Abstract
Evaluating IAM through the lens of System of Systems: Results and Next Steps

Nabih Naeem[†,‡], Nazlican Cigal[†], and Prajwal Shiva Prakasha[†]
[†]*Institute of System Architectures in Aeronautics, German Aerospace Center (DLR),*
[‡]*Nabih.naeem@dlr.de;*

Innovative Air Mobility refers to the safe, secure and sustainable mobility of passengers and cargo enabled by integrating new technologies (such as eVTOLs) into a multimodal transportation system. As such it involves numerous stakeholders with their own interest in the IAM System of Systems. IAM necessitates significant innovation and development to achieve the desired capabilities, relating to all aspects including aircraft, vertiport, airspace management and more.

This work presents the System of Systems approach to evaluating IAM/AAM following a product push paradigm, where the objective is to identify how a given aircraft can be embedded into the existing transport system while ensuring profitability, sustainability and value addition. Furthermore, through the use of Value/Business Models representing the satisfaction of each major stakeholder, this work evaluates how stakeholder satisfaction varies with the SoS design space. The SoS evaluation of the IAM is carried out using an Agent-Based Simulation of IAM built using the SoSID Toolkit [1–3] where the active stakeholders, their actions and interactions are modelled. Where possible, a parametric approach is adopted in the modelling to allow for broad design space exploration across all active stakeholders. The work carried out as part of the COLOSSUS Project [4], focuses on the integration of a fixed eVTOL concept into the existing Transport System.

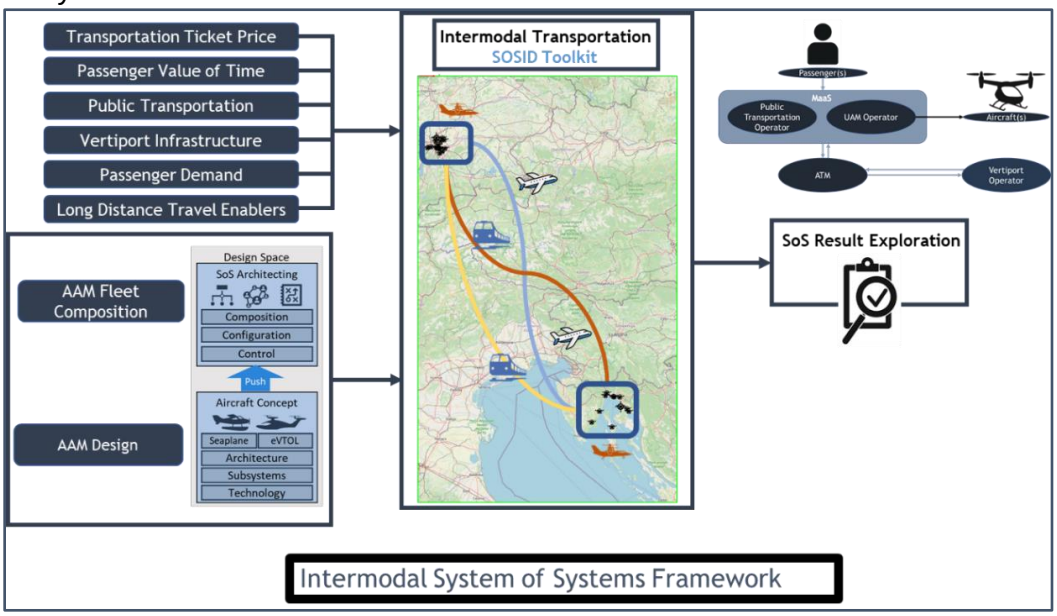

Figure 1 IAM SoS Framework

The research employs an Intermodal SoS analysis framework as depicted in

Figure 1. The simulation model takes inputs of the aircraft and fleet composition, vertiport infrastructure, passenger demand and type, public transportation metrics, and long-distance travel enablers. Vehicle to passenger allocation model is based on a bidding algorithm where each aircraft agent estimates the earliest it can serve a passenger request. The bidding algorithm includes multiple factors, such as the load factor associated with the request, energy needed and time taken.

The study evaluates the Architecture choices of the SoS that lead to a profitable, sustainable and beneficial IAM. By varying the aforementioned model inputs, and evaluating against the Objective Functions and Value/Business Models; the best architecture can be identified. As the IAM SoS has diverse stakeholders with different interests in the SoS, a particular interest is given to how the stakeholder interests can be managed while also considering the overall effectiveness of the SoS. In this regard, multi-criteria decision making from the Stakeholder perspectives will also be carried out. It will explore how accounting for stakeholder preferences impact the best SoS architecture in contrast to considering only the objectives of the SoS.
A preliminary view of the stakeholder metrics that will be considered are as follows:

1. Passenger-Centric Metrics

These metrics measure how well the system meets individual travelers' needs and preferences:

- **Total Travel Time**
  Sum of all journey segments including transfers and waiting. Reflects convenience and efficiency.
- **Number of Transfers per Journey**
  Indicates complexity of the route. Lower values generally correspond to higher satisfaction.
- **Waiting Time**
  Time spent at stations or vertiports before boarding the next mode. A proxy for system responsiveness.

2. Operator-Centric Metrics

These reflect vehicle and infrastructure efficiency, critical for IAM service providers:

- **Revenue**
  Revenue generated by the IAM Operations.
- **Passengers Transported**
  The number of passengers choosing IAM services and transported.
- **Deadhead Ratio**
  Percentage of total flights without passengers (repositioning flights). Lower values imply better fleet planning.
- **Fleet Utilization Rate**
  Ratio of active flight time to total available flight hours. High utilization indicates efficient deployment.

3. Environmental Metrics

These measure the ecological impact of different transport configurations:

- **Emission Savings from Modal Shifts**
  Difference in emissions when passengers shift from higher-impact modes to lower ones (e.g., PT or AAM with clean energy).
- **Total Carbon Emissions**
  Calculated using emission factors for each mode. Compared across scenarios (e.g., PT-only vs. PT+AAM).
- **Average Emissions per Passenger-Kilometer**
  Standardized measure to account for travel distance and passenger load.

In future work, through the IAM-OSA project, the work will be extended with a deeper consideration of the active stakeholders such as vertiport operator, airspace management, passenger and more, by embedding expert knowledge through models into the established IAM Simulation.

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Biography

Nabih Naeem

Nabih Naeem is a researcher at the Institute of System Architectures in Aeronautics at the German Aerospace Center (DLR). His research focus is on System of Systems where Innovative Air Mobility and Aerial Wildfire Fighting use cases are evaluated with a holistic view point.