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Abstract

This document outlines the functional requirements definition for the Schedule Design Solution (SOL2) which aims to design passenger-centric coordinated multimodal schedules for air and rail. The document describes the functional architecture view of the SOL2 and the functional requirements necessary to use the solution and its different components, as well as the assumptions that were taken in its development. This document is an intermediate version, and the final version, titled "Functional Requirements Document”.

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MultiModX

INTEGRATED PASSENGER-CENTRIC PLANNING OF MULTIMODAL NETWORKS

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1 Executive summary

The Schedule Design Solution (SOL400/SOL2) aims to design passenger-centric coordinated multimodal schedules for air and rail. The passenger-centric aspect comes from the passenger flows calculated using SOL399/SOL1, taking into account the sensitivities of passengers with regard to several travel aspects (mode (air, rail, multimodal), travel time, price and CO2 emissions) when selecting a specific path, and mode(s), to reach their desired destination. The flows of each path determine the demand to be satisfied by the schedules. The schedules are designed to accommodate the passenger flows as well as possible and, therefore, prioritise coordinating the connections with higher demand.

Using the available data, the Schedule Design Solution generates coordinated air and rail schedules.

SOL400/SOL2 is capable of implementing optimised schedules with the constraints of moving existing services only up to the industries' acceptable thresholds (about 20 minutes in accordance with the Industry Board’s feedback). Relaxing these constraints for broader changes will be explored in the experiments.

The objectives when creating the schedules are amongst or a combination of the following:

minimise waiting times or total travel times for passengers;

maximise the number of people travelling;

minimise the deviations from the original schedules;

by accommodating passenger flows as defined from SOL399/SOL1

This document outlines the functional architecture view and the functional requirements of the solution and its components.

2 Introduction

2.1 Purpose of the document

This document defines the functional requirements (FRD) for SESAR solution 400 at TRL2.

This document is a functional requirements document (FRD) that details the functional architecture and requirements for the Schedule Design Solution (SOL2), a solution for the integrated planning of air and rail networks (TRL2) that optimises the waiting times at transfer nodes to offer more and better options for multimodal passengers. The outcome of the Schedule Design Solution is a set of schedules for air and rail that can be evaluated by the Performance Assessment Solution (SOL1).

The primary objective of this document is to detail the functional requirements of the solution and its components, its input and its output. First, the document delves into the functional architecture view of the solution, through the overview of the solution, the capabilities it covers and the involved stakeholders. Then, the functional requirements, i.e. the expected behaviour, applicable to the Schedule Design Solution and its components are listed. Finally, the assumptions taken for the development and application of the solution are detailed.

2.2 Scope

The FRD presents the functional requirements of the Schedule Design Solution. The overall scope of the FRD covers the definition of the functional architecture view (including within the SESAR architecture) and the requirements for the methods and algorithms developed for SOL2 for integrated schedule design. Its development takes place in two iterations:

- implementation of an integrated multimodal schedule design, optimising the schedules for both air and rail services. The optimisation is based on a mathematical representation of the multimodal scheduling problem for a multi-level network using mixed-integer linear programming. The Schedule Design Solution takes the expected demand levels, the capacity of all modal networks, and the available resources as inputs.

The outcome of the Schedule Design Solution is a set of schedules for air and rail to be evaluated by the Performance Assessment Solution (SOL1). The solution shall be able to provide the expected output schedules for the project's case studies.
These activities **address the Objective O4 of the project** as stated by the Grant Agreement (GA):

- Analysis of functional requirements and existing models and algorithms for rail and air schedule design.
- New coordination and cooperation principles for multimodal schedule design.

- Mathematical optimisation models and algorithms for optimal multimodal schedule design considering passenger behaviour (e.g. preferences/constraints regarding transfer times), available vehicles (aircraft, rolling stock), infrastructure capacity, and interdependencies between the air and rail networks.
- Experimental testing and evaluation of the new integrated Schedule Design Solution.

2.3 Intended readership

The readers of this document typically include a range of stakeholders involved in the rail and aviation industry, transportation planning, and policy-making. These may include SESAR JU, SESAR IR Projects, SESAR ER projects, EU-Rail, airlines, airports, rail operators, train stations, transportation planners, policymakers, urban planners, researchers and academics, consultants and advisory firms, technology developers, and environmental organizations.

2.4 Background

The schedule design solution builds upon previous projects from aviation and rail. The approach for timetable synchronisation developed within the SESAR H2020 ER TRANSIT [1] project will be extended into a more comprehensive solution to be able to deal with multimodal passenger-centred schedule design at a network level, with the purpose of optimally coordinating air and rail services to minimise the overall passenger journey times and impacts of everyday stochastic disruptions, while taking into account the resources needed by airlines and railway undertakings and the infrastructure capacity. This will benefit from the insights into the airline schedule and strategic passenger flow and schedule generator developed in the SESAR H2020 ER Modus [2] project.

The approaches for optimal railway timetabling from EU FP7 project ON-TIME [3], such as micro-macro models [4], and the integrated passenger-centric multimodal scheduling algorithms from the ERA-NET SORTEDMOBILITY [5] project, like MASP [6], which currently integrate rail and bus services, will be extended towards integrating airline operations.

The synchronisation of air and railway timetables has been drawing growing attention recently. Most of the studies focused on the synchronisation at transfer hubs with one airport and one train station. The authors of [7] studied a feeder railway timetabling problem at one transfer hub, in which the flight timetable is given and the feeder railway timetable is optimised to maximise the number of synchronisations and the coverage of synchronised flights and minimise passenger transfer penalties. In [8] a joint design model was proposed that adjusts the given flight and train timetables to increase passenger accessibility at a transfer hub and minimise the time shift of initial timetables. In [9] the authors proposed a demand-driven train timetabling method to minimise passenger waiting time, in which the number of waiting passengers is calculated by the cumulative arrival and service passenger curves. In [10], the authors integrated the rescheduling model of air-rail timetable and passenger flow forecasting to capture the interaction of timetable and passenger flow distribution. In [11], a time-space network-based formulation was proposed for the synchronisation problem of train, aircraft, shuttle and passenger flows.

Very few research studied the air-rail timetable synchronisation problem at a network level. The adjustment of the service timetable at one station not only affects the passengers transferring at the station but also has an impact on other passengers taking the service and other services on the network sharing the same infrastructure. In [12] an optimisation model for air-rail timetable synchronisation to minimise passenger transfer discomfort and schedule deviation was studied. Some network characteristics are considered in the model including the network effect of adjusting the departure time at one station and some operational constraints at stations and airport. The proposed model assumes the transfer demand of each connection is fixed. However, new connections are possible in the synchronised timetable, and passengers may re-choose their itinerary.

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The development of SOL2 partly fills in this gap by taking into account demand and building a passenger-centric approach to scheduling by optimising both the air and rail network to account not only for waiting time, but also for capacity whilst also minimising timetable deviation.

2.5 Structure of the document

Chapter 2 of this document serves as an introduction, providing general information about these functional requirements document. In Chapter 3, the context of the functional architecture view, containing details such as the supporting reasons for this SESAR solution, the capabilities addressed and the stakeholders impacted by the SOL2 is explained. Chapter 4 outlines the general functional requirements and those of the two components of the solution. Finally, Chapter 5 details the general assumptions of the solution and those specific to its two components.

2.6 Glossary of terms

Term	**Definition**	**Source of the definition**
OD pair	Origin and Destination pair. Refers to the start and end points of each passenger's journey. The number of O&Ds also indicates the size and complexity of a network.	ATPCO Glossary
path	A succession of nodes (airports, rail stations) in the graph which represent a possible or potential succession of nodes to travel from a given origin to a given destination	own elaboration
itinerary	A succession of services (flights or trains) which represent a possible trip for a passenger.	own elaboration
service	A specific train or flight, defined by a succession of stations/airports and its schedule.	own elaboration
unserved demand	Passenger demand that cannot be assigned to specific services either before or after the Schedule optimisation.	own elaboration
air and rail network	Collection of nodes (representing airports or train stations) and relations (connections or transfers) between the nodes.	own elaboration
route-based strategy	Strategy used in the optimisation process, in which a service might be cancelled or added. It can be used jointly with time-based strategy	own elaboration
time-based strategy	Strategy used in the optimisation process, in which a service schedule can be modified. It can be used jointly with route-based strategy.	own elaboration
lexicographic optimisation	Multi-objective optimisation method for which the functions to optimised are ranked based on importance.	own elaboration

Table 1: glossary of terms

2.7 List of acronyms

Term	Definition
ATM	*Air traffic management*
DES	*Digital European Sky*
FRD	*Functional requirements document*
GA	*Grant agreement*
GDPR	*General data protection regulation*
HE	*Horizon Europe*
ID	*Identifier*
OSED	*Operational service and environment description*
SESAR	*Single European sky ATM research*
SESAR 3 JU	*SESAR 3 Joint Undertaking*
TRL	*Technology readiness level*
DCB	*Demand Capacity Balancer*

Table 2: list of acronyms

3 Functional architecture view

3.1 SESAR solution overview

SOL2 takes the supply (i.e., rail timetable and flight schedules) and demand (i.e., itineraries) characteristics from SOL1 to improve the transfer experience of passengers in the air-rail integrated system by simultaneously coordinating the services and allocating as much demand as possible. The output is the coordinated rail timetables and flight schedules, which can be fed into the strategic evaluator of SOL1 to:

Calculate the KPIs at the strategic level

Re-assign the passengers to the coordinated services

SOL2 first identifies the demand and services of interest (i.e., transfer demand and corresponding services). Time-based (i.e. timetable shift) are then applied to generate a coordinated schedule of trains and flights. SOL2 also identifies the better itineraries in the coordinated schedule and assigns passengers to shift their itineraries. A preliminary implementation of route-based strategies will be implemented for the final dissemination event.

Multiple objectives are considered in the optimisation model (i.e. unserved demand, transfer time and timetable deviation). Some operational constraints (e.g. running time, dwell time, headway, airport capacity) and passenger assignment constraints (e.g. minimal connection time and seat capacity) are imposed in the model to guarantee the feasibility of the solution.

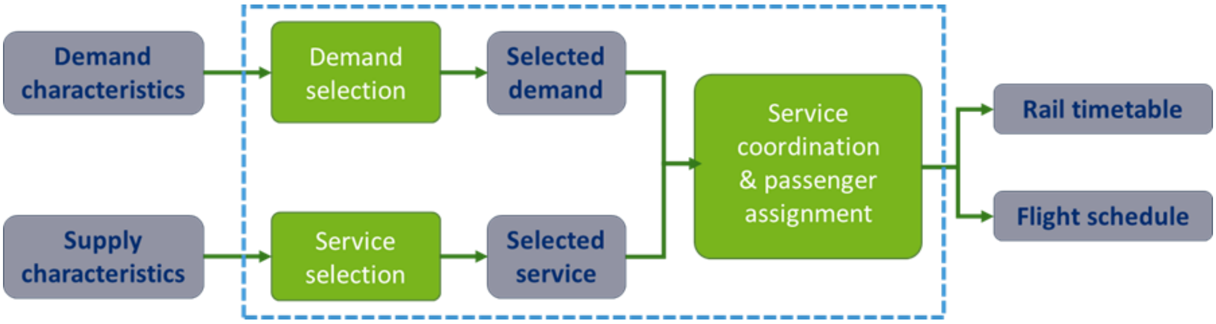

Figure 1: Overview of SOL2

3.1.1 Supporting reasons for this SESAR solution

Europe's long-term vision documents on aviation research, described in the Flightpath 2050 and the new Fly the Green Deal documents ([13],[14]), envisage a future in which air transport becomes an integrated part of a multimodal transport system that, by the year 2050, makes it possible for 90% of travellers within Europe to complete their door-to-door journey within 4 hours.

In parallel, the European Commission's Sustainable and Smart Mobility Strategy [15] has defined a multitude of goals and respective flagships that pave the way towards zero-emission, resilient and inclusive mobility, creating seamless and efficient connectivity and establishing the European Union as

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a connectivity hub. One of the goals is a stronger focus on multimodality, which encompasses, inter alia, a fully integrated and seamless multimodal mobility system and a high quality transport network with high-speed rail (HSR) services on short-haul distances and with clean aviation services improving the coverage of long-haul routes. A seamless passenger experience and interoperability between different transport providers will be enabled by integrating airports as multimodal nodes in the air traffic management (ATM) network, contributing to increasing network resilience and the reliability and predictability of journeys. Coordinated planning and collaborative decision-making, based on information sharing and common situational awareness across transport modes, are key enablers to realise this vision.

In recent years, a number of research projects have demonstrated the potential of multimodal coordination mechanisms to increase the efficiency and resilience of the transport network. At the strategic level, schedule synchronisation between different transport networks can significantly reduce total door-to-door travel times by optimising transfer times; this will foster multimodal trips, especially when combined with integrated ticketing, facilitating the use of the most efficient transport mode for each leg of the trip [1]. Furthermore, closer cooperation between air and rail may enhance capacity allocation across modes and address shortages on specific routes or at airports, as well as improve access, egress and connectivity between modes at airport nodes expanding the possibility for multimodal itineraries beyond airports with medium and long distance rail stations on them [2].

The goal of SOL2 is to develop a Schedule Design Solution for the integrated planning of air and rail networks that optimises the waiting times at transfer nodes in order to offer more and better options for multimodal passengers, a step towards innovative multimodal solutions and decision support tools for the coordinated planning and management of multimodal transport networks.

In a nutshell, the main general benefits that SOL2 can provide to SESAR and ATM are a better multimodal integration of airports and increased passenger satisfaction. It is a step-forward in seamless European multimodal travel.

3.1.2 ATM capabilities addressed by the SESAR solution

Since SOL2 is a schedule design tool, it does not fit into the SESAR architecture and the ATM capabilities. It will neither impact, nor change any of the current capabilities. However, we have identified one ATM capability which is an enabler of SOL2, in line with the assumptions A5 and A7 and one capability related with multimodality.

SESAR solution capabilities			Comments on potential updates required at capability level
Information Management	Data Management	Single ticketing	Single ticketing is an enabler of SOL2
Service Delivery Management	Performance Management (operational)	Multimodal Performance Management (Air)	This capability will not affect directly SOL2 but it is in line with the assumptions of the project.

Table 3: SESAR solution 400 capabilities

Further to the 'Multimodality and passenger experience in the SESAR Performance Framework' workshop held on 15 January 2025 (at the University of Westminster, London), attended by members of the MultiModX, PEARL [11] , AMPLE3 [12] and SIGN-AIR [13] projects (*inter alia*; and as reported under separate cover), the following is a summary of exchanges between participants during the discussions and by subsequent e-mail correspondence. Certain "operational capabilities" of the Transformation View (*ibid*.), as flagged above, were discussed, focusing on terminology changes to various 'multimodal' elements. It was proposed that SIGN-AIR would make the corresponding Change Requests in STELLAR, although this might be submitted under the multimodality 'flagship'. This is currently TBD, pending AMPLE3 (WP2) internal coordination. Currently, there is no opportunity to include new capabilities at Level 1. The multimodality capabilities (below) are in scope for inclusion at Level 2 or 3 – also TBD, whilst noting that under #3 below ("Multimodal performance management (air)") is a placeholder for a new capability at Level 3.

1. Regarding "**Aerodrome accessibility** – door-to-door journey disruption management", it was proposed **instead** "Airport connectivity – door-to-door journey facilitation". The rationales were:

- "airport" is used elsewhere in the model, and is more ***inclusive*** (from the multimodal perspective) than "aerodrome";

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- "accessibility" is often ***unidirectional*** (cf. 'access' and 'egress' as standard/common terms);
- "journey facilitation" is more ***inclusive*** than "disruption management" (and includes nominal states and strategic planning).

2. Regarding "**Flight prioritisation**", the **addition** of "IROPs" (as a standard IATA term) was proposed. TBD if this would **replace** "Flight delay criticality management" (dependent on what is intended to be covered within this criticality).

3. Regarding "**Multimodal performance management (air)**", using the terminology of "air journey" was discussed, but, on further discussion, it is currently proposed to retain the name as-is. The term "air" in parenthesis (simply) signifies that we should measure performance within the remit of ATM.

4. Regarding "**Single ticketing**", the latest proposal in correspondence is that this be written as "(Single) Ticketing" in the corresponding box to reflect that this also includes one-leg (air) tickets (not only multi-leg air and/or multimodal). This box should ideally be connected to other capability consequences in the model (i.e. actions), even when the ticket is one-leg ('simple'). It was noted that this also carries liability implications (e.g. Reg 261), which could impact (2) and (3), and suggests various dependent PIs (e.g. re. 'a/c wait' (gate), 'a/c accelerate' (e/r)).

3.1.3 Stakeholders impacted by the SESAR solution

Stakeholder	**Involvement**	**Why it matters to the stakeholder**
Aviation community (airlines)	Integration of SOL2	SOL2 can assist the stakeholder in more effectively planning for the multimodal coordination of scheduling.
Railway community (railway operators, infrastructure managers)	Integration of the SOL2	SOL2 can assist the stakeholder in more effectively planning for the multimodal coordination of scheduling.
European and national authorities, regulatory bodies (National and regional governments, European Commission, other decision makers, ERA, EU Joint Research Centre, OECD)	Exploitation of the projects' results	The results of the experiments conducted for SOL2 will be relevant for the decision process of future policies and the integration of multimodality.
GDS (Global Distribution Systems) organisations (Amadeus)	Exploitation of the project's results	The results of the experiments conducted for SOL2 will be relevant for a better integration of multimodality in transport search engines.

Scientific community (ANSP, EUROCONTROL, SESAR JU, researchers, academics, conference chairs, coordinators of ongoing and former relevant projects)	Reuse of the project's code, framework, and assumptions Exploitation of the project's results	SOL2 can be reused for further research and deepening of the themes covered within the scope of the Solution. Moreover, the results can serve as the basis to direct and justify future research.
Cities and regions, urban planners (ARC regional council members)	Exploitation of the project's results	Planners can use SOL2 to identify interesting policies regarding multimodality
SESAR JU	Planning for the future of multimodal transport and scheduling	SOL2 can assist the stakeholder in more effectively planning for the future development of multimodal scheduling.
Project Partners	Use of the experiments' results	The project's partners will use the results of the experiments conducted in SOL1 and SOL3.

Table 4: SESAR solution 400 stakeholders

3.2 SESAR solution functional view

3.2.1 Interaction(s) identification

SOL2 interacts with:

- DCB: The schedule generator may involve strategic DCB considerations, such as identifying specific slots that could be adjusted to enhance multimodal connectivity. Additionally changes in airline schedules may change demand and have an impact on DCB measures.
- Airlines: These stakeholders will supply the current air schedules as input and, following the optimisation process, will implement the newly generated schedules.
- Railway operators: These stakeholders will supply the current rail schedules as input and, following the optimisation process, will implement the newly generated schedules.

Additionally, SOL2 interacts with various components of SOL1. The new Schedules generated by SOL2 can be fed back to the Multimodal performance evaluator to assess the multimodal KPIs. When optimising for unserved demand, SOL2 assumes that the underlying demand does not change as a consequence of schedule optimisation. The Strategic Evaluator of SOL1 can be used to calculate the induced changes in the demand occurring due to Schedule optimisation. This new demand can potentially be used to optimise the schedules again, as an iterative process.

3.2.2 Functional decomposition

SOL2 takes the demand and supply characteristics of the air-rail system as input to coordinate rail timetables and flight schedules and provide better connected air-rail services. The function of SOL2 can be divided into five building blocks as shown in Figure x: demand selection, service capacity recalculation, service selection, demand regrouping, and service coordination and passenger assignment.

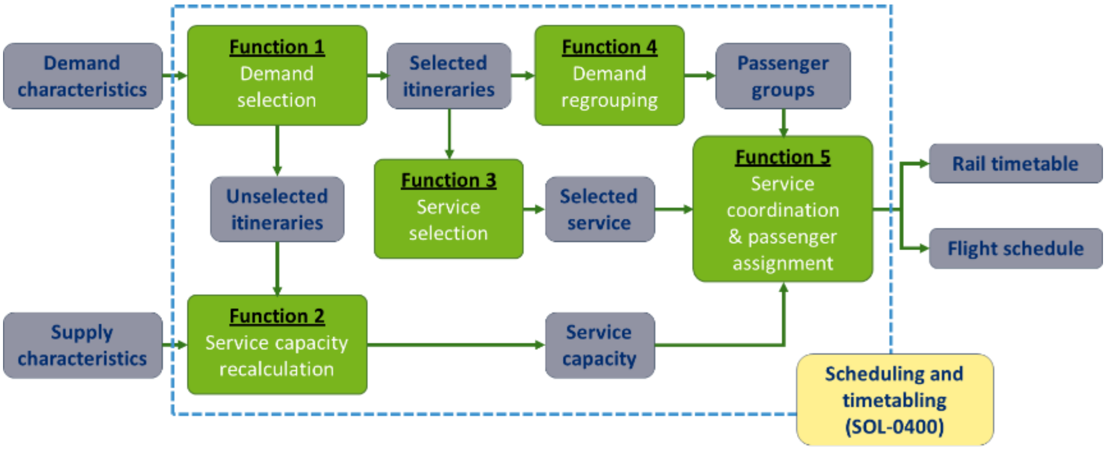

Figure 2: SESAR solution 400 functional view

Function 1 – Demand selection

Definition: Function 1 selects the itineraries with transfers.

Function inputs: Itineraries generated by SOL1.

Function outputs: Selected itineraries and unselected itineraries.

Function description: The itineraries generated by SOL1 include all the itineraries using the air and rail services (direct rail itinerary, direct air itinerary, rail itinerary with transfer, air itinerary with transfer and air-rail itinerary). SOL2 aims at improving the connection of services, so this function selects the itineraries with transfers as the focus of SOL2 (i.e. rail itinerary with transfer, air itinerary with transfer and air-rail itinerary). The demand of the unselected itineraries (i.e. direct rail itinerary and direct air itinerary) affects the services synchronisation by occupying the seat capacity of services.

Function 2 – Capacity recalculation

Definition: Function 2 calculates the service capacity available for the itineraries with transfers.

Function inputs: Service seat capacity and unselected itineraries from function 1.

Function outputs: Available service seat capacity.

Function description: This function takes seat capacity and the demand of the unselected itineraries to determine service seat capacity availability for the demand of selected itineraries. The function calculates the background demand for each service. The background demand of a service refers to the sum of the demand for the unselected itineraries using the service. The background demand is considered fixed (i.e. not change with the timetable adjustment for service synchronisation). The difference between the original seat capacity and the background demand is the available service seat capacity for the demand of the selected itineraries (i.e. rail itinerary with transfer, air itinerary with transfer and air-rail itinerary)

Function 3 – Service selection

Function definition: Function 3 selects the potential adjusted services.

Function inputs: Selected itineraries from function 1.

Function outputs: Selected services.

Function description: The function identifies the candidate services to be potentially adjusted. The selected services include the trains and flights used by the selected itineraries and other services (i.e. departing at different times) serving the same route as the used services.

Function 4 – Demand regrouping

Function definition: Function 4 regroups the demand in the selected itineraries by their paths.

Function inputs: Selected itineraries

Function outputs: Passenger groups

Function description:

An itinerary includes a path on the infrastructure network and corresponding services. The path represents a sequential set of infrastructure segments (i.e. rail tracks and flight routes). Each segment in the path is matched with a service, representing the segment served by the service. The path is considered as fixed but the passengers are allowed to shift their itineraries with the synchronised services.

The function extracts the path of each itinerary and sums up the demand on each path. The demand on each path is then regrouped into multiple groups with a given group size (provided as an input). The number of the groups N_p for a path p is determined by the total demand D_p and group size GS, which is $N_p = \lceil D_p/GS \rceil$. Thus, the demand of each passenger group does not exceed the predetermined group size. A passenger group is then represented by its path and demand. Table 1 give an example of selected itineraries and passenger groups with a group size of 10.

Selected itineraries

Itinerary id	Path id	Service id	Demand
1	1	A,B,C	100
2	2	D,E	200
3	2	F,E	100

Passenger groups

Group id	Path id	Demand
1	1	10
…	…	…
10	1	10
11	2	10
…	…	…
40	2	10

Function 5 – Service coordination and passenger assignment

Function definition: Function 5 coordinates the services to provide better connections.

Function inputs: Passenger group, selected services, service capacity

Function outputs: Rail timetable and flight schedules.

Function description: The function improves the transfer experience of passengers in the air-rail integrated system by simultaneously coordinating the services and assigning passengers to services. Service coordination takes an initial schedule of trains and flights as input. Time-based (i.e. timetable shift) are applied to the initial schedule to generate a coordinated schedule, which improves the transfer experience of passengers. Passenger assignment identifies the better itineraries in the coordinated schedule and assigns passenger groups to the itineraries. Multiple objectives are considered in the optimisation model (i.e. unserved demand, transfer time and timetable deviation. Some operational constraints (e.g. running time, dwell time, headway, airport capacity) and passenger assignment constraints (e.g. minimal connection time and seat capacity) are imposed in the model to guarantee the feasibility of the solution.

The service coordination problem is modelled as a mathematical programming problem. The decision variables are divided into scheduling variables and assignment variables. The scheduling variable determines if a service is added or cancelled and the corresponding departure time and arrival time of the service at the station or airport. Assignment variables determine if a passenger group is served and which itinerary to assign the passenger group.

Some operational and assignment constraints are considered in the proposed model. From the infrastructure perspective, each segment (railway track and flight route) in the network has a minimal and maximal running time. There is a minimal and a maximal dwell time for each station. The timetable shift of services may lead to some conflicts of services on specific infrastructure (e.g. segment and switch). A minimal headway for two successive services is attached to each rail segment due to the safety restrictions. The airport capacity is also considered by limiting the departure flights and arrival flights in a time period. For services, the number of passengers assigned to each service cannot exceed the seat capacity. The deviation between the synchronised timetable and the initial timetable is in each time shift range. The time shift range is service-specific and provided by the operators according to the limit of other processes such as vehicle circulation plans. The total number of flights and trains is not more than the initial number. A minimal transfer time is attached to each transfer arc. Passengers can only transfer on the transfer arc when the time difference between the departure time of the next service and the arrival time of the previous one is larger than the minimal transfer time.

Three objectives are considered in the proposed model: unserved demand, passenger transfer time and timetable deviation. With limited service capacity, the system may reject some passengers, so the model minimises the unserved demand, which is the total demand of unserved passenger groups. To improve the passenger transfer experience, the model also minimises the total transfer time of passengers. The total transfer time is defined by the passenger flow and the transfer time on each connection. A larger timetable deviation provides more space for the model to achieve a better-synchronised timetable, while the operator prefers to keep the timetable deviation low to reduce the impact of timetable adjustment on operation. The timetable deviation of a service refers to the absolute value of the difference between the departure times from the origin in the initial timetable and the synchronised timetable.

The multi-objective problem is solved in a lexicographic manner (i.e. minimise three objectives in order). The model takes the unserved demand as the first objective and minimises it. Then, the model minimises the passenger transfer time without increasing unserved demand. Finally, the model minimises the timetable deviation without increasing unserved demand and transfer time.

3.3 High level impact of the SESAR solution on the baseline SESAR architecture

All the functionalities of SOL2 are independent of the SESAR architecture. Therefore, we do not expect to impact any role or functionality of the SESAR architecture. We have presented the study on the impact on the SESAR capabilities in section 3.1.2.

4 Functional requirements

The following coding, based on the DES HE requirements and validation/demonstration guidelines is used for the requirements of SOL400/SOL2: REQ-SOL400-[OP/FR]-[*****][0-99].[0-999] where:

- OP: Operational requirement
- FR: Functional requirements
- SD00: Schedule Designer – General
- SD01: Schedule Designer – Function 1: Demand selection
- SD02: Schedule Designer – Function 2: Capacity calculation
- SD03: Schedule Designer – Function 3: Service selection
- SD04: Schedule Designer – Function 4: Demand regrouping
- SD05: Schedule Designer – Function 5: Service coordination

This nomenclature has been harmonised with the other solutions. We note that in order to simplify the requirements, inputs, intermediate outputs and outputs data formats are described in Annex A – Inputs and Outputs formats.

4.1 Operational requirements

4.1.1 REQ-SOL400-OP-SD00.001

Identifier	**REQ-SOL400-OP-SD00.001**
Title	Provide optimised flight schedules and rail timetable
Requirement	SOL400 shall provide optimised flight schedules and rail timetables
Status	Completed
Rationale	Defined in SOL400 OSED
Category	Operational

4.2 Functional requirements

4.2.1 REQ-SOL400-FR-SD01.001

Identifier	**REQ-SOL400-FR-SD01.001**
Title	Itinerary selection

Requirement	SOL400 shall take as inputs flight schedules, rail timetable, connecting times, possible itineraries, and passenger demand in those itineraries to construct an itinerary selection (file IO1)
Status	Completed
Rationale	The itinerary selection will allow to select the services to be optimised
Category	Functional

4.2.2 REQ-SOL400-FR-SD02.001

Identifier	**REQ-SOL400-FR-SD02.001**
Title	Capacity calculation
Requirement	SOL400 shall use the itinerary selection file and the service seats capacity to calculate the service capacity (file IO3)
Status	Completed
Rationale	The information about service capacity will be used to assign passengers to these services.
Category	Functional

4.2.3 REQ-SOL400-FR-SD03.001

Identifier	**REQ-SOL400-FR-SD03.001**
Title	Service selection
Requirement	SOL400 shall use the itinerary selection (file IO1) to obtain the service selection (file IO2)
Status	Completed
Rationale	These services are the ones whose schedule will be optimised
Category	Functional

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4.2.4 REQ-SOL400-FR-SD04.001

Identifier	**REQ-SOL400-FR-SD04.001**
Title	Demand regrouping
Requirement	SOL400 shall take the selected itineraries (file IO1) to retrieve the paths of the passengers and group them according to their path (file IO4). The group size is an input.
Status	Completed
Rationale	The groups of passengers will be assigned to new itineraries.
Category	Functional

4.2.5 REQ-SOL400-FR-SD05.001

Identifier	**REQ-SOL400-FR-SD05.001**
Title	Optimisation method
Requirement	SOL400 shall provide optimised flight schedules (file O1) and rail timetables (file O2) using the lexicographic method optimising first for unserved demand, then for waiting time minimisation and finally for timetable deviation
Status	Completed
Rationale	Defined in SOL400 OSED
Category	Functional

4.2.6 REQ-SOL400-FR-SD05.002

Identifier	**REQ-SOL400-OP-SD05.001**
Title	Optimisation strategies
Requirement	SOL400 shall optimised train and flight schedules using time-based strategies.
Status	Completed
Rationale	Defined in SOL400 OSED
Category	Functional

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4.2.7 REQ-SOL400-FR-SD05.003

Identifier	**REQ-SOL400-FR-SD05.001**
Title	Network constraints
Requirement	SOL400 shall optimise the schedules taking into account the network constraints (segment capacity, dwell times and airport capacity).
Status	Completed
Rationale	Defined in SOL400 OSED
Category	Functional

4.2.8 REQ-SOL400-FR-SD05.004

Identifier	**REQ-SOL400-FR-SD05.002**
Title	Main schedule optimisation
Requirement	SOL400 shall provide new flight schedules (O1) and rail timetable (O2) usable for Strategic Multimodality Evaluator such as SOL1.
Status	Completed
Rationale	It is expected that, as a result of Schedule optimisation, the demand of the passenger change. Thus, the use of the Strategic Multimodality Evaluator can be used to reflect those changes. The demand allocated by the Strategic Multimodality Evaluator along with the optimised flight schedules and rail timetable can then be used as input in SOL2 again to see whether the schedules can be further optimised.
Category	Functional

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5 Assumptions

5.1 Common assumptions for Schedule Design Solution

ID	Title	Description	Justification	Impact Assessment
A1	Case studies coverage	It is assumed that the case studies provide an interesting variety in terms of regional specificities and situations of multimodal transport (national case study and international corridor with an integrated HSR station in an airport).	Regional archetypes have been studied and the case studies cover a national and an international case.	Medium
A2	Regional archetypes	It is assumed that results derived from the regional archetypes can be translated and upscaled to a EU level using different regional archetypes as examples	The different regional archetypes represent a real combination of air and rail characteristics within a region or a transport corridor, and thus, the variety of multimodal conditions within the EU	Low
A3	Passenger archetypes coverage	It is assumed that the set of passenger archetypes considered are representative for the entirety of travellers.	Extensive research has been conducted to ensure that those passenger archetypes represent the variety of travellers.	Medium
A4	Data availability	It is assumed that the required data (demand for each passenger archetype, travel times, infrastructure capacity, passenger preferences, etc.) are available in the regions under study.	Data is required to execute the solution but modelling assumptions could be established if needed.	Medium

A5	Existence of multimodal governance	It is assumed that a multimodal performance scheme and multimodal governance is in place, allowing cooperation between modes of transport (shared data, information, incentive…).	The interest of the project lies in studying the impact of a multimodal and collaborative framework.	High
A6	Fixed demand per OD pair	It is assumed that the demand for each OD pair is fixed, meaning that the choice of passengers to travel is independent of the schedules (there will be no more or less demand) and their destination will not change as a result of the schedule optimisation.	It is considered sufficiently precise to have demand flows per OD pair and archetype for each scenario (including the impact of policies). The reaction of demand to the supply is considered to have a potential small impact only.	Medium
A7	Coordination between air and rail	The schedule coordination occurs between rail and air, leaving aside other long-distance ground transportation means as long-distance buses.	The scope and focus of the project is on air and rail collaboration. For future projects it would be interesting to include road transport.	Medium
A8	Fixed prices	It is assumed that the prices of the different paths are fixed as an input of the solution and will not be updated within the solution.	The reaction of the price to the demand through an economic model is considered out of the scope and interest of the project. Price variations may come from the policies defined in the scenarios.	Low
A9	Considered times	Scenarios, case studies, experiments and use cases will be performed at two distinct times. The reference will be the year 2019 using existing pre-COVID data and a baseline targeting a future development in the time frame 2030-2035 with subject data availability.	It is assumed that maturation of the solution from TRL 1 to TRL 2 can be sufficiently performed by using a) historical data and b) one future reference year.	Medium

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5.2 Specific assumptions for schedule coordination

ID	Title	Description	Justification	Impact Assessment
A1	Predetermined coordination strategy	For each service, the available coordination strategies (e.g. time shift, cancellation, rerouting) are predetermined according to the service type, route and other operation constraints.	The coordination strategies should consider the constraints of the infrastructure network and the requirements of operators. The availability of strategies can be predetermined by checking these constraints and requirements in advance.	Low
A2	Availability of rolling stock	The violation of the original rotations of trains and aircraft and the rolling stocks for the new services are not considered in the coordinated schedule design.	The rotation planning problems with a given schedule have been extensively studied for trains and flights. The scope of this project lies in the design of a coordinated schedule. The rotation planning problem can be solved again to accommodate the new schedule.	Medium

5.3 Specific assumptions for passenger assignment

ID	Title	Description	Justification	Impact Assessment
A1	Fixed path and mode choice	For each group of passengers, their path and transfer stations on the infrastructure network are fixed. The assignment focuses on matching passengers with services.	The path and mode choice of passengers are modelled in SOL1. The shift of path and mode choice under the coordinated schedule can be performed and evaluated by SOL1 separately.	Medium
A2	Shortest travel time	Passengers are assigned to the shortest available path within the service network regarding travel time. The availabilities of paths are determined by service capacities.	With a fixed path and mode choice, it is assumed that travel times are the main factor in the passenger choice of services.	Low

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6 References

6.1 Applicable documents

This FRD complies with the requirements set out in the following documents:

Content integration

[1] …

Content development

[2] …

System and service development

[3] …

Performance management

[4] …

Validation

[5] …

System engineering

[6] …

Safety

[7] …

Human performance

[8] …

Environment assessment

[9] …

Security

[10] …

Project and programme management

[11] 101114815 MultiModX Grant Agreement, 31/05/2023

[12] SESAR 3 JU Project Handbook – Programme Execution Framework, 13/01/2023, 1.0

6.2 Reference documents

[1] https://www.transit-h2020.eu/

[2] https://www.sesarju.eu/projects/modus

[3] https://cordis.europa.eu/project/id/285243

[4] Bešinović, N., Goverde, R., Quaglietta, E., Roberti, R., 2016. An integrated micro–macro approach to robust railway timetabling, Transportation Research Part B Methodological 87:14-32

[5] https://www.sortedmobility.eu/about

[6] Trepat, J., Bešinović, N., 2021. Scheduling multimodal alternative services for managing infrastructure maintenance possessions in railway networks, Transportation Research Part B: Methodological, vol. 154(C), pages 147-174.

[7] Ke, Y., Nie, L., Liebchen, C., Yuan, W., Wu, X., 2020. Improving Synchronization in an Air and High-Speed Rail Integration Service via Adjusting a Rail Timetable: A Real-World Case Study in China. Journal of Advanced Transportation 2020, 1-13.

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[10] Tan, Y., Li, Y., Wang, R., Mi, X., Li, Y., Zheng, H., Ke, Y., Wang, Y., 2022. Improving Synchronization in High-Speed Railway and Air Intermodality: Integrated Train Timetable Rescheduling and Passenger Flow Forecasting. *IEEE Transactions on Intelligent Transportation Systems* 23(3), 2651-2667.

[11] Ke, Y., Wu, X., Nie, L., Yao, Z., Chen, Y., 2024. Synchronizing train, aircraft, shuttle, and passenger flows in intermodal timetabling: A time–space network-based formulation and a decomposition algorithm using Alternating Direction method of multipliers. *Transportation Research Part C: Emerging Technologies* 159.

[12] Buire, C., Marzuoli, A., Delahaye, D., Mongeau, M., 2024. Air–rail timetable synchronisation: Improving passenger connections in Europe within and across transportation modes. *Journal of Air Transport Management* 115.

[13] European Commission: Directorate-General for Mobility and Transport and Directorate-General for Research and Innovation, *Flightpath 2050 – Europe's vision for aviation – Maintaining global leadership and serving society's needs*, Publications Office, 2011

[14] European Commission: Directorate-General for Research and Innovation, *Fly the Green Deal – Europe's vision for sustainable aviation*, Publications Office of the European Union, 2022

[15] European Commission: Mobility Strategy.

[16] PEARL -- Performance Estimation, Assessment, Reporting and simulation -- Performance Estimation, Assessment, Reporting and simuLation | PEARL Project | Fact Sheet | HORIZON | CORDIS | European Commission

[17] AMPLE3 -- SESAR3 ATM Master Planning and Monitoring – SESAR3 ATM Master Planning and Monitoring | AMPLE3 Project | Fact Sheet | HORIZON | CORDIS | European Commission

[18] SING-AIR -- Implemented Synergies. Data Sharing Contracts and Goals between transport modes and air transportation – https://sign-air.eu/

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Appendix A Input/Output formats

This Annex presents the format of the input and output datasets for SOL2.

A.1 Data approach

Instead of using a database approach, the input and output of both evaluators are in csv format. This faciliates the sharing, editing, reviewing and analysis of the different experiments and their outputs.

A.2 Files summary

Table A.1 provides a summary of all the files used by the SOL2. Some files are shared with the Strategic Evaluator of SOL1, as shown in the table below. The files are divided between Input, Intermediate Output (generated by some functions and subfunctions within the Strategic Multimodal Evaluator pipeline) and Output.

Type	Name	Short description
Input	I1. flight_schedules	I1 in SOL1
Input	I2. GTFS rail	I2 in SOL1
Input	I3. MCT air	I8 in SOL1
Input	I4. MCT rail	I9 in SOL1
Input	I5. flight_schedules_proc_#.csv	IO1 in SOL1
Input	I6. rail_timetable_all_gtfs_#.csv	IO4 in SOL1
Input	I7. transition_layer_connecting_times.csv	IO5 in SOL1
Input	I8. possible_itineraries_clustered_pareto_filtered_#.csv	IO11 in SOL1
Input	I9. pax_assigned_to_itineraries_options_#.csv	IO16 in SOL1
Intermediate output	IO1. itineraries_selection.csv	Information on which itineraries are considered
Intermediate output	IO2. services_selection.csv	Information on which services are considered
Intermediate output	IO3. service_capacity.csv	Service seat capacity available for the itineraries considered
Intermediate output	IO4. passenger_groups.csv	Passenger groups with their paths and demand

Output	O1. flight_schedules_proc_(#+1).csv	Synchronised flight schedules for the next iteration. The number is #+1 rather than # because these schedule have been iterated. .2.2
Output	O2. rail_timetable_all_gtfs_(#+1).csv	Synchronised rail timetable for the next iteration

Table A.1: Summary of all input, intermediate output and output files used and generated by the SOL2

A.3 Files Description

This section provides for each input, intermediate and output file a description of the different fields contained. This is therefore a description of the format of the data used by the Strategic Multimodal Evaluator.

A.3.1 Input files

I1. flight_schedules

- Flight schedules to be used to compute paths and itineraries

Field	Type	Mandatory	Other info
service_id	string	yes	Unique id per flight
origin	string	yes	ICAO code
destination	string	yes	ICAO code
dept_terminal	string	no	
arr_terminal	string	no	
sobt	datetime	yes	yyyy-mm-dd hh:mm:ss (in UTC time)
sibt	datetime	yes	yyyy-mm-dd hh:mm:ss (in UTC time)
sobt_tz	time delta	yes	(+/-)hh:mm timezone difference with UTC of sobt (should be +00:00 as sobt in UTC already)
sibt_tz	time delta	yes	(+/-)hh:mm timezone difference with UTC of sibt (should be +00:00 as sibt in UTC already)
sobt_local	datetime	yes	yyyy-mm-dd hh:mm:ss (in local time)
sibt_local	datetime	yes	yyyy-mm-dd hh:mm:ss (in local time)

sobt_local_tz	time delta	yes	(+/-)hh:mm timezone difference with UTC of sobt_local
sibt_local_tz	time delta	yes	(+/-)hh:mm timezone difference with UTC of sibt_local
provider	string	yes	airline operating the flight (required if to be considered when computing options)
ac_type	string	yes	aircraft type
seats	int	yes	number seats in aircraft
gcdistance	float	yes	great circle distance between origin and destination (km)

I2. GTFS rail

- Standard GTFS format (e.g. calendar.txt, calendar_dates.txt, stops.txt, stop_time.txt, trips.txt).
- Codes used in GTFS for stops should be consistent (e.g. if country code used) with codes used in other files when referring to train stops (e.g. when having id of rail stops in access/egress files).

I3. MCT air

- Information on MCT for air-air connections (per airport and with standard, international and domestic connections).

Field	Type	Mandatory	Other info
icao_id	string	yes	
standard	int	yes	Used if only one value is to be used, i.e. no diferentiation between domestic and international connections
domestic	int	no	Used for domestic connections
international	int	no	Used for international connections

I4. MCT rail

- Information on MCT for rail-rail connections (per rail station). If nothing provided then in config file a default value to be given.

Field	Type	Mandatory
stop_id	string	yes
default transfer time	int	yes

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I5. flight_schedules_proc_#

- Flight schedules used to compute possible/potential paths

Field	Type	Other info
service_id	string	As in I1. flight schedule
origin	string	ICAO
destination	string	ICAO
dep_terminal	string	
arr_terminal	string	
sobt	yyyy-mm-dd hh:mm:ss	In UTC
sibt	yyyy-mm-dd hh:mm:ss	In UTC
sobt_tz	(+/-)hh:mm	Time zone difference value of sobt and UTC (00:00)
sibt_tz	(+/-)hh:mm	Time zone difference value of sibt and UTC (00:00)
sob_local	yyyy-mm-dd hh:mm:ss	In local time
sib_local	yyyy-mm-dd hh:mm:ss	In local time
sobt_local_tz	(+/-)hh:mm	Time zone difference value of sobt_local and UTC (00:00)
sibt_local_tz	(+/-)hh:mm	Time zone difference value of sibt_local and UTC (00:00)
provider	str	airline id
ac_type	str	
seats	int	number seats in ac
gcdistance	float	Great circle distance (km) from origin to destination
alliance	str	Either the alliance of the airline (as in I15 airline alliances) or the id of the provider if airline not in an alliance
cost	float	Expected average cost of flight (EUR)
emissions	float	Expected emissions of CO2 per pax (kg)

I6. rail_timetable_all_gtfs_#.csv

- Table with rail services in GTFS format but with all the stops.
- Here trips between two stops are different rows in the data. So for example service id: 123 could go from stop 1 to stop 2 in the service (123_1_2) or from stop 1 to stop 3 (123_1_3) or from stop 2 to stop 4 (123_2_4), etc.

Field	Type	Other info
service_id	string	Id of the service encoded in this way: trip_stoporigin_stop_destination (e.g. 1_3_5) is trip 1 between stops 3 and 5.
origin	string	Id of the stop origin
destination	string	Id of stop destination
departure_time	yyyy-mm-dd hh:mm:ss	Departure datetime from origin (as in GTFS, so by default in local time)
arrival_time	yyyy-mm-dd hh:mm:ss	Arrival datetime to destination (as in GTFS, so by default in local time)
provider	string	
alliance	string	We could have alliance for rail operators too, by default it's just the same id as the provided. By default also all rail providers can link with any air provider.
cost	float	Expected average cost (EUR)
seats	int	Number of seats of service (note this is for the whole service not between these two stops necessarily)
emission	float	Expected average emissions per pax (CO2) in kg
country	str	Country of service (this comes from config.toml file)
lat_orig	float	latitude of stop of origin
lon_orig	float	longitude of stop of origin
lat_dest	float	latitude of stop of destination
lon_dest	float	longitude of stop of destination
gcdistance	float	Great circle distance in km from origin to destination

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I7. transition_layer_connecting_times.csv

- Transition times gate-to-platform (G2P), platform-to-gate (P2G) between layers used.

Field	Type	Other info
origin	string	Id of infrastructure of origin, either ICAO code for airport or stop_id for rail stations (as in GTFS)
destination	string	Id of infrastructure of destination, either ICAO code for airport or stop_id for rail stations (as in GTFS)
layer_id_origin	string	name of the layer of origin (either rail or air) to identify if origin is airport or rail station. Note potential changes between rail stations or airports could be allowed (e.g. Atocha - Chamartin)
layer_id_destination	string	name of the layer of origin (either rail or air) to identify if origin is airport or rail station. Note potential changes between rail stations or airports could be allowed (e.g. Atocha - Chamartin)
avg_travel_time	float	travel time between infrastructure (as in I10. infrastructure transitions)
pax_type	str	pax type that this applies (by default all)
mct	float	MCT adding to avg_travel_time the airport/rail processes as required to obtain the total p2p, p2g, g2p and g2g as required.

I8. possible_paths_avg_#.csv

- Possible paths to go between regions considering services schedules and connecting times.
- Group the itineraries by path and compute statistics on them.

Field	Type	Other info
path_id	int	Id of each path
itineraries	int	Number of itineraries for this path
origin	string	Id of the origin (region, in our case NUTS)
destination	string	Id of the destination (region, in our case NUTS)
path		
option	int	option within origin-destination (i.e., numbering of path for origin-destinatino)

total_avg_travel_time	float	Average total d2d travel time for itineraries in path
total_travel_time_min	float	Minimum total d2d travel time for itineraries in path
total_travel_time_max	float	Maximum total d2d travel time for itineraries in path
total_avg_cost	float	Average total cost (EUR) for itineraries in path
total_avg_emissions	float	Average total emissions per pax (CO2) for itineraries in path
total_avg_waiting_time	float	Average total waiting time (min) for itineraries in path
nmodes	int	Number of modes in path
earliest_departure_time	datetime with timezone	yyyy-mm-dd hh:mm:ss +00:00. In UTC (even for rail)
latest_arrival_time	datetime with timezone	yyyy-mm-dd hh:mm:ss +00:00. In UTC (even for rail)
journey_type	str	air, rail, multimodal, none
access_avg_time	float	minutes d2infrastructure
egress_avg_time	float	minutes i2d
origin_#	str	id of infratrcutrue of origin for service number # (e.g. origin_0)
destination_#	str	id of infrasture of destination for service nubmer # (e.g. destination_0)
mode_#	str	mode of service # (air, rail)
travel_avg_time_#	float	average travel time (min) for itineraries in path for service #
cost_avg_#	float	average cost (EUR) for itineraries in path for service #
emissions_#	float	average emissions (CO2) kg per pax for itineraries in path for service #
mct_avg_time_#_$	float	average MCT between services # and $ for itineraries in path
connecting_avg_time_#_$	float	average connecting time between services # and $

waiting_avg_time_#_$	float	average waiting time between services # an $
connecting_time_#_$_max	float	maximum connecting time between services # and $
waiting_time_#_$_max	float	maximum waiting time between services # and $

I8. possible_itineraries_clustered_pareto_filtered_#.csv

- Cluster of itineraries considering KPIs describing those itineraries, i.e., *equivalent* itineraries.
- Note, by default the number of services difference is set to 0, so if two itineraries have different number of services they are clustered separatelly. The same applies to journey_type, all journey_types are clustered separately.
- Only keep the ones that dominate the others (Pareto) within some margins and per mode type (rail, air, multimodal).

Field	Type	Other info
origin	string	Id of the origin (region, in our case NUTS)
destination	string	Id of the destination (region, in our case NUTS)
journey_type	str	Type of journey: air, rail, multimodal, none
cluster_id	int	Numerical id for cluster for origin-destination (id of first itinerary in cluster)
alternative_id	str	Unique id per cluster formed as origin_destination_cluster_id (e.g. ES111_ES112_0)
options_in_cluster	list of int	List of id of itineraries which belong to this cluster. I.e., list of ids from option from possible_itineraries_#.csv (e.g. [0, 1, 2, 3, 4])
total_travel_time	float	Average total travel time of all itineraries in cluster
total_cost	float	Average total cost (EUR) of all itineraries in cluster
total_emissions	float	Average emissions per pax (CO2) for all itineraries in cluster
total_waiting_time	float	Average total waiting time (min) for itineraries in cluster
nservcies	int	Average number of services (flights, trains) in itineraries in cluster.
alternative_id	string	Unique id of the cluster for which this itinerary belongs (e.g. ES111_ES112_0)
cluster_id	int	cluster_id: Int id of the cluster for the o-d pair of this itinerary (e.g. 0)

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I9. pax_assigned_to_itineraries_options_#.csv

Field	Type	Other info
id	int	Numerical id of cluster (used internally)
option_number	int	Number of option for the origin-destination
alternative_id	str	Unique id of cluster composed of origin_destination_int(of first option in cluster) (e.g. ES111_ES112_0)
nid_f#	string	Id of the # service (flight or rail)
total_waiting_time	int	Total waiting time of the itinerary considering all connections (waiting time = connecting time - mct) (min)
total_time	int	Total time of trip (min) (door-to-door estimation)
type	str	Type of itinerary as concatenation of modes used: e.g. rail, flight, flight_flight, rail_flight, rail_rail, rail_flight_rail, etc. Note, it could be empty if no mode is used (only access/egress from infrastructure)
volume	float	Number of pax assigned to the cluster from the logit model. Note this is not the number of pax of this itinerary but of this cluster (i.e., to be shared by all the itineraries in the cluster)
fare	float	Average fare of the itinerary
volume_ceil	int	Volume applied ceil to transform float to int of pax
pax	int	Number of passengers the passenger assigner (disaggregator) has put in this particular itinerary. Could be 0.

A.3.2 Intermediate outputs

IO1. itineraries_selection.csv

- Indicates if the itinerary is selected or not.

Field	Type	Other info
id	int	Numerical id of cluster (used internally)
option_number	int	Number of option for the origin-destination
alternative_id	str	Unique id of cluster composed of origin_destination_int(of first option incluster) (e.g. ES111_ES112_0)
selected	boolean	Indicates if the itinerary is selected (0, no; 1, yes)

IO2. service_selection.csv

- Indicates if the service is selected or not.

Field	Type	Other info
service_id	string	Unique id per service
selected	boolean	Indicates if the service is selected (0, no; 1, yes)

IO3. service_capacity.csv

- Seat capacity availability of services.

Field	Type	Other info
service_id	string	Unique id per service
seats	int	Number of seat available

IO4. passenger_groups.csv

- Passenger groups with their paths and demand

Field	Type	Other info
group_id	string	Unique id per group
path	list of infrastructure ids	List of all infrastructures that are in the path, either stop_id for rail stops or ICAO code for airports. For example: ['007131412', ‘007131400'] ['LEBL', 'LEMD’]
pax	int	Number of passengers in the passenger group

A.3.3 Outputs

O1. flight_schedules_proc_(#+1).csv

- Same format as the initial flight schedules I1.

O2. rail_timetable_all_gtfs_(#+1).csv

- Same format as the initial rail timetable I6.

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