Modelling passengers in air-rail multimodality

Delgado, L., Bolic, T., Cook, A.J., Zareian, E., Gregori, E. and Paul, A.

A paper presented at the 11th EUROSIM Congress. Amsterdam, The Netherlands 03 - 05 Jul 2023.

Modelling passengers in air-rail multimodality

Luis Delgado[1], Tatjana Bolić[1], Andrew Cook[1], Elham Zareian[1], Ernesto Gregori[2], and Annika Paul[3]

[1] University of Westminster, London, United Kingdom
{l.delgado,t.bolic,cookaj,e.zareian}@westminster.ac.uk
[2] Fundación Instituto de Investigación Innaxis, Madrid, Spain
eg@innaxis.aero
[3] Bauhaus Luftfahrt, Munich, Germany
annika.paul@bauhaus-luftfahrt.net

Abstract. Air-rail mobility has the potential to play a significant role in addressing European mobility challenges such as emissions reduction and capacity shortages. Rail can complement the air network in different ways: enlarging airport catchment areas, supporting operations in case of disruption or replacing air links to obtain environmental benefits. There is, however, still a need to better understand the potential role of rail when substituting current air links both from a strategic and a tactical mobility perspective, particularly when passenger connections are considered. This was initially assessed, considering passengers' door-to-door itineraries, as part of the Modus project (H2020 - SESAR 2020) with an innovative approach towards data driven, integrated air-rail modelling. Further considerations, such as the evaluation of strategic and tactical multimodal solutions, will be explored in the MultiModX project (Horizon Europe - SESAR 3). This discussion paper presents the modelling challenges addressed in Modus and the approach defined for MultiModX to evaluate and model multimodal door-to-door solutions.

Keywords: Multimodal mobility · Integrated modelling · Air-rail networks · Passenger door-to-door transport.

1 Introduction

The topics of multimodality, passenger experience and inclusion, and creation of a seamless mobility system within Europe that meets the goals of the Paris Climate Agreement are gaining traction [11]. In line with this, airports are considered to be multimodal nodes of the future [1, 10].

Coordinated planning and collaborative decision-making, based on information sharing and common situational awareness across transport modes, are key enablers to realise this vision [17]. Railway planning can help enlarge airport catchment areas and shift passengers from feeder flights to high speed rail (HSR) connections, reducing green house gas (GHG) emissions and releasing airport capacity [13]. At the strategic level, schedule synchronisation between different transport networks can significantly reduce total door-to-door (D2D) travel times by optimising transfer times [18, 15]. At tactical level, coordinated passenger re-booking, re-routing, re-planning and dynamic rescheduling can help deal with the many unexpected events that occur in any transport network [6], rendering the transport system more resilient against disruptions [18].

Therefore, the interactions between different transport modes are manifold. They can take the form of substitution, for example, by competing for the best service to travellers, or as complementary services by covering different segments of a door-to-door journey and serving as a feeder mode for one another. There is still a need to better understand the potential role of rail when substituting current air links both from a strategic and a full mobility perspective.

Recent discussions and developments in the air-rail context focused on the replacement of short-haul air routes by HSR, where applicable. A shift from air to rail on routes with feasible HSR replacement options is being evaluated across several European countries, with France at the forefront of introducing such a mandate [4].

This discussion paper presents some of the work conducted in the Modus project from the SESAR 2020 (Horizon 2020) programme[4]. Modus modelled future scenarios where multimodality is present, considering the passengers' full D2D mobility. The focus on this contribution is on highlighting some of the challenges of modelling these scenarios, describing the novel approach adopted. Moreover, MultiModX, a new SESAR 3 (Horizon Europe) project (Grant Agreement underway) will further explore the design and evaluation of strategic and tactical multimodal solutions. This will be achieved by:

- identifying and characterising current and future scenarios for long-distance passenger multimodal transport in Europe;
- developing a multimodal performance, modelling and evaluation framework (Performance Assessment Solution);
- developing a Schedule Design Solution for the integrated planning of air and rail networks; and
- developing a Disruption Management Solution based on coordinated air and rail tactical schedule adjustments and passenger reallocation.

2 Air-Rail replacement: Needing a dedicated multimodal modelling

The substitution potential of air and rail applying modal choice analysis has been the subject of various studies [2, 3]. Focusing on the environmental impact, CO_2 emissions for air transport are higher than those for rail [12]. Similar results are found in [16] where CO_2 emissions per passenger-km are considered.

However, these replacements are not always simple to implement due to the complexity of passengers' itineraries. A network analysis carried out in Modus assessed the maximum potential air replacement that can be achieved with the use of HSR network focusing on Spain, France, Italy and Germany. One of the

[4] https://modus-project.eu/ (Accessed April 2023)

challenges of replacing flights by rail is the impact these replacements have on passenger connectivity at airport hubs. To analyse this, data from a busy day in 2014 schedules and passenger itineraries were used [9, 14]. Rail alternatives are extracted considering 2019 routes from the MERITS database[5] [19].

The analysis assessed the impact of banning flights, shorter than a given distance, where HSR alternative is possible. Figure 1 shows the results obtained as a function of the distance between origins and destinations where to impose the ban. A relative low number of flights would be impacted by bans up to 1200 km. For example, with a ban of 800 km only 1800 flights would be affected, *i.e.*, 15.1% of all flights. Considering passengers itineraries, the number of connecting passengers impacted would be low in number (around 18% of all passenger transported) but a significant number of flights would have at least one connecting passenger on them. From the 1800 replaced flights more than 1500 have some passengers with connections. This highlights the importance of coordinated networks and passenger connectivity on these short segments.

Connecting passengers are not too significant in volume (around 20-25% of all passengers potentially moved to rail), but present a significant challenge due to the required synchronisation of processes. Multimodal itineraries are therefore a must when these substitution policies are considered. Focusing only on individual flights without considering the airline network (with connections) and passengers door-to-door itineraries is too limiting as journeys would be impeded.

Dedicated models are therefore required for these analysis. These should rely on the modelling of passengers itineraries rather than a more traditional flight-centric approach used in the field of air transport. This is the basis of the mobility simulator Mercury developed over several European research projects: first as a flights and passengers itineraries gate-to-gate simulator (POEM and Complexity-Costs projects) [5]; then including first and last mile mobility (DATASET2050[6] and Vista[7] projects) [8]; the model was redesigned following an Agent-Based paradigm (Domino[8] project) [14]; and finally multimodal (rail) itineraries were included (Modus project) [7]. The different components of a journey are independently modelled with different level of resolution, *e.g.* door-to-kerb can be estimated as a function of passenger and city archetypes, while in the gate-to-gate phase flights (and connections) are individually simulated, including aspects such as congestion or reactionary delay. This modular and flexible approach enabled us to incorporate new processes and complex travel architectures, *e.g.* a rail-air multimodal itinerary can be simulated as the succession of: door-to-platform (access to rail), platform-to-platform (rail leg), platform-to-kerb (rail to airport), kerb-to-gate (airport processes), gate-to-gate (air leg(s)), gate-to-kerb (airport processes), kerb-to-door (airport to door).

[5] Multiple East-West Railways Integrated Timetable Storage (MERITS) is a database, owned by UIC (International Union of Railways), containing the integrated timetable data of many European railway undertakings.

[6] https://cordis.europa.eu/project/id/640353 (Accessed April 2023)

[7] https://cordis.europa.eu/project/id/699390 (Accessed April 2023)

[8] https://cordis.europa.eu/project/id/783206 (Accessed April 2023)

The approach followed in Modus (scenario definition, multimodal trip processes segmentation, archetypes definition, etc.) will be discussed with further detail in the presentation along with some key results.

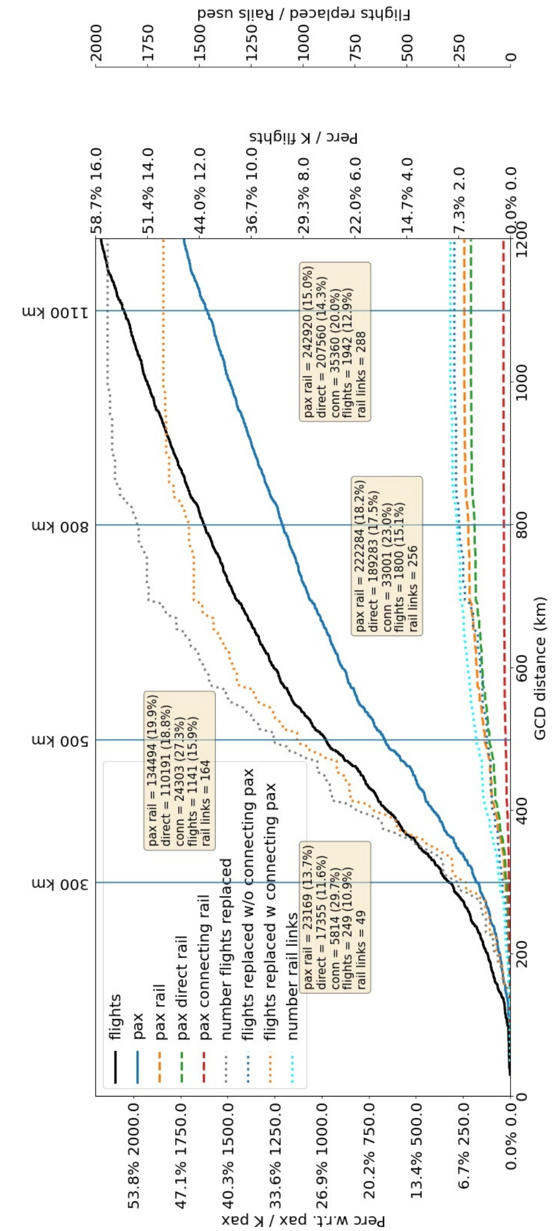

Fig. 1. Rail and air network considered.
Impact of introducing air ban as a funciton of Great Cirlce Distance (CDG).

3 The need for evaluation of integrated solutions

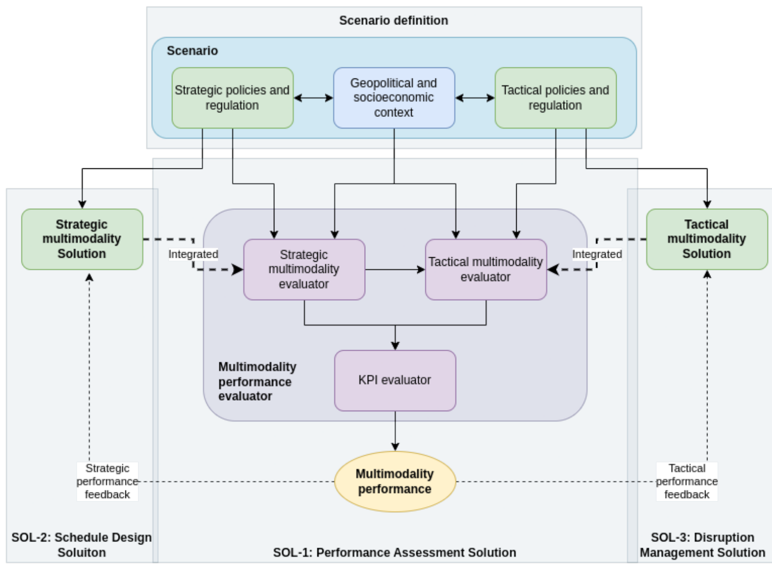

Fig. 2. MultiModX concept

As previously indicated (and following Modus' results), further research is required to provide a fully integrated multimodal transport system. These opportunities will be explored in MultiModX project, as shown in Figure 2.

In particular, there is a need for a multimodal *Performance Assessment Solution* which enables the evaluation of a multimodal framework with two performance evaluators: strategic and tactical. The software architecture of the *Performance Assessment Solution* will enable the seamless integration of strategic and tactical multimodality Solutions so that they can be evaluated under different configurable scenarios.

A *Schedule Design Solution* will enable the coordinated design of air and rail schedules according to expected demand behaviour following the requirements defined in future scenarios. Finally, tactically a *Disruption Management Solution* will support decision-makers responding to disruptive events in real time, in order to minimise the impact on passengers, profiting from the extension of the A-CDM concept to other transport modes.

The presentation will expand these concepts and describe the approach for their development and validation.

Acknowledgment

The Modus project was funded by the European Union's Horizon 2020 – SESAR programme under Grant Agreement No. 891166. The MultiModX project is to be funded by the European Union's Horizon Europe – SESAR 3 programme (Grant Agreement underway).

References

1. Advisory Council for Aviation Research and Innovation in Europe (ACARE): Strategic Research and Innovation Agenda - 2017 update. Tech. rep. (2017)
2. Arich, P., Bolic, T., Laplace, I., Lenoir, N., Parenty, S., Paul, A., Roucolle, C.: Substitution path between air and rail in europe: a measure of demand drivers. Air Transport Research Society World Conference (2022)
3. Behrens, C., Pels, E.: Intermodal competition in the london–paris passenger market: High-speed rail and air transport. Journal of Urban Economics **71**, 278–288 (2012)
4. Convention Citoyenne pour le Climat: Avis de la convention citoyenne pour le climat sur les résponses apportées par le gouvernement à ses propositions (2021)
5. Cook, A., Delgado, L., Tanner, G., Cristóbal, S.: Measuring the cost of resilience. Journal of Air Transport Management **56**, 38–47 (2016). https://doi.org/10.1016/j.jairtraman.2016.02.007
6. Corman, F., Meng, L.: A review of online dynamic models and algorithms for railway traffic management. IEEE Transactions on Intelligent Transportation Systems **16**(3), 1274–1284 (2015). https://doi.org/10.1109/TITS.2014.2358392
7. Delgado, L., Cook, A., Zareian, E., Bolic, T., Gregori, E., Paul, A.: Challenges of multimodal door-to-door mobility modelling. In: 12th SESAR Innovation Days (SIDs). Budapest , Hungary (Dec 2022)
8. Delgado, L., Gurtner, G., Cook, A., Martín, J., Cristóbal, S.: A multi-layer model for long-term KPI alignment forecasts for the air transportation system. Journal of Air Transport Management **89**, 101905 (2020). https://doi.org/10.1016/j.jairtraman.2020.101905
9. Delgado, L., Gurtner, G., Mazzarisi, P., Zaoli, S., Valput, D., Cook, A., Lillo, F.: Network-wide assessment of atm mechanisms using an agent-based model. Journal of Air Transport Management **95**, 102108 (2021)
10. European Commission: Flightpath 2050. Europe's Vision for Aviation (2011)
11. European Commission: Sustainable and smart mobility strategy: Putting european transport on track for the future (2020)
12. European Environment Agency: Transport and environment report 2020: Train or plane? Tech. rep. (2020)
13. Givoni, M., Banister, D.: Airline and railway integration. Transport Policy **13**(5), 386–397 (2006). https://doi.org/10.1016/j.tranpol.2006.02.001
14. Gurtner, G., Delgado, L., Valput, D.: An agent-based model for air transportation to capture network effects in assessing delay management mechanisms. Trans. Research Part C: Emerging Technologies **133**, 103358 (2021). https://doi.org/10.1016/j.trc.2021.103358
15. Modus Consortium: D3.2 Demand and Supply Scenarios and Performance Indicators. Tech. rep. (2021)

16. Montlaur, A., Delgado, L., Trapote-Barreira, C.: Analytical Models for CO2 Emissions and Travel Time for Short-to-Medium-Haul Flights Considering Available Seats. Sustainability **13**(18) (2021). https://doi.org/10.3390/su131810401
17. SESAR JU: Strategic Research and Innovation Agenda – Digital European Sky. Tech. rep. (2020)
18. TRANSIT Consortium: D6.1 Impact Assessment of New Intermodal Concepts and Passenger Information Services: Conclusions and Recommendations. Tech. rep. (2022)
19. UIC: Multiple East-West Railways Integrated Timetable Storage (MERITS) database (Accessed on February 2023), https://uic.org/passenger/passenger-services-group/merits