

Airport integration in the and rail network: case study of Beja Airport, Portugal

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Abstract

Integration between different modes of transport is a key-factor to increase the efficiency of public transport and a modal shift from cars. This is an essential contribution to the energy transition and to the achievement of greenhouse gas emissions and climate change targets stated in the European New Green Deal. This research is focused on the linking of two infrastructures which serve as long-distance transport hubs: airports and railway networks. Our case-study is the Beja airport in Portugal and the rail link between Lisbon and Beja. There has been a large discussion in Portugal about the creation of a new airport to substitute or complement the Lisbon airport due to its saturation. Recently, the Portuguese Government approved the installation of a new airport at Montijo. However, it has been involved in controversy due to its social and ecological impact, and the absence of a mandatory strategic environmental assessment. The hypothesis of this study is to use the existing, underused, Beja airport as the complementary airport for Lisbon. Beja should be primarily used for long-haul flights and have a high-performance rail link to Lisbon. The methodology comprehended the following: a survey targeting potential airport users and the population of the Alentejo region; a detailed analysis of the rail link to Beja and the air traffic in Lisbon to identify the improvements needed to the infrastructure; and computation of performance indicators to compare Montijo and Beja solutions. The survey shows public interest in the Beja alternative. The overall analysis shows that the qualification of the Lisbon-Beja rail line and the necessary expansion of the Beja air terminal will have an investment cost several times lower than the Montijo airport, with none of the major impacts, and more in line with commitments regarding climate change and energy transition.

Keywords: airport; railway; air-rail intermodality; air traffic segregation; modal shift.

1. Introduction

Facing climate change requires a reform of the economic and social model. The European Green Deal reinforces the commitment to promote more sustainable mobility based on decarbonization and energy transition towards carbon neutrality.

Railways are one of the most energy and environmentally efficient modes of transport, so it is crucial to invest on rail to reduce carbon emissions and to mitigate climate change (IEA, 2019; EC, 2021). Air travel is the preferred mode for long-distance travel, yet it has high energy consumption, high GHG emissions intensity, even at full capacity, and is one of the most challenging modes of transport to decarbonise (Givoni and Banister, 2007; IEA, 2019; Postorino et al., 2018).

The relationship between rail and airports can be defined in three categories: competition, when train and plane compete for the same journey; cooperation, which occurs when one of the modes complements or relieves the services of the other; and integration, which can vary between replacing or complementing the air service, becoming the most viable option for air-rail interaction as it provides a more fluid and convenient passenger experience (Givoni and Banister, 2006). Up to distances of 800 km it is possible to have competition between air and rail. The replacement of short-haul air traffic by rail and the connection of all airports to the rail network is mentioned in the White Paper on Transport as one of the strategies to achieve climate targets by 2050 (EC, 2011).

Evidence suggests that when a railway connection is materialised at airports, airport operators consider the complementarity advantageous because it enables the creation of new business models. Following the Hub-and-Spoke model, air-rail integration can occur, for example, when the journey from the hub airport to the destination airport can be made by train (spoke) instead of a second flight. Givoni and Banister (2007) refer a set of criteria that can make air-rail integration feasible and efficient, namely: ticket integration, proximity between terminals, baggage handling, timetable synchronization, and frequent services (Postorino et al., 2018).

Lian and Rønnevik (2009) and Givoni and Banister (2007) point out that air passengers value more the time of access than the distance, so they are more predisposed to travel to a more distant airport with cheaper fares and better service. On leisure travel, as there is a greater volume of luggage to be transported, passengers are willing to pay more for modes of transport that value the passenger experience and comfort, and provide intuitive and safe baggage handling during long journeys to access the airport (Pels et al., 2003; Tsamboulas and Nikoleris, 2008).

Air travel is considered a decisive factor of regional development and quality of life, however, the existence of transport infrastructure does not dictate development, but the opposite. The market and viability of an airport depends on the social and economic dynamics that will determine the need for transport (e.g. population, flight propensity, economic activity and access time), and the services that the airport offers (Postorino et al., 2018). In Portugal, Melo et al (2020) propose a doctrine for the use of railway as the mainstay of in-country long distance passenger mobility, including the transfer of all regional air traffic to rail.

Before the pandemic, Lisbon airport, located on the city limits, was approaching saturation. Several solutions have been proposed, but all have severe limitations. A strategic environmental assessment is

required by European and Portuguese law for major regional-scale transport developments such as a new airport. However, such a study was not carried out, even though the government already approved the construction of a new airport at Montijo, located at 40 km from Lisbon and close to the Natural Preserve of the Tagus estuary to complement Lisbon airport. Among other solutions, the existing Beja airport was never considered to be a viable alternative due to its distance from Lisbon (170 km).

Based on the doctrines of complementarity between airport and railway and air traffic segregation, this paper examines the possibility to consider the underused Beja airport as a complement to Lisbon airport, avoiding the construction of a new infrastructure with potentially more negative impacts.

This study addresses several SDGs: SDG 7, as electrification of the railway will eliminate the need of diesel and consequently invest in renewable sources for electricity (7.2,7.3); SDG 8, as improved access to the interior of the country could promote the socioeconomic development and attractiveness of a less developed region (8.1,8.2,8.3,8.9); SDG 9, as the requalification for more efficient and sustainable infrastructure will promote the establishment of companies and industries (9.1,9.2,9.3); SDG 11, regarding the inclusiveness of communities in the interior of the country (11.2,11.3,11.a); and SDG 15 (15.1,15.2), as it takes in consideration the protection and conservation of the Natural Preserve of the Tagus estuary Tagus Estuary.

2. Methods

The study was developed in six steps:

1. A brief characterization of the case study is made involving Baixo Alentejo subregion, the rail connection from Lisbon to Beja, Beja airport “Terminal Civil de Beja” (TCB), and Lisbon airport “Aeroporto Humberto Delgado” (AHD).
2. Online survey to the population and visitors of Beja, to those interested in the promotion of Beja airport (Questions in Table 1). Its purpose was to analyse the satisfaction with the current rail link to Beja, identify the aspects that need to be improved, and find out the population’s opinion about the potential use of the Beja airport as a complement to Lisbon airport.
3. Analysis of the technical components of the rail link, based on the Network Directory 2022 (IP, 2020) and IP (2021).
4. To determine the approximate volume of long-haul passengers that TCB could receive from AHD, the EUROCONTROL (2021) classification was used: regional (<500 km); short-haul (500-1500 km); medium-haul (1500-4000 km); and long-haul (>4000 km), and the data from demand of the most popular air links in 2019 (INE, 2020). The same database was used to identify the number of passengers of regional flights.

5. The quantification of GHG emissions of airport link was based on the European average emission factors reported by the UK Government for rail (0.0277 kg CO₂eq/pkm) due to the different share of generation efficiency and electricity sources, and for taxi (0.1455 kg CO₂eq/pkm) (Hill et al., 2020).
6. A brief comparison between the options of Montijo and Beja was made, based on costs, travel time, distance, GHG emissions from access, and constrains that are worth highlighting.

Table 1. Questions of the survey.

<ol style="list-style-type: none">1. Do you usually go to Beja?2. If the rail connection to Beja was improved and of high performance, would you be more interested in frequenting the region?3. What is the reason why you travel?4. What is your municipality of residence?5. What mode of transport do you use most to get to Beja? 6.6. What are the most important factors in your choice of mode of transport?7. Are you satisfied with the current rail connection to Beja?8. How satisfied are you with the following aspects of the current railway connection to Beja?9. Do you think that there is a need to mention any other aspect besides the ones already mentioned?10. If the railway connection were to be upgraded, would you be willing to change your mode of transport?11. What advantages could an improved, high performance rail link have in Beja?12. Do you think that Beja airport has the potential to be complementary to Lisbon airport, hosting intercontinental flights?13. Justify.14. Could the improvement of the Lisbon-Beja rail link promote Beja airport as complementary to Lisbon airport?15. Justify.16. In your opinion, what conditions are missing for Beja airport to operate as complementary to Lisbon airport?17. If Beja airport were operational, what more advantages could it bring to the region?18. Imagine that Beja airport is an extension of Lisbon airport and hosts intercontinental flights. There is a high-speed rail link between the two airports, which allows the Lisbon-Beja connection to be made in 1h15. What do you think?

3. Case study

Baixo Alentejo is characterized by having the lowest population density at national level and high rates of ageing and population loss that, combined with the lack of settlement by young and working-age population, affects the region's development and competitiveness. The main economic activity is agriculture.

The railway line that ends in Beja, called "Linha do Alentejo" (see Figure 1) is a single track 166 km long and operates since 1884. The line is electrified up to Casa Branca and to continue to Beja it is required to transfer to diesel traction. Although the state of conservation is good due to the complete renovation of the track in the 1980s, the line is underused and the nominal speed on the Casa Branca-Beja section is well below the technical speed threshold (IP, 2020; Furtado, 2020).



Figure 1. Rail connection to Beja.

Beja airport is built on the site of the Air Base no. 11 of the Portuguese Air Force, also used for years by the German Air Force for operational trainings. When the German Air Force left, in 1992, it was converted for mixed use, civil and military. This location was chosen for the local conditions of the area: good weather and visibility, uncongested airspace, relative distance to urban centres and the absence of natural barriers (Freitas and Sousa, 2011). Beja airport’s main runway is the only one in mainland Portugal to operate the A380, and the only one considered for a possible emergency landing of NASA’s Space Shuttle (Airportwatch, 2013). Beja airport has very poor connection to the transport network, being only achievable by car (individual or taxi), although a railway connection was projected if the demand of the airport was high enough. Despite many attempts to attract airlines, the use of the infrastructure has always been far below expectations (Freitas and Sousa, 2011). Nowadays, the Beja airport (TCB) is used mostly for aircraft parking and maintenance. Beja airport is an exemplary case that the existence of an infrastructure does not lead to socio-economic and regional development.

Lisbon airport (AHD) is the biggest Portuguese airport having received in 2019 about 31 million passengers. Nowadays, it is associated with noise and air pollution impacts and for being congested in several sectors of operation: declared capacity of the runway, processing passengers and cargo in terminals, aircraft parking, and curbside. Given that the infrastructure is surrounded by densely populated urban agglomeration which limit physical expansion, relocation or the complementary option has been studied for over 50 years (Roland Berger, 2012). Currently, the alternative preferred by the Portuguese Government for “Lisbon+1”, which involves the capacity expansion of the AHD and the construction of a new airport, is the Air Base no. 6 site at Montijo, despite the absence of a mandatory strategic environmental assessment, the lack of rail connection, and the conflict with the Tagus Estuary Preserve and Natura 2000 site. Figure 2 shows both locations.



Figure 2. Beja airport and Montijo Air Base no.6.

4. Results and discussion

The survey gathered a sample of 1110 answers. The people enquired revealed that when they travel to Beja, they give preference to individual rather than public transport given the poor offer of quality services, mainly due to the lack of schedule flexibility, comfort, and autonomy. On the railway service, the survey reveals that 92% of the respondents are dissatisfied with the current railway connection Lisbon-Beja (Figure 3).

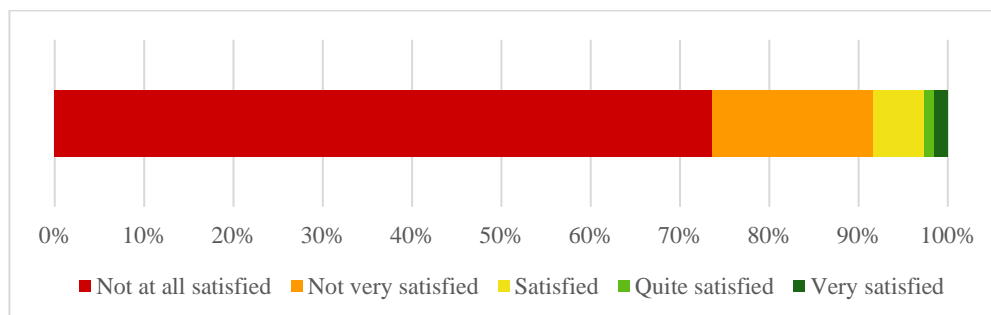


Figure 3. Level of satisfaction of the current rail connection to Beja.

The satisfaction of several aspects of the current rail link to Beja shows, in general, total dissatisfaction with these features, as it is shown in Figure 4.

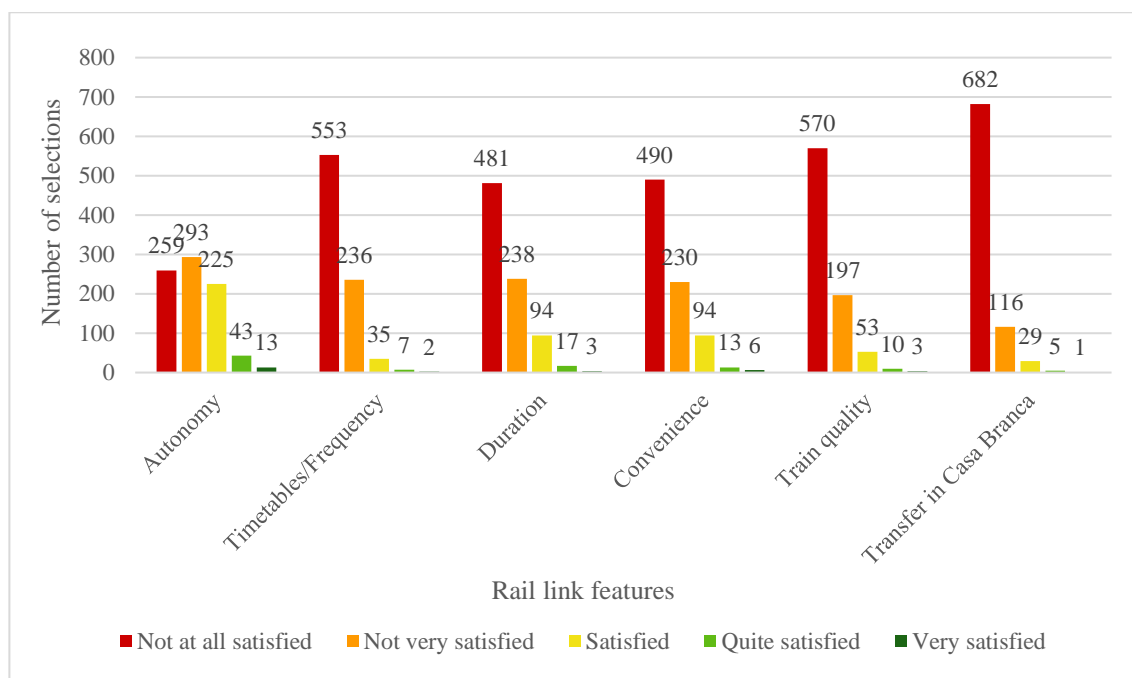


Figure 4. Level of satisfaction with features of the current rail connection to Beja.

The most criticised aspect is the transfer in Casa Branca, necessary due to the absence of electrification of the section between Casa Branca and Beja. Exchanging from an intercity train to diesel powered old railcars of lower quality and efficiency, in addition to extending the travel time, is an uncomfortable process for the passengers, especially for the elderly and with reduced mobility. The lack of coordination of timetables with the need of the population can be overcome with demand analysis since there is demand from other modes of transport (e.g. express bus).

The proposed solutions to improve the service and enable homogeneous circulation at 200 km/h are: in technical terms, electrification, sealing of the railway channel, elimination of level crossings, straightening the route and modernisation of safety and traffic management systems; and in terms of operation and service, to consider increasing the frequency of intercity and regional services and adaptation of support infrastructures to the population (IP, 2021, 2020). The investment in technical requalification of the infrastructure, including the deviation of the line to serve Beja airport, totals 120 M€ (Refer, 2015).

A high-performance rail link to Beja will allow the travel time to Lisbon city center to be reduced from 2h15min to 1h20min, with a strong accessibility to the public transport network on the capital and to Lisbon airport. About 81% of the respondents mentioned that, with such a modernisation of the railway connection they were willing to change their mode of transport to Beja.

Beja airport has favourable conditions for air traffic and is fully operational, although terminal facilities would have to be expanded to serve as an alternative to Lisbon airport.

The requalification of the national railway network and the improvement of long-distance services are foreseen in national strategic plans, so it is possible to consider the substitution of regional flights (<500 km) to rail.

Regarding the complementarity between Lisbon and Beja airports, the proposed strategy is to shift long-haul air traffic from the AHD (Lisbon) to Beja. Long-haul passengers have more luggage and local transfer is a small part of total travel time, so they are more predisposed to go to a more distant airport that offer cheaper fares, if the transfer is efficient. Moreover, increasing traffic in the TCB will have low impact on the surrounding environment, since it was already accounted for when the airport was built. The construction of a railway bypass to Beja airport is an innovative strategy that complies with the CE (2011) guidelines, as none of the other Portuguese airports are integrated in the rail network.

On Table 1 is presented the approximate number of passengers on AHD in 2019, according to EUROCONTROL classification.

Table 2. Number of passengers on AHD in 2019 according to the type of air traffic.

AHD air traffic	Passengers
Regional (<500 km)	3 429 869
Short-haul (500-1500 km)	4 318 135
Medium-haul (1500-4000 km)	11 121 982
Long-haul (>4000 km)	5 027 814

Source: INE (2020).

Table 2 shows the number of long-haul passengers and the corresponding number of passengers per hour generated, considering a fully occupied 300-passenger aircraft and the AHD operating hours (06:00-24:00).

Table 3. Number of passengers/hour in Beja airport after the transfer of long-haul passengers from AHD.

Long-haul passengers	Flights/year	Passengers/hour
5 027 814	16 759	765

The TCB has a processing capacity of 250 passengers/hour, so the expected hourly volume of passengers is nearly three times the current capacity of the passenger terminal. Assuming this strategy, Beja airport terminal will have to be expanded. However, it should be noted that the pandemic situation has affected the aviation sector, so the recovery of air traffic seen in 2019 will probably be delayed. The Beja terminal expansion will certainly be more expedient than building a new airport at Montijo.

The integration of air and rail services require high levels of cooperation and data sharing among the operators and stakeholders involved, and a service focused on the passenger experience should be promoted. Therefore, options such as schedule coordination among services, ticket integration with the option of accumulation air miles, and the offer of quality services on board the train (e.g. incorporated check-in and baggage management, Wi-Fi, meals) can be considered.

The differentiated use and exploitation of Beja airport (e.g. commercial, maintenance, parking) can contribute to the attractiveness of the Alentejo aeronautical cluster and attract investments, new residents, younger and qualified population.

Considering the demand of 2019, the air-rail modal substitution of regional air traffic and the relocation of long-haul flights to Beja airport would contribute to a 25% reduction in the number of passengers using Lisbon airport, which would greatly help the management of operations and reduce congestion in the infrastructure. Medium-range flights may also be reduced in the long term due to substitutions of some travel with teleconference, particularly regarding European institutions and some business travel.

When comparing the two alternatives, Beja and Montijo, the difference in the predicted investments is clear (Table 4). Montijo, including the expansion of the AHD, is more than ten times more expensive than Beja, considering the requalification of the railway, including the link to the TCB. It was not possible to compute air terminal expansion cost. In terms of accessibility, Montijo lacks an integrated accessibility plan, as the current accessibility system is based on road transport and there are no consistent plans to change that (Roland Berger, 2016).

Table 4. Brief comparison between Beja and Montijo alternatives based on a few indicators.

Indicators	Beja airport	Montijo airport
Distance to Lisbon (km)	174	37
Travel time from Lisbon	1 h 20 min (modern train)	35 min to 1 h (taxi)
GHG emissions (kg CO ₂ eq/passenger)	5.1	5.3
Predicted investment	120 M€ (rail upgrade) plus terminal upgrade	1 500 M€ (expansion of AHD and construction of new airport)
Constrains	- Requires upgrading of the rail link and the air terminal.	- Absence of rail link; - Impacts on the Tagus Estuary, a natural reserve and a site of the Natura 2000 network; - Higher risk of accidents with aircraft due to birdstrike; - Impacts on population safety and well-being.

Source: Refer (2015), Dinheiro vivo (2021), *Google Maps*.

Another evidence that can be drawn from the study is the potential savings on GHG emissions when traveling to airports. Although it is more distant to Lisbon and the direct train trip to Beja airport is slightly longer, it offers a convenient quality of service and passenger comfort and autonomy, besides having lower intensity of emissions than travelling by taxi or car to Montijo. In addition, the improvement of the Lisbon-Beja rail link will certainly improve GHG emissions resulting from modal transfer from car and bus to train, for traffic not airport-related.

Regarding the impacts on biodiversity conservation, the Montijo option affects the protected area of the Tagus Estuary, which is part of the Natura 2000 network as a Special Protection Area in accordance with the Birds (17/409/CEE) and Habitats (92/43/CEE) Directives and is also a Wetland of International Importance under the Ramsar Convention. The local authorities of the municipalities affected by the operation of the future airport of Montijo have also reproved this option, given the impacts and risks it imposes on the population. Environmental NGOs advocate a strategic environmental assessment to analyse other alternatives with fewer impacts. Even with the implementation of measures to mitigate impacts on public health and biodiversity, the risk is still significant.

5. Conclusions

Our research concludes that, according to the concepts of air and rail integration, the implementation of a high-performance rail link makes it possible to consider Beja airport as a complementary solution to Lisbon airport, based on the transfer of long-haul air traffic from Lisbon to Beja. An inquiry to the population supports this idea, consolidating with the potential socio-economic and environmental benefits and promotion of an undeveloped Region. Respondents also pointed out that after the modernisation of the line, travellers would be more interested in using the railway as a mode of transport.

In total, the transfer of long-haul flights to Beja and the regional traffic to rail reduces the volume of passengers at AHD by at least 25%, which allows to increase the lifespan of the infrastructure, to focus on other markets, and a reduction of environmental and noise impacts in Lisbon.

Compared to Montijo, Beja airport has many advantages from an economic, social, and environmental point of view. It is built in an area relatively remote from urban centres, so conflicts and impacts on the surrounding environment are modest. Because rail is so much more efficient than cars, Beja with a modern rail link compares well with Montijo, despite the difference in distance. So, "Lisbon+1" at Beja is worth considering as an alternative to a new airport.

The combination of proposed solutions prioritises sustainable mobility, air-rail intermodality, airport integration with the rail network, and the use of rail on long-distance travel. This approach supports energy transition, decarbonisation, and biodiversity conservation objectives, demanded by the European Green Deal, as well as the Portuguese goal to carbon neutrality by 2050.

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