

EDITORIAL

Reviews and Responses for Airlines' Network Analysis on an Air-Rail Multimodal System

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1. Original paper

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2. Review - round 1

2.1 Reviewer 1

This is a timely paper with increasing interest in considering air as part of a multi-modal network. The paper covers a lot of ground with a simple premise of banning shorter-haul flights and replacing them with equivalent train routes for the same segments. A couple of suggested areas of improvement -

1. When presenting multi-modal alternatives, it would be helpful to present a more detailed discussion of what the travel time extensions mean for the passengers. It is clear from figure 10 that the simplest alternative (rail) doubles the travel time. Are these alternatives worth considering if they are not appealing at all to travelers?
2. The higher number of multi-modal alternatives for air-rail transfers seems to be a consequence of the assumed transfer times. How sensitive are the alternative counts to the transfer times? Maybe start with an equal assumption of air-rail and rail-air transfers to establish a baseline.

The results section figures are understandable but the writing felt a little hard to follow, especially in section 3.2. Also the description of the rail and air network database could possibly be simplified and the detailed descriptions moved into an Appendix

2.2 Reviewer 2

The authors undertake an analysis, focused on the Spanish peninsula, of the impacts of flight bans on passenger trip substitutions between air travel and rail travel. Specifically, under a constructed set of assumed passenger itineraries and air/rail substitution rules, the authors examined bans on flights of varying scheduled block times on the air and rail network, quantifying both infrastructure impact (e.g., change in demand at the airport nodes) as well as sustainability impacts (e.g., reduction in CO₂ from a shift away from flying to rail travel). I enjoyed reading the paper – it was well-written, well-motivated, and the data processing/data characteristics are particularly well-described. I have several comments/feedback that I would love to see addressed by the authors, which I detail below.

1. The authors examine a limited set of air traffic data for analysis, only using 1 weeks worth of traffic in May 2023. Furthermore, this week has a couple of irregular days, such as the public holiday mentioned on May 2nd. I would suggest that the authors provide a stronger justification for why this single week might be reasonably generalized to, say, a schedule for an entire season or for a year (probably more so for a season, since airlines themselves overhaul schedules from season to season, particularly when strategic airport slots/seasonal destinations are considered). Additionally, I was hoping that the authors could comment on potentially incorporating air traffic data from historical weeks/timeframes where there were significant disruptions in air travel (e.g., due to convective weather) – my thought here being, I'm actually wondering if the potential substitution benefits might be greater, since I would assume that rail networks might be disrupted less than air networks for the same kinds of precipitating events.

2. The authors follow a prescribed process for estimating the scheduled block times for each flight, using assumptions regarding the en route time, as well as taxi-in and taxi-out times. I would suggest that the authors either add in a discussion regarding how far off these assumed constant times are to actual times, or potentially perform a small sensitivity analysis, especially on the taxi-in and taxi-out times. While the en route times might be reasonably approximated using the procedure described herein, there may be large discrepancies between nominal taxi-in and taxi-out times between airports, particularly if the airport is a large hub airport versus a small regional one. I am wondering how much these assumed constant times and SIBT/SOBT inference procedures would affect the authors' conclusions and results.

3. On a more minor note, I wonder if the authors could provide a visualization of the flight data as well as the rail network data. For example, given my lack of familiarity with rail network data such as the one described by the authors, would plotting, e.g., a geographical network with rail trip densities or other useful information be easy to do? If so, I think that would greatly enhance the interpretability for readers (e.g., readers can begin to see how one network might substitute in for the other, etc.)

4. It would be great if the authors could push a bit deeper into the discussion regarding infrastructure usage. While I understand that a full, quantitative analysis will definitely be out of scope, given that the focus of this paper and journal is on aviation, there is an intriguing multimodal perspective here as well: Assuming that the flight bans occur in the manner described herein, and that demand shifts to the rail networks, the access journey to (and egress journey from) the airports will also be greatly modified in terms of passenger flows. Instead of X amount of passengers going to the airport, there is now going to be some $X - \delta$ amount to the airports and $+\delta$ amount to the train station, so there will be an impact on infrastructure usage outside of just the airport and the train stations.

5. The parameters of the (1.) minimum connecting time, (2.) the maximum train length time of 4.5 hours, and (3.) the 1.5x connecting flight penalty are critical to generating possible passenger itineraries. Similar to my comment above regarding the usage of the heuristic to estimate the SIBTs and SOBTs, I would suggest that the authors provide stronger justification on the usage of these parameters, either through data-driven approaches, or through a small sensitivity analysis.

6. I am very curious about this "plateau" which occurs between a ban of approximately 6-7 hours, until a 13-hour ban. The authors note that nothing significant happens until the 13-hour ban length, but is there something about the flight/train network/network topology/network connectivity within Spain that results in this lack of sensitivity to the ban time length between 6-7 hours to 13 hours? This might be important to understand especially if, for example, an airline is able to "perturb" this plateau by adding a sparse number of flights, in which case it may be important to distinguish between, say, a 10 vs. 11 hour ban, even though in the current network, it does not really seem to make a difference if the ban is 10 hours versus 11 hours.

7. A minor note, but if the authors could increase the font size on the axes labels/ticks for Figures 4 and 5, that would greatly enhance legibility. Thanks!

8. Is there an equivalent of Figure 7 (which is great for airport operators to look at the impacts of rail substitution) but for the train stations in question?

3. Response - round 1

3.1 Response to reviewer 1

When presenting multi-modal alternatives, it would be helpful to present a more detailed discussion of what the travel time extensions mean for the passengers. It is clear from figure 10 that the simplest alternative (rail) doubles the travel time. Are these alternatives worth considering if they are not appealing at all to travelers?

Response

As highlighted by the reviewer, the travel time will have a significant impact on the preference of passengers for alternatives. In this article, however, we focus on the impact of a flight ban, which includes connecting flights, on total travel time for the passenger and not on the travel preferences.

Note that for direct flights vs. direct rail, the rail can nearly double the flight time, but these are block times. As described in the literature, the access and egress times tend to be longer to airports than to rail stations, which renders door-to-door travel times of the two modes similar even with longer train travel. We have clarified this in the text.

The higher number of multi-modal alternatives for air-rail transfers seems to be a consequence of the assumed transfer times. How sensitive are the alternative counts to the transfer times? Maybe start with an equal assumption of air-rail and rail-air transfers to establish a baseline.

Response

The transfer time plays a role in the potential multimodal alternatives. As requested by the first reviewer (see comment R1.5), we have clarified the assumptions on the minimum connecting time between modes of transport

The results section figures are understandable but the writing felt a little hard to follow, especially in section 3.2. Also the description of the rail and air network database could possibly be simplified and the detailed descriptions moved into an Appendix.

Response

The description of the databases is summarised in Table 1. There is a lengthy description of the data preparation, but we consider this to be needed to understand the study's assumptions and ensure the reproducibility of the work. We have reviewed the whole manuscript with a particular focus on Section 3.3 – Fleet usage (previously Section 3.2), and Section 2 – Data and approach, to improve the readability.

3.2 Response to reviewer 2

The authors examine a limited set of air traffic data for analysis, only using 1 weeks worth of traffic in May 2023. Furthermore, this week has a couple of irregular days, such as the public holiday mentioned on May 2nd. I would suggest that the authors provide a stronger justification for why this single week might be reasonably generalized to, say, a schedule for an entire season or for a year

(probably more so for a season, since airlines themselves overhaul schedules from season to season, particularly when strategic airport slots/seasonal destinations are considered). Additionally, I was hoping that the authors could comment on potentially incorporating air traffic data from historical weeks/timeframes where there were significant disruptions in air travel (e.g., due to convective weather) – my thought here being, I’m actually wondering if the potential substitution benefits might be greater, since I would assume that rail networks might be disrupted less than air networks for the same kinds of precipitating events.

Response

Some regions within Spain are not served daily; therefore, extending the air analysis to a week enabled us to ensure that schedules covering all possible origin-destination pairs were covered.

The use of the week that included bank holidays was to analyse if those days could impact the rail availability. Moreover, being a public holiday could potentially increase the number of movements within Spain. Results, however, showed that there was not a high variability for the rail services. As the analysis focuses on the potential connectivity and fleet usage, the movement of passengers does not impact these results. Note that the presented results are averaged for the seven days analysed.

The characteristics of the Spanish air and rail network (see reply to comment R.13) ensure that from a potential mobility perspective, the results are expected to be generalisable to operations in Spain. However, we agree with the reviewer that further analysis should be done to cover different seasons if demand patterns are to be analysed.

We have added a comment in the conclusions indicating this extension of the analysis to other seasons and clarified the impact of selecting those days in Section 2.1 – Data description and preparation.

The authors follow a prescribed process for estimating the scheduled block times for each flight, using assumptions regarding the en route time, as well as taxi-in and taxi-out times. I would suggest that the authors either add in a discussion regarding how far off these assumed constant times are to actual times, or potentially perform a small sensitivity analysis, especially on the taxi-in and taxi-out times. While the en route times might be reasonably approximated using the procedure described herein, there may be large discrepancies between nominal taxi-in and taxi-out times between airports, particularly if the airport is a large hub airport versus a small regional one. I am wondering how much these assumed constant times and SIBT/SOBT inference procedures would affect the authors’ conclusions and results.

Response

One of the limitations of using ADS-B data is that a trace exists for a flight only when the ADS-B receivers pick it up. This means that in some cases, the flight is picked up already a few kilometres away from their departure and might disappear a few kilometres away from landing. For this reason, some computations on the missing flight times have been performed assuming nominal climb and descent profiles for medium-size aircraft. This provided an estimation of take-off to landing times. Therefore, the route time is mostly based on the traces reported by OpenSky and can be considered rather accurate. Only the last few kilometres are estimated. We have clarified this in the text. When estimating the connectivity, the in-block and off-block times are needed. For this, an average taxi-in and taxi-out of 10 and 20 minutes have been used, respectively.

According to EUROCONTROL - Summer taxi times 2021, the average taxi-in time for all Spanish airports was 4.8 minutes (9.1 minutes for Madrid, 5.5 minutes for Barcelona). The 90th percentile was 7 on average across all airports, more than 10 minutes just in Madrid (14 minutes). Therefore, assuming 10 minutes for taxi-in seems reasonable as, in most cases, it will be an overestimation, which could account for schedule padding not available in OpenSky data and ensure that possible itineraries are

feasible.

Similarly, the reported average taxi-out time was 10.6 minutes for all airports in Spain, with a maximum average value of 15 minutes for Barcelona. On average, across all airports, the 90th percentile was 14 minutes, with a maximum of 23 minutes for Madrid Barajas. Once again, using 20 minutes as an estimate is justified, as it represents a slight overestimation for most airports.

We acknowledge that this is a limitation on the dataset and that more precise values could be used. However, when computing potential connectivity between flights, the values used seem to be already large enough. Reducing them might increase the possible connectivity marginally, but it would be difficult to be used as schedules. Increasing them would artificially reduce the potential connectivity and increase the travel times. We have added EUROCONTROL reference to the article and these justifications for the times selected in Section 2.1.1 – Airline network data preparation

On a more minor note, I wonder if the authors could provide a visualization of the flight data as well as the rail network data. For example, given my lack of familiarity with rail network data such as the one described by the authors, would plotting, e.g., a geographical network with rail trip densities or other useful information be easy to do? If so, I think that would greatly enhance the interpretability for readers (e.g., readers can begin to see how one network might substitute in for the other, etc.)

Response

Figure 3 presents the air and rail network in Spain. Figure 3.a) shows the flights considered, while Figure 3.d) shows the rail network used with a ban of 9h. Besides that, we have added a new Section (Section 3.1 – Spanish air and rail network) to briefly describe the characteristics of the Spanish air and rail network. Here, we include a set of Figures describing the connections by air and rail.

It would be great if the authors could push a bit deeper into the discussion regarding infrastructure usage. While I understand that a full, quantitative analysis will definitely be out of scope, given that the focus of this paper and journal is on aviation, there is an intriguing multimodal perspective here as well: Assuming that the flight bans occur in the manner described herein, and that demand shifts to the rail networks, the access journey to (and egress journey from) the airports will also be greatly modified in terms of passenger flows. Instead of X amount of passengers going to the airport, there is now going to be some $X - \delta$ amount to the airports and $+\delta$ amount to the train station, so there will be an impact on infrastructure usage outside of just the airport and the train stations.

Response

This is an interesting observation. In the work done, we computed the number of seats that would be transferred from air to rail and computed that, on average, they represent a maximum of 22% of the rail capacity (14% for a 3-h ban). We are not considering an increase in rail supply above current operation levels. Therefore, we assume that the rail infrastructure would not be affected by the extra passengers.

However, it is true that this requires the capacity to be available on the rail system, which might not be the case depending on the route and time of the day. Moreover, passengers will arrive at the airport for their multimodal connection in a pattern which might differ from current operations, and the ground mobility system required to do this transfer might also be strained.

All these aspects would require a deeper analysis considering the actual demand rather than the potential connectivity done in this article. We have expanded Section 3.4 – Infrastructure usage, to include some of these previous reflections.

The parameters of the (1.) minimum connecting time, (2.) the maximum train length time of 4.5 hours, and (3.) the 1.5x connecting flight penalty are critical to generating possible passenger itineraries. Similar to my comment above regarding the usage of the heuristic to estimate the SIBTs and SOBTs, I would suggest that the authors provide stronger justification on the usage of these parameters, either through data-driven approaches, or through a small sensitivity analysis.

Response

1. Minimum connecting time between air and rail systems are defined considering Google Maps travel times between modes using public transport and some assumptions on kerb-to-gate and gate-to-kerb time as follows:

- Madrid-Chamartin – LEMD: 22 minutes train journey, 15/2 minutes average time between trains, 10 minutes walking, 45 minutes kerb-to-gate/gate-to-kerb processes: 84.5 minutes →85 minutes
- Madrid-Atocha – LEMD: 45 minutes train/metro journey, 15/2 minutes average time between trains, 10 minutes walking, 45 minutes kerb-to-gate/gate-to-kerb processes: 107.5 minutes →108 minutes
- Madrid-Principe Pio – LEMD: 50 minutes train/metro journey, 15/2 minutes average time between trains, 10 minutes walking, 45 minutes kerb-to-gate/gate-to-kerb processes: 112.5 minutes →113 minutes
- Barcelona-Sans – LEBL: 30 minutes train/metro journey, 15/2 minutes average time between trains, 10 minutes walking, 45 minutes kerb-to-gate/gate-to-kerb processes: 92.5 →93 minutes

2. The maximum train duration is not considered to be 4.5 hours in the analysis, but when computing possible itineraries with connecting flights; we only consider them if there are no train alternatives of 4.5 hours or less between the origin and final destination. This is to avoid itineraries which require two flights when a fast direct train is available. This constraint could be simplified by estimating the total travel time to identify trips which are too long by air if a rail alternative is possible.

3. The 1.5 factor is used, once again, to avoid possible connections by air when sufficient fast direct flights are available.

Note that in this article, we compute potential trips, and we don't have data on actual passenger demand. This means that spurious trips can be generated. The factors are set to filter these. Some calibration has been performed to ensure that the obtained connections are suitable for the characteristics of the Spanish region. We have clarified this in the text. As suggested, we could analyse the impact of these assumptions with some sensitivity analysis, but using the passenger data would circumvent most of the listed issues, and will be considered in future research. We have added this in the text in Section 2.2 – Methodology

I am very curious about this "plateau" which occurs between a ban of approximately 6-7 hours, until a 13-hour ban. The authors note that nothing significant happens until the 13-hour ban length, but is there something about the flight/train network/network topology/network connectivity within Spain that results in this lack of sensitivity to the ban time length between 6-7 hours to 13 hours? This might be important to understand especially if, for example, an airline is able to "perturb" this plateau by adding a sparse number of flights, in which case it may be important to distinguish between, say, a 10 vs. 11 hour ban, even though in the current network, it does not really seem to make a difference if the ban is 10 hours versus 11 hours.

Response

As indicated by the reviewer, this is due to the characteristics of the Spanish network. Once 6-7 hours ban is applied, most of the links to-from Madrid by rail are already covered. Mostly the routes that link the periphery of Spain are maintained due to the lack of high-speed rail infrastructure. These origin-

destinations are still served by flights, but increasing the ban does not perturb them as there are no suitable rail alternatives. When the ban reaches 13 hours direct trains crossing the whole of Spain are possible and therefore further flights get banned.

We have added these explanations in the text linking them to the description of the Spanish network in new Section 3.1 – Spanish air and rail network

A minor note, but if the authors could increase the font size on the axes labels/ticks for Figures 4 and 5, that would greatly enhance legibility. Thanks!

Response

We have increased the labels/ticks as suggested.

Is there an equivalent of Figure 7 (which is great for airport operators to look at the impacts of rail substitution) but for the train stations in question?

Response

This wouldn't apply as we don't modify the rail supply. Therefore, in terms of rail movements (services), there wouldn't be any change. We could consider this analysis for the demand of rail services which could potentially have multimodal itineraries but the total demand would be the same.

4. Review - round 2

4.1 Reviewer 1

All comments have been adequately addressed

4.2 Reviewer 2

I really appreciate the time that the authors took to address all of my comments. In many cases, the authors have also expanded on the discussions within the paper as well. I have no more comments, and am happy to recommend acceptance.