlining systemic commonalities and differences between railway standards in the EU and OSJD has taken place. With regard to TAP TSI, mostly commonalities exist, as both parties based most of their standards on UIC leaflets. This has been reflected in the customer experience directly, as buying tickets from Berlin to Vladivostok has been possible through connected reservation systems.

[94] https://cinea.ec.europa.eu/programmes/connecting-europe-facility_en
[95] https://cinea.ec.europa.eu/programmes/connecting-europe-facility/transport-infrastructure_en
[96] https://en.osjd.org/

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Outside of Europe, partnerships exist with organizations in North and South America, while these efforts are not highly related to telematic system standardization.

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A.1.9 Petra Söderqvist - EU Commission

The following answers have been submitted on 8. September 2023 in written form.

Ms. Söderqvist works as a Policy Officer as part of the European Commission in the Directorate-General for Mobility and Transport (DG MOVE), unit B4 Sustainable and Intelligent Transport.

Hearing from her about the status of new proposals and the decision-making process within the EU Commissions has been identified as a key addition to conclude this research and reevaluate the EU position based on their position towards current developments.

Customers mainly fail to purchase international rail ticketing due to limited through-ticket availability. How will the EU Commission counteract this issue?

In line with the objectives outlined in the Sustainable and Smart Mobility Strategy [97] and the 2021 Action plan to boost long-distance and cross-border passenger rail [98], the Commission is working on the barriers limiting the uptake of international rail. The recent review of the Rail Passenger Rights Regulation that entered into force this summer already includes some important improvements with regard to through tickets. Companies that are 100% under the same ownership now have to offer journeys as a single contract/through ticket. At the same time, the offer for through-tickets combining services of different operators remains very limited. When passengers book these tickets as separate contracts, they are not protected by passenger rights [99] in case they miss a train due to delays or disruptions. This is an issue we plan to address in the upcoming initiative on Multimodal Digital Mobility Services [100]. The initiative looks at ensuring journey continuation and protection in case of missed connections for passengers traveling on combined separate tickets in rail.

Customers mainly fail to purchase international rail ticketing due to limited through-ticket availability. How will the EU Commission counteract this issue? While National Access Points improve the availability of open data, international timetable data is mainly provided by two closed data integrators. Is the EU Commission planning to address this issue and enforce data exchange on the European level?

With the revision of the Delegated Regulation on EU-wide multimodal travel information services (MMTIS) [101], currently ongoing and planned for adoption during autumn 2023, we are strengthening the importance of cooperation amongst ITS stakeholders, such as the EU-project NAPCORE [102]. This project aims to improve the cooperation amongst national ac-

[97] https://transport.ec.europa.eu/transport-themes/mobility-strategy_en
[98] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0810
[99] https://transport.ec.europa.eu/transport-themes/passenger-rights/rail_en
[100] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13133-Multimodal-digital-mobility-services_en
[101] https://eur-lex.europa.eu/eli/reg_del/2017/1926/oj
[102] https://napcore.eu/

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cess points in the Member States. In addition, the Commission is currently also working on a communication for a common EMDS[103], aiming amongst other things to facilitate the pooling and sharing of mobility data in a controlled and secure way.

The industry proposed the Open Sales and Distribution Model (OSDM), which is discussed to be integrated into a future TAP-TSI recast. What's the current status of this recast? Are there any adjustments mandated to the proposed standard?

The Commission is currently revising current framework of rail interoperable data sharing (Telematics) as triggered in its Smart and Sustainable Mobility Strategy (SSMS) through a TSI on Telematics Applications. The revision intends to introduce a more robust governance of these specifications as well as enforcement mechanisms. On ticketing aspects, this regulation will implement the principle of single source of through mandating operating carriers to collaborate for providing access to their timetables and fares through existing National Access Points (NAPs). With regards to standards referenced in this Regulation, OSDM in one of the option foreseen still subject to our assessment.

To create a One-Stop-Shop for international rail tickets, third parties must be able to combine offers of multiple carriers on agreed-upon rules. Is the EU Commission planning to bring fair, reasonable, and non-discriminatory access conditions to sell integrated rail tickets to third-party resellers?

The Commission is planning an initiative on Multimodal Digital Mobility Services [104] in order to enhance comparability of mobility offers and to facilitate access to these offers which, in turn, would support sustainable and multimodal mobility in the Union. Today, the accessibility of transport offers differs between modes. Whereas some modes (aviation) are already widely available due to liberalization of the market and resulting competition, other modes (rail) are not easily accessible for MDMS, which makes it more difficult to combine rail services into multimodal offers. Our objective is therefore to unlock multimodal offers. To achieve this, we are considering obligations for transport operators (including airlines) and MDMS platforms, which should be obliged to enter into commercial agreements based on FRAND (fair, reasonable, and non-discriminatory) principles for re-linking or for re-sell.

[103] https://digital-strategy.ec.europa.eu/en/policies/mobility-data
[104] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13133-Multimodal-digital-mobility-services_en

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A.2 Additional Infographics

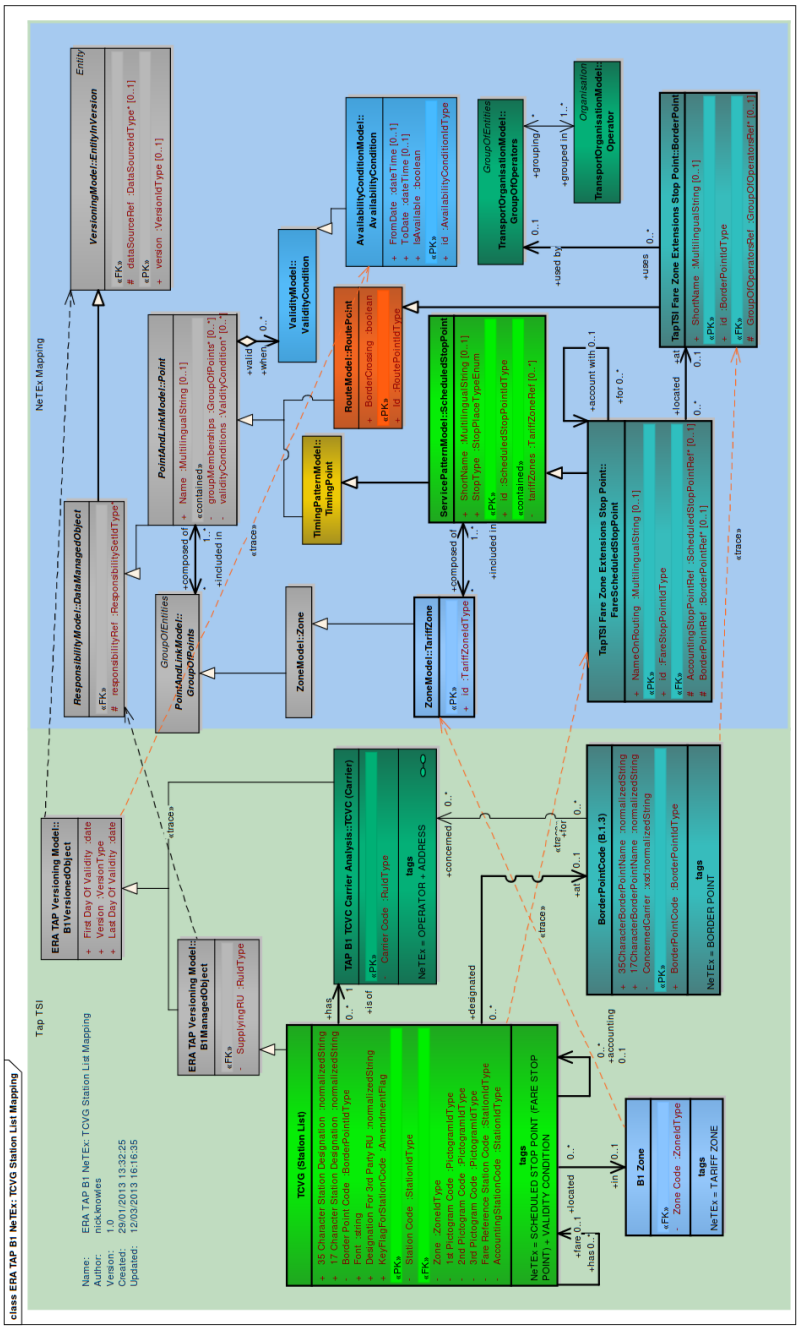

Figure 45: Mapping of TAP-TSI Annex B.1 to the NeTEx fare model, c.f. [111, p. 9]

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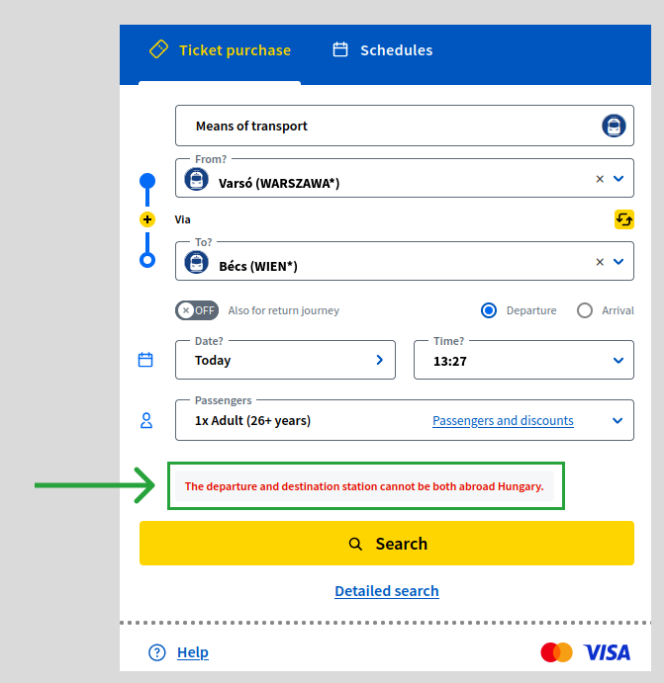

Figure 46: Screenshot of MAV booking platform, limiting international rail ticket distribution via Hungary

Figure 47: Screenshot of international.bahn.de, showing error message

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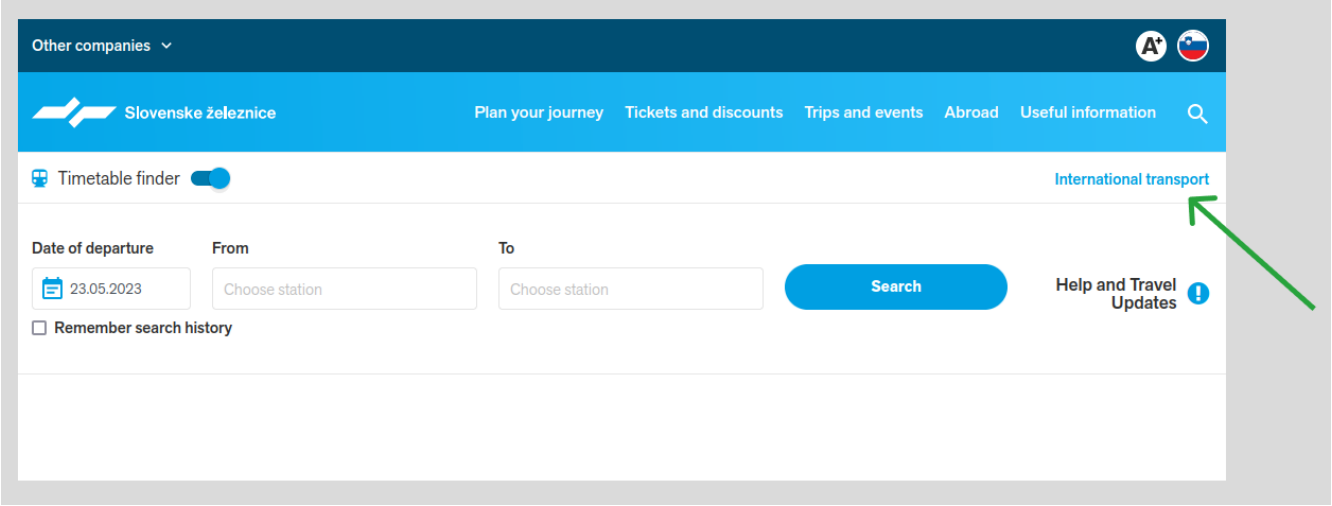

Figure 48: Screenshot of Slovenske železnice, showing link to international tickets (linking to reiseauskunft.bahn.de)

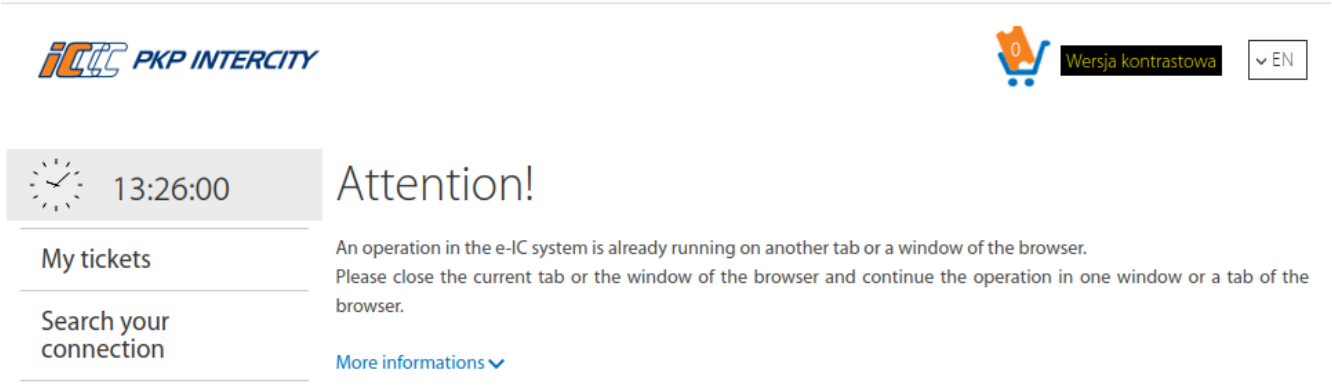

Figure 49: Screenshot of PKP-Intercity, showing error message as another page instance is opened in another browser tab.

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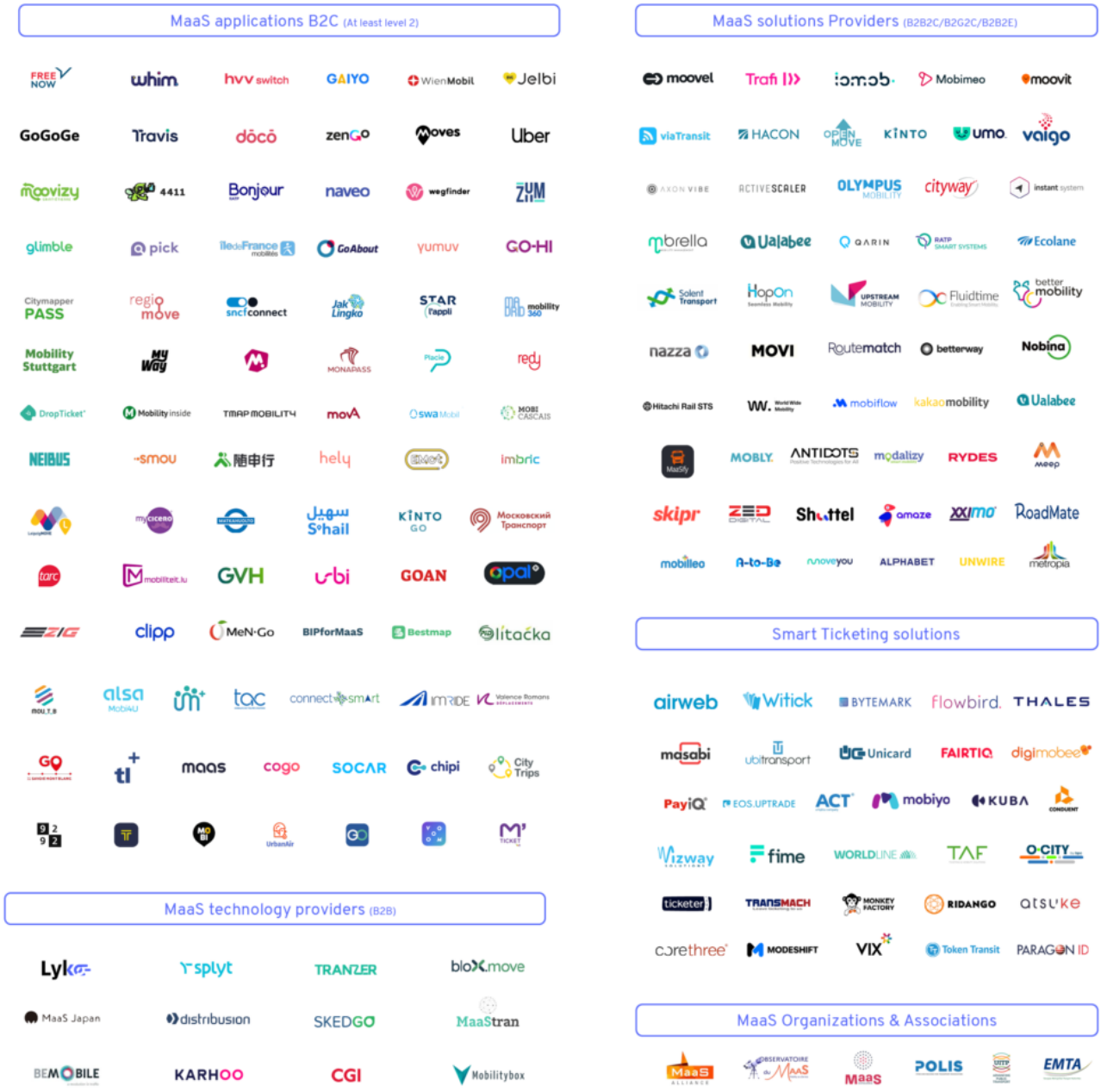

Figure 50: Lyko analysis of MaaS market participants [78]

Education Level	Austrian Public	International Travel
Level 1 (< ISCED 2)	17.3%	13.2%
Level 2 (< ISCED 6)	63.0%	68.8%
Level 3 (>= ISCED 6)	19.20%	29.9%

Table 19: Education level of the inhabitants and Austrian international travelers in 2022 Source: [108], [109]

List of Survey Questions

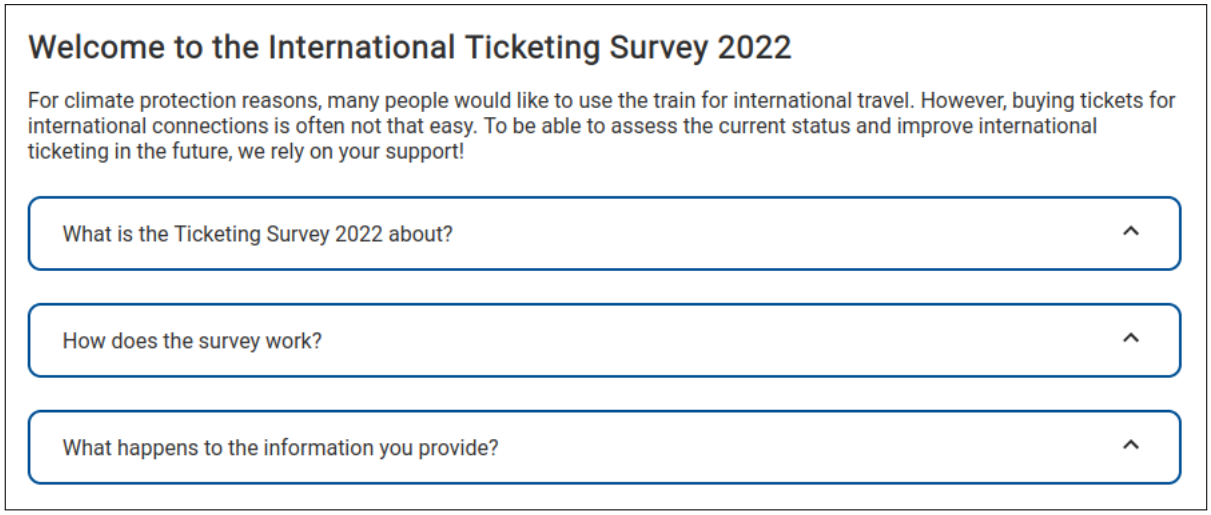

Figure 51: Screenshot of survey step ”Start”, cf. Figure 7

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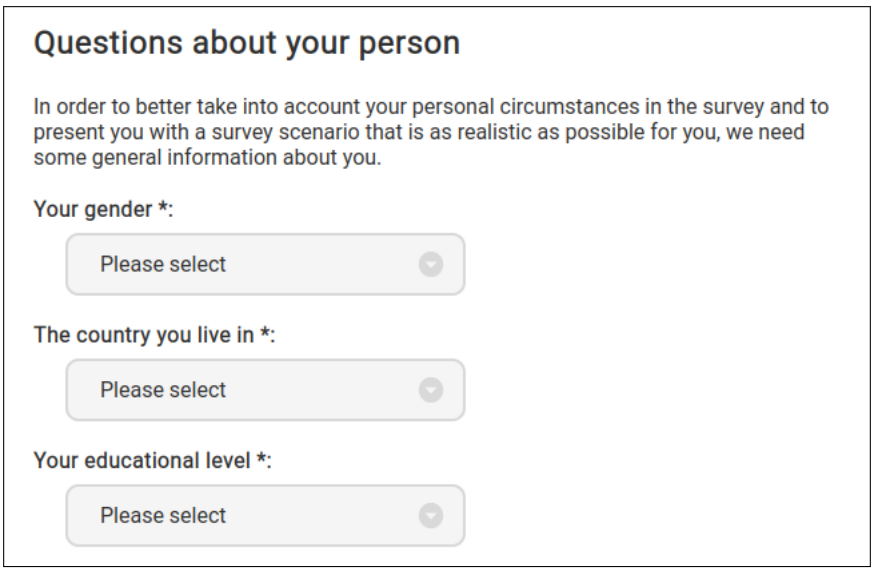

Figure 52: Screenshot of survey step ”Personal Info”, cf. Figure 7

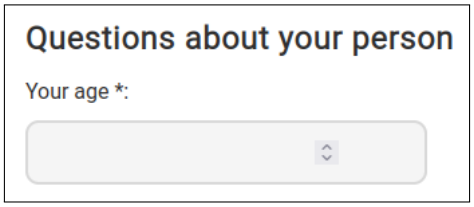

Figure 53: Screenshot of survey step ”Age”, cf. Figure 7

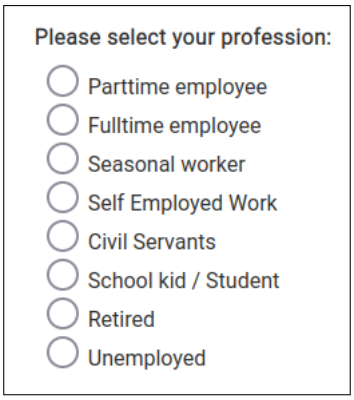

Figure 54: Screenshot of survey step ”Job”, cf. Figure 7

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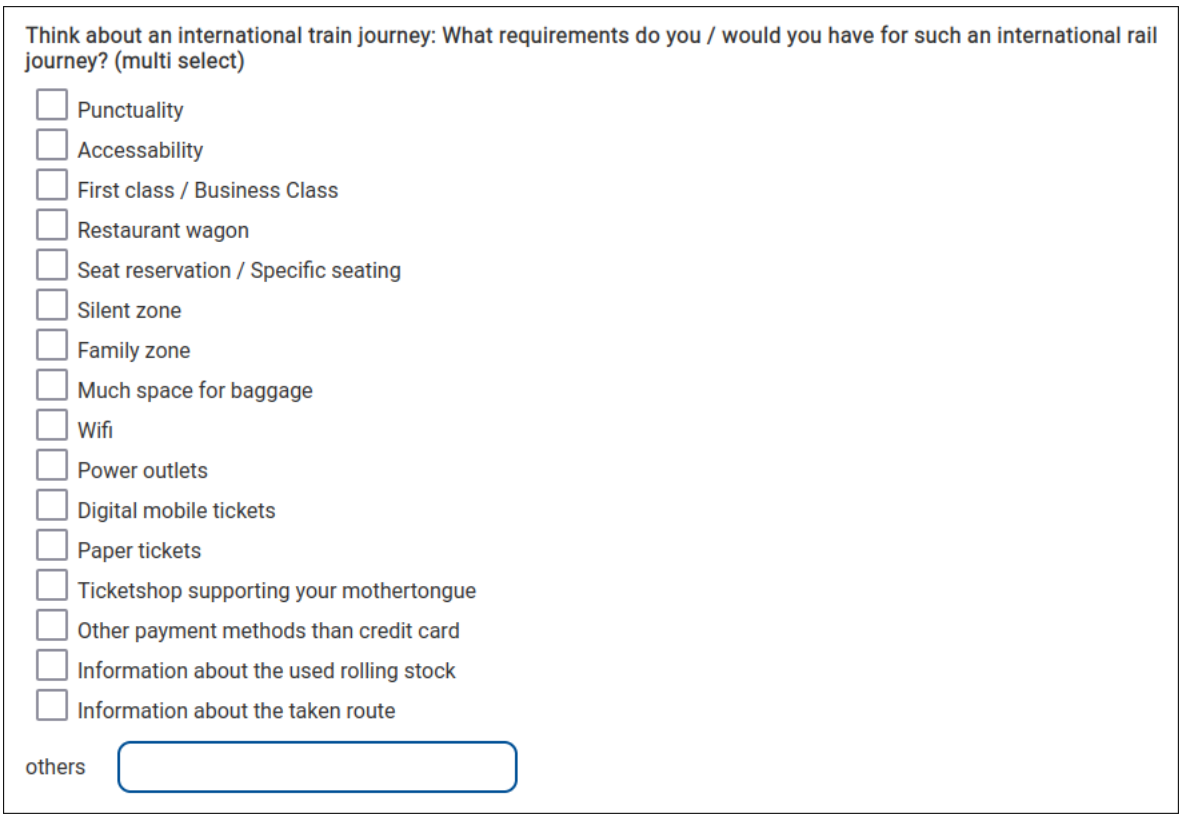

Figure 55: Screenshot of survey step ”Required Amenities”, cf. Figure 7

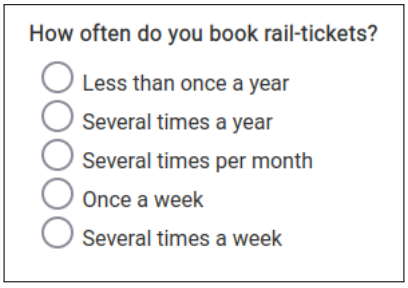

Figure 56: Screenshot of survey step ”Rail Booking Affinity”, cf. Figure 7

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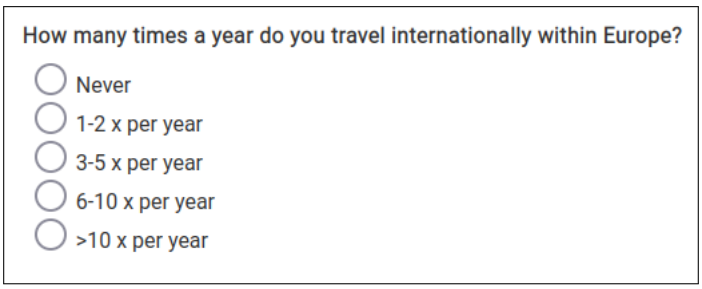

Figure 57: Screenshot of survey step ”Trips Abroad”, cf. Figure 7

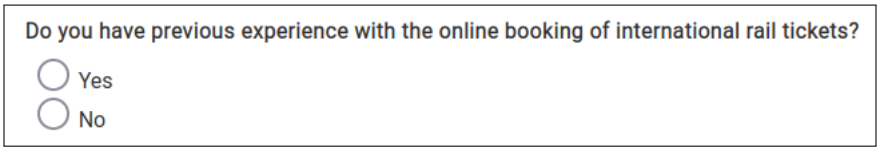

Figure 58: Screenshot of survey step ”International Ticketing Experience”, cf. Figure 7

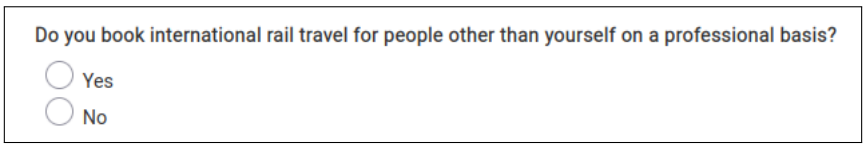

Figure 59: Screenshot of survey step ”Regularly Booking for Others”, cf. Figure 7

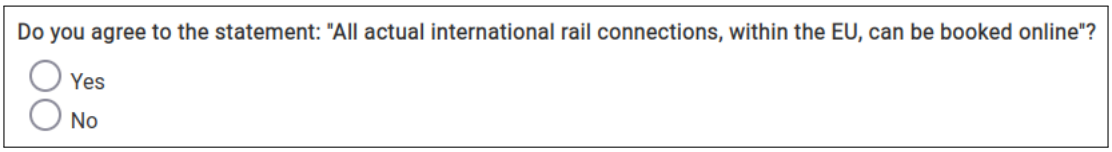

Figure 60: Screenshot of survey step ”All Trains Bookable”, cf. Figure 7

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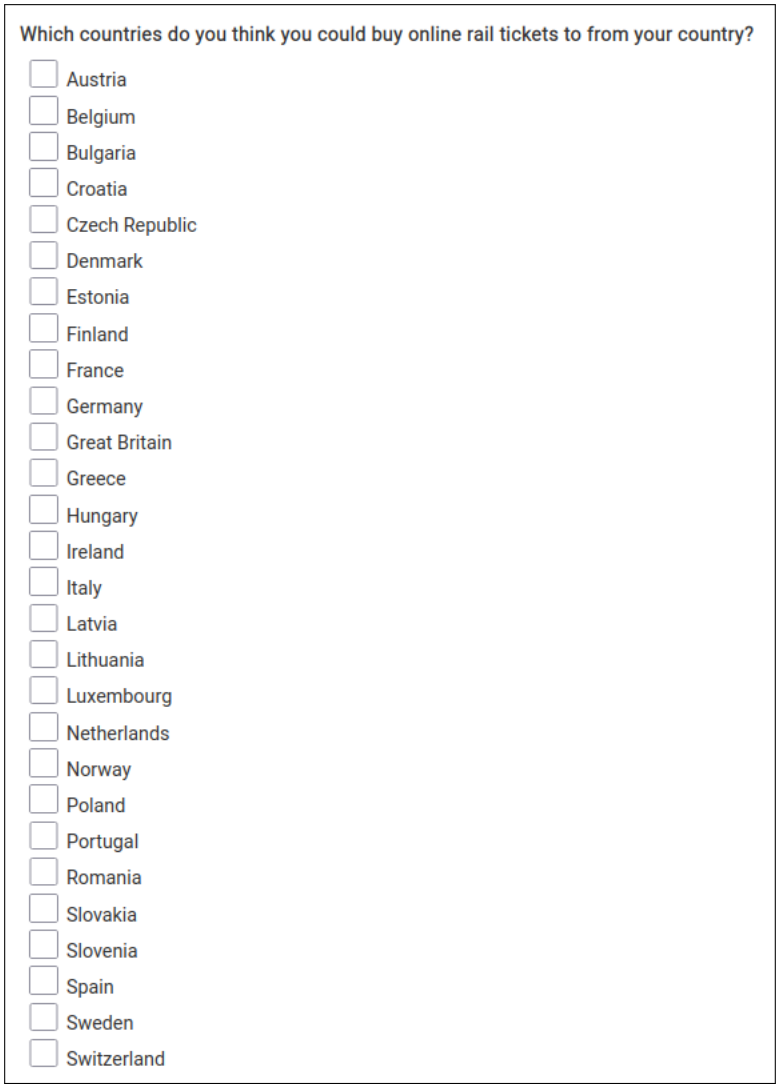

Figure 61: Screenshot of survey step ”Countries Reachable with Through-Ticket”, cf. Figure 7

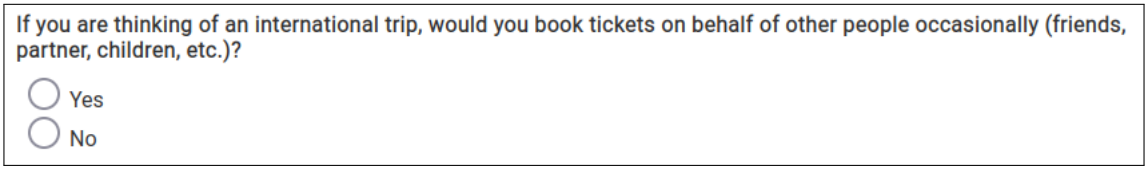

Figure 62: Screenshot of survey step ”Usual Accompany”, cf. Figure 7

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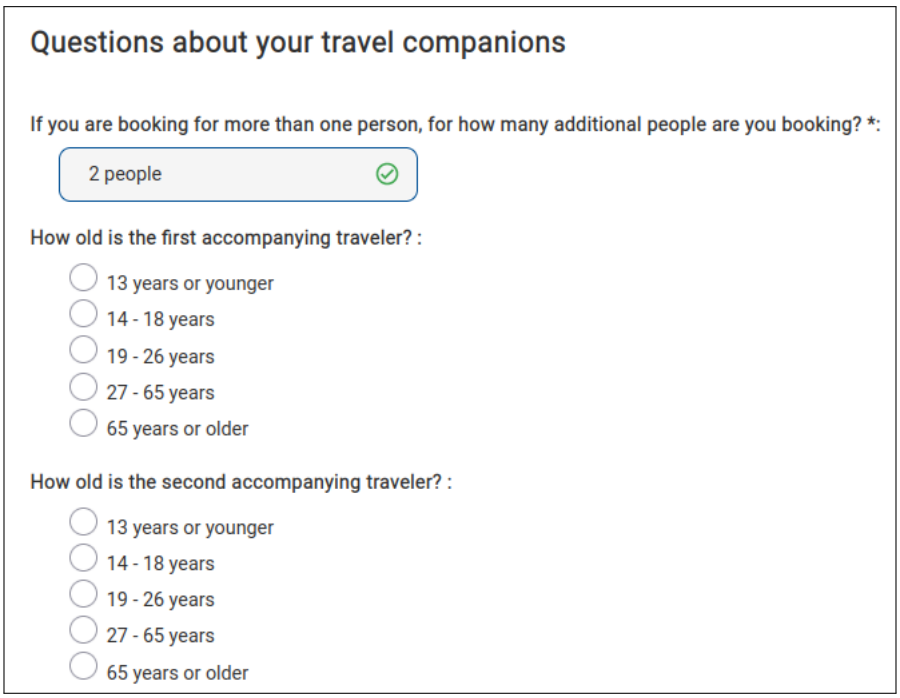

Figure 63: Screenshot of survey step ”Accompany Age”, cf. Figure 7

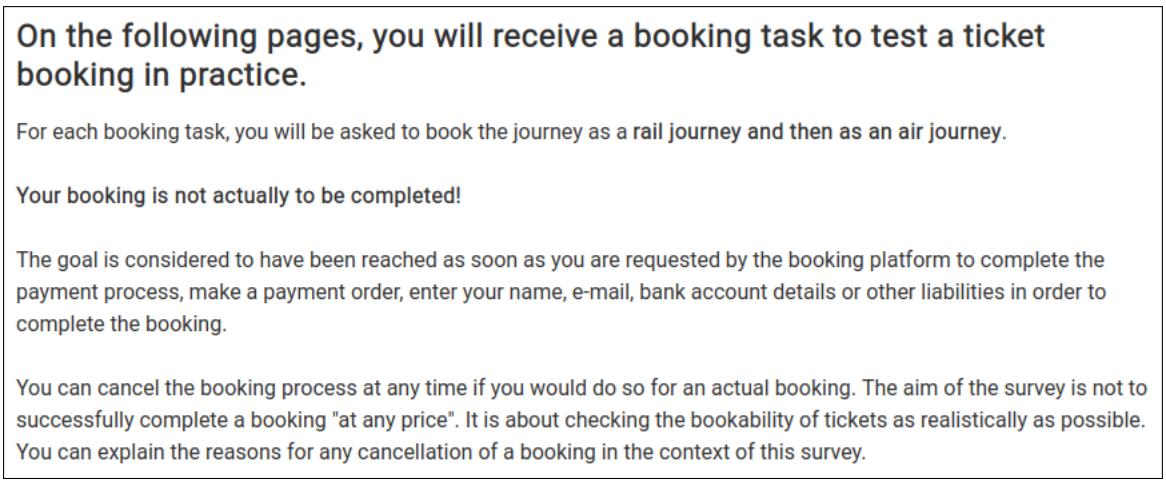

Figure 64: Screenshot of survey step ”Scenarios Information”, cf. Figure 7

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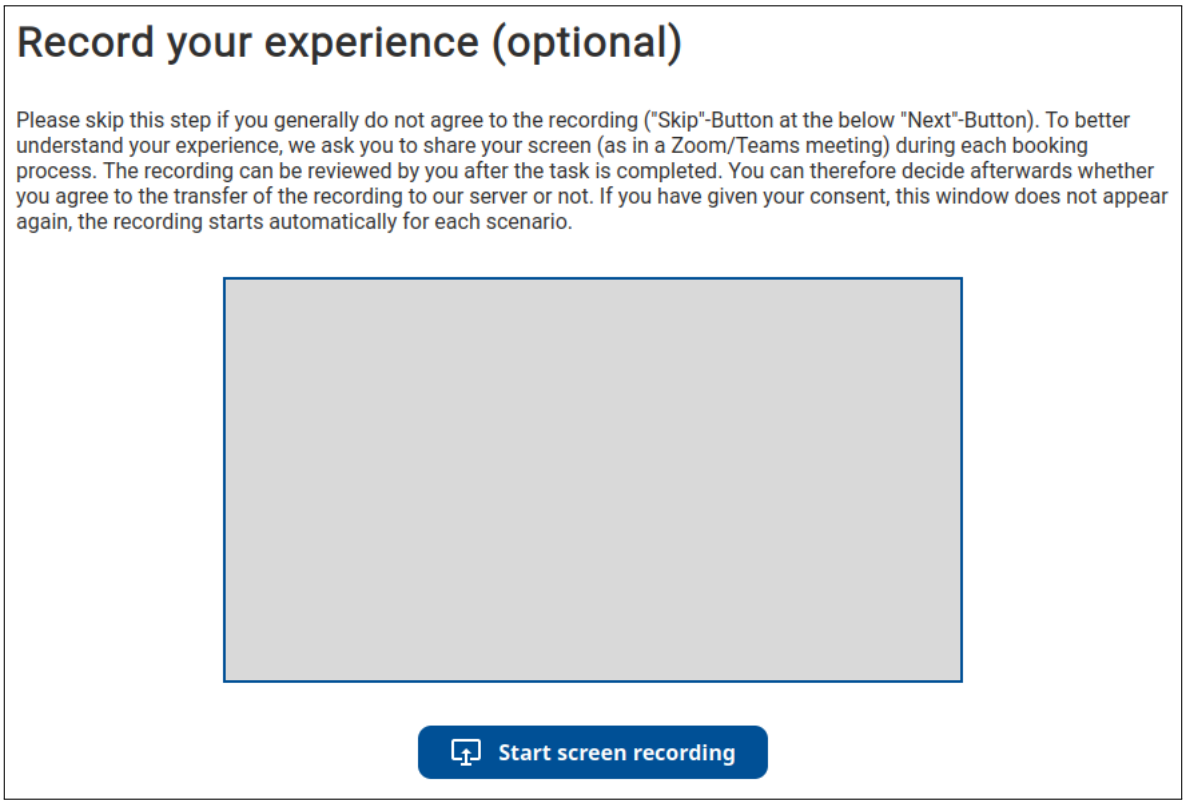

Figure 65: Screenshot of survey step ”Recording Info”, cf. Figure 7

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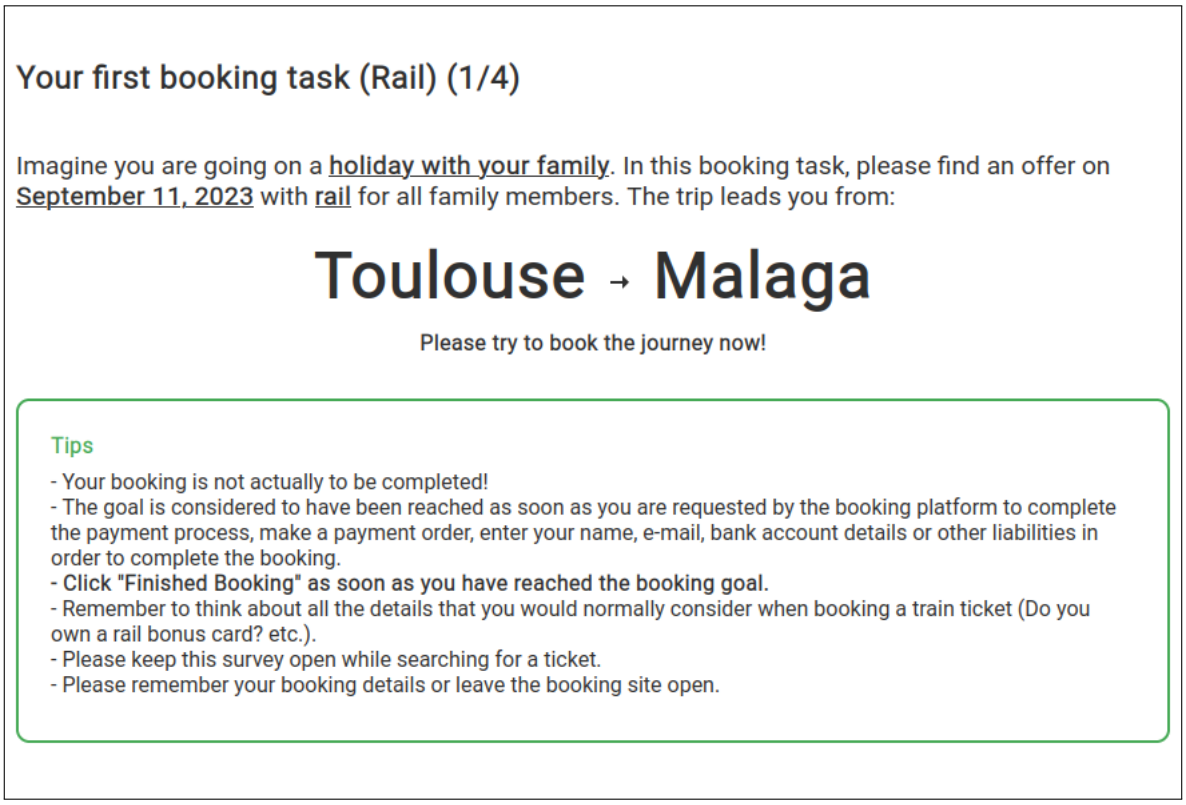

Figure 66: Screenshot of survey step ”Mission Information”, cf. Figure 7

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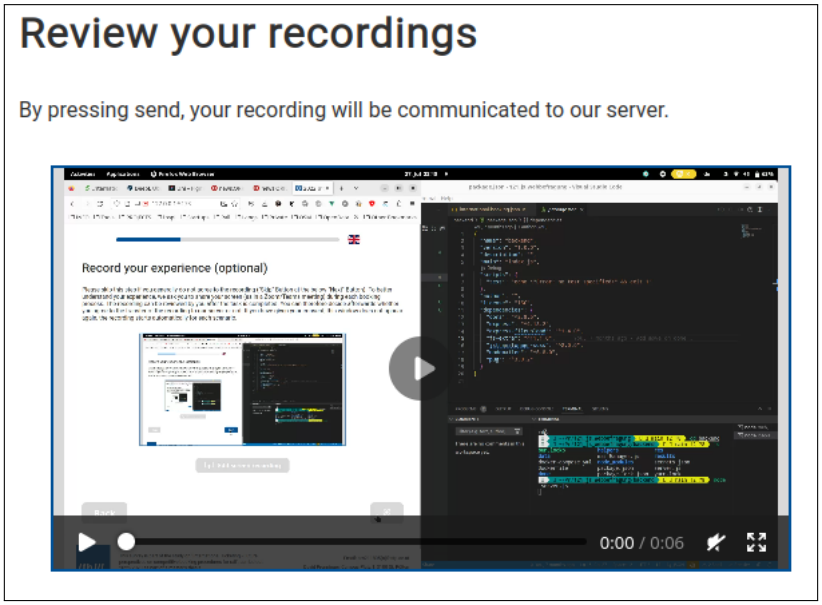

Figure 67: Screenshot of survey step ”Recording Review”, cf. Figure 7

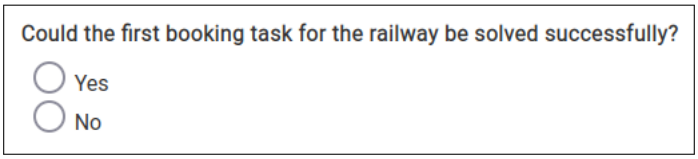

Figure 68: Screenshot of survey step ”Mission Successful”, cf. Figure 7

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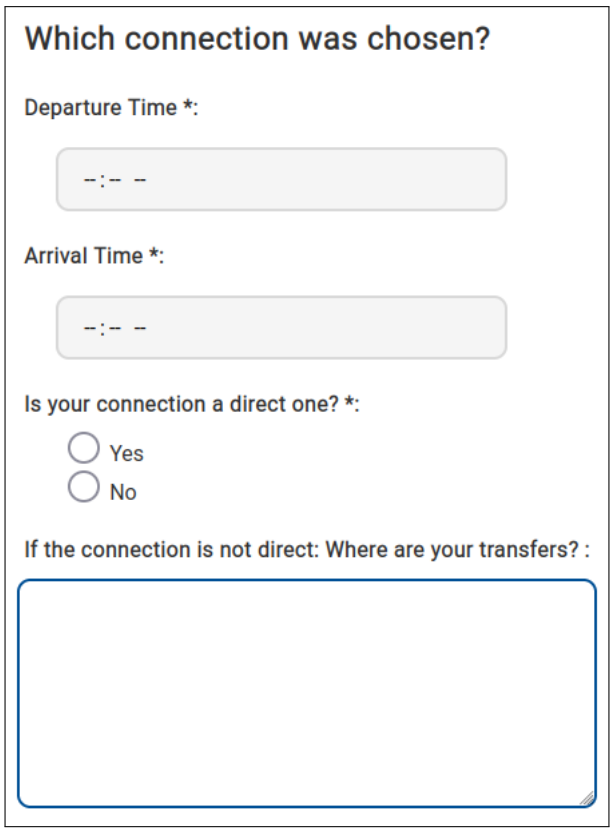

Figure 69: Screenshot of survey step ”Connection Chosen”, cf. Figure 7

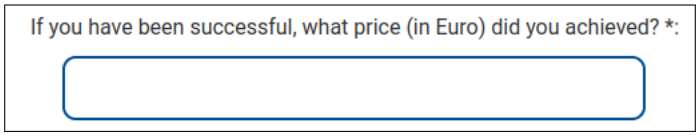

Figure 70: Screenshot of survey step ”Ticket Price”, cf. Figure 7

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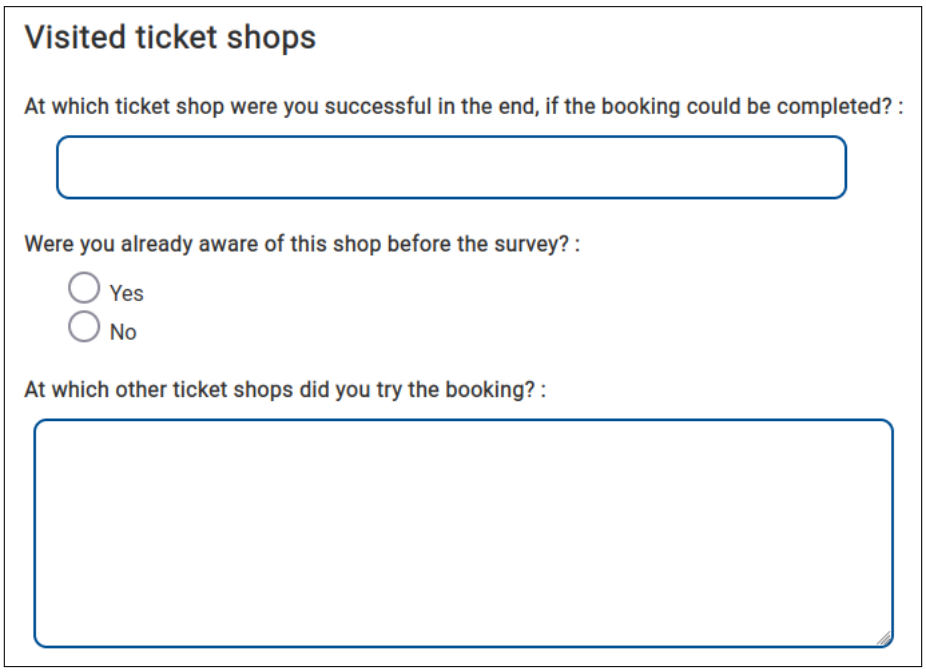

Figure 71: Screenshot of survey step ”Visited Shops”, cf. Figure 7

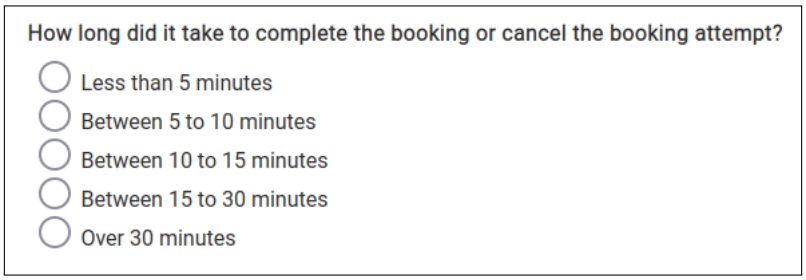

Figure 72: Screenshot of survey step ”Perceived Duration”, cf. Figure 7

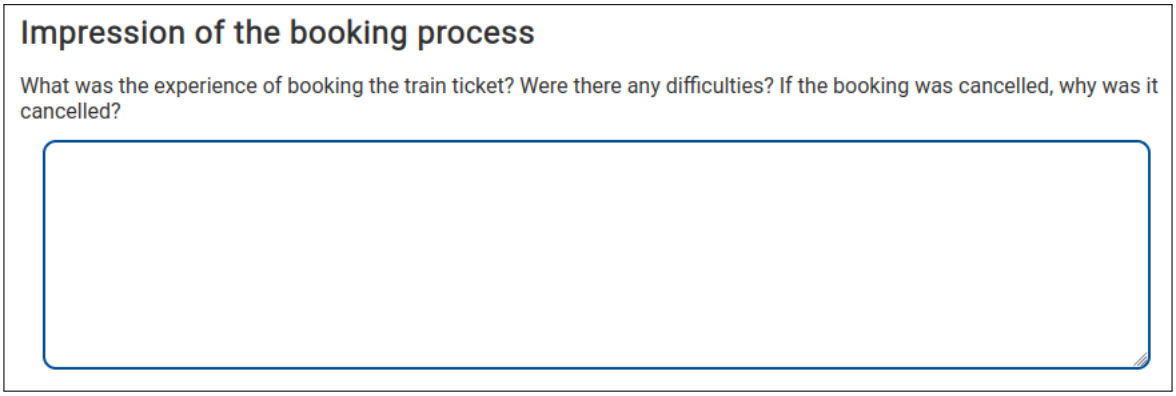

Figure 73: Screenshot of survey step ”General Impression”, cf. Figure 7

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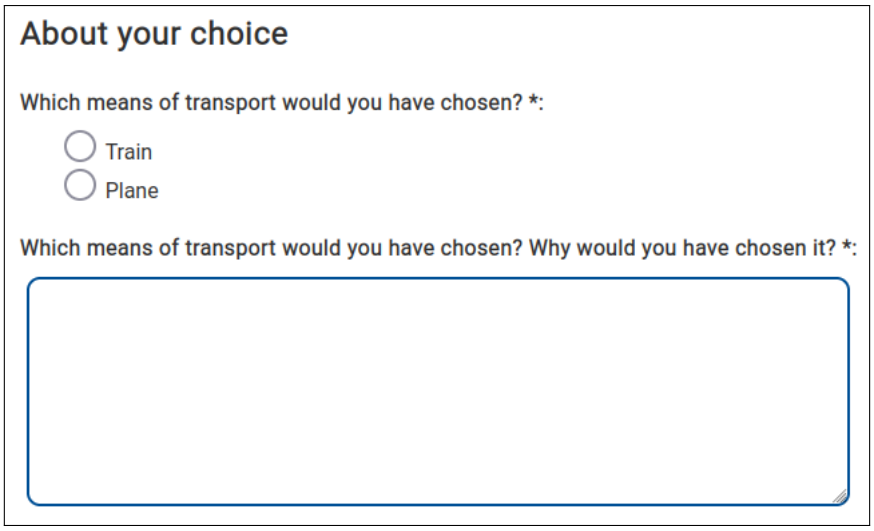

Figure 74: Screenshot of survey step ”Choice Scenario”, cf. Figure 7

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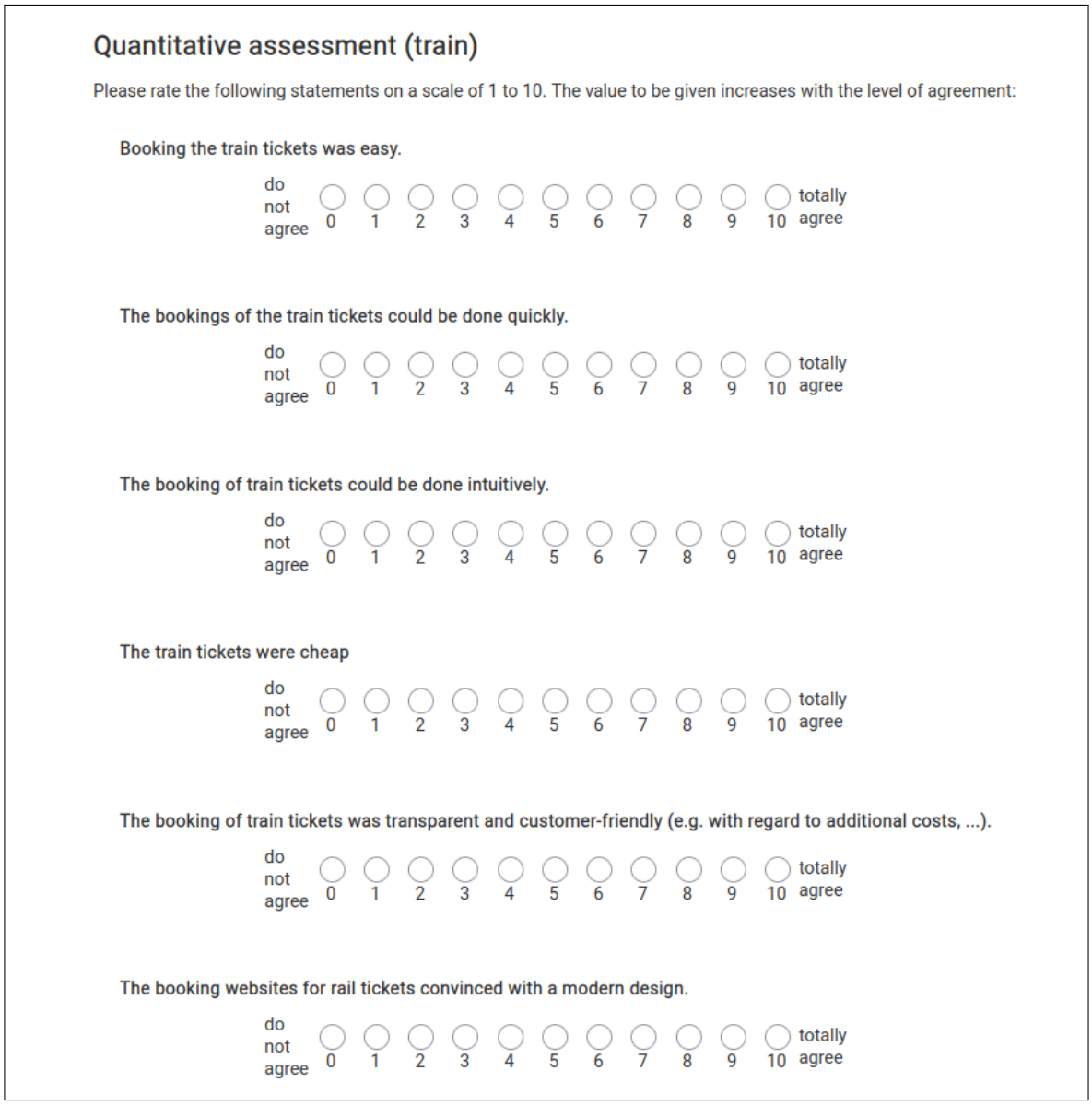

Quantitative assessment (train)

Please rate the following statements on a scale of 1 to 10. The value to be given increases with the level of agreement:

Booking the train tickets was easy.

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

The bookings of the train tickets could be done quickly.

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

The booking of train tickets could be done intuitively.

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

The train tickets were cheap

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

The booking of train tickets was transparent and customer-friendly (e.g. with regard to additional costs, ...).

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

The booking websites for rail tickets convinced with a modern design.

do not agree ○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9 ○ 10 totally agree

Figure 75: Screenshot of survey step ”Quantitative Rating of Rail Booking”, cf. Figure 7

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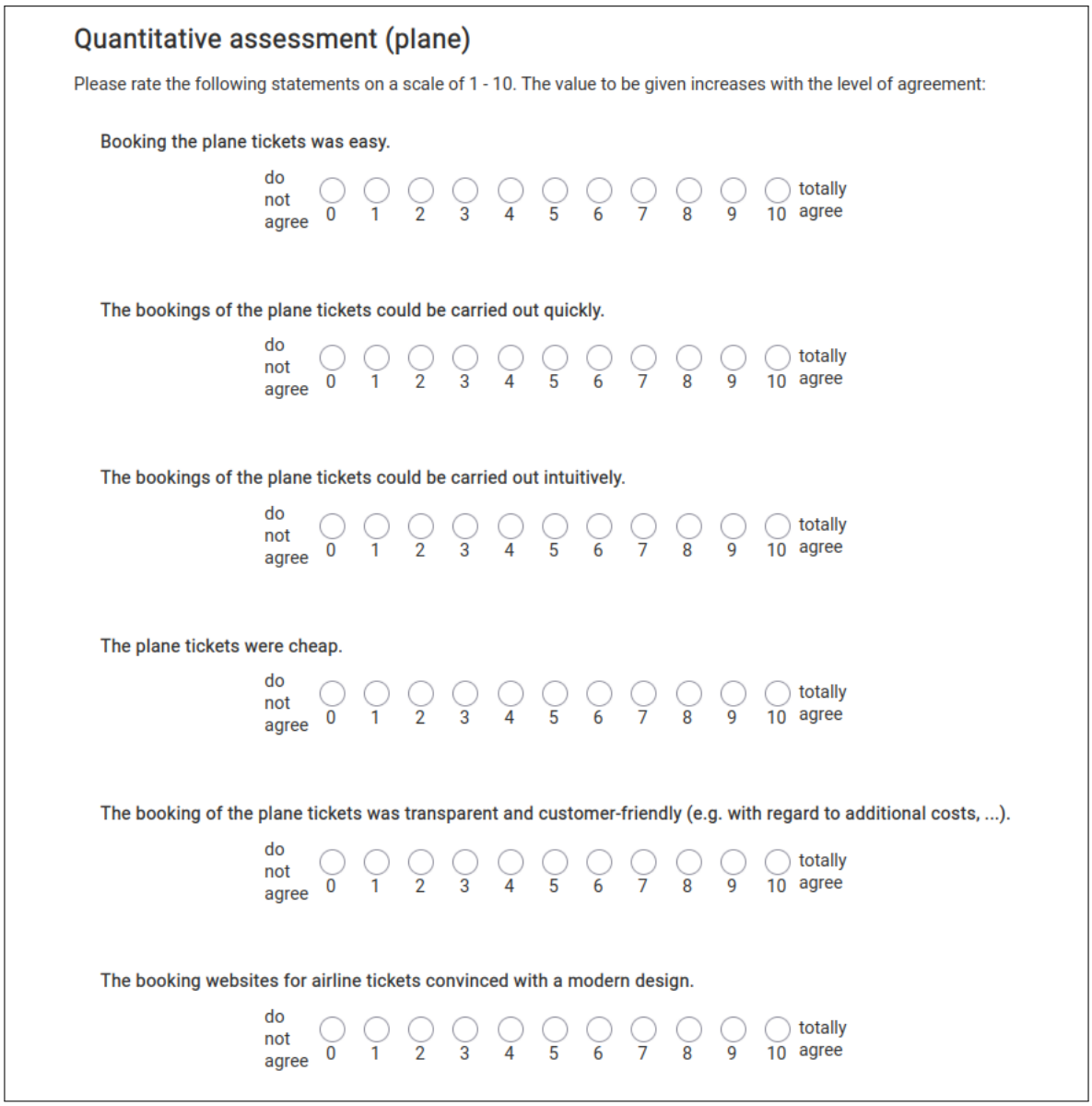


Quantitative assessment (plane)

Please rate the following statements on a scale of 1 - 10. The value to be given increases with the level of agreement:

Booking the plane tickets was easy.

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

The bookings of the plane tickets could be carried out quickly.

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

The bookings of the plane tickets could be carried out intuitively.

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

The plane tickets were cheap.

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

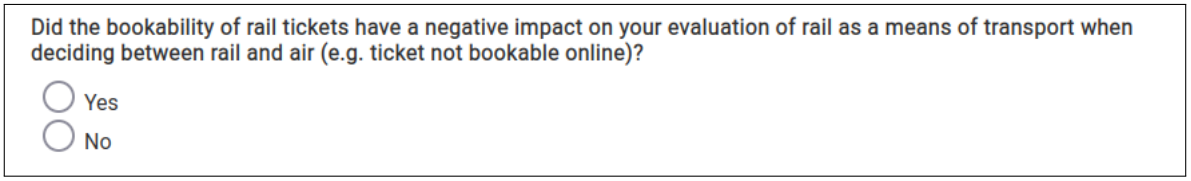
The booking of the plane tickets was transparent and customer-friendly (e.g. with regard to additional costs, ...).

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

The booking websites for airline tickets convinced with a modern design.

do not agree 0 1 2 3 4 5 6 7 8 9 10 totally agree

Figure 76: Screenshot of survey step ”Quantitative Rating of Flight Booking”, cf. Figure 7



Did the bookability of rail tickets have a negative impact on your evaluation of rail as a means of transport when deciding between rail and air (e.g. ticket not bookable online)?

Yes
No

Figure 77: Screenshot of survey step ”Did the Bookability Affect Choices?”, cf. Figure 7

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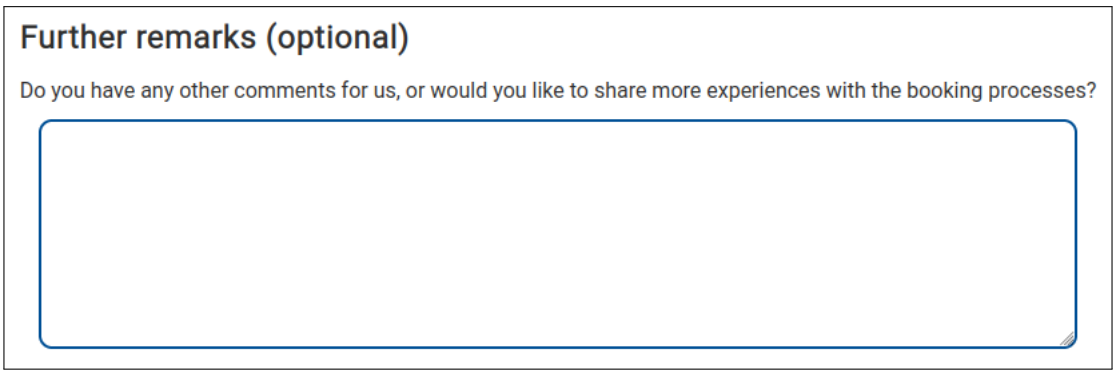

Figure 78: Screenshot of survey step ”Further Feedback”, cf. Figure 7

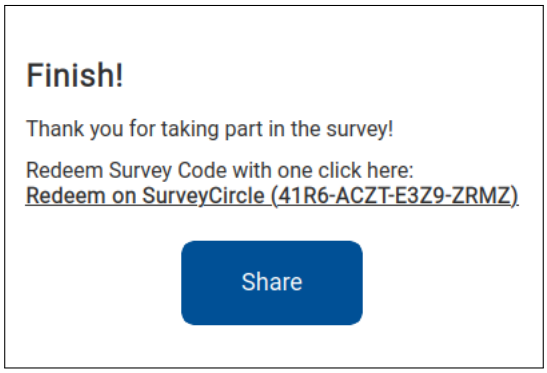

Figure 79: Screenshot of survey step ”End”, cf. Figure 7

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List of Relations

Vienna ↔ Berlin	Salzburg ↔ Hamburg	Amsterdam ↔ Copenhagen
Vienna ↔ Prague	Salzburg ↔ Hamburg	Amsterdam ↔ Reims
Vienna ↔ Warsaw	Salzburg ↔ Den Haag	Bratislava ↔ Cluj Napoca
Vienna ↔ Gdansk	Bucharest ↔ Sofia	Turin ↔ Geneve
Vienna ↔ Ljubijana	Lisbon ↔ Seville	Stuttgart ↔ Lyon
Vienna ↔ Rom	Lyon ↔ Milan	Ljubljana ↔ Zagreb
Vienna ↔ Rimini	Warsaw ↔ Amsterdam	Luxembourg ↔ Leipzig
Vienna ↔ Bern	Warsaw ↔ Frankfurt	Luxembourg ↔ Utrecht
Vienna ↔ Paris	Warsaw ↔ Budapest	Palermo ↔ Paris
Vienna ↔ Nice	Warsaw ↔ Prague	Klagenfurt ↔ Zürich
Vienna ↔ Madrid	Paris ↔ Madrid	Prague ↔ Kosice
Vienna ↔ Zagreb	Paris ↔ London	Zagreb ↔ Budapest
Vienna ↔ Rjieka	Munich ↔ Valencia	Eindhofen ↔ Nantes
Vienna ↔ Amsterdam	Munich ↔ Trieste	Hamburg ↔ Stockholm
Vienna ↔ Brussels	Madrid ↔ Porto	Toulouse ↔ Malaga
Vienna ↔ London	Milan ↔ Ljubijana	Oslo ↔ Malmö
Vienna ↔ Copenhagen	Manchester ↔ Saarbrücken	Kosice ↔ Sofia
Vienna ↔ Bucharest	Brussels ↔ Barcelona	Gent ↔ Bilbao
Vienna ↔ Timisora	Brussels ↔ Copenhagen	Groningen ↔ Oslo
Linz ↔ Naples		

Table 20: List of tested city pairs

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Test of Relations

from	to	Trainline	Omio	rail.ninja	Raileurope[10]	Incumbent[10] (from)	Incumbent[10] (to)	carrier names
Vienna	Prague	x	x	x	x[1]	x[1]	x[1]	ÖBB, CD
Vienna	Warsaw	o	o	x[2]	x[2]	x[2]	x[3]	ÖBB, PKP Intercity
Vienna	Gdansl	o	o	o	o[8]	x[2]	x[3]	ÖBB, PKP Intercity
Vienna	Ljubijana	x	o	x[4]	x	x	x[5]	ÖBB, SZ
Vienna	Rome	x[2]	x[6]	x[6]	x[6]	x[2]	x[6]	ÖBB, Trenitalia
Vienna	Rimini	x[2]	o	o	x[8]	x[2]	x[2]	ÖBB, Trenitalia
Vienna	Bern	x[2]	x[2]	o	x	x[2]	x	ÖBB, SBB
Vienna	Paris	x	o	o	x[2]	x[2]	x	ÖBB, SNCF
Vienna	Nice	o	o	o	x	o[7]	x	ÖBB, SNCF
Vienna	Madrid	x	o	o	x	o[7]	o	ÖBB, RENFE
Vienna	Zagreb	x	x	o	x	x[2]	o	ÖBB, HZPP
Vienna	Rjieka	o	x	o	x	x[2]	o	ÖBB, HZPP
Vienna	Amsterdam	x	x[2]	o	x[2]	x[2]	x	ÖBB, NS
Vienna	Brussels	x	x[2]	x[2]	x[2]	x[2]	x[2]	ÖBB, SNCB
Vienna	London	x	o	o	x[2]	o"	o	ÖBB, Eurostar
Vienna	Copenhagen	x	x[2]	o	x[2]	x[2]	x[2]	ÖBB, DSB
Vienna	Bukarest	o	o	o	o	x[2]	x	ÖBB, CFR
Vienna	Timisora	o	o	o	o	x[2]	x	ÖBB, CFR
Salzburg	Hamburg	x	x[2]	o	x[2]	x[2]	x[2]	ÖBB, DB
Manchester	Saarbrücken	o	o	o	x[2]	o	o	DB, Avanti Westcoast
Salzburg	The Hague	x	x[8]	o	x[8]	x[2]	x[2]	ÖBB, NS
Linz	Naples	o	o	o	o	x[2]	o	ÖBB, Trenitalia
Klagenfurt	Zurich	x	x[2]	o	x	x[2]	x	ÖBB, SBB
Amsterdam	Copenhagen	x	x	o	x	x[2]	x	NS, DSB
Amsterdam	Reims	x	o	o	x	x[2]	o	NS, SNCF
Warsaw	Frankfurt	x	x	o	x	o	x*	PKP Intercity, DB
Warsaw	Amsterdam	x	x	o	x	o	o[7]	PKP Intercity, DB
Prague	Kosice	x[2]	x[2]	x[2]	o[7]	x	x	CD, ZSSK
Zagreb	Budapest	o	x[2]	o	o	o	x	HZPP, MAV
Milano	Ljubijana	x	o	o	x	o[9]	o	Trenitalia, SZ
Lyon	Milano	x[2]	x[2]	o	x[2]	x	x[2]	SNCF, Trenitalia
Turin	Geneva	x	x	o	x	x	o[7]	Trenitalia, SBB
Paris	Madrid	x	x[2]	x[2]	x[2]	x	o	SNCF, RENFE
Paris	London	x	x	x	x	x	x	Eurostar
Brussels	Barcelona	x	o	o	x	x	o	SNCB, RENFE
Brussels	Copenhagen	x	x	o	x	x	x	SNCB, DB
Ljubljana	Zagreb	o	x	o	o	x[2]	o	SZ, HZPP
Eindhofen	Nantes	x	o	o	x	x	x	NS, SNCF
Munich	Triest	x	o	o	o	x[2]	x[2]	DB, Trenitalia
Stuttgart	Lyon	x	x	o	x	x[2]	x	DB, SNCF
Hamburg	Stockholm	o	x	o	x	x[2]	x[6]	DB, SJ
Luxembourg	Utrecht	x	x	o	x	x	x	CFL, NS
Madrid	Porto	o	o	o	o	o	o	RENFE, CP
Toulouse	Malaga	o	o	o	x	o	o	SNCF, RENFE
Luxembourg	Leipzig	x	x	o	x	x	x	CFL, DB
Warsaw	Budapest	o[7]	o	x[2]	o[7]	x[2]	x	PKP International, MAV
Palermo	Paris	x	o	o	x	x[2]	x[2]	Trenitalia, SNCF
Oslo	Malmö	o	o	o	o	x[2]	x	SY, SJ
Bratislava	Cluj Napoca	o	o	o	o	o[7]	o[7]	ZSSK, CFR
Kosice	Sofia	o	o	o	o	o[7]	o	ZSSK, BDZ
Gent	Bilbao	x	o	o	o	o	o	SNCB, RENFE
Groningen	Oslo	o	o	o	o	o	o	NS, DB, VY
Lissabon	Sevilla	o	o	o	o	o	o	CP, RENFE
Bucarest	Sofia	o	o	o	o	x	o	CFR, BDZ
Warsaw	Prague	o[7]	o	x	o[7]	o[7]	x[2]	PKP Intercity, CD
Munich	Valencia	x	o	o	x	o[7]	o	DB, RENFE

1)	Private operators not displayed	6)	Only nighttrain connections available
2)	Not all journeys bookable	7)	Timetable information but connection not bookable
3)	Ticket only available at the counter	8)	Seperate booking possible on site
4)	Only direct connections available	9)	Error occures when booking
5)	Customers are forwarded to DB	10)	Not showing any new entrances (e.g., WESTbahn, Regiojet, Italo)

Figure 80: Results of qualitative bookability checks

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List of Personas

Person	University student	School kid	Self-employed person	Retiree
Age	23	17	40	65
Job	Student	Student	Self-employed	Retired
Qualification	Moderate - High	Moderate	High	Low - Moderate
Intl. travel frequency	5x per year	2x per year	20x per year	6x per year
Public transport affinity	Hight - Commutes by train to university	Involuntarily high - rides the bus to school	Moderate - Uses public transport partially for business trips	Moderate - Likes to use public transport for longer distances
Budget	Low - Moderate	Low - Moderate	High	Low - Moderate
Szenario	City trip	Holiday	Businesstrip	Family visit
Booking for	1x Student	1x School kid	1x Adult > 65 years	1x Adult
Travel partner	1 Friend	2 Friends	-	-
Special needs	WIFI, Power, Reserve Seats next to each other	WIFI, Entertainment	WIFI, Power, Comfort, Dining Car, Ensured Connection	Luggage space, Reading light, Barrier free access, Entertainment
Sales channel	App, Desktop/Browser	Desktop/Browser	App, Desktop/Browser	Desktop/Browser
Information source	App, Internet	App	App, Internet, Business network	Travel Center, Kids / Grandchildren
Upfront booking	30 Days	30 Days	3 Days	30 Days

(a)

Person	Young adults	Third party booker #1	Remote worker	Young adult
Age	27 and 29	50	46	28
Job	Nurse / Cashier	State employed	Craftsman	Part-time employee
Qualification	Low - Moderate	High	Low - Moderate	Low - High
Intl. travel frequency	4x per year	3x per year	6x per year	3x per year
Public transport affinity	Low - Usually drive car and want to try public transport	Moderate - Uses public transport mainly for business trips	High - Does not own a car	High - Commutes by public transport
Budget	Low	High	Low	Moderate
Szenario	Städtetrip	Businesstrip	Vacation in the home country	Tour within Europe
Booking for	2x Adult	1x Adult (Colleague)	1x Adult	1x Adult
Travel partner	-	-	Colleagues	-
Special needs	Seat reservation next to each other, WIFI	WIFI, Power	Luggage space, WIFI, Ensured Connection	Ensured Connection, WIFI, Power
Sales channel	App, Desktop/Browser	Desktop/Browser	Internet	App, Desktop/Browser
Information source	App, Internet	Internet, Colleagues	App, Internet, Colleagues	App, Internet
Upfront booking	60 Days	14 Days	30 Days	60 Days

(b)

Person	Third party booker #2	Familiy with kids #1	Familiy with kids #2	Entusiast
Age	30	38	45	30
Job	Secretary	Teacher	Craftsman / Employee	Railway Employee
Qualification	Low - Moderate	High - Moderate	Low - High	Low - High
Intl. travel frequency	3x per year	2x per year	2x per year	10x per year
Public transport affinity	Low - Hardly ever rides public transport, only makes bookings.	Low - usually drive by car	Low - Children go to school by public transport	High - Train entusiast
Budget	High	Moderate - High	Low - Moderate	Moderate
Szenario	Bussinessreise für Mitarbeiter*in	Holiday	Holiday	Rail adventure
Booking for	1x Adult (Colleague)	2x Adults, 1x Kid 6y, 1x Kid 4y	2x Adults, 1x Kid 12y., 1x Kid 10y.	1x Adult
Travel partner	-	-	-	Friends
Special needs	WIFI, Power, Ensured Connection	Seat reservation next to each other, WIFI, Entertainment, Table	Plätze nebeneinander, WIFI, Entertainment, Table	Historical wagon material, unusual relations
Sales channel	Desktop/Browser	Desktop/Browser	Desktop/Browser	App, Desktop/Browser
Information source	Internet, Friends	App, Internet, Travel agent	App, Internet, Travel agent	App, Internet
Upfront booking	14 Days	60 Days	60 Days	7 Days

(c)

Figure 81: Details of personas partially used for participant selection

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