

Project Title

Autonomous Aircraft Logistics: Challenges and Opportunities

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Research Needs

The rise of autonomous vehicles of all types has created a new landscape of autonomous logistics that is rather complex and filled with uncertainties. Autonomous-electric taxis, trucks, trains, aircrafts, and ships are underway because of global *push* and *pull* factors (Bridgelall & Tolliver, 2020). Technological advancements in energy storage, capacity, computing, communications, and lightweight structural materials have reduced the cost, size, noise, and risks of vehicle operations. As a result, there has been a manufacturing *push* of many variants into the marketplace. The commercial *pull* is motivated by anticipated improvements in cost-efficiency, safety, reliability, speed, and pollution reduction (Marechal, 2020). As carriers initiated partnerships with major retailers and restaurants to deliver groceries and food with autonomous road and sidewalk robotic vehicles, the global pandemic of 2019 has solidified and accelerated those trends (Kapsner, Abdelrahman, & Bernecker, 2021). These developments resulted in a blossoming new field called *autonomous logistics*.

This research focuses on the subfield of autonomous aircraft logistics. Advancements in low-cost sensing and artificial intelligence have increased the affordability of unmanned aircraft systems (UAS), more commonly known as drones. Beyond cargo logistics, businesses are using drones for myriad of other applications such as aerial photography, search and rescue, terrain mapping,

safety inspections, crop monitoring, storm tracking, law enforcement, and air-taxis (Mazur, Wiśniewski, & McMillan, 2016). This proposal focuses on the subfield of autonomous aircraft *cargo* logistics (AACL) to directly contrast it with autonomous aircraft *passenger* logistics (AAPL) or flying taxis. The FAA Urban Air Mobility (UAM) program covers both cargo and passenger modes of autonomous aircraft logistics (FAA, 2020).

There are many uncertainties about AACL adoption. Wing Aviation LLC (a division of Alphabet, Google's parent company), UPS, and Amazon were among the first companies to gain FAA approvals for commercial package delivery drone operations beyond visual line of sight. Meanwhile, DHL, Uber, and Walmart have been testing drone-based delivery services in preparation to launch those services within the next few years. Hence, AACL will potentially compete with trucks and other modes of ground transportation. The potential disruptions from AACL are likely to upend business models and change the landscape for logistics.

Research Objectives

The **goal** of this research is to understand the scope of AACL applications, prospects for adoption, deployment challenges, and the potential implications for planners and policymaking. The technical **objectives** of this research are to classify AACL applications, identify adoption challenges, identify opportunities and synergies with other technologies, establish a technology roadmap based on emerging multi-technology trends, and identify implications to transportation planning and policymaking. The non-technical objectives are workforce development and technology transfer that will result in scholarly publications and curricula refinements that focus on intelligent transportation solutions. The research objectives are as follows:

1. *Application Classification*: Logistics categories beyond “last-mile” include “middle-mile,” “emergency supply,” and “emergency repair.” Research and identify application categories to further examine the scope and different considerations.
2. *Identify Adoption Challenges*: Regulations continue to evolve with this new mode of transportation. Other challenges include constraints such as payload capacity, flight range, refueling strategies, reverse logistics, and cybersecurity.
3. *Identify Opportunities*: Blockchains and AI are evolving to help secure the supply chain and enhance operations. Examine how such technologies complement the coordination of surface transportation and air cargo.
4. *Establish Technology Roadmap*: New structural materials, batteries, sensors, communications, and algorithms will drive the technology roadmap. Examine their potential impacts on performance, cost, safety, and security.
5. *Identify Implications*: Adoption will affect all aspects of ground and manned air cargo logistics. Review the literature on potential impacts and propose relevant research questions for further exploration.
6. *Workforce Development and Technology Transfer*: One graduate student and one post-doctoral researcher will work closely with the PIs to develop conference presentations, journal papers, and a project report.

Research Methods

Business models are ripe for AACL deployments. BI Intelligence found that half of Walmart’s potential customer base for a drone delivery service is within six miles of a store, which is within the current flight range of a typical drone (Camhi, Pandolph, & Newman, 2017). According to Amazon’s FAA petition, approximately 85% of the company’s shipped orders weigh less than 5 pounds, which is within the current payload capacity of a typical drone (FAA, 2019). An analysis by Ark Invest determined that based on conservative estimates for capital and operating costs, it would cost Amazon less than \$1 to deliver a package within 30 minutes using drones as compared with \$2 to \$8 using ground transportation (Keeney, 2015).

In addition to cost reduction, AACL could increase the population proportion that shippers can reach for same-day delivery. Direct path accessibility by air enables faster delivery by avoiding frequent stops and road traffic. Robots can work non-stop, day and night, and without a salary, holidays, or sick leave. The persistent shortage of truck drivers can accelerate AACL adoption (Trick & Peoples, 2021). Autonomous trucks in the future are not likely to compete with AACL for “last-mile” logistics because autonomous truck operations are currently better suited for long-distance travel on highways versus local urban roads (Kassai, Azmat, & Kummer, 2020). The significant reduction in cost of using drones instead of helicopters could drastically decrease a need for the latter in the short-term. However, the above hypotheses cannot be tested without further analysis to understand the prospects for AACL adoption.

The research methods will include a literature review, stakeholder engagement, information synthesis, data and trend analysis, and the development of a cognitive framework to forecast implications on transportation planning and policymaking.

- *Literature Review*—the literature on AACL is broad and rapidly evolving. This task explores the existing knowledge, identifies gaps, and proposes research questions for further exploration.
- *Stakeholder Engagement*—the research team will exchange information with the North Dakota Department of Commerce (NDDOC), North Dakota Department of Transportation (NDDOT), the North Dakota UAS Test Site, and their relevant customers to assemble use cases, business development initiatives, and technology forecasts.
- *Information Synthesis*—the knowledge gathered from the literature review and stakeholder engagement will inform a *taxonomy* development to classify applications and relate them to a variety of terminologies currently in use or emerging.
- *Data and Trend Analysis*—the literature review and stakeholder engagement will generate data about equipment type, capabilities, costs, and operational characteristics to expose trends and inform the development of a technology roadmap. Research will include alignment with the established roadmaps for key components such as structural materials, batteries, electronics, sensors, communications, and cybersecurity.
- *Cognitive Framework*—the knowledge gathered will feed into a matrix that will become a tool to aid cognition about potential implications to transportation planning and policymaking. The framework will leverage previous work that studied the evolution and adoption of connected and autonomous vehicles (Bridgelall & Tolliver, 2020).

Expected Outcomes

The expected outcomes are educational benefits and technology transfer to support business development in UAM. The findings will support broad initiatives within North Dakota to expand AACL applications that can utilize the statewide deployment of a beyond visual line of sight (BVLOS) network. Stakeholder engagements will help to enrich the study with practical considerations based on real-world needs. Planners will gain an understanding of how the technology roadmap will affect the potential for future adoption within the state, nationally, and internationally. Planners will evaluate the identified adoption challenges and relate them to local issues that will guide policymaking to encourage adoption. Gaps identified in the literature will generate ideas for future research. The final report will serve as a reference baseline for knowledge gained in this snapshot of the technology evolution and will serve as a benchmark to evaluate impacts from future developments.

Relevance to Strategic Goals

This study relates to the strategic goal of *State of Good Repair* based on the anticipated mode shifts towards lower-cost and more efficient electrified air transport. This mode shift will move traffic off roadways to prolong service life and reduce pollutive emissions.

Educational Benefits

The project will include at least one graduate student who is working towards a Ph.D. The student will incorporate some of the methodologies and findings of the project into a dissertation. The PI will advise the student in both an academic and professional development capacity. The project will help the student hone research, presentation, and writing skills needed for advancements in the professional world. The broader educational benefits will be knowledge products and tools that feed into curricula development and laboratories in multimodal transportation systems. The PIs intend to incorporate knowledge and models from this research into curricula focused on intelligent transportation solutions.

Technology Transfer

Students will gain expertise in technology development to enhance business practices and logistical operations. The research team will utilize the project findings and models to prepare publications and outreach material that would encourage further adoption in the real world. Knowledge gained from the project will encourage business development in several new logistical arenas that can benefit from AACL. The team will utilize traditional methods such as journal papers, conference presentations, project reports, web page postings, and other marketing or outreach materials. In addition, the team will engage stakeholders throughout the project to review intermediate findings and to suggest future research directions. The PIs will notify the progress-reporting system (PPPR) of any publications generated from this project, as well as technology transfer activities.

Work Plan

The work plan consists of the following tasks that the team will complete over a two-year period, with the month indicated relative to the project start date:

1. *Literature Review*: Starts and ends in the 1st and 9th month, respectively.

2. *Stakeholder Engagement*. Conducted throughout the project.
3. *Application Classification*. Starts and ends in the 10th and 18th month, respectively.
4. *Adoption Challenges*. Starts and ends in the 13th and 20th month, respectively.
5. *Opportunities*. Starts and ends in the 10th and 21st month, respectively.
6. *Technology Roadmap*. Starts and ends in the 16th and 24th month, respectively.
7. *Implications*. Starts and ends in the 16th and 21st month, respectively.
8. *Final Report*. Starts and ends in the 22nd and 24th month, respectively.

Project Cost

Total Project Costs:	\$366,000
MPC Funds Requested:	\$183,000
Matching Funds:	\$183,000
Source of Matching Funds:	In-kind contributions from private sector UAV service providers, contributed time from state agency partners, and NDSU returned F&A.

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