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Project Title

Strategic Deployment of Drone Centers and Fleet Size Planning for Drone Delivery in Utah

University

University of Utah

Principal Investigators

Cathy Liu, Ph.D.
Associate Professor
Dept. of Civil and Environmental Engineering
University of Utah
Phone: (801) 587-8858
Email: cathy.liu@utah.edu
ORCID: 0000-0002-5162-891X

Research Needs

In a 2017 report by the RAND corporation, analytical methods for calculating the total energy consumed by a mix of delivery trucks and drones were developed and shown to be highly dependent on the layout of distribution centers as well as distance traveled by delivery vehicles. This suggests that the city layout, i.e., street connectivity and other network parameters, are important considerations for energy-conscious policies. While industry stakeholders must determine the market viability of drone delivery, they are not required to calculate the external and indirect costs that may be associated with this burgeoning industry. Furthermore, the unstructured airspace proposed by some stakeholders can have an undesirable monopolistic effect caused by the computational aspects of this approach. The research proposed here will produce a state-wide drone network, and hence a structured airspace, that can potentially increase the accessibility of the airspace while ensuring a higher degree of safety.

Research Objectives

The motivation for this work is to provide regulators, policymakers and industry stakeholders with a data-driven framework for assessing the energy costs and trade-offs of large-scale drone delivery in the state of Utah. The primary objective of this research project is to produce a computer program that takes inputs of state-wide road network, the total number of (drone-deliverable) packages to deliver on a given day and their destinations, and energy and cost assumptions per vehicle, and produces a state-wide airspace network, delivery schedule, and truck/drone fleet mix. Such airspace network is optimized to ensure that drones are strategically deconflicted as required by NASA and the total energy over that day is minimized. This program will provide the state with more clarity about the energy impacts of large-scale drone delivery, as well as a viable airspace network.

Research Methods

Large-scale drone delivery is on the horizon nationwide, as it has the potential to decrease pollution and help alleviate road congestion. Up until now, industry is mainly concerned with the market viability of drone deployment, and very little attention has been paid on external costs such as energy tradeoff. The benefits of drone deployment, however, is largely dependent upon layout of distribution centers and distance traveled. To this end, this research will employ a data-driven approach to strategically replace ground-based delivery networks with air-based drone deployment. Built upon our preliminary work, we will structure the air space by regulating and treating it as lanes, and optimize drone dispatch. Figure 1 shows the methodological framework of our research.

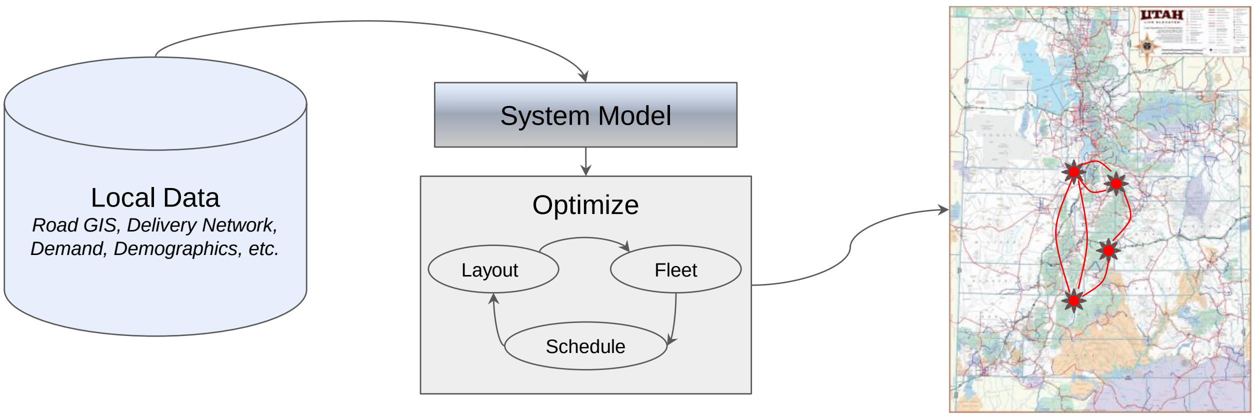

Figure 1: Methodology Framework of Proposed Drone Network Optimization

The proposed research will first gather data on the state-wide roadway network, projected freight volume for the future year (e.g., 2025) in terms of origin and destination, and estimated truck fleet size and energy consumption. This data will be fed into an optimization model to determine the schedule and deployment of drones within the study area. The developed system model with the optimization component will be implemented onto a web-based platform where people can assess different assumptions of the model and run "what-if" scenarios by generating animation of the optimized airspace network.

Expected Outcomes

The research project will produce a state-wide airspace network, delivery schedule, and truck/drone fleet mix. Such airspace network is optimized to ensure that drones are strategically deconflicted as required by NASA and the total energy over that day is minimized. The results will be implemented as an automated computer program hosted on a web-based platform to provide the state with more clarity about the energy impacts of large-scale drone delivery, as well as a viable airspace network. The research will also help inform the UDOT Division of Aeronautics to develop policies and negotiate with industry stakeholders.

Relevance to Strategic Goals

This project primarily addresses USDOT strategic goal of "Environmental Sustainability". Companies such as Amazon, UPS, and Google are already exploring delivery options with drones instead of trucks, as such alternative appears to be promising in terms of reducing costs, saving fuels, and potentially reducing carbon emissions. A statewide policy regarding drone delivery plan will assist public agencies such as the UDOT to take a holistic view on the regional impact of drone delivery and improve the environmental sustainability and competitiveness of the state.

The proposed project also ties closely with MPC's center focus of "preserving the existing transportation system". The project involves incorporating advanced and emerging technologies for preserving the ground transportation infrastructures while providing ground-breaking guidance on expanding transportation options. The utilizations of optimization techniques, geographic information system, and visualization will enable the fostering of next generation traffic engineers for leveraging advanced skillsets in analyzing infrastructure conditions.

Educational Benefits

One graduate student will be heavily involved in this research. He/she will lead the preparation of journal publications resulting from the work, and in most cases, deliver conference presentations. The project will serve as a basis for his/her dissertation work. The PI is currently offering a graduate level course "Transportation Network Modeling" every Fall semester. The quantitively modeling framework developed in this research will lead to new material included in the course to teach the students practical skills on visualization and analytic techniques for modeling air transportation network.

Technology Transfer

The research will inform the UDOT Division of Aeronautics to develop policies and negotiate with industry stakeholders. The web-based platform will enable UDOT professionals to assess the results of different assumptions that were made through the project.

The potential audiences for this research are individuals involved in the urban air mobility and transportation network planning (both ground and air), including transportation planners, modelers and senior leaders at FHWA, state DOTs, and MPOs. The following agencies, offices, and committees are those most likely to take a leadership role in implementing the research results:

- Utah Department of Transportation (UDOT)
- FHWA Office of Planning
- Wasatch Front Regional Council (WFRC)

The proposed principal investigator routinely interacts with UDOT, WFRC, UTA, and FHWA. The 2021 TRB Annual Meeting will be an opportunity to share early results and future directions of the research project. The proposed principal investigator will work with several committee chairs to possibly get a presentation on the project added to the agenda. The proposed principal investigator and her graduate students routinely attend TRB's annual meeting as well. At least one TRB paper on this work will be submitted for presentation and publication.

Work Plan

The following major tasks are anticipated:

Task 1. Stakeholder meetings (1 month)

Assemble a group of stakeholders from UDOT, WFRC, and MAG to advise the research. A total of three meetings is envisioned: 1) kick off and introduce the project; 2) present initial data collection efforts and assumptions of proposed optimization model; and 3) present findings from modeling and analysis of the structured airspace.

Task 2. Data collection (3 months)

Assemble data from multiple agencies to be used for airspace optimization. The data include but are not limited to: road network structure, commercial truck trips (origin and destination), packages demand, and energy and cost for drones and trucks.

Task 3. Optimization model development (4 months)

Build an optimization model for the state-wide airspace network to produce optimal solutions of delivery schedule and truck/drone fleet mix, considering minimized energy consumption and NASA requirement for drone operation.

Task 4. Computer program development (4 months)

Create a computer program to allow UDOT to assess different assumptions of the model and run "what-if" scenarios by generating animation of the optimized airspace network. Such airspace network is optimized to ensure that drones are strategically deconflicted as required by NASA and the total energy over that day is minimized. This program will provide the state with more clarity about the energy impacts of large-scale drone delivery, as well as a viable airspace network.

Project Cost

Total Project Costs:	$ 80,000
MPC Funds Requested:	$ 30,000
Matching Funds:	$ 50,000
Source of Matching Funds:	Utah Department of Transportation