



INTERMODAL RAIL-AIR TRAVEL – RECOMMENDED FUTURE SERVICES

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Abstract – When travelling by plane, people often use private cars or taxis as a means of transport to the airport, or short-haul flights for longer distances. There are two main reasons why public transport or the train are often not used: 1) For many people, taking luggage to the airport is more complicated than using a car or a short-haul flight. 2) Many people are used to the ‘world of aviation’ but feel overwhelmed when using ‘unfamiliar’ systems (e.g. public transport in other countries). The AirWorld-Door2Door exploratory project investigated whether AI-based services could enable a seamless ‘aviation experience’ from door to door, utilising sustainable transport modes for the pre- and post-flight journey. Given the diversity of application areas and the complexity of AI usage, an initial exploratory analysis was conducted to identify existing gaps in appeal and appropriate measures. Based on this, systems were designed, such as facilities to facilitate baggage transport (e.g. through baggage drop-off on the feeder train) or a virtual escort service along the entire travel chain, which provides information tailored to personal needs at every stage of an intermodal journey. Real-time information is particularly important in the event of disruptions (e.g. service disruptions or delays) and targeted instructions on what to do to still reach the flight on time.

Keywords – intermodal transport, air-rail-services, baggage handling.

1. INTRODUCTION

When travelling by plane, people often use private cars or taxis as a means of transport to the airport, or short-haul flights for longer distances. There are two main reasons why public transport or the train are often not used:

- 1) For many people, taking luggage to the airport is more complicated than using a car or a short-haul flight.
- 2) Many people are used to the ‘world of aviation’ but feel overwhelmed when using ‘unfamiliar’ systems (e.g. public transport in other countries).

Most air travellers prefer feeder flights to feeder trains, for example on medium-distance routes. This applies in particular to people who live near regional airports and therefore have comparable alternatives. The same applies to the first and last mile to and from airports, which is often covered by taxi/rental car or private car rather than sustainable public transport. Cooperation between rail and aviation companies, such as AIRail in Austria, enables through-ticketing from the railway station and offers a connection guarantee in the event of delays. However, pre- and post-journey stages, including access to information, booking to and from the station, baggage handling, orientation during the journey, uncertainty about delays, ticketing, and navigation on the first and last mile, still often present major hurdles to using rail as a feeder service and/or public transport for the first and last mile.

The aim of the AirWorld-Door2Door project was to explore future organisational and technical possibilities, for example by using new technologies such as artificial

intelligence, and to identify measures that could be particularly suitable for offering air travellers a seamless door-to-door travel experience. The goal was to remove systemic barriers outside the traditional aviation environment, such as those affecting the first and last mile, and to significantly increase willingness to use sustainable alternatives for travel to and from airports. The members of the project consortium were: netwiss (project lead), TU Wien, N+P Experience Design, Flughafen Wien, Austrian Airlines, ÖBB, FH JOANNEUM Graz, Hilfgemeinschaft.

Desk research served as the foundation for all subsequent steps. Building on this, the following additional methods were applied:

1. Networking workshops and focus groups: An important task in the project was to bring together various stakeholders (travellers, passenger representatives, tourism representatives, public transport operators, railways, aviation, disability associations). The aim was to gain an in-depth understanding of the current challenges facing intermodal rail-to-air travel, both from the perspective of travellers and companies.

2. Surveys: Passengers were surveyed via Austrian Airlines and Vienna Airport about their reasons for (not) using sustainable mobility options when travelling by air and their requirements for future systems, using paper questionnaires and online surveys.

3. Internal concept workshops & system design: Within the consortium, the findings were discussed in depth in three workshops, during which services were conceived and defined to close current gaps using new

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technologies. Working groups within the consortium designed specific suitable systems, the potential suitability of which was continuously reviewed by the stakeholders in the consortium.

2. STATE OF THE ART

There are various approaches to improving the continuity of intermodal air travel chains, but so far no truly seamless service has been established in Europe that has generated correspondingly high demand. [1]

2.1. Cooperation models between railways and airlines

High-speed rail allows railways to compete directly with air travel on distances of up to 750 km. [2] This has led to cooperation between railways and airlines, which offer services such as check-in, baggage transport and ticketing. [3] Depending on the degree of cooperation, the offers are classified as follows: [4]

Low: Quick arrival/departure to/from the airport, e.g. via Rail&Fly. [5,6] Through tickets are issued, e.g. from Vienna Airport to/from the Austrian provincial capitals, which can be used for arrival/departure from any stop in the respective province. However, there is no seamless baggage handling and no "connection guarantee".

Moderate: There are codeshare agreements between railways and airlines, and the respective train is also assigned its own flight number. The advantage for travellers is that in the event of delays, necessary measures such as rebooking are taken care of by the airline or railway company (e.g. AIRail in Austria (ÖBB/Austrian), Lufthansa Express Rail in Germany (DB/Lufthansa) and tgvair in France (SNCF/AirFrance). However, there is no seamless baggage handling.

High: The so-called integration also provides for luggage transport, among other things. An example of this was the AIRail cooperation between Lufthansa and DB, where until 2007 travellers could check in their luggage at the check-in counters in Cologne and Stuttgart. [7] However, this service was discontinued due to a lack of appeal and profitability. Travellers now check in their luggage at the AiRail terminal in Frankfurt and collect it there on their return journey. [8]

In some cases, there are additional services for baggage transport. In Switzerland, for example, there is the SBB's "Fluggepäck" service, [9] which allows baggage to be dropped off at railway stations or even at an address. It is then transported to the destination airport, and the service also works in the opposite direction. The disadvantage is that in most cases, luggage must be registered at least one day in advance or will be delivered one day later on the return journey.

In several countries, e.g. Japan, it is possible to have luggage delivered to your hotel. However, when travelling to the airport, a lead time of up to two days is also required. [10] In several European cities, including Vienna, the company Airportr [11] offers the option of having luggage delivered directly to an address or picked

up from there in cooperation with Austrian and British Airways. In Vienna, when using the CityAirportTrain, it is possible to drop off luggage at the station in station Wien Mitte. [12] This can be done up to 75 minutes before departure, but only works for departures and not in the opposite direction.

In the TerminalAufSchiene research project, a system was developed whereby luggage can be dropped off immediately after boarding the feeder train for through AIRail bookings. The advantage is that, in Austria, all Railjet stops can be used, no station infrastructure is required for baggage handling, travellers do not have to be at the station early, and short transfer times can be achieved at the airport when changing to the aircraft, as baggage drop-off is no longer necessary. However, trial operations by Austrian and ÖBB [13] showed that the manual baggage unloading and transfer process to the airport sorting facility is cost-intensive and was therefore not pursued further, even though the system would be technically and operationally feasible.

Particular challenges in baggage transport on intermodal travel chains arise from travellers having to handle bulky luggage themselves, from the treatment of special items in external unaccompanied baggage services (such as bicycles or ski bags), and from legal requirements such as customs checks on entry.

2.2. Consistent provision of information and booking

Apart from rail or long-distance bus connections that are booked as part of the flight (e.g. AIRail, Rail&Fly, Lufthansa Express Bus/Rail), there are practically no connecting travel bookings or information available as part of the flight booking.

In tourist regions in Europe, often multi-day flat-rate tickets covering all modes of public transport can be purchased – sometimes free of charge. Information on this is often available online, with varying degrees of reliability, including on Google Maps. However, using such offers requires doing your own research, downloading several apps and registering, which can be daunting for the uninitiated due to the complexity and variety of booking systems.

2.3. Lack of planning security and deviations

Intermodal travel with many transfers and touchpoints (e.g. border controls, check-in, baggage drop-off) carries risks such as long waiting times, delays and missed connections. If you miss your flight through your own fault, you will not receive any assistance, such as rebooking. The complexity and risk make this option unattractive, especially for those unfamiliar with it, who either avoid the journey or leave too early, which increases travel time and reduces the appeal.

3. SYSTEMIC CHALLENGES IN EUROPE

The implementation of seamless intermodal mobility solutions in Europe is associated with considerable systemic, regulatory and technological challenges.

Compared to successful individual examples outside Europe, institutional fragmentation, heterogeneous market structures and complex legal frameworks are particularly inhibiting factors here. Key barriers can be divided into cooperation, regulatory, infrastructure and integration problems. At the cooperation level, diverging business models, fare logic and competitive interests make integration difficult. In air transport in particular, aggressive pricing models and dynamic fare structures mean that selective, low-cost flight offers are preferred over intermodal solutions. Different booking and distribution systems also prevent the establishment of uniform platforms. From a regulatory perspective, data protection requirements – particularly under the GDPR – pose significant barriers to cross-system data exchange. However, intermodal travel chains require precisely this data linkage to enable ticketing, information and service coordination. In addition, national transparency requirements and differing legal provisions lead to a fragmented legal situation that complicates cross-border solutions. Physical and infrastructural deficits also have a limiting effect. Uncoordinated timetables, a lack of integrated luggage systems, inadequate information services and insufficient barrier-free access impair usability. Deficits in charging infrastructure and bicycle parking facilities further reduce the attractiveness of sustainable options. The "last mile problem" thus remains a key obstacle to acceptance.

To overcome these barriers, seven areas of technological action were identified in the AirWorld – Door2Door project. Digital luggage solutions – such as:

- Automated drop-off points
- RFID tracking (Radio-Frequency Identification)
- Autonomous logistics and
- Biometric verification-address a key obstacle to convenience.
- Information and navigation systems based on
 - AR (Augmented Reality)
 - NLP (Natural Language Processing) and
 - Beacon technologies improve orientation and reduce cognitive barriers, especially for people who are unfamiliar with the system or have limited mobility.

Integrative booking and fare systems, such as one-stop-shop platforms with CO₂ transparency, dynamic pricing and open interfaces, can simplify travel chains, but face regulatory and economic constraints. AI-based forecasting models, multimodal re-routing and real-time communication offer relevant potential for dealing with irregularities. Accompanying and assistance systems enable personalised support along the entire travel chain, for example via digital travel companions and user-centred profiles. For the last mile, demand-responsive transport, ride pooling and autonomous micro-mobility are gaining in importance, but their availability varies from region to region. There are recurring challenges across all technologies: data protection, lack of interoperability, infrastructure requirements and unresolved responsibilities in terms of operation and

liability. The analysis shows that many technological building blocks already exist. The central challenge lies less in the development of new technologies than in their integration, standardisation and scaling. Common interface standards, robust data models and new forms of cooperation between transport companies and technology providers are crucial to success. The results thus form a viable basis for further system concepts and pilot projects.

4. SYSTEM DESIGNS

Based on the findings from the needs and technology analysis, different system concepts were developed that address various weak points along intermodal travel chains. These fall into three overarching development areas: Luggage logistics as the key to reducing congestion; Digital support, assistance and information; and System integration & connection logic.

4.1. Luggage logistics as the key to reducing congestion

A central focus was on separating passengers and luggage along the travel chain. The ideas range from early luggage drop-off at drop-off stations in rural and urban areas, to luggage rental models, smart luggage racks on trains, and autonomous door-to-door luggage services. Particularly noteworthy is the use of a smart luggage rack on trains, which can be unloaded directly at the airport and exchanged for an empty one. The rack would be designed so that it could be easily pushed out of the train by on-board staff in the low-floor carriage area. An autonomous and digitally networked transport vehicle (AGV) then can take over the onward transport across the platform to the airport's baggage handling system. This system would make it possible to check in baggage digitally during the train journey without the need for additional staff on the railway or airport side. In combination with end-to-end baggage tracking systems, this could create a high degree of transparency, security and control along the entire travel chain. At the same time, partial automation would make processes more efficient. For users, this would not only mean a more comfortable travel experience, but also a noticeable simplification of multimodal transfers.

4.2. Digital support, assistance and information

The second group comprises digital travel companion services, such as a VR/AR-based (Virtual / Augmented reality) assistant, uniform information interfaces and transparent booking tools. The aim of the concept is to provide in future travellers – especially those who are unfamiliar with the system or belong to vulnerable groups – with more consistent and accessible support.

Real-time navigation, situation-specific information and central booking interfaces could reduce uncertainty along the travel chain and noticeably improve service quality. Technically savvy unaccompanied minors would also benefit from these solutions, for example through interactive interfaces, simplified operating logic or

automatic notifications to caregivers – an additional benefit that could build trust and promote independence. Predictive travel planning could extend this approach by using individual preferences, routines and past behaviour patterns to intelligently plan future journeys – even when changing modes of transport or dealing with complex processes. The use of gamification elements will also become increasingly relevant in this context in order to strengthen user loyalty to digital services. Playful interactions, reward systems or progress indicators could enrich the travel experience emotionally, promote the use of digital tools and increase reuse – for example, through travel achievements, CO₂ savings targets or personalised recommendations. This could create new incentives to interact with sustainable mobility options.

In addition, the concept of a digital one-stop shop would be promising, where the entire door-to-door travel chain could be planned and booked centrally. Travellers would not only receive an integrated overview of available options, but could also transparently compare individual factors such as carbon footprint, travel price and duration. This would provide a sound basis for making sustainable travel decisions – tailored to personal priorities. The one-stop shop could also offer the potential to seamlessly integrate additional services such as travel insurance, support services along the travel chain or luggage options, thus making access to sustainable mobility significantly more accessible and user-friendly.

4.3. System integration & connection logic

A third area of development concerns the smart connectivity of individual mobility services, for example through a connection guarantee in public transport. In theory, digital travel data, real-time tracking and defined conditions could be used to ensure a reliable connection – for example, in the event of delays in upstream transport. A promising approach could lie in the use of existing real-time tracking technologies, such as those already used by ÖBB in SimplyGo for automated fare calculation. These technologies could be expanded to record the actual journey, not for billing purposes, but as proof in the event of a guarantee claim. This would allow passengers to travel with existing tickets (e.g. a yearly pass) and still benefit from a guaranteed rebooking in the event of a delay in the connecting service. The interface – for example, with the airline or an insurance partner – would define the time by which the point of departure must be left in order to trigger the guarantee. This would enable a transparent and automated system without additional effort for users and would build on existing infrastructure. In practice, however, it is clear that such concepts fail less because of technical limitations than because of organisational, regulatory and political constraints. A genuine connection guarantee in public transport is currently difficult to implement because responsibilities, fare responsibilities and liability issues are not uniformly regulated. The transfer of sensitive travel data between transport operators has also not yet been standardised

across the board. There is a considerable need for action here in order to make the technical potential systematically usable.

5. CONCLUSION

The system concepts developed were described at a conceptual level within the project and subjected to a qualitative assessment of their feasibility, potential impact, and scalability. This shows that:

- Many of the solutions presented are based on existing technologies or require only moderate further development.
- Obstacles are often not technical, but systemic – for example, in the cooperation between different actors, data transfer or regulatory issues.
- Pilotability exists above all where individual services can be tested in isolation (e.g. luggage drop-off, travel assistant, information interfaces).
- A particular lever lies in the intelligent combination of several system ideas, such as linked luggage racks, hybrid escort services or user-centred platforms.

The system concepts developed and the assessments of feasibility illustrate that the vision of a seamless, sustainable door-to-door aviation experience is conceptually and technically feasible – provided that the appropriate conditions for cooperation, data integration and governance are created. The ideas developed provide a sound basis for further pilot projects, demonstrators or in-depth planning in selected regions or use cases. Specifically regarding the topics of ‘automated baggage drop-off’ on trains and ‘end-to-end mobility support services for intermodal journeys’, the project consortium has already devised two concrete development projects and submitted them to the Austrian Federal Ministry for Innovation, Mobility and Infrastructure for funding.

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