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Integrated Door-to-Door Transport Services for Air Passengers: From Intermodality to Multimodality

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Abstract: Intermodal and multimodal door-to-door journeys refer to the usage of various transport modes (air, rail, bus, road or maritime) by the traveler to complete a single journey. The main difference between these two approaches is that multimodal transport is executed under a single transport contract (a single ticket) between the passenger, on the one hand, and transport operators, on the other hand. The benefits of this type of service are reflected in the potential to save time and money. Such systems would make the transport sector greener and more sustainable, promote growth and reduce carbon emissions. The purpose of this paper is to define the concept of an air passenger multimodal transport system, identify factors and challenges that determine such a system's development within Europe and to provide recommendations and directions for future research. The research carried out so far has indicated that market segmentation and transport system characteristics, as well as economic, social and political factors, have direct impacts on system development. This paper provides the basis for introducing single ticket, timetable synchronization and data sharing services, as well as the need to update the related regulations in order to move towards air passenger multimodality in both research and practice.

Keywords: multimodal air passenger transport; seamless journey; European transport market; door-to-door travel; data sharing

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1. Introduction

The terms intermodality and multimodality have been used commonly with reference to freight transport. The systems termed as above have been designed and used with a view to providing more efficient, effective and socially and environmentally friendlier door-to-door freight transport by combining various transport modes in consecutive order [1,2]. In intermodal freight transport, there is a separate contract for each individual leg of the journey, and accordingly there is more than one entity responsible for the successful achievement of the transport. In multimodal transport, one contract covers the entire journey. One operator takes sole responsibility and ensures door-to-door delivery is completed, even if other operators are involved in the journey [3].

Any journey involving air travel is by nature intermodal due to the combination of the trip to the airport via surface modes and the trip by air. On the other hand, analogously to freight transport, multimodality could also be considered for passenger door-to-door transport. Namely, air passengers have to access the origin airport via different surface transport modes and their systems in order to join the air transport service. Upon completion of the air travel, these modes and systems are again used from the destination airport to the final destination. The achievement of seamless multimodal passenger journeys is one of the goals of the Transport White Paper, which aims to establish a common European multimodal transport system with the potential to ensure that each mode of transport is carried out in the most efficient manner (in terms of comfort, price, speed, flexibility, reliability, etc.). Multimodality in this paper will imply the coordination and integration of different modes of transport. In this context, the main attributes of the fully coordinated multimodal service are given in Table 1, together with the corresponding attributes in the case of an intermodal, non-coordinated or partially coordinated service [4].

Table 1. Non-coordinated or partially coordinated vs. fully coordinated transport service attributes [4].

Non- or Partially Coordinated—Intermodal Transport	Fully Coordinated—Multimodal Transport
Separate tickets	Single ticket
Timetables—non-synchronized arrival/departure times causing longer waiting times at transfer points	Timetables—synchronized arrival/departure times among transport operators, enabling shorter waiting times at transfer points
Longer walking distance between terminals during transfer due to current location of terminals and stops	Better location of terminals and stops—shorter walking distance between terminals during transfer
Multiple information sources	Single information platform
Responsibility of passenger or transport operator involved (each mode independently)	Responsibility of passenger or responsibility shared among transport operators involved
Luggage check-in at the airport	Possibility of remote luggage check-in
Access facilities (elevators, ramps, vertical and horizontal escalators, automated people movers)	Additional access facilities at transfer between terminals and stations for all modes of transport

However, despite the existence of intermodality, coordination between different air and surface transport modes and their systems is missing at the larger scale, indicating the lack of the real multimodality. In general, such multimodality implies providing integrated door-to-door services to air passengers via a single transport operator similarly to air freight logistics service operators providing their integrated door-to-door services (DHL, FEDEX, UPS, etc.), ref. [5].

The objectives of this paper are as follows:

- Elaborate on the developments of integrated air travel through shifting from intermodality to multimodality;
- Consider the multimodal service within the European market;
- Identify major factors that stimulate multimodal transport demands;
- Emphasize and analyze the challenges and opportunities for development of multimodal service;
- Provide recommendations and research directions to move towards future air passenger multimodality.

In addition to this introduction, this paper is organized as follows. Section 2 provide a literature review and indicates the contributions of the paper. Section 3 presents the air transport system with the main relevant transport phases. The research methodology is described in Section 4. Section 5 contains the main findings in terms of relevant factors, challenges and opportunities in multimodal service development, including recommendations for future policies. Finally, Section 6 presents concluding remarks and future research directions.

2. Literature Review

In the relevant literature and related work, the terms intermodality and multimodality can be found to have different meanings. These terms have often been used with ambiguity, although they refer to different transport service concepts. In most of the cited papers in Table 2, the use of more than one transport mode within a given period of time is referred to as multimodality. Therefore, this paper contributes by clearly stating the differences between intermodality and multimodality. Namely, as mentioned before, intermodal passenger transport is the existing transport service, while multimodal passenger transport, which indicates a fully integrated transport system (as described in Table 1), is the future service that should be achieved.

Table 2. Selected papers on multimodality.

Reference	Problem Considered	Case Study	Aspects of Multimodality
[6]	Factors relevant to any competition assessment of air–rail intermodal agreements.	Europe	Considers only the link between air and rail, door-to-door is not considered.
[7]	Travel trends among young adults: declining car travel demand and the understanding of 'peak travel'.	Germany	Limited to city transport, without air transport
[8]	The environmental impact of introducing a high-speed air–rail link.	Spain	Considers only the link between air and rail, door-to-door is not considered.
[9]	How the change in urban mobility cultures affects the variability of mode choice (from urban monomodality to multimodality)	Germany	Limited to city transport, without air transport (multimodality—using different modes of transport without coordination)
[10]	Ways to improve public transport services by using intermodal passenger transport.	Romania: Timisoara	Limited to city transport, without air transport
[11]	Evaluation of Urban Public Transport intermodal hub quality through level of service—total transfer time.	Russia: Moscow	Limited to city transport, without air transport
[12]	Relation between high level of multimodality and less car use	England	Considers only ground modes, multimodality—using different modes of transport without coordination
[13]	Model for estimation of full door-to-door travel time between two cities using either the train or the plane.	Europe	Considers only total travel time in the current intermodal system
[14]	Survey of real door-to-door travel times in long-distance traffic by air and rail	Germany	Considers only total travel time in the current intermodal system
[15]	Provision of effective transport services for vulnerable populations and areas and identification of methods to overcome these challenges.	General	Limited to city transport, without air transport
[1]	Intermodality is a key solution for sustainable cities in terms of societal changes and mobility trends.	Berlin, Paris, Copenhagen, Hamburg	Limited to city transport, without air transport
[16]	Survey on multimodal choice behaviors of intercity travelers (airplane, High Speed Rail-HSR, traditional train, and express bus).	China: Xi'an	Multimodal choice, not multimodal trip
[17]	Different approaches to information sharing, common situational awareness and real-time collaborative decision-making between airports and ground transport stakeholders.	Europe	Considers systems to help integration of different modes
[18]	Factors which influence service quality of multimodal transportation of a hub with different types of public transport: metro, bus and rail.	Anand Vihar, Delhi	Limited to city transport, without air transport
[19]	Walking time distributions for transfers from bus to rail platform are examined (based on smart card data and automatic vehicle location data).	Denmark	Considers only walking time between two modes, without air transport
[20]	A bi-level model for a multimodal network design problem is developed.	General	Without air transport

Table 2. *Cont.*

Reference	Problem Considered	Case Study	Aspects of Multimodality
[21]	Air–rail integration: causal relationship between passengers' psychological and behavioral variables; identification of different passenger groups for service improvement.	China: Shijiazhuang Zhengding International Airport	Considers only the link between air and rail, door-to-door is not considered.
[22]	Designing a personalized multimodal travel service to recommend a route based on individual preferences, and to improve its performance.	China	Limited to city transport, without air transport
[23]	A route choice model for a large-scale multimodal public transport network. Metro, urban rail, local trains, regional trains and busses are included.	Greater Copenhagen Region	Limited to city transport, without air transport
[24]	Sustainable integrated transport and reduced bottlenecks in PT infrastructure, increasing the capacity of existing transport services.	Albania, Italy, Greece, Bosnia and Herzegovina, Croatia, Serbia, Montenegro, Slovenia	Without air transport
[25]	Future urban air-taxi services—models and algorithms for pooling and scheduling and for routing and recharging; synchronization of different transport modes.	General	Limited to city transport

Considering the selected papers given in Table 2, it can be observed that the research has been mostly limited to the city transport and has not included air passenger transport. Few papers have considered only the link between air and rail [6,8,21], while only [25] took into consideration air transport, although this was for future urban air mobility rather than passenger air transport. Additionally, the importance of transport system integration and its advantages, as well as the importance of data sharing in such a system, are indicated in [22]. Furthermore, possible issues related to data security and privacy are pointed out, but without proposing a solution. It should be noted that [17] also investigates data sharing with a focus on systems to help in the integration of ground modes and air transport. In order to fill the gaps in the literature, our approach considers different aspects of air passenger transport integration into a multimodal system.

3. Air Passenger Journey

Air passenger journeys are realized through five phases, from planning to ending, as shown in Figure 1.

Figure 1. Simplified scheme of the five phases of air passenger journey.

As can be seen, every journey begins with the planning phase when passengers consider their travel options before making a decision. This is followed by the phase of booking and purchasing tickets, when air passengers consider the available travel options related to the airlines and their services (time of departure, direct vs. indirect flights; other service attributes, such as priority boarding, extra legroom, lounge access, etc.), make a choice and purchase the service [26].

During the airport access phase, passengers mainly consider the selection of access transport modes and their systems in terms of availability, travel time and cost [27]. Airports and airlines can provide passengers with a variety of pre-flight and in-flight services, respectively. Airports usually deal with service quality by providing shuttle services, improved parking facilities, restaurants and shops [28]. Airlines provide online check-in and text messages and email notifications about flight delays and changes. Moreover, airlines have cooperated in the past decades through mergers, alliances and codeshare agreements and consequently improved their network connectivity, including facilitating passenger journeys at every step of their air travel (single ticketing for a set of flights, seamless check-in, bag tracking, etc.). Finally, the passenger post-flight phase, including immigration control, luggage processing and again surface access from the airport to the final destinations (doors), should be considered as well [29].

Taking the above-mentioned phases into account, a door-to-door journey for an air passenger actually represents an intermodal chain consisting of the following stages: access to the airport via different surface transport modes or systems, the airport and non-airport activities at the terminal(s) before the flight, the airline flight, the activities at the airport terminal(s) after the flight and egress from the airport to the final destination via different surface transport modes or systems. Traditionally, different transport modes and systems have been considered independently, particularly in terms of the funding and transport services providers involved. Despite the fact that particular transport service providers operate in this way, passengers usually consider their journeys altogether. This implies that when planning a journey, passengers consider the costs, convenience and complexity of the entire journey instead of a particular phase [30].

4. Research Methodology

4.1. General

Moving towards multimodality, air passenger transport is a very complex process that faces many constraints (e.g., new infrastructure, new measures) and resistance (e.g., passenger behavioral change, transport operators hesitate to cooperate). By using the five-step approach presented in Figure 2, we attempt to address this problem and provide some guidelines on how to move closer to the realization of multimodality. The research in this paper is exclusively related to the European transport market.

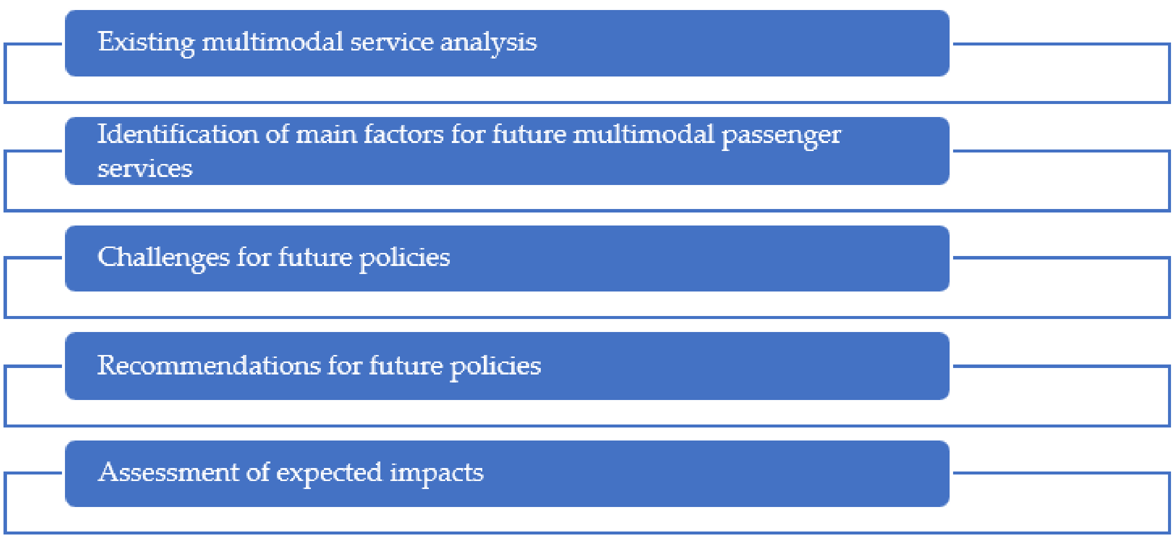

Figure 2. Five steps of the proposed research approach.

This process starts with an overview of the existing collaborations between transport operators in Europe, where at least one is from the aviation industry. An important step to understand the problem is to identify and define main factors that influence and shape the multimodal service (Figure 2). The factors are identified based on an analysis of the existing multimodal services, as well as on the basis of previous knowledge and literature related to the individual transport developments. Further, we discuss several challenges related to establishing a multimodal system and which set out the opportunities for improving the future transport system. Subsequently, a set of recommendations to overcome the presented challenges, in the form of pre-conditions that need to be met, is developed. The final step includes an assessment of the possible impacts of a multimodal system on passengers, the transport industry, the environment and policy makers.

4.2. Existing Multimodal Service Analysis

The existing examples of multimodal agreements among transport operators in Europe, of which at least one is from the air transport sector, are very limited, which are given in Table 3. The most common are the intermodal agreements between airlines and rail operators. Among these examples, one may observe two different approaches in developing this type of cooperation. The most common approach is that an airport–rail link is offered as part of a mainline rail or commuter rail service. This is a dedicated railway line that connects the main rail station in the city and the station at the airport terminal and is operated by express, intercity and commuter trains. In addition to passengers traveling to the airport, these lines are also used by passengers who continue their journey by train. The other approach is to build a rapid transit or light rail system between the airport terminal and the city center that offers a non-stop service with a high frequency. Along with air passengers, these lines are also used by employees who work in the airport area on a daily basis.

Either way, these agreements have found a level of political support in the European Union because certain environmental externalities can be reduced by transferring passengers from air transport to high-speed rail (HSR) or by lessening congestion at some European hubs that operate under capacity constraints [31].

Table 3. Existing multimodal agreements among transport operators in Europe and their characteristics.

Name	Contract Parties	Characteristics
Rail&Fly [32]	Deutsche Bahn-German Rail Company Airlines Tour operators	• Train ride from any train station to any airport in Germany; • Service can be booked only in combination with an international flight ticket; • The ticket price is reduced in comparison to when separate tickets for air and rail are bought; • For flight bookings in the economy class, train tickets are for the 2nd class, and for flights in the first class, train tickets are for the 1st class; • The ticket is valid the day before the flight departure, the day of the flight departure, the day of the flight return and the following day after the flight return;
***AIRail* (Germany)** [33]	Deutsche Bahn Airlines Lufthansa, American Airl. Emirates	• The service is provided from Cologne, Stuttgart and Dusseldorf to Frankfurt airport; • The ticket has the train number and flight number of the operating airline; can be booked in the operating airline booking systems; • Check-in for the final destination is enabled at the train stations in Cologne and Stuttgart, resulting in two boarding passes, one for the train and one for the flight; • When returning, passengers will receive the boarding pass for the train at the embarkation airport; • The luggage can be checked only at the departure airport.

Table 3. *Cont.*

Name	Contract Parties	Characteristics
***AIRail* (Austria)** [34]	Austrian Federal Railway (ÖBB) Austrian Airlines	• The service is provided from Linz and Salzburg main train stations to Vienna airport; • From Linz and Salzburg there are hourly AIRail connections; • Single ticket for the train ride and the flight; • Members of the Miles and More loyalty program earn awards and status miles on all AIRail trips.
City Airport Train (CAT) [35]	CAT Airlines-Austrian Lufthansa Eurowings Swiss Brussels Airl.	• A rapid non-stop connection between the city center and Vienna airport (travel time is 16 min); • Very important airport transfer alternative due to high punctuality rate (close to 98%); • 'City Check-In' service—a check-in hall within the CAT City Terminal with all the amenities of an international airport; the passenger receives a boarding pass and hands over flight luggage, free of charge; • Austrian ticket counter in the city terminal for rebooking or buying tickets, as well as free parking at the Wien Mitte car park.
Fly Rail Baggage Check-in [36]	Swiss Railway Zurich airport Berne airport Geneva airport	• Check-in flight luggage at 56 train stations in Switzerland and the boarding pass reception; the checked luggage receives its own IATA-Code; • At the destination, the luggage can be delivered to the specified address or the passenger can collect it from the local station; • The service is charged with fixed price for each bag.
Train + Air [37]	French National Railway (SNCF) Air France	• Available for international departures and arrivals at Charles de Gaulle and Orly airports; • Single ticket for the arrival or departure with the high-speed train (TGV) and the flight; • In case of late arrivals, it is guaranteed that the passenger will be rebooked for the next flight or train; • Members of the Flying Blue loyalty program earn miles on the train route; • Taxi transfer between Paris-Orly airport and Massy TGV train station is provided by Air France free of charge.

All of the examples mentioned above offer a number of potential advantages for the parties involved, i.e., airlines, rail operators, intermodal airports and passengers. They enjoy strong political support in Europe, in part because of the perceived contribution they can make to the achievement of environmental policy targets [38].

4.3. Identification of Main Factors Influencing Future Multimodal Passenger Service

In order to provide conditions that enable the introduction of complete multimodality in air passenger transport with air transport as the central mode, it is necessary to learn how passengers perceive the whole process and behave while making their choice of surface access mode on their way to and from the airport(s). Bearing in mind that air passengers have different preferences depending on the purpose of their journeys, it is important to gather information related to different categories and segments in order to understand their behavior.

In the following sections, the objective is to examine the key factors that influence the use of multimodal transport by passengers who travel by plane, namely air passenger segmentation, demographic and socio-economic characteristics, airport access mode choices and economic and political factors.

Air passenger segmentation: In air transport, there are two basic trip purposes: transport taken primarily for business and transport taken for a number of non-business reasons (e.g., holiday, visiting friends and relatives (VFR), education). Business travelers are time-sensitive and relatively indifferent to price, while non-business (leisure) travelers are price-sensitive and show more flexibility over travel time.

In addition to the trip purpose, air transport planners and researchers further segment the air travel market by applying different attributes. For example, the following approaches in passenger segmentation are identified: (i) the situational segmentation methodology based on grouping passengers according to booking preferences and travel requirements; (ii) the socio-economic segmentation approach based on personal and social characteristics, such as gender, nationality, religion, age, physical (dis)abilities (which may require special assistance, such as use of wheelchairs), relationship status, income, first language, occupation and education or qualifications, as well as whether passengers are traveling alone, in a social group, in a family group or with babies or young children; (iii) the psychographic segmentation approach based on criteria such as personal values, behavior and attitudes (trip motivation, destination, length of flight, length of total time away from home, travel class, cultural background of the passenger, airline preference, membership in an airline or alliance loyalty programme and environmental considerations) [39].

Passenger segmentation is the subject of many studies, and the two main groups, business and leisure, have been thoroughly examined, along with the various sub-segments in each of these two major groups. However, the sustainable development of air transport requires air services to be continually adapted and for new ones to be offered in order to serve more markets. In order to be viable, such services must be acceptable to air passengers, meaning the sustainable development of air transport depends on the willingness of passengers to use these new transport services.

Demographic and socio-economic characteristics and attitudes: Demographic and socio-economic characteristics have been proven to be critical determinants of transport mode choices, the most important of which that can be singled out are gender, household members, income and car ownership. Overall, younger people (the age group of 16–19) and older people (55+) are less likely to fly than middle-aged passengers. In terms of socio-economic groupings, the largest groups of infrequent flyers are junior managerial or skilled manual workers, with more frequent flyers than infrequent flyers within then middle and senior managerial staff groups [40]. Gender has been studied with regard to travel purposes, and it was found that men tend to travel more often than women for business, but women travel more often for leisure purposes. Gender differences in the peak age for travel only exist in business travel, with travel for women tending to peak earlier than travel for men [41].

Generally, in order to travel, passengers need to perceive traveling as safe, to have the confidence to travel and there need to be favorable economic conditions [42]. In air transport, the choices are reduced to choosing the airport, airline and transport mode to and from the airport. The purpose of air travel (e.g., business travel vs. non-business travel) has been proven to be a major factor when choosing among available airports [43,44]. With regard to airline choice, the fare is another decisive factor affecting the choice, whereby business passengers are willing to pay more for a shorter travel time than non-business passengers [44].

Airport access mode choice: Since the airport itself is not the primary destination, consideration must be given to access to the airport via different transport modes and systems. At most large airports, the surface access is provided by the road and rail transport modes. The former include cars, taxis and buses. Those of the latter include light rail transit (LRT), subway and metro systems, regional and national conventional rail and HSR systems, the Transrapid Maglev (TRM) system and the recent, futuristic hyperloop (HL) system. All of the abovementioned modes and their systems usually operate either through cooperation or competition. At smaller regional airports, the road-based transport mode is most frequently the airport surface access mode, i.e., cars, taxis and buses [45].

Factors influencing the choice of airport surface access mode are availability, access time, access cost, transport service frequency, reliability, resilience (resilience is commonly used to describe the ability of an entity or system to bounce back to a normal condition after its original state has been affected by a disruptive event [46]), punctuality, convenience of the arrival time at the airport, convenience of storing and retrieving luggage and whether the access involves transfers [30,47,48]. The access time and cost are directly proportional to the airport access distance for almost all access modes and systems across many European and US airports [45]. Among all options (e.g., car, taxi and public transport), car transport usually has the largest share due to the greater comfort, convenience, personal security and reliability perceived by passengers [49]. Thus, to become attractive alternatives, taxi and public transport options should meet passengers' needs and preferences by understanding the main factors that influence their choices.

Along these lines, access cost and travel times to and from the airport are considered the two most significant parameters that negatively affect the access mode choice regarding alternative-specific attributes [27,50]. Reliability is the next most important factor for air passengers, because late arrivals at the airport cause high amounts of stress due to the high possibility of missing a flight [51]. Some studies have shown that price is less important than time if a new, more reliable public transport system is available to access the airport [52].

Economic factors: The economic development of a region will impact both the amount of investment that may be made in the local transport system, as well as the travel behavior patterns of its residents and visitors [15]. Moreover, the economic characteristics of the population area that is served must be taken into consideration when allocating transport resources to allow for factors such as access to a private vehicle, working hours or other travel patterns, availability of funds for public transport fares, familiarity with the local transport network and other characteristics that may reflect the overall economic status of the prioritized area [53].

Many efforts have been undertaken to reduce market entry barriers and enhance competition; hence, the level of development in terms of fair competition varies across Europe. The process unfolds very slowly because the EU states are still protecting their companies, meaning there is a mixture of different national transport systems and not a single transport market.

Political factors: The multimodal transport concept does not operate in isolation; the multimodality is part of a large integrated transport system. For multimodality to be successful, policy makers at all levels (municipal, regional and national) must consider transport as a whole, not in unimodal segments. Therefore, to ensure maximum connectivity in multimodal transport, there must be no regulatory bottlenecks. Some of the regulatory bottlenecks can result from some other policy objectives, and these can have direct effects (e.g., safety and quality inspections and security measures) and indirect effects (e.g., cabotage restrictions such as restrictions on domestic transport) [54].

Legal diversity is often an obstacle to commercial operations between partners from different legal systems, i.e., different countries. Laws and regulations should be made compatible, promoting the free interchange of passengers from one mode to another.

5. Prospective and Future Developments

5.1. Challenges for Policies

The key challenges the transport industry will face in developing a multimodal service are primarily focused on how to create an attractive and efficient multimodal network. This section analyzes the main challenges, as they should provide valuable insight for future guidelines when building the corresponding transport policies.

Four hour door-to-door travel: The challenge of providing 4 h door-to-door travel within the EU (the goal set by Flightpath 2050 [55]) can be considered as an initial step towards multimodality in the given context. The concept of 4 h door-to-door journey time within the EU [13,56] is presented in Figure 3.

Here, t_{ga} is the surface access travel time from the origin to the departing airport; t_{pre} is the time that the passenger spends at the airport before boarding the flight (passport control, security control, waiting time and non-aviation activities, boarding time); t_{air} is the time spent on the flight; t_{post} is the time that the passenger spends at the airport after arriving (passport control, waiting time in the luggage claim, custom control); t_{eg} is the surface travel time from the arriving airport to the final destination.

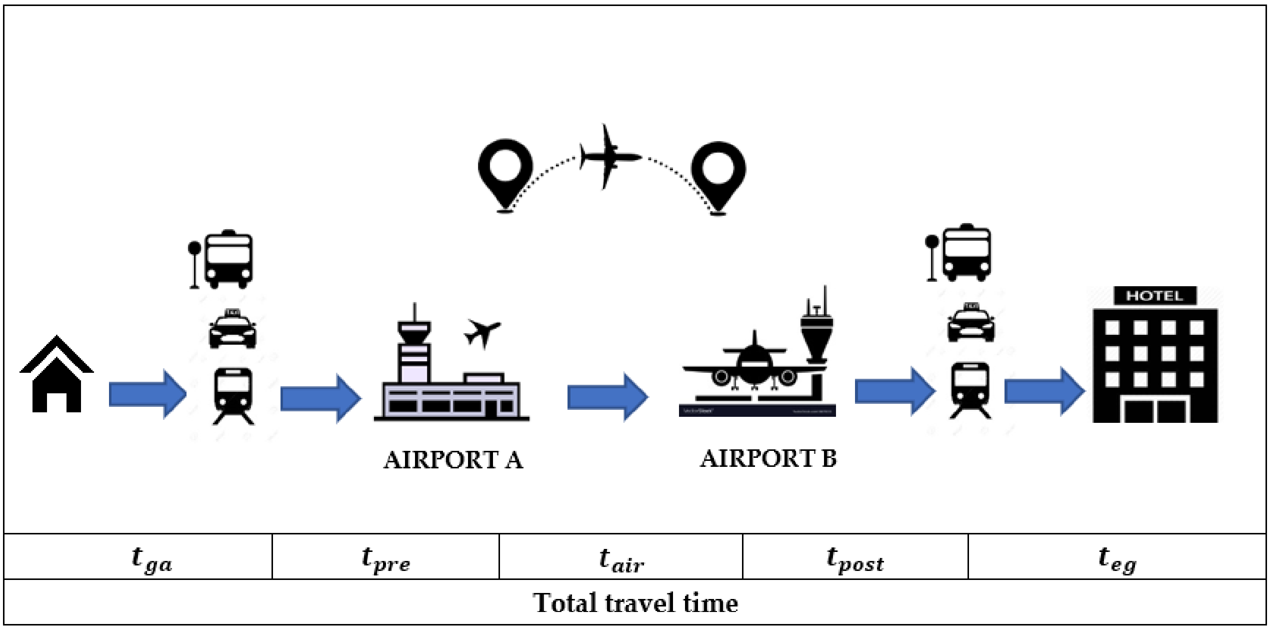

Figure 3. Door-to-door passenger travel time.

The 4 h door-to-door travel time via different airport surface access modes and their systems within the EU is difficult to achieve due to the time requirements for all parts of the travel chain [57]. Theoretically, 90% of trips involving **at least one flight segment** and airport access and egress **only by car** could be completed door-to-door within 4 h within and between the EU-28 member states [58].

Single ticket and payment system: Price integration across all transport modes has not been a common practice for transport authorities across the region and beyond, but it will make the multimodal system easier and facilitate transfers [59]. When purchasing a single ticket, the system should automatically calculate different price combinations from the beginning of the journey to the destination, allowing the passenger to choose the most suitable one. The revenue should be split between the transport operators based on the transport means the passenger traveled with.

However, a prerequisite for a multimodal single ticket and payment system is free access to price data from the transport operators involved. At present, there are no common EU rules on access to fare data (beyond the Delegated Regulation 1926/2017 on EU multimodal travel information services). This means that data are collected and made available in different formats only based on common standards developed by the parties of the commercial agreement [59]. The evident lack of interoperability between the application programming interfaces (APIs) of various stakeholders and the application of different standards, which additionally increase costs and discourage investment, is a technical challenge that has delayed the development of this system [59].

Synchronization of timetables: Another problem is working out how to synchronize timetables from different transport operators at intermediate points, such as railway stations, bus terminals or airports, in order to maximize the number of synchronized train or bus arrivals at transfer nodes (e.g., airports) or to minimize the total transfer waiting times experienced by passengers. Most of the European airports are very busy hubs where departure and arrival times are strictly given without the possibility of change. However, due to the large number of train and bus arrivals and departures per hour, it is not possible and not even necessary to make interconnections between all flights from a particular airport and arrivals and departures of other public transport modes individually. For small, secondary airports, which are not congested, timetable synchronization is much easier.

The most important criteria from the passengers' perspective related to timetables are synchronization at interchange nodes, operational reliability, information availability and supplementary services [60]. There are many different approaches and criteria leading to solutions for the timetable synchronization problem available in the literature [61]. Based on the overview of the proposed solutions, it can be concluded that there is not only one approach and one universal solution to this problem. Individualized solutions are necessary for each specific situation.

Luggage integration: The transport of luggage is one of the decision-making factors involved in the choice of transport mode. Despite the increasing costs and increasing traffic problems, the car is still the most popular means when accessing the airport, above all due to luggage handling. The reason is that compared to all other flexibility aspects, flexibility with luggage is highly valued [62]. Thus, the public transport must be highly attractive and should operate within the framework of an overall airport feeder system.

Around 130 airports worldwide have rail connections [38], with further railway connections being planned. However, there are only a few airport rail operators that offer an in-town check-in service for passengers to drop off their luggage before the flight at the central railway station (some examples can be found in Table 3).

Data sharing: Towards ensuring reliable and efficient operations, as well as accurate passenger information, many public transport systems today rely on digital information systems. However, transport operators appear to be more reluctant to share their data for the fear of it being misused [59]. Some of the data might not be suitable for sharing due to privacy, competition laws or commercial restrictions and concerns.

In order to create a multimodal ecosystem and to exploit the full benefits of digitalization, access to high-quality data, including data on routes, schedules, fleet availability, accessibility information, road works, traffic and disruptions, will have to be ensured [63]. This problem is further deepened by the fact that no common EU rules or standards for access to fare data exist (beyond the 2017 Delegated Regulation) [59]. This is the reason why data are still being collected and made available in different formats.

Revenue sharing: The most important concern of the stakeholders involved in multimodal transport is the matter of ticket revenue sharing. Public service obligations (PSOs), in particular, were highlighted as an obstacle for revenue sharing in integrated ticketing [59]. The integration of public (usually subsidized) transport services and commercially viable services can be difficult, because the subsidization of operations can serve to determine how transport operators can sell their tickets. PSO operators may be exempted from providing access to price data under clauses related to the subsidized prices [59]. This is why revenue sharing between multiple parties in a multimodal service system requires new models for price and revenue collections. A government body may be responsible for setting rules for cost and revenue sharing and for settling all transactions.

Responsibility sharing: When the transport service is provided by more than one transport operator and involves different transport modes, the rules of responsibility and the laws related to these operators are important points. The main question in terms of passenger rights and responsibilities is: When a journey is disrupted (e.g., in the case of a delays, cancellations, lost luggage and injury or death to passengers), who is responsible?

In the current system, if a journey is conducted by different transport operators, passengers may not be fully protected throughout their journey, because the existing passenger rights legislation may be applied independently to each individual transport mode [64]. In other words, passenger rights cannot be guaranteed when a disruption occurring during one transport segment affects the following one if the latter segment is operated via another mode of transport.

The existing multimodal services are generally based on cooperation agreements between an airline and a high-speed rail operator (Table 3). General terms and conditions regarding multimodal services offered by these transport companies do not seem to include any specific provisions addressing the issues of passenger rights in a multimodal context [64].

Thus, in the case of multimodal transport services that are sold under a single contract of carriage, it is very important to implement new measures (recommendations, rules, laws, etc.) that will provide a proper balance between protecting the passenger rights, on the one hand, and profit for the transport operators, on the other hand.

5.2. Recommendations for Policies

The conditions that made seamless door-to-door journeys in the European Union (EU) possible include technological progress, big data usage, strengthening of the EU and the synergistic attitudes of countries and companies [4]. The purpose of this section is to present recommendations concisely within the context of the development of a multimodal system.

Future air passenger segmentation: For door-to-door air passenger journeys, particular attention should be given to the following two segments: (a) empowered travelers who control their own trips, independently access the information, plan and reserve certain parts of the trip independently, react to plans and adapt them to the circumstances; (b) guided travelers who entrust most of their planning and delivery to agents and rely on them to possibly adjust the itinerary to new circumstances [65]. Six profiles of future air passengers have been identified (for the year 2035), reflecting major developments in the European transport market, as shown in Figure 4 [66].

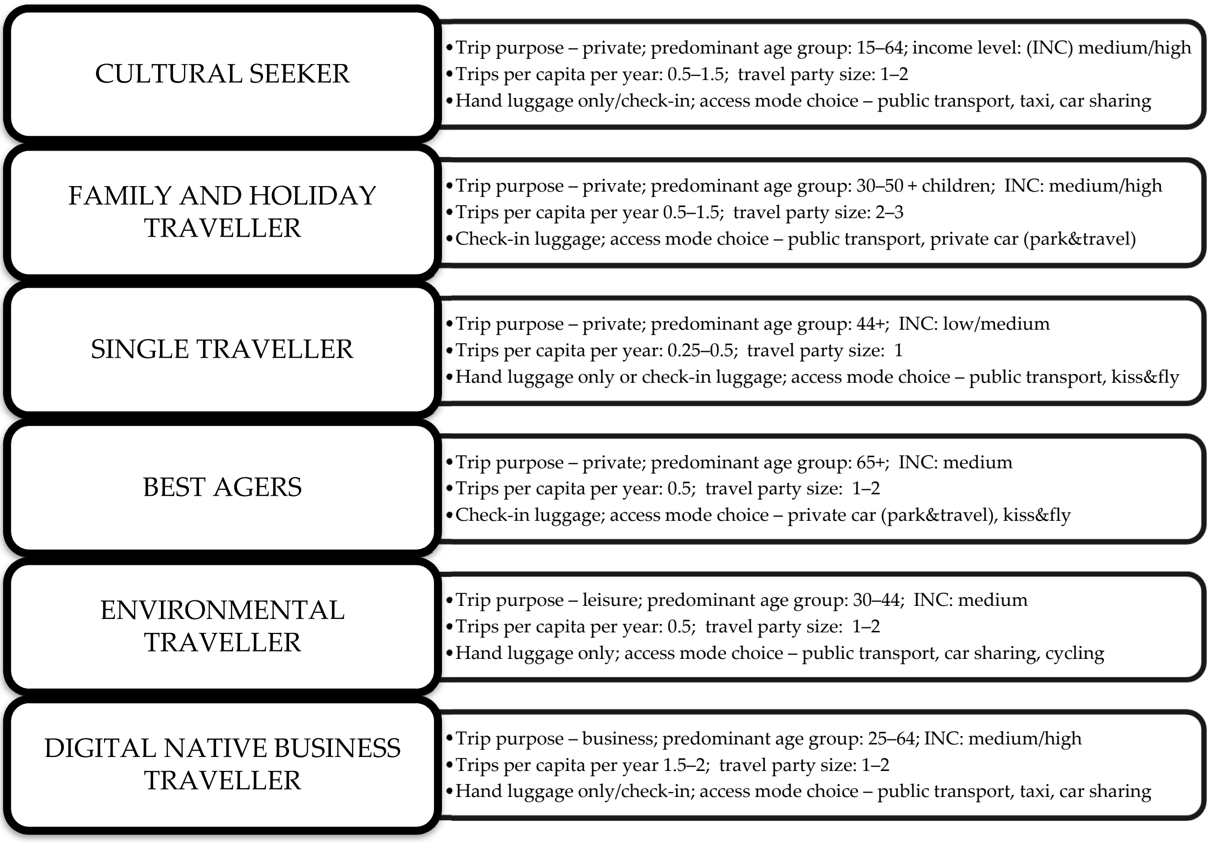

Figure 4. Future passenger profile identified in DATASET 2050 (data are taken from [66]).

What is certain is that the price will remain the main driver behind the customer's choice. Additionally, it can be expected that business travelers will still value their time above all. However, people are becoming increasingly concerned about the environment, which will further influence their travel choices. For one segment of passengers, simply traveling by air will not be enough and they will be looking for something extra. Some operators will pay special attention to adolescents and offer them special sections on their larger aircrafts for meetings, playing games and establishing friendships with people of their own age. The number of passengers from developing countries using air transport services for the first time is also expected to increase [67].

It is expected that the COVID-19 pandemic will influence the market segmentation in the airline industry [68] and in other modes of transport as well, so it is important to understand how air passenger traffic will evolve in the short term during the industry restart. Moreover, future market research efforts may indicate new segments based on passengers' attitude to travel due to the pandemic or other external global disruptions.

Harmonization of legal frameworks for multimodal transport operations: There has been an effort made to harmonize certain rules for door-to-door transport operations involving several modes of transport where the origin and destination are not in the same country. Directive 2010/40/EU7 provided the legal framework for the development of intelligent transport systems (ITS) and effective information systems and for the collection of traffic data throughout all modes of transport; however, the passengers' rights legislation remains mode-specific. In 2015, the European Parliament called in a resolution for a proposal covering multimodal journeys with clear and transparent protection of passengers' rights in the multimodal context, taking into account the specific characteristics of each transport mode and integrated multimodal ticketing.

As far as multimodal transport is concerned, there is no international treaty that covers transport operations involving more than one mode of transport that is in force and implemented. The starting points for developing these types of rules could be the existing agreements on the combined or intermodal transport of goods: (1) the European Agreement on Important International Combined Transport Lines and Related Installations (AGTC) and (2) the Agreement on Organizational and Operational Aspects of Combined Transportation between Europe and Asia. The AGTC defines a common infrastructure quality standard for combined transport in the main European transport corridors. It contains an annex that lists all of the lines and corridors to which this minimum standard will apply. The annex is updated regularly in light of information received from the participating states [69].

Four hour door-to-door journey: The Flightpath 2050 goal is to enable a door-to-door travel time of four hours or less for 90% of all intra-European travelers. Achieving this goal will require multimodal and procedural improvements to create a favorable operational environment that supports time-efficient and affordable travel. Generally, transfers from one mode to another have a negative effect on the overall travel satisfaction [70]. Thus, the satisfaction with trips with a large number of legs, such as metro, train and air trips, is expected to depend on the transfer experience. Thus, the overall passenger satisfaction can be improved by reducing these travel critical phases; however, this will not suffice. Reductions in airport access time must also be achieved, which will be made possible by upgrading airports into real multimodal transport nodes.

In general, the 4 h door-to-door journey time goal in Europe could be possible under the following conditions:

- Short-haul non-stop flights must be taken (flight duration should be approximately 1 h);
- The smooth movement of passengers and their luggage through the terminal must be ensured;
- An appropriate airport ground access system at origin and destination airports should be provided, along with high-quality infrastructure. Travel times will vary depending on the timetable (departure and arrival times), as well as the time of the day when the journey is taken (peak or off-peak);
- The location of origin and the final destination within the catchment area should be accessible within a determined time (no more than 45 min). Each airport has a catchment area, so the travel times to and from the airport will depend on the place where the journey begins and ends.

Single ticketing and payment system: For multimodal ticketing and payment systems, it is essential that the data are shared among transport operators and transport modes, because transport can be coordinated only if these are fed with quality data generated by the different transport systems [59]. The computerized reservation systems (CRS) used in the airline industry can be used as an example of good practice. This system is used for booking and scheduling information by travel agents on behalf of airlines, but it also provides information on hotels, car rental services and other activities. For this purpose, data sharing regulations were imposed on airlines both in the US and in the EU to force transparency and neutrality in the display of information via these platforms [59].

Another good example is the Finnish Act on Transport Services, which sets out three obligations to open up APIs. It mandates access to essential data concerning mobility services, the granting of access to a sales interface for single tickets or a reservation interface for transport and access to a sales interface when acting on someone else's behalf [59]. This act mandates that public service providers operating under a PSO comply with interoperability requirements. In addition, the relevant provisions of Regulation EC 1370/2007 on revenue allocation between the contracting authority and the transport operator provide the legal basis for appropriate interventions [59].

Synchronization of timetables: Timetable synchronization is a very complex problem affected by numerous other conditions and factors. The most important one is the transfer time between two modes of transport (i.e., arrival time of the vehicle from one mode and the corresponding departure time of the vehicle for the other mode). Transfer times that are too long can cause passengers to have to wait, meaning the attractiveness of this service will be low, while those that are too short can decrease the level of comfort and increase the stress caused by the fear of missing connections [71]. Another important factor is the demand distribution over time, due to the high demand variability.

Although it is very hard to propose a single solution in terms of timetable synchronization, some recommendations can be highlighted [71]:

- Shorter transfer times can be applied to those connections with predominantly business passengers because they travel frequently, alone, with less luggage and know the process very well;
- Longer transfer times can be applied to those connections with leisure passengers because they carry more pieces of luggage, usually travel in a group and often search for additional information;
- In order to cope with demand variations, time should be divided according to the transport extent (e.g., according to the day—working day, weekend—or according to the time of day—peak, off-peak, morning, evening, etc.) and the process should be optimized according to each individually considered time period with different operational features.

Luggage integration: There is great interest among air passengers in using the train for arrival to the airport if a luggage check-in system at the train station is offered [62]. This will certainly encourage a modal shift of the intra-European short-haul air-feeder traffic, as well as the airport-feeder traffic overall to the train.

Data sharing: In order for seamless multimodal transport to be achieved, mobility platforms are needed, although these require access to data. Moreover, data sharing among transport operators is also necessary because in this way it will be easier to coordinate their services [63]. However, data sharing regulations play an essential role in supporting sustainable mobility. An example of a data sharing policy framework is based on good practices from the existing policies and data sharing initiatives and consists of five interdependent and complementary layers [72]:

- *Use and analysis*: Policies to enable public, private or other third parties to access shared data and to ensure the ethical use of data to protect public interests.
- *Governance and accountability*: Policies that establish roles and rights of parties over their data and shape the structure of the governing bodies.
- *Data infrastructure*: Policies related to the development of physical and digital infrastructure to allow management over data resources and flows of data.
- *Data standards*: Policies to support the development and adoption of data and metadata standards to ensure interoperability across multiple stakeholders.
- *Data collection and merging*: Policies to enable the collection of data generated from diverse sources and the assembly of data sources within a data sharing initiative.

Big data opportunities: Digital transformations and the associated utilization of big data technologies (mobile phones, Twitter, credit cards, Google data, FlightRadar24 data, etc.) have created good opportunities by allowing the collection of unprecedented volumes of data across all modes and transport systems. In terms of door-to-door passenger journeys, the information that can be collected relates to the passenger profile, residence or accommodation at the destination, time of stay at the destination, places visited, frequency of trips, another factors. In the kerb-to-gate and gate-to-kerb terms, the obtained data could be used to identify and predict bottlenecks and to collect real-time information about airport services [73]. Information from personal mobile devices combined with information available from different stakeholders and infrastructure and vehicles could be used for short-term predictions of passenger flow, for strategy development and in case of disruptions [17].

Multimodal terminal transfer distance, speed and time: A multimodal passenger terminal has to ensure the efficient and safe transfer of passengers between road, rail and air transport modes. This is the point at which several modes of transport are physically and operationally integrated (a user-friendly walking environment between stations), which complement each other to facilitate the passenger's journey from origin to destination. In a multimodal system, airports are seen as the main multimodal terminals. Although building a new multimodal terminal has its advantages, this is a very time-consuming and costly option, especially within Europe. Another option is to adapt the existing airports to the requirements of this specific service by implementing new multimodal transport options.

A multimodal terminal should provide the following:

- Suitable local accessibility to the site for all users (especially the disabled);
- Platforms for passengers to arrive or leave the terminal;
- Direct access between different platforms for all modes of the terminal (rental car facilities, offsite parking, public transport and airport);
- Adequate facilities facilitating transfers between modes;
- Reduced travel and waiting times compared to the time needed for the same journey without a transfer;
- A common area to wait for transfers, where passengers can do other activities;
- Timetables and information desks for the different modes located all over the terminal.

Attractiveness: Attractive service features tailored to air passengers are essential for the acceptance of public transport. Most European cities have well-developed public transport networks, although the problem is that these networks work mostly independently from one another. This reduces the overall attractiveness of public transport in comparison to private cars.

To attract users, public transport must offer services that are fast, reliable and performed at high frequency. Additionally, public transport is expected to be safe and operated to high environmental standards. By making public transport seamless, more people could shift from using private cars to public transport for trips to the airport, which will in turn lead to less congestion, lower air and noise pollution and greater safety.

A successful multimodal transport system will require that passengers are provided with practical and reliable information about their journey in real time, such as potential changes, connection times, alternative routes and alternative transport options. Offering affordable tickets, ticket discounts and special services is also a way to quickly attract potential passengers.

Other requirements will be to facilitate market access and to protect fair competition by discouraging discriminatory practices. These will need to be accompanied by adequate enforcement measures.

Some other attributes that can attract people towards using public transport, i.e., the future multimodal service, are [63]:

- Simplifying the ticketing system with a user-friendly interface and customized and transparent reporting, along with multiple ticketing choices and ways to buy tickets;
- Facilitating seamless connections at all stages of the journey (providing better interchange facilities) and providing interoperable systems among transport modes;

- Increasing the system resilience, which will be of particular importance in multimodal systems, which tend to be more sensitive than individual transport systems because they consist of more than one mode of transport.

Multimodal alternatives: There are three business models operated under a single contract that can be implemented for multimodal transport:

1. A single contract resulting from an agreement between two or several operators to offer a multimodal product, in which one of the operators acts as the single contracting party towards the passenger. In such case, provisions regarding liability sharing are included in the agreement between the operators involved, e.g., Maas;
2. A single contract consisting of a product offered by an intermediate entity (such as an online seller or a tour operator, for instance), which includes transport services from all operators involved. The passenger enter a transport contract with the intermediate entity, e.g., charter airlines;
3. A single multimodal transport operator that has a fleet of vehicles (e.g., aircraft, trains, buses) at its disposal, either through direct ownership or under lease, and that offers the multimodal service as a single entity and has its own insurance coverage arrangements, since it will be accepting liability for the entire transport process, e.g., cargo integrators.

5.3. Assessment of Expected Impacts

In this paper, we address the potential impacts that the multimodal concept is expected to have on passengers, transport operators, the environment and policy makers.

The multimodal service is expected to have a positive impact on passengers in terms of providing better connectivity. The expansion of a transport network as a result of multimodal connectivity should bring about better links to regional and urban areas, which in turn should increase tourism, the city's attractiveness and the citizens' well-being. It is also expected that passengers will have access to an improved transport service with better legal protection if a disruption occurs during a multimodal journey [64]. In particular, this type of service should have positive impacts for people with disabilities as it will provide them with access to multimodal transport systems and services tailored to their specific needs [46]. In order to succeed in the market, this modal integration has to allow generalized cost reductions for some journeys [31].

Transport operators should benefit from the increased demand due to the improved connectivity and interchange opportunities, as well as the decreased congestion and better legal protection of passengers. By providing services from remote cities to airport hubs, surface modes can increase air passenger demand to their major market [6]. A multimodal service can help in linking different businesses and markets, which in turn should lead to improved operating efficiency and profitability.

Regulators and policy makers nowadays are constantly searching for transport solutions that will reduce congestion, pollution and energy consumption and increase safety. It is believed that such services will protect the environment by promoting transport modes that are more sustainable, i.e., by ensuring an optimal modal combination (a shift from the use of private cars to public transport) [8]. However, this will require the use of new communication and information technologies in order to provide passengers and transport operators with real-time data, to build new infrastructure to facilitate seamless transport and to adopt new policy measures specific to multimodal journeys (legislation).

6. Conclusions

A multimodal air passenger transport system is envisaged for Europe to optimize the comparative advantages of each transport mode involved to achieve more sustainable transport within and between countries. In order to provide seamless multimodal services, it is necessary to connect individual transport operators through efficient transport infrastructure and services at the national and international levels.

This paper proposes a systematic approach and recommendations based on an analysis of the main factors and challenges in developing a multimodal air passenger transport system and services.

These main factors include air passenger market segmentation, demographic and socio-economic characteristics, airport accessibility, economic conditions and political circumstances.

The main challenges in developing a functional multimodal air passenger transport system in Europe enabling 4 h door-to-door journeys within the EU include a single ticketing system, timetable synchronization and luggage integration, as well as data, revenue and responsibility sharing.

The recommended possible future actions to be undertaken in order to face the above-mentioned challenges and forthcoming trends for air transport system development are summarized as follows:

- Air passenger market segments must evolve due to the influence of digitalization and the increased use of new information technologies, along with changes in environmental and political awareness, which should be taken into account;
- The rules must be harmonized to cover the relationships between the operators of the different modes of transport involved, both nationally and internationally;
- New policy and legislative measures specific to multimodal journeys and related to data, revenue and responsibility sharing need to be adopted; special attention should be paid to the regulation of data sharing, since data sharing is the first step towards an integrated ticketing and payment system;
- New communication and information technologies should be employed in order to provide passengers and transport operators with real-time data;
- A remote luggage check-in system should be offered;
- Seamless connections should be facilitated at all stages of the journey (via better interchange facilities and timetable synchronization) to ensure the acceptance of public transport as a transport mode.

The ways in which individual transport modes and the environment interact can give rise to economic benefits, whereby the impacts of the multimodal service as a whole will be greater than when each service operates individually. However, the impacts of each transport mode and the overall multimodal performance will vary across the markets. The success will depend on transport infrastructure developments, access to facilities, passenger attitudes and behavior and economic factors. Therefore, an appropriate strategy should be developed for each market, setting the main priorities that cover all modes of transport and striving to achieve a fair and efficient single market. After this, the priorities for each individual transport mode should be addressed.

Regardless of the prevailing circumstances, these recommendations are fundamental to allow the multimodal service to operate optimally while reducing congestion and emissions. It is expected that private and public transport operators, as well as governments, could use these results as guidelines for a feasibility study of multimodal transport.

Further research on the topic of air passenger multimodality systems could be performed as follows:

- A thorough impact assessment of the participants in future systems;
- Strategy and scenario planning and studies on data usage and passenger rights in a multimodal operation environment;
- Evaluations of the already established and conceptual systems;
- Examinations of the willingness of transport operators and passengers to use fully integrated multimodal air passenger transport systems through interviews or surveys.

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References

1. Goletz, M.; Haustein, S.; Wolking, C.; L'Hostis, A. Intermodality in European metropolises: The current state of the art, and the results of an expert survey covering Berlin, Copenhagen, Hamburg and Paris. *Transp. Policy* **2020**, *94*, 109–122. [CrossRef]
2. He, Z.; Navneet, K.; van Dam, W.; Van Mieghem, P. Robustness assessment of multimodal freight transport networks. *Reliab. Eng. Syst. Saf.* **2021**, *207*, 107315. [CrossRef]
3. Containerships. Available online: https://www.containerships.eu/news/intermodal-vs-multimodal-what-is-the-difference (accessed on 14 February 2022).
4. Kalić, M.; Kukić, K.; Dožić, S.; Krstić Simić, T.; Babić, D. SYN + AIR: D4.4 Impact Assessment of Data Sharing, H2020-SESAR-2019-2. Available online: http://syn-air.eu/wp-content/uploads/2022/05/SYNAIR-D4.4_v01.00.00_Submitted.pdf (accessed on 14 February 2022).
5. Bilotkach, V. Air Cargo. In *International Encyclopedia of Transportation*, 1st ed.; Vickerman, R., Ed.; Elsevier: Amsterdam, The Netherland, 2021; Volume 5, pp. 258–262.
6. Chiambaretto, P.; Baudelaire, C.; Lavril, T. Measuring the willingness-to-pay of air-rail intermodal passengers. *J. Air Transp. Manag.* **2013**, *26*, 50–54. [CrossRef]
7. Kuhnimhof, T.; Buehler, R.; Wirtz, M.; Kalinowska, D. Travel trends among young adults in Germany: Increasing multimodality and declining car use for men. *J. Transp. Geogr.* **2012**, *24*, 443–450. [CrossRef]
8. Zanin, M.; Herranz, R.; Ladousse, S. Environmental benefits of air–rail intermodality: The example of Madrid Barajas. *Transp. Res. Part E Logist. Transp. Rev.* **2012**, *48*, 1056–1063. [CrossRef]
9. Klinger, T. Moving from monomodality to multimodality? Changes in mode choice of new residents. *Transp. Res. Part A* **2017**, *104*, 221–237. [CrossRef]
10. Rușet, P.; Ionescu, D.; Diaconescu, A.; Prostean, G. Transposing constraints into feasible alternative solutions by using intermodal passenger transport in Timisoara city. *Procedia—Soc. Behav. Sci.* **2018**, *238*, 331–339.
11. Kopylova, T.; Mikhailov, A.; Shesterov, E. A Level-of-Service concept regarding intermodal hubs of urban public passenger transport. *Transp. Res. Procedia* **2018**, *36*, 303–307. [CrossRef]
12. Heinen, E.; Mattoli, G. Does a high level of multimodality mean less car use? An exploration of multimodality trends in England. *Transportation* **2019**, *46*, 1093–1126. [CrossRef]
13. Monmousseau, P.; Marzuoli, A.; Feron, E.; Delahaye, D. Door-to-door Travel Time Analysis from Paris to London and Amsterdam using Uber Data. In Proceedings of the 9th SESAR Innovation Days, Athens, Greece, 2–6 December 2019.
14. Sauter-Servaes, T.; Krautscheid, T.; Schober, A. A Level Playing Field for Comparing Air and Rail Travel Times. *Open Transp. J.* **2019**, *13*, 46–58. [CrossRef]
15. Cottrill, C.D.; Brooke, S.; Mulley, C.; Nelson, J.D.; Wright, S. Can multi-modal integration provide enhanced public transport service provision to address the needs of vulnerable populations? *Res. Transp. Econ.* **2020**, *83*, 100954. [CrossRef]
16. Li, X.; Tang, J.; Hu, X.; Wang, W. Assessing intercity multimodal choice behaviour in a Touristy City: A factor analysis. *J. Transp. Geogr.* **2020**, *86*, 102776. [CrossRef]
17. Mujica Mota, M.; Scala, P.; Herranz, R.; Schultz, M.; Jimenez, E. Creating the future airport passenger experience: IMHOTEP. In Proceedings of the 32nd European Modeling & Simulation Symposium, 17th International Multidisciplinary Modeling & Simulation Multiconference, Virtual Online Conference, 16–18 September 2020.
18. Chautan, V.; Gupta, A.; Parida, M. Demystifying service quality of Multimodal Transportation Hub (MMTH) through measuring users' satisfaction of public transport. *Transp. Policy* **2021**, *102*, 47–60. [CrossRef]
19. Eltved, M.; Lemaitre, P.; Petersen, N.C. Estimation of transfer walking time distribution in multimodal public transport systems based on smart card data. *Transp. Res. Part C Emerg. Technol.* **2021**, *132*, 103332. [CrossRef]
20. Ye, J.; Jiang, Y.; Chen, J.; Liu, Z.; Guo, R. Joint optimisation of transfer location and capacity for a capacitated multimodal transport network with elastic demand: A bi-level programming model and paradoxes. *Transp. Res. Part E Logist. Transp. Rev.* **2021**, *156*, 102540. [CrossRef]
21. Yuan, Y.; Yang, M.; Feng, T.; Rasouli, S.; Li, D.; Ruan, X. Heterogeneity in passenger satisfaction with air-rail integration services: Results of a finite mixture partial least squares model. *Transp. Res. Part A* **2021**, *147*, 133–158. [CrossRef]
22. Xu, G.; Zhang, R.; Xiu Xu, S.; Kou, X.; Qiu, X. Personalized Multimodal Travel Service Design for sustainable intercity transport. *J. Clean. Prod.* **2021**, *308*, 127367. [CrossRef]
23. Nielsen, O.A.; Eltved, M.; Anderson, M.K.; Prato, C.G. Relevance of detailed transfer attributes in large-scale multimodal route choice models for metropolitan public transport passengers. *Transp. Res. Part A* **2021**, *147*, 76–92. [CrossRef]

24. Pazzini, M.; Lantieri, C.; Vignali, V.; Simone, A.; Dondi, G.; Luppino, G.; Grasso, D. Comparison between different territorial policies to support intermodality of public transport. *Transp. Res. Procedia* **2022**, *60*, 68–75. [CrossRef]
25. Bennaceur, M.; Delmas, R.; Hamadi, Y. Passenger-centric Urban Air Mobility: Fairness trade-offs and operational efficiency. *Transp. Res. Part C* **2022**, *136*, 103519. [CrossRef]
26. Amadeus. Future Traveller Tribes 2030: Building a More Rewarding Journey. Available online: https://amadeus.com/documents/en/blog/pdf/2015/07/amadeus-traveller-tribes-2030-airline-it.pdf (accessed on 14 February 2022).
27. Birolini, S.; Malighetti, P.; Redondi, R.; Deforza, P. Access mode choice to low-cost airports: Evaluation of new direct rail services at Milan-Bergamo airport. *Transp. Policy* **2019**, *73*, 113–124. [CrossRef]
28. Fodness, D.; Murray, B. Passengers' expectations of airport service quality. *J. Serv. Mark.* **2007**, *21*, 492–506. [CrossRef]
29. Midkiff, A.H.; Hansman, J.R., Jr.; Reynolds, T.G. Airline Flight Operations. In *The Global Airline Industry*, 1st ed.; Belobaba, P., Odoni, A., Barnhart, C., Eds.; John Wiley & Sons: Hoboken, NJ, USA, 2009; Volume 8, pp. 213–252.
30. De Neufville, R.; Odoni, A.; Belobaba, P.; Reynolds, T. *Airport Systems: Planning, Design and Management*, 2nd ed.; McGraw Hill Education: New York, NY, USA, 2013.
31. Román, C.; Martín, J.C. Integration of HSR and air transport: Understanding passengers' preferences. *Transp. Res. Part E Logist. Transp. Rev.* **2014**, *71*, 129–141. [CrossRef]
32. Rail&Fly. Available online: https://www.bahn.de/service/buchung/bahn_und_flug/rail-and-fly-english (accessed on 13 February 2022).
33. AIRail. Available online: https://www.lufthansa.com/ie/en/rail-and-fly (accessed on 13 February 2022).
34. AIRail. Available online: https://www.austrian.com/gr/en/airail-and-fly (accessed on 13 February 2022).
35. City Airport Train. Available online: https://www.cityairporttrain.com/en/home (accessed on 13 February 2022).
36. SBB Company. Available online: https://www.sbb.ch/en/station-services/before-your-journey/luggage.html (accessed on 13 February 2022).
37. Train + Air. Available online: https://www.airfrance.fr/FR/en/common/resainfovol/avion_train/reservation_avion_train_tgvair_airfrance.htm (accessed on 13 February 2022).
38. Chiambaretto, P.; Decker, C. Air–rail intermodal agreements: Balancing the competition and environmental effects. *J. Air Transp. Manag.* **2012**, *20*, 36–40. [CrossRef]
39. Wittmer, A.; Hinnen, G. Airline Passengers. In *Air Transport Management*, 1st ed.; Budd, L., Ison, S., Eds.; Routledge: London, UK; New York, NY, USA, 2016; Volume 9, pp. 139–150.
40. Graham, A.; Metz, D. Limits to air travel growth: The case of infrequent flyers. *J. Air Transp. Manag.* **2017**, *62*, 109–120. [CrossRef]
41. Collins, D.; Tisdell, C. Gender and Differences in Travel Life Cycles. *J. Travel Res.* **2002**, *41*, 133–143. [CrossRef]
42. Graham, A.; Kremarik, F.; Kruse, W. Attitudes of ageing passengers to air travel since the coronavirus pandemic. *J. Air Transp. Manag.* **2020**, *87*, 101865. [CrossRef] [PubMed]
43. Ashford, N.; Benchemam, M. Passengers' choice of airport: An application of the multinomial logit model. In Proceedings of the 67th Transportation Research Board, Washington, DC, USA, 11–14 January 1988.
44. Lee, J.K.; Kim, S.H.; Sim, G.R. Mode choice behavior analysis of air transport on the introduction of remotely piloted passenger aircraft. *J. Air Transp. Manag.* **2019**, *76*, 48–55. [CrossRef]
45. Janić, M. *Landside Accessibility of Airports, Analysis, Modelling, Planning, and Design*, 1st ed.; part of Springer Nature 2019; Springer International Publishing AG: Cham, Switzerland, 2019. [CrossRef]
46. Henry, D.; Emmanuel Ramirez-Marquez, J. Generic metrics and quantitative approaches for system resilience as a function of time. *Reliab. Eng. Syst. Saf.* **2012**, *99*, 114–122. [CrossRef]
47. Bolland, S.; Ndoh, P.; Ashford, N. *An Investigation of Ground Access Mode Choice for Departing Passengers*; Department of Transport Technology, University of Loughborough: Loughborough, UK, 1992.
48. Kazda, A.; Caves, R.E. *Airport Design and Operation*, 2nd ed.; Emerald: Bradford, UK, 2008.
49. Budd, T. An exploratory examination of additional ground access trips generated by airport 'meeter-greeters'. *J. Air Transp. Manag.* **2016**, *53*, 242–251. [CrossRef]
50. Bergantino, A.S.; Capurso, M.; Hess, S. Modelling regional accessibility to airports using discrete choice models: An application to a system of regional airports. *Transp. Res. Part A Policy Pract.* **2020**, *132*, 855–871. [CrossRef]
51. Tam, M.L.; Tam, M.L.; Lam, W.H.K. Analysis of airport access mode choice: A case study in Hong Kong. *J. East. Asia Soc. Transp. Stud.* **2005**, *6*, 708–723.
52. Jou, R.C.; Hensher, D.A.; Hsu, T.L. Airport ground access mode choice behavior after the introduction of a new mode: A case study of Taoyuan International Airport in Taiwan. *Transp. Res. Part E Logist. Transp. Rev.* **2011**, *47*, 371–381. [CrossRef]
53. Di Ciommo, F.; Lucas, K. Evaluating the equity effects of road-pricing in the European urban context—The Madrid Metropolitan Area. *Appl. Geogr.* **2014**, *54*, 74–82. [CrossRef]
54. APEC. The Economic Impact of Enhanced Multimodal Connectivity in the APEC Region, Asia-Pacific Economic Cooperation Secretariat. Available online: https://www.apec.org/Publications/2010/06/The-Economic-Impact-of-Enhanced-Multimodal-Connectivity-in-the-APEC-Region (accessed on 14 February 2022).
55. Flightpath 2050, Europe's Vision for Aviation, Report of the High Level Group on Aviation Research, DG for Research and Innovation. Available online: https://op.europa.eu/en/publication-detail/-/publication/296a9bd7-fef9-4ae8-82c4-a21ff48be673 (accessed on 14 February 2022).

56. García-Albertos, P.; Cantú Ros, O.; Herranz, R.; Ciruelos, C. Understanding Door-to-Door Travel Times from Opportunistically Collected Mobile Phone Records. A Case Study of Spanish Airports. In Proceedings of the 7th SESAR Innovation Days, Belgrade, Serbia, 28–30 November 2017.
57. Rothfeld, R.; Straubinger, A.; Paul, A.; Antoniou, C. Analysis of European airports' access and egress travel times using Google Maps. *Transp. Policy* **2019**, *81*, 148–162. [CrossRef]
58. Grimme, W.; Maertens, S. Flightpath 2050 revisited—An analysis of the 4-hour-goal using flight schedules and origin-destination passenger demand data. *Transp. Res. Procedia* **2019**, *43*, 147–155. [CrossRef]
59. Finger, M.; Montero-Pascual, J.J.; Serafimova, T. Towards EU-wide multimodal ticketing and payment systems. *Policy Briefs Florence Sch. Regul. Transp.* **2019**, *2019*, 19.
60. Kleprlík, J.; Matuška, J. The demand for public transport and modelling decision-making process of passengers. In Proceedings of the 21st International Scientific Conference Transport Means, Kaunas, Lithuania, 20–22 September 2017.
61. Wu, Y.; Tang, J.; Yu, Y.; Pan, Z. A stochastic optimization model for transit network timetable design to mitigate the randomness of travelling time by adding slack time. *Transp. Res. Part C* **2015**, *52*, 15–31. [CrossRef]
62. Ruger, B.; Albl, C. Terminal on Rail—Air Baggage drop off during train ride to the airport. In Proceedings of the 7th Transport Research Arena TRA 2018, Vienna, Austria, 16–19 April 2018.
63. Dožić, S.; Babić, D.; Kalić, M.; Kukić, K.; Krstić Simić, T.; Noutsou, S.; Ottomanelli, M.; Colovic, A.; Stroumpou, I. SYN + AIR: D4.1 Report on Planning and Operational Activities of TSPs, H2020-SESAR-2019-2. Available online: https://syn-air.eu/ (accessed on 14 February 2022).
64. European Commission. Rights of Passengers in Multimodal Transport. Available online: https://ec.europa.eu/smart-regulation/roadmaps/docs/2017_move_005_passenger_rights_multimodal_transport_en.pdf (accessed on 14 February 2022).
65. Laplace, I.; Marzuoli, A.; Féron, É. META-CDM: Multimodal, Efficient Transportation in Airports and Collaborative Decision Making. 2014. FP7 project. Available online: http://www.meta-cdm.org/Articles_AUN_2014-META-CDM_0.pdf (accessed on 14 February 2022).
66. Hullah, P.; Paul, A.; Schmalz, U.; Cook, A.; Gurtner, G.; Ureta, H.; Cristobal, S. DATASET 2050: D4.1 Current Supply Profile. 2016. H2020 project.IATA Vision 2050. Available online: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5af286431&appId=PPGMS (accessed on 14 February 2022).
67. IATA Vision 2050. Available online: https://www.iata.org/contentassets/bccae1c5a24e43759607a5fd8f44770b/vision-2050.pdf (accessed on 14 February 2022).
68. Kukić, K.; Dožić, S.; Babić, D.; Kalić, M. Delphi survey: The future of air transport in Serbia. In Proceedings of the XLVIII International Symposium on Operational Research (SYM-OP-IS 2021), Banja Koviljača, Serbia, 20–23 September 2021.
69. ESCAP (Economic and Social Commission for Asia and the Pacific). Harmonization of Legal Frameworks for Multimodal Transport Operations in Asia and the Pacific. Available online: https://digitallibrary.un.org/record/3881925 (accessed on 14 February 2022).
70. De Abreu e Silva, J.; Bazrafshan, H. User satisfaction of intermodal transfer facilities in Lisbon, Portugal: Analysis with structural equations modeling. *Transp. Res. Rec.* **2013**, *2350*, 102–110. [CrossRef]
71. Bulíček, J. Timetable synchronisation: Urban public transport in busy hubs of long-distance transport. *MATEC Web. Conf.* **2018**, *239*, 02001. [CrossRef]
72. World Business Council for Sustainable Development (WBCSD). Sustainable Mobility: Policy Making for Data Sharing. Available online: https://www.wbcsd.org/Programs/Cities-and-Mobility/Transforming-Urban-Mobility/Digitalization-and-Data-in-Urban-Mobility/Policy-to-Enable-Data-Sharing/Resources/Sustainable-mobility-Policy-making-for-data-sharing (accessed on 14 February 2022).
73. BigData4ATM, Passenger-Centric Big Data Sources for Socio-Economic and Behavioural Research in ATM, 2016–2018. H2020 SESAR 2020. Available online: https://www.sesarju.eu/projects/bigdata4atm (accessed on 14 February 2022).