Agentic AI for Adaptive and Resilient Middle-Mile Freight Operations

Vision Statement

What if we could deliver freight faster, at lower cost, and with greater reliability by transforming the middle mile into an adaptive AI-driven network?

Topic Area:	Optimization
Applicant Type:	Individual
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Abstract The U.S. middle mile—the network of sorting hubs, distribution centers, and regional facilities that moves freight between producers and final delivery—operates through a fragmented decision process. Centralized plans are generated days and hours in advance; when disruptions occur, each facility responds on its own, without visibility into how its adjustments affect the rest of the network. The result: 20–35% of truck miles driven empty, average load factors near 57%, and disruptions that take 2–4 hours to resolve while delays compound at downstream hubs. The problem is not that better algorithms are needed at individual facilities—it is that no mechanism exists for these facilities to coordinate their decisions across the network as conditions change.

This project develops a *coordination-aware decision architecture* that fundamentally changes how freight networks operate. Distributed AI agents at each facility autonomously resolve targeted operational decisions—dock scheduling, load assignment, dispatch sequencing—through scoped, incremental updates rather than full replanning, while exchanging compact signals with neighboring hubs. Agents update only when conditions change meaningfully, and decisions propagate selectively across the network in minutes rather than hours—enabling coordination without centralized control or full data sharing.

The proposed 36-month, $2.3–$2.6M R&D effort progresses from single-hub feasibility through multi-hub coordination to pilot deployment within operational freight networks. The target users are freight carriers, parcel networks, and third-party logistics operators that manage multi-facility systems. The architecture is modular: operators can deploy individual agents independently and expand to full network coordination as needs grow. Deployment proceeds through shadow mode (decisions logged without affecting operations), advisory mode (recommendations reviewed by operators), and autonomous mode (decisions executed with human oversight)—enabling adoption within existing systems without replacing them.

The project targets disruption response under 15 minutes, facility utilization of 80–90%, and delivery reliability of 97–98%—to be validated through simulation and pilot deployment. U.S. freight logistics represents over $2 trillion annually; if the architecture performs as designed, even modest improvements in utilization and empty miles at network scale would yield significant reductions in fuel consumption, operating costs, and emissions. The proposed system aligns with U.S. DOT priorities in freight efficiency, supply chain resilience, and infrastructure utilization, and provides a foundation for extending coordinated decision-making to rail, port, and intermodal operations.