Challenges of multimodal door-to-door mobility modelling

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Moving Towards a Multimodal European Transport System

Manifold challenges ahead!

- Enabling a **seamless passenger journey**, including multiple providers and information
- Meeting **environmental goals** and facilitating a sustainable transport system
- Identifying and developing **new business models** that enable multimodal transport
- Rethinking the use of **infrastructure development** and future challenges

Modus

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Joint Air-Rail Mobility in Europe

Substitution and/ or complementarity between air and rail

- Restrictions and replacement of short-haul flights
- High-speed rail providing connectivity for airports, (or enlargement of catchment areas)
- Multimodal cooperation to facilitate synergies (*e.g.*, Deutsche Bahn as Star Alliance Member)
- Rescheduling in case of disruptions or delays

Consideration of **door-to-door travel chain** and **passenger expectations**

European short-haul flight and rail network

Objectives and Approach

- The **overall performance of the (future) European transport system** will strongly depend on the alignment and optimisation of multimodal transport.
- Potential **role of rail** when substituting current air links.
- Development of innovative approach towards **data-driven, integrated air-rail modelling**, considering **passenger door-to-door (D2D) itineraries.**
- Evaluate the **impact** of an improved, joint air-rail transport system on **different key performance areas** (*e.g.*, D2D travel times, CO_2 per passenger).

Multimodal Scenarios and Modelling Experiments

Scenario 1: Pre-pandemic recovery

- Network structures remain similar to todays
- Implementation of innovative technologies facilitates the reduction of emissions in air transport

Scenario 2: European short-haul shift

- High share of short-haul air traffic replaced by air-rail cooperation
- High quality of transport network with HSR services on short-haul distances

Scenario 3: Growth with strong technological support

- Higher growth rates of the transport sector until 2040 than the baseline
- Uptake of technological innovations to both reduce emissions and alleviate capacity shortages in air transport

Scenario 4: Decentralised, remote and digital mobility

- Population becomes more dispersed across rural and remote regions with increased options for remote working and virtual meetings
- More decentralised air transport network, additional railway stations
- Technological innovations for regional aircraft

Experiment	Air layer[1]	Rail layer
1. Current baseline	Air traffic and passenger itineraries for 2019	Rail traffic 2019
2a. Future baseline	Air traffic and passenger itineraries for 2040 regulated growth	Rail infrastructure and traffic for 2040
2b. Short-haul ban	Air traffic and passenger itineraries for 2040 regulated growth, removing flights less than 500km in France, Germany, Italy, Spain	Rail infrastructure and traffic for 2040
3a. Future high growth (with technology)	Air traffic and passenger itineraries for 2040 global growth	Rail infrastructure and traffic for 2040

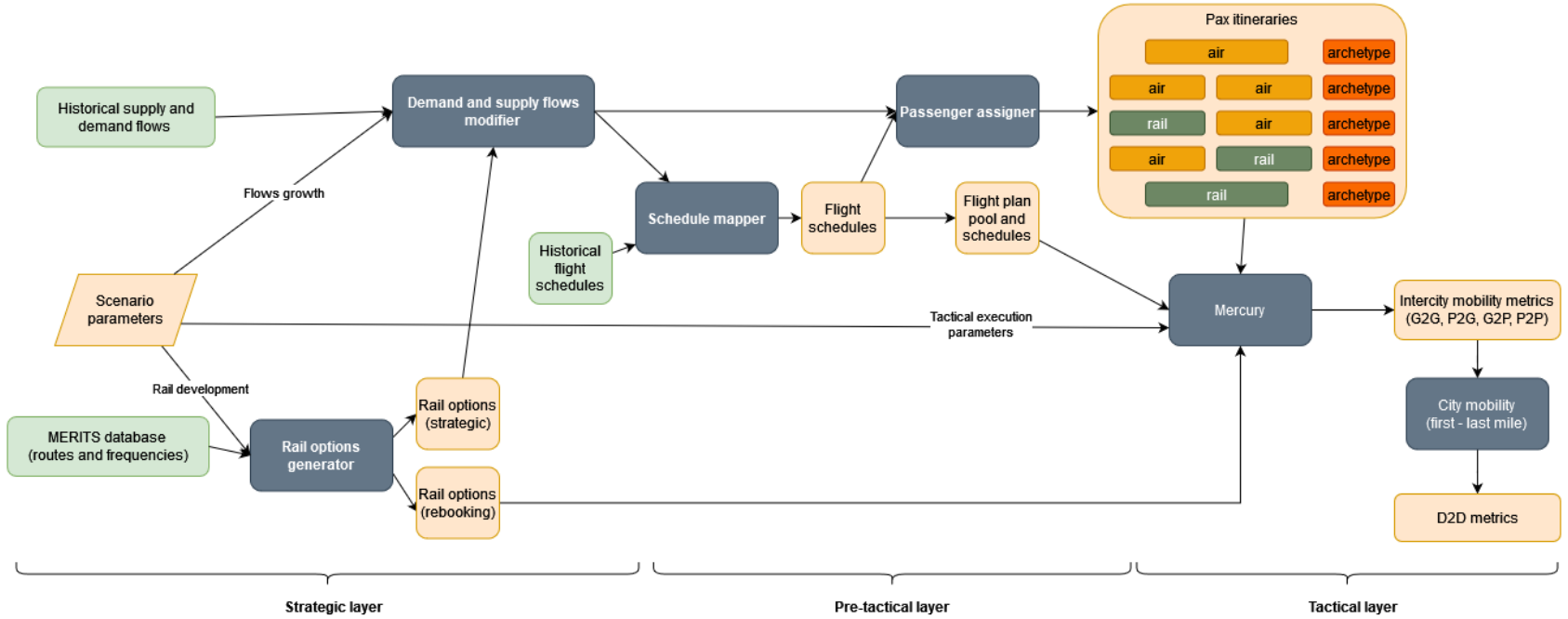
[1]The air traffic and passenger demand are grown based on the Regulation and Growth and Global Growth forecasts from EUROCONTROL's Challenges of Growth forecast.

Multimodal Passenger Mobility Modelling

Mercury focused on the modelling of the G2G phase of the passenger itineraries.

The model has been expanded to consider **multimodal journeys**.

The model covers three phases of transport.



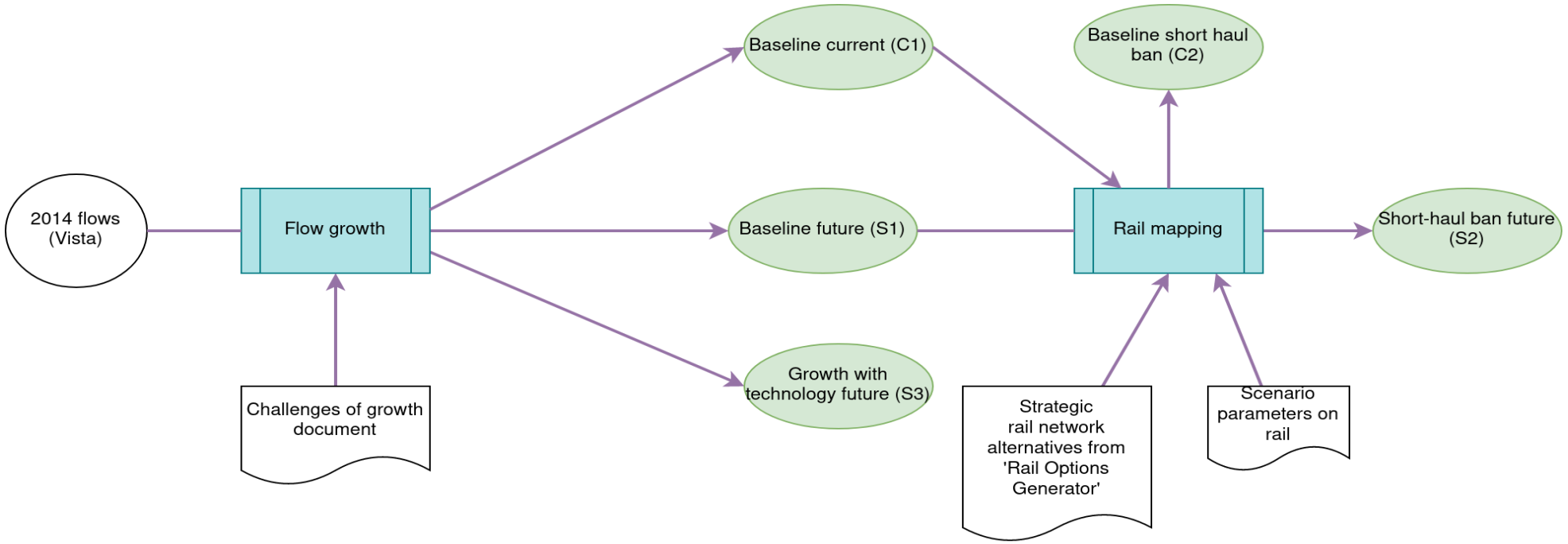
Generating demand and supply flows and rail alternatives.

Translate flows into individual schedules and passenger itineraries.

Execution of the itineraries in the tactical layer (+ disruptions).

Demand and Supply Flows Modifier

- The demand and supply flows modifier component lies in the strategic layer, which produces the future flows and passenger itineraries.
- Flows represent the future supply of seats, while passenger itineraries represent the future demand in aggregated volume of passengers.
- The generated supply and demand volumes are varied across scenarios.



Schedule Mapper and Passenger Assigner

Schedule mapper

For each experiment individual airline schedules and planned flight rotations are generated.

Required inputs:

- airport data,
- (historical) flight schedules,
- turnaround times,
- aircraft data (e.g. aircraft leasing prices, aircraft ranges), as new aircraft need to be added to the schedules,
- supply data (e.g. number of seats per origin-destination)
- airline data (e.g. type of airline).

Passenger assigner

Creates future passenger itineraries and requires the following inputs:

- future schedule generated by the schedule mapper,
- future itineraries, created in the flow modifier component,
- airport data (e.g. coordinates, minimum connecting time).

The passenger assigner considers actual seat capacity as provided by the schedules and connecting times.

Rail Layer Modelling

Rail options generator

Exploring interconnectivity between air and rail

New layer of Mercury to find rail alternatives to scheduled air routes (total substitution of air; collaboration of both means of transport

Rail-based parameters for each possible direct rail route (fed into flow modifier and Mercury):

- Average travel time
- Average waiting time
- Time of first/ last train of the day

1. **Rail station-airport mapping**

Railway stations within 40km of an airport are selected.

2. **Rail data processing**

Find existing rail routes to substitute air routes

3. **Waiting time estimation**

Calculated for given route, computing each waiting time and mean; expected waiting time as a result

Introduction of Use Cases

Strategic route planning

Rail as a substitute and complement of air itineraries (full replacement of the whole trip or connection to/from the hub).

- Demand and supply modifier application
- Focus on Spain, Italy, France and Germany (development of high-speed rail network).
- Options: 1. the rail station located at the hub, 2. the rail station located in the city centre.
- Estimation of multimodal segments for different airports.

Tactical disruption management

Two regions impacted by a large air disruption, rail to reroute some of affected passengers.

- All rail schedules are considered, regardless of the countries involved, duration, speed (high speed rail/regular) and distance.
- Madrid and Paris regions
- Cancellation of 90% of short-haul flights
- Comparison to rail network and cities directly reachable by train
- Experiments 1 and 2: trip cancellation if no rail connection/ rail journey twice as long
- Experiment 3: Rail option with higher utility (thrice journey time allowed)

Mercury and Door-to-Door Modelling

Mercury

- Gate-to-gate modelling expanded to multimodal journeys
- Stochastic, agent-based model (representing main elements of ATM system) at individual flight and passenger level
- Capturing European-wide network effects; non-linearities between delay for flights and passengers due to missed connections

First and last mile modelling

- D2D model to combine outcome of different trip segments

Door-to-door flight segment	Door-to-door rail segment
Door-to-kerb (D2K)	Door-to-platform
Kerb-to-gate (K2G)	
Gate-to-gate (G2G)	Platform-to-platform
Gate-to-kerb (G2K)	
Kerb-to-door (K2D)	Platform-to-door
Multimodal segments	
Gate-to-platform (G2P)	
Platform-to-gate (P2G)	
Kerb-to-platform (K2P)	
Platform-to-kerb (P2K)	

Mercury Results (1 of 3) Traffic and passenger flows with D2D averages

Exp. #	Description	Disruption	Air	Rail	Key metrics				
					Flights	Air pax¶	Pax S2R Cancelled pax	Network D2D average¶	Short-haul ban states D2D average† ¶
1	Current baseline	×	2019 traffic	2019 network	**31 080**	**4 029 k** *1 950 k*	-	*467 mins*	*422 mins*
								≈	≈
2a	Future baseline	×	2040 base growth	2040 network	**44 900**	**5 920 k** *2 720 k*	-	*469 mins*	*424 mins*
2b	2a + short-haul ban†	×			**1360 banned**	*110 k* banned	= *110* k *1.6* k‡	*445 mins*	*402 mins*
								≈	≈
3a	Future high growth	×	2040 high growth		**52 200**	**7 190 k** *3 220 k*	-	*439 mins*	*394 mins*

† Values in this row/col refer to the four countries in which the short-haul ban is applied (GCD < 500 km not operated by air in DE/FR/ES/IT, *where rail alternatives exist*)

¶ Values in italics refer to passengers travelling on the OD pairs within the 176 European airports for which Modus applied city/airport archetypes

‡ Cancelled due to exceptional circumstances, e.g. substitute air-rail-air itineraries being impractical

Mercury Results (2 of 3) Passenger flows with G2G CO_2 and flight waits

Exp. #	Description	Disruption	Air	Rail	Key metrics				
					Air pax¶	G2G network CO_2	G2G short-haul ban states CO_2 †	Network flight wait	Short-haul ban states flight wait †
1	Current baseline	×	2019 traffic	2019 network	**4 029 k** *1 950 k*	94 kg/pax	99 kg/pax	149 mins	122 mins
2a	Future baseline	×	2040 base growth	2040 network	**5 920 k** *2 720 k*	86 kg/pax	91 kg/pax	133 mins	112 mins
2b	2a + short-haul ban†	×			*110 k* banned	87 kg/pax	92 kg/pax	137 mins	112 mins
3a	Future high growth	×	2040 high growth		**7 190 k** *3 220 k*	85 kg/pax	89 kg/pax	125 mins	101 mins

† Values in this row/col refer to the four countries in which the short-haul ban is applied (GCD < 500 km not operated by air in DE/FR/ES/IT, *where rail alternatives exist*)

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Mercury Results (3 of 3) Disruption flows with cancelled pax and CO_2 saved

Exp. #	Description	Disruption	Air	Rail	Key metrics				
					Flights cancelled	Air pax cancelled	Pax S2R	Cancelled pax	CO_2 saved
1*	Current baseline	✓	2019 traffic	2019 network	898	69.8 k	**4.81 k**	**93 %**	20 kg/pax
2a*	Future baseline	✓	2040 base growth	2040 network	1460	104 k	**7.27 k**	**93 %**	19 kg/pax
2b*	2a + short-haul ban†	✓			1170	95 k	**3.14 k**	**97 %**	20 kg/pax
3a*	Future high growth	✓	2040 high growth		1530	122 k	**17.5 k**	**86 %**	18 kg/pax

* These experiments are subject to disruption.

† Values in this row refer to the four countries in which the short-haul ban is applied (GCD < 500 km not operated by air in DE/FR/ES/IT, *where rail alternatives exist*)

Modus Project Results

Demand and supply drivers | Traveller archetypes

- Drivers for multimodal transport in Europe
- Development and analysis of future traveller archetypes, behaviour and requirements
- Evaluation of modal choice behaviour and air-rail market shares

Gaps, barriers and recommendations

- Interactive stakeholder engagement from different mobility domains, esp. air and rail
- Identification and evaluation of enablers and barriers for multimodal transport

Future multimodal scenarios

- Identification and development of various future pathways for future European mobility
- Addressing key aspects contributing to achieving seamless, climate-neutral mobility in Europe

Passenger mobility modelling and performance indicators

- Data-driven, integrated air-rail modelling, considering passenger door-to-door itineraries.
- Assessment across different scenarios regarding varying impacts on capacity, predictability, environment