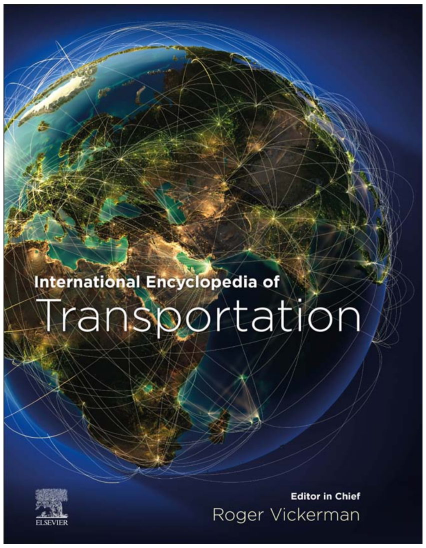

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Airport Network Planning and Its Integration with the HSR System

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Introduction

The aviation sector is one of the crucial components that facilitates and boosts the world economy, moving passengers and cargo from different origins in countries all over the world to the final destinations. In doing so, it needs the complementarity from other transport modes as it is not possible to imagine a single pure air door-to-door trip, so air transport is in essence multimodal. For this reason, it produces a lot of spill-over effects in other transport modes as well as in other economic activities. De Neufville and Odoni (2013) contend that the aviation sector in the early 21st century is characterized by three important trends: (1) Long-term growth. An increase of 4% per year worldwide has implied that the traffic has been doubled about every 15–20 years. Thus, airports' expansions and new developments have been the norm in the sector. (2) Organizational change. The economic deregulation of the sector as well as the new open-skies agreements have been spread worldwide following the good results observed in the United States and the European Union. The privatization of airlines and airports has created new opportunities in the sector. (3) Technical change. This has been mainly observed in aircraft and air traffic control, but ICT is also expected to disrupt all industries and it is obvious that the aviation sector will not be an exception. The new technology will reshape the way some airport processes are performed, especially for safety, security screenings, and border controls. The new developments will increase airports' efficiency and airports need to be ready to this new era of rapid changes.

The increased demand for flights produces in many circumstances some delays, especially in those congested airports that suffer from lack of adequate capacity and operate near to the maximum capacity during some periods of the day, some weekdays, or certain peak moments. The Airports Council International (ACI) (2018) publishes the Annual World Airport Traffic Report (WATR), and finds that all regions experience a growth with a passenger and air cargo increase of 7.5% and 7.7% in the years 2017 and 2016, respectively. The aircraft traffic movements increased only by 3%. All in all, the airports worldwide accommodate 8277.7 million passengers, 118.6 million metric tons of cargo, and 95.8 million aircraft movements. The center of gravity of the sector shifts eastward as most of the world's fastest growing large airports are located in emerging markets. Sixteen of the fastest growing top 30 airports with over 15 million passengers are located in just two countries, China and India, and 13 airports out of the top 30 busiest passenger hubs are nowadays located in the Asia-Pacific region.

The International Air Transport Association (IATA) (2018) publishes the Annual Review and concludes that in 2017 airlines provided a record number of regular services to more than 20,000 city pairs. This figure doubles the number of existing connections reported in the year 1995. In the period 1995–2017, the flight tickets prices decreased by more than half in real (inflation-adjusted) terms. Some capacity shortages have been detected as airport construction was not able to keep pace with the increase in demand for aircraft movements. In 2017, more than 190 airports worldwide were slot constrained because they had insufficient capacity to meet demand at all hours of the day. The growth in air transport demand is directly transferred into major airport project developments, and the norm is that a number of massive investment projects for airport expansions or new construction are evolving conjointly at any time. Besides expansions and new constructions of airports, the capacity and congestion problems can also be tackled by innovation. According to De Neufville and Odoni (2013), the US aviation sector has led the major innovations affecting the airport planning and design worldwide. Some of the major innovations found by the authors are the following: economic deregulation; Southwest LCC model; US open skies policies; airline alliances; integrated air cargo services; transfer hubs; midfield concourses; automated people movers; and global positioning systems.

Another interesting trend observed in the last 30 years is that governments and public companies are participating less in the aviation sector. Thus, the market forces are nowadays more important than the highly regulated political context of the past, in which the outcomes were better explained by political and national interests. The aviation sector is converging very rapidly to a worldwide global industry. Privatization or corporatization in the airport industry can increase social welfare by the improvement of cost

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efficiency, customer service, long-term investments, and innovation. The success of airport privatization or corporatization should be measured in terms of social welfare and not in isolated criteria like for example rates of return to governments or investors.

Similarly to the consolidation of the three global alliances, star, oneworld, and skyteam airports around the world have also explored whether the establishment of airport alliances, like for example, the Galaxy International Cargo Alliance (GICA), Aviation Handling Services (AHS), Pantares, and Aéroports de Paris (ADP)-Schiphol alliance will benefit the competitiveness of each individual airport. Technological spillovers and know-how transfer economic gains have been cited as the main motivations of this trend (Forsyth et al., 2010, 2011; Jiang et al., 2019). The results so far are not promising as most of the airport alliances have failed.

The new context is more oriented than ever to new commercial and economic challenges. Airport planners and designers are nowadays facing a variety of demands beyond the former petitions which were more oriented to standard norms. The business interests do not only include those from airlines but from different types of concessionaires. It is difficult to provide an exhaustive list of the main stakeholders involved in the airport network planning in a country but to cite some of them, it is possible to start with transport governmental policy makers, especially those working for the respective Aviation Administration Bodies, Airport Authorities or Aerospace National Agencies; consultants and practitioners whose professional careers are mainly developed in the field as, for example, CEOs of Airlines, Air Navigation Service Providers, Engineering and Architecture Firms, Oil Companies, Aircraft Manufacturers, Security-Planning-Environmental-Construction Companies, Parking-Airport Lounges-Retail, and Food and Beverages Development Solutions and Information and Communication Companies; and other CEOs of complementary and ancillary services, like for example, Air Traffic Control, Land Transport Companies, Railways, and Hotels. All these main stakeholders have different objectives, and this means that today airport planners need to think in terms of the social benefits taking into account multiple individual interests. De Neufville and Odoni (2013) summarize this by saying that the objectives of airport planners should consequently focus more on performance than on monuments with more low-cost and efficient terminals. Value for money, good service, and functionality are becoming the protagonists.

Airport planning guidance has been largely focused on individual airports, and less attention has been given to the interaction between airports at regional or national level, and to the interaction between the air transport and other transport modes at the time of developing intermodality. Nevertheless, Caves and Gosling (1999) highlight the need to analyze the context of the airport system when individual airport planning is considered. This need is supported by two main causes: (1) the existence of national or regional funding programs that aid airports' development; and (2) the emergence of multi airport city systems that exist in some important world metropolis. The interaction analysis is necessary because the catchment area of the airport developments in one jurisdiction might be extended to hundreds, if not thousands, of kilometers away. Thus, Caves and Gosling (1999) believe that the development of an integral planning of a system of airports, considering at least the main interactions between the airports and other transport modes, will result in a more efficient use of resources for a given provision of air transport services.

Morrel (2010) analyzes the European Commission's policy of encouraging airports to be intermodal hubs, highlighting that the successful cases will be based on something that airports and airlines have known for many years. The modal integration between air and other surface transport modes expands the airport's catchment area and enables airlines to compete in more origin–destination markets without providing additional air legs. High-speed rail (HSR) has been proven to be an excellent candidate for such development, especially as in the cases of Schiphol, Paris Charles de Gaulle, and Frankfurt International, where the HSR station is well connected with the airport and is fully integrated within the railways system. Thus, the passengers can travel from/to more destinations on the first or final leg of the trip without the requirement of making an additional connection. This is not achieved when there is a HSR direct connection between the airport and an important central station like, for example, the London Heathrow Express. The Commission's policy vision is aimed to move EU traffic from air to HSR, with alleged social benefits generated by the time savings, the better comfort provided by the HSR, the reduced congestion in the air approximation movements and the reduction in environmental costs.

The remainder of the chapter is organized as follows: "Literature Review" section reviews the previous studies highlighting mainly the integration between air and HSR. "Theoretical Models" section describes the analytical or theoretical models emphasizing mainly the modal integration between air and HSR. "Empirical Applications" section presents the main empirical applications on the topic. Finally, "Summary and Conclusions" section discusses the future research agenda and presents the main conclusions.

Literature Review

Jiang et al. (2017) highlight that the many of the airlines' hub-and-spoke networks could be used to complement air transport in the hub airports by HSR and other transport modes. Thus, one of the legs in which passengers are nowadays using the air transport will be substituted by HSR or other transport mode if a win-win situation is developed for airlines, HSR, terminals, and especially passengers. This type of integration has been mainly developed for HSR, conventional trains and interurban buses. It seems obvious that if HSR is a very competitive transport mode for trips of around 600 km, then these air legs can be substituted by HSR with an integrated service that can be viewed as a special type of "code sharing"—that is, two airlines cooperate to offer a hub-and-spoke operation with each offering one leg of a trip. Givoni and Banister (2006) analyze the possible relationships between air and HSR transport, finding three interesting states: competition, cooperation, and integration (see **Table 1**). The introduction of the HSR has given the chance to the railway to become a substitute to the aircraft on routes of about 600 km or a 1 h flight, and it has offered comparable or shorter travel times (from city center to city center). Therefore, transport modes have become substitutes for each

Table 1 Air and HSR relationship

	Market (city)	Relationships between air and rail		Rail link to airport?
		Modes	Operators	
Competition	City center (a) – City center (b)	Substitution	Substitution	No
Cooperation	Airport (a) – City center (a)	Complementary	Complementary	Yes
Integration	Airport (a) – city center (b)	Substitution/Complementary	Complementary	Yes

Source: Givoni and Banister (2006).

other since passengers can either use the aircraft or the railway. Considering that each transport mode is operated by a different operator, competition between them cannot be avoided.

Airports are located at the edge of cities and rail is usually used to access the airport. Therefore the two transport modes can be considered complementary since they both are chosen by users to travel from the origin to the destination and the service providers complement each other. This type of relationship defines cooperation since the two transport modes cooperate given that each mode is contributing and feeding traffic into the other network.

When railway infrastructure is provided at the airport, including the means for a fast and continuous transfer between the aircraft and the train, airlines can use railway services as spokes on their own services. While the airlines provide the service, the train companies can operate it and the two operators complement each other. The railway could serve destinations which were not served by the airline until now or could serve destinations already served. In the first case, the two transport modes work in a complementary way, that is, mode substitution does not exist, while in the second case transport mode substitution takes place and they are used in a complementary way (a flight and a railway journey are used in combination) and are substitutes (on one section either the aircraft or the train can be chosen).

As said, the integrated service should provide a win-win situation for the main stakeholders involved in such development. Jiang et al. (2017) find as the main driving forces of the cooperation the following: (1) Airlines win. Some short-haul flights are unprofitable and only provide value to the airline to maintain the network. Thus, some of the connecting trips can be substituted by HSR (Givoni and Banister, 2006); (2). Hub airports win. Some hub airports, especially in the EU, are very congested and intermodal cooperation can permit that some short-haul slots could be transferred to long-haul routes because passengers in the short-haul route are transported by HSR under this new integrated scenario (Givoni and Banister, 2006; Janic, 2011; Jiang and Zhang, 2014). (3) Society wins. Policy makers usually favor the intermodality because it is usually believed that network integration is more efficient than isolated transport networks as the integration permits to better exploit the network externalities. In addition, in short-haul routes, the substitution of air passengers with HSR passengers is environmentally beneficial (D'Alfonso et al., 2015, 2016). (4) Some foreign airlines win. Some foreign airlines do not have the freedom to enter in some domestic markets, but with the help of the integrated service, the airlines can make a detour and increase the market presence competing with other domestic airlines (Chiambaretto and Decker, 2012; Chiambaretto, 2015). As seen, there are many stakeholders involved, but, so far, airlines have been the more active agents of the integrated services, but it is true that policy makers, HSR operators, the hub airport and the passengers are also actively involved in such development.

Analytical models that analyze Air-HSR modal integration and change the focus from competition to cooperation started in 2010s (Socorro and Viecens, 2013; Jiang and Zhang, 2014; Avenali et al., 2018; Xia and Zhang, 2016, 2017; Jiang et al., 2017). In most of the cases, Air-HSR integration is studied throughout a very basic agreement and network features, in which the costs associated to the integrated terminal seem to come out of the blue. There are some exceptions, Avenali et al. (2018) consider the effects of the sunk costs of the integrated terminal, and Jiang et al. (2017) extend the previous papers considering two important features that were not sufficiently explored: (1) the basics of the network is extended because the HSR operator might cooperate with more than one airline; and (2) the type of modal integration is more heterogeneous, ranging from basic service that only considers a sort of protection agreement that covers major delays to more advanced integrated services with features like seamless tickets, dedicated carriage, coordinated scheduling, and baggage push. Nevertheless, dedicated carriage trains for the luggage are nor common, and there is an opportunity for other tertiary service providers that could take care of the O-D luggage traffic.

The Air-HSR modal integration phenomenon has emerged very intensively because of the existing interests of policy makers who have pushed toward the formation of some Air-HSR partnerships, especially in the EU. The empirical applications that deal with Air-HSR also started in 2010s but are less present in the international literature w.r.t. the theoretical ones (Román and Martín, 2014; Brida et al., 2017; Li and Sheng, 2016; Song et al., 2018). Moreover, it is odd to observe that the few empirical existing studies have not been used in the theoretical models to analyze the diversity of Air-HSR scenarios. The empirical applications have better grounds in the real world than the corresponding theoretical models. Thus, it is fair to suggest using the insights found in the empirical applications and to infer some proxies for the intervening parameters of the theoretical models.

Theoretical Models

Most of the international literature looks at transport mode alternatives in competition with each other proposing theoretical approaches to model this phenomenon. Not many are the contributions on the potential for their integration. Givoni and Banister (2006) argued that in the case of aircraft and HS train services the potential benefits from integration between modes and operators are greater than the benefits from competition. Indeed, the increase of the airport's capacity, through a railway station instead of a new runway, produces social-economic benefits at a lower environmental cost. Moreover, the presence of a railway station in an airport represents a step toward an integrated transportation system. Airlines use railway services as spokes in their network of services from a hub airport to complement and substitute for conventional air services. Railways play an important role in the future of air transport and the Givoni and Banister's (2006) recommendation was to extend the definition of air transport infrastructure in order to integrate the railways. This is fundamental in order to make policy makers thinking about the two transport modes as part of one transport network promoting airline and railway integration. Furthermore, it is necessary to guarantee adequate planning of railway services to and from airports. In order to provide direct, fast, and high-frequency services to many destinations from the airport, the airport itself should be a stop on a conventional railway main line and preferably also on a HSR line, with the result of having a terminal where all services can stop. This can be applied to large airports as well as to smaller ones, with some small modifications.

Grimme (2007) suggested that the decisive prerequisites of successful intermodal products were the availability of the comparable HSR journey time and the integration of airports into the HSR network. Moreover, he reported that very limited slots were freed for alternative use. Chiambaretto and Decker (2012) discussed some competitive issues associated with the AH intermodal agreements. The latter provide a number of potential advantages for airlines, rail operators, intermodal airports, and consumers of transportation services. These agreements involve a form of cooperation between airlines and operators that could, in principle, raise competition concerns. This is the case where agreements involve air and rail services that operate in parallel on a given route, and where the two services are potential substitute forms of transportation.

These contributions have demonstrated the advantages and disadvantages of air–railways integration services. However, they usually adopted a qualitative and descriptive approach and thus failed to quantitatively analyze the effects of the air–railways intermodality on the air transport markets.

Socorro and Viecens (2013) proposed a theoretical model to analyze the social and environmental impacts of airline and HSR integration in two different scenarios, that is, airports with capacity constraints and airports with low airline competition. They considered an economy composed of an oligopolistic sector and a competitive sector summarizing the rest of the economy. The theoretical model developed allows explaining formally why companies can benefit from air–rail integration. When mode substitution takes place due to integration, the companies that integrate can enjoy a higher market power. Moreover, if marginal costs are lower for the HSR, integration implies efficiency gains. It is also shown that integration is always profitable for the airline and for the HSR company when they have access to a new market due to integration. Moreover they showed that airline and HSR integration is more likely to be welfare enhancing if the airport is capacity-constrained. These results would justify, from a social point of view, airline and railway integration in airports that are highly congested.

Integration releases airport slots but the environmental question to promote integration is less straightforward given that more trips take place. In contrast, with no capacity constraints, integration does not necessarily imply a higher covered demand, and, in this case, mode substitution sets some trade-offs, that is, mode substitution is environmentally positive, but on the other hand, it eliminates competition in the market. They found also that in monopoly markets, the main impact of integration is to foster competition. When an airline and the HS train integrates, their combination results in an alternative way of traveling for passengers, thus removing the monopoly status of the airline that was already operating the market. Therefore, integration may introduce competition in markets where competition between airlines is low and particularly in those routes where the HS train is seen as a good substitute for the airline. In this case, integration would mean more competition and therefore lower prices, more variety for consumers, and higher social welfare.

Jiang and Zhang (2014) proposed a different analytical framework to address the welfare effects of air and HSR cooperation under hub airport constraint. They analyzed the economies of traffic density, and vertical differentiation between modes and heterogeneous passenger types. In their model, they assumed that the passenger demand function was specified as linear function. They found that such cooperation reduces traffic in markets where prior modal competition occurs but may increase traffic in other markets of the network. The cooperation improves welfare, independent of whether the hub capacity is constrained, as long as the modal substitutability in the overlapping markets is low. However, if the modal substitutability is high, then hub capacity plays an important role in assessing the welfare impact: if the hub airports are significantly capacity-constrained, the cooperation improves welfare: otherwise, it is likely welfare reducing.

Forecasting passenger demand for the intermodal service is important for stakeholders to evaluate the economic viability of the AH intermodal service. In practice, the passenger demand for such intermodal service is affected by various factors, such as connection time, the luggage through-handling service level, the integrated ticket price, and the competition from other travel modes. Chiambaretto et al. (2013) proposed a conjoint analysis to measure the willingness-to-pay (WTP) of passengers for using the AH intermodal service under different service levels. They showed the differences in the reservation price of passengers according to passengers' socioeconomic characteristics. Zhi-Chun and Sheng (2016) investigated the mode choice behavior of intercity passengers among air transport, HSR, and AH integration services. Stated preference surveys were employed and mode share models were estimated based on the collected data. The models developed were used to identify the key factors affecting users' mode choices and to estimate the modal share of passenger travel demand for some intercity transportation markets. Sensitivity analysis was carried out as well with the objective of revealing the market potential of the AH integration service. It was then demonstrated that when the intercity travel distance exceeded a threshold, passengers became less sensitive to the connection time of the AH service. The most competitive haul distance for the AH service was between 1200 km and 1600 km and the en route travel time was the most important factor affecting the market share of the AH service.

Empirical Applications

Since the introduction of the first HSR line connecting the cities of Paris and Lyon, many empirical applications have analyzed the competition between HSR and air transport for distances no longer than 1000 km (see e.g., Chang and Chang, 2004; Román et al., 2007; Jiménez and Betancor, 2012; Dobruszkes et al., 2014; Jung and Yoo, 2014; D'Alfonso et al., 2015; Zhao et al., 2018). In these contributions, the focus was mainly on the identification of the different factors affecting the competition between these two transport modes which are considered substitutes rather than complementaries.

On the contrary, the empirical literature regarding the integration or cooperation between HSR and air transport is less rich, considering that most of these studies focused on passengers' perception of the main attributes that define the level of service of a given transport mode choice context, namely, transfer time, in-vehicle time, luggage transfer services, effort or transfer convenience, degree of fare integration considering different levels of risk split, and access/egress time. As for the area of application, most of the case studies have been conducted in Spain, the leading European country in developing the HSR network, and more recently in China, which has the world's largest HSR network.

The first paper dealing with the analysis of the mode choice behavior in the context of the integration of air and HSR is that of Román and Martín (2014). This work is based on a discrete choice experiment where passengers traveling between Gran Canaria (Canary Islands) and some peripheral cities in mainland Spain are confronted with the choice between the current air–air alternative and an integrated and hypothetical air-HSR option, where several scenarios of integration are considered. Results show that the different components of travel time, specially that used in making the connection between the two modes, as well as the fare integration are highly valued by passengers. In contrast, luggage integration resulted only significant for those who check in luggage and travel for leisure purposes. In a later work using the same data set, Brida et al. (2017) investigate how different market segments, obtained from a previous cluster analysis, have an influence in being more proactive to change to HSR for the second leg in the multimodal trips. Specifically, the results "*confirm the existence of groups of passengers differing in terms of their preferences for integrated multimodal services. A group of individuals appear to gather extra utility for the Air-HSR alternative. The likely factors characterizing this segment are travelling to the central business district as the final destination; higher attitude to work or have a meeting during the trip; interest to use mobile phone and WIFI during the trip; and younger age*" (p. 931).

Li and Sheng (2016) conducted a stated preference survey to passengers travelling in four city pairs located along the Beijing–Guangzhou corridor in China considering air, HSR, and the integrated Air-HSR as the different transport mode alternatives. Different choice models were estimated in order to identify the main drivers affecting mode choice and to determine the potential market share for integrated Air-HSR services in China. They found that haul distances between 1200 and 1600 km make the integrated Air-HSR alternative more competitive, and the in-vehicle travel time is the most important attribute affecting the market share for this option.

In a more recent work, Song et al. (2018) used last generation choice models to analyze how the variety-seeking attitude affects travelers' preferences in the context of Air-HSR intermodality in China. These models are based on the methodological framework proposed by Ben-Akiva et al. (2002) that integrates a latent variable model into the choice model, and are usually referred as integrated choice latent variable models (ICLV) or hybrid choice models. The data used in the analysis were obtained from a survey conducted at Shanghai Pudong International Airport, where travelers responded to different choice tasks and provided information about some attitudinal statements regarding the variety seeking. Thus, in the proposed ICLV, the utility of the different alternatives is explained not only by their characteristics but also by the latent construct of variety seeking which in turn explains the attitudinal statements. The main research findings "*suggest that variety-seeking has different impacts across modes, where variety seekers would be more likely to choose the newly-introduced integrated HSR-air option whereas variety avoiders have a higher propensity to choose car-air or traditional separate HSR-air alternative*" (p. 99).

Summary and Conclusions

De Neufville and Odoni (2013) contend that policy makers need to think strategically and to be flexible in developing tools for airport planning, management, and design. The economic and financial outputs associated with airport operations are nowadays more important than ever due to the observed trend of more commercial and private airports. Technical engineering capability is no longer enough to deliver an optimal social welfare for airports' planning, and a system approach that considers other transport modes and the mobility dynamics of the region and country is compulsory. The standards created in the past for some governments and international agencies are nowadays outdated, as they were mainly based on the planning of an isolated infrastructure without measuring adequately the important interactions that exist with other airports and transport modes. An airport is not independent; it is part of a worldwide transport networks system that is more or less interconnected. Airport planners need to study these interactions, locally in its hinterland, domestically within the same country, and, internationally, analyzing each of the world regions. Conventional master plans have evolved into dynamic and flexible strategic plans.

De Neufville and Odoni (2013) also observe that many aspects of airport planning, design, and management are diverse across the world, regarding the level of innovation, the legal procedures or simply deep-grounded and traditional ways of doing. The cultural context usually imposes constraints on the main stakeholders involved in airport planning. The authors make the following list: (1) the role of central political power compared to that of the regions; (2) the permissible and desirable level of participation of private business; (3) the relative importance of technical experts and managers; (4) the criteria for excellent performance; and (5) the rights and capabilities of workers. They conclude saying that there is no single right answer—the concept of excellence depends on the context, and the "best practice" of one region may not be transferable to another. The authors find that, for example, in North America, the access to airports is mainly developed putting emphasis in the private cars and automobiles, so the provision of parking spaces is usually generous. Meanwhile, in the rest of the world, the emphasis is given to public ground transport, especially railways and HSTs.

Nowadays, an integrated approach between transport systems that facilitates intermodality such as rail and air services represents an important topic to discuss in the political agenda. It is considered a valid solution to the many transport problems that modern societies face (e.g., rising levels of accidents, emissions, and noise from transport) and plays an important role by enabling better mobility for travelers.

The sustained growth in demand for air travel has led airlines to rethink how they can maximize the effectiveness of their networks. One possibility is to improve the links with other transport modes. Intermodality at airports can involve a combination of: (1) accessibility to airports: local services between the airport and the neighboring city (e.g., via train); (2) complementary feeder services between the airport and the different parts of the surrounding region (mainly provided by buses, conventional trains, and more recently HSTs); (3) competing services between major city centers of neighboring regions; and alternative services that fully replace airline feeder services to airports (in general for those services of less than three hours' train ride).

Partial or full substitution for air can be considered successful on short- or medium-haul journeys of up to 3 h provided by a HSTs (e.g., between Brussels and Paris). In this case, the train link can also be used to complement air travel, which can be used for the return journey or even at the beginning or end of an intercontinental flight, thus requiring that rail and air schedules, fares, and other transport facilities are carefully coordinated (www.atag.org).

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