

A System of Systems Framework for Evaluating Innovative Air Mobility in Middle Mile Logistics

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Abstract

Innovative Air Mobility (IAM) offers opportunities to integrate cargo drones and electric vertical take-off and landing (eVTOL) aircraft into regional logistics networks. Middle-mile logistics encompasses transport between logistics facilities, connecting regional hubs with local distribution centres or production sites. Aerial services may be particularly useful for time-critical cargo and routes with limited ground access. Their integration requires coordination between independently operated transport services and hub infrastructure. A System of Systems (SoS) perspective captures these interdependencies and how decisions within individual systems affect the performance of the cargo chain. Existing research gives considerable attention to last-mile parcels and simplified truck–drone operations. Middle-mile studies often simplify cargo compatibility and rarely consider shared handling capacity and aircraft charging together with fleet decisions. Representing these interactions is essential to evaluating the contribution of IAM to existing logistics networks.

This work presents an agent-based simulation framework for evaluating IAM concepts in middle-mile cargo logistics. The simulation represents shipment assignment and transport execution, accounting for cargo compatibility and delivery deadlines. Capacity-limited handling and aircraft charging create queues at hubs, affecting vehicle availability and subsequent deliveries. Stochastic operations and disruptions enable the assessment of adaptive dispatching and recovery from interrupted services. The framework supports decisions on eVTOL integration by linking fleet configurations and operating strategies to the performance of the complete cargo chain. A regional cargo scenario demonstrates its application through a comparison of ground-only and combined air–ground operations. The comparison evaluates when aerial services improve delivery performance and how these improvements depend on operating costs and available hub capacity.

Keywords: System of Systems, agent-based modelling, middle-mile logistics, air–ground cargo transport



Figure 1. Simulation view of a regional air–ground cargo demonstration scenario.