Corvus: Urban Air Mobility Solutions for Package Delivery

(Technical Paper)

Socioeconomic and Ecological Impacts of Urban Rail Transportation

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

The transportation infrastructure within American cities is in a state of inadequacy and inefficiency. Both goods and people suffer from a lack of access to reliable, sustainable, and effective methods of getting from point to point. These deficiencies hamper the economic potential of urban areas, contribute to widespread atmospheric pollution, and lead to more operational time wasted. To address the issue of insufficient assets for the sustainable and rapid transportation of goods in urban areas, a design study will be performed. This effort, undertaken as a part of the NASA University Design Contest, will seek to design an unmanned aerial system (UAS) that will deliver packages in urban environments. This future network will replace or augment existing automotive package delivery systems, cutting costs for both companies and consumers, and improving atmospheric pollution and roadway congestion by taking delivery vehicles off of the roads. This system will be successful through its implementation of next-generation technology and economic integration with existing commercial infrastructures. Through performing a thorough aeronautical design, successful market analysis, and cooperating with proposed drone infrastructure, the development of a well-functioning and efficient urban air package delivery system will be accomplished.

When considering the costs associated with legacy methods for package delivery, many of these same issues arise when considering urban rail transportation. Operational networks are too small, timetables are inconvenient, and infrastructure is outdated and crumbling. These factors combine to cause many to take more pollutive forms of transportation, such as cars and buses, to locations where many travel to. Additionally, many who more heavily rely on public transit, such as those in less advantageous socioeconomic situations, are underserved by existing infrastructure (House of Commons, 2013). This lack of service hampers the ability of city residents to find a job, increase their level of wealth, and improve their social mobility. Improving the accessibility to reliable transit should be a priority of city planners, however it is imperative that these networks are in fact a net benefit. Pollutive forms of transit provide a smaller advantage over automobiles, property values near train tracks can both rise and fall depending on the circumstances, and government corruption and lobbying can result in mismanagement of assets (BBC, 2019). Analyzing the successes and failures of current systems, both domestic and international, can provide valuable insight in how to best construct a well-functioning rail transit network. In order to improve the current state of urban rail transportation in the United States, a series of case studies examining the successes and failures of existing systems will be undertaken, emphasizing economic, social, and political issues.

Technical Topic - Urban Air Mobility Solutions for Package Delivery Methods

The objective of this project is to "Design a safe, reliable autonomous system to deliver small packages to extremely short take-off and landing platforms within an urban environment (NASA, 2019)." There has been exponential growth in the field of urban air mobility over the last decade, so NASA's Aeronautics Research Mission Directorate (ARMD) created the annual Aeronautics University Design challenge for 2019-20 to explore this area. The ultimate goal is to enable the rapid delivery of goods, and eventually people, through a fully autonomous, unmanned aerial system.

This project will be undertaken by a class of 13 aerospace engineering students over the course of an academic year. To assist in this process, engineering students will divide into groups specializing in aerodynamics, performance, and propulsion, and research state of the art technologies in each category. Students will also collaborate with students from the McIntire School of Commerce, or economics students to help develop the business plan. As the autonomous drone topic is not directly suited to the team topics, there will also be research into the state of the art of electronics and machine learning systems. The final deliverable will be a system that is a combination of the state-of-the-art research and the ideas of individual students in the class.

This goal is a technical stretch, and will require numerous innovations and developments to see successful implementation. The foremost factor restricting advances in drone development currently is the power source. Batteries and electric propulsion fulfill all the stated design requirements for noise, economics, and sustainability, but currently do not have a sufficient energy density to supply all of the systems needed with sufficient margin of error to be safe (Ng & Datta, 2019). While many battery powered drones do exist, the power needed to power both a detect and avoid system and fleet autonomy alongside propulsors is not currently available in commercially available batteries. Conventional fuels currently have almost 60 times as much energy per unit mass as lithium ion batteries, and are projected to still have more than 20 times the energy in 15 years (Brelje & Martins, 2019). However, conventional fuels require combustion engines to produce thrust, which are noisy, polluting, and expensive because of fuel consumption, which all represent serious drawbacks for a UAS reliant on fossil fuels. Unfortunately, this project will rely on projected improvements to electric power technology using models and trends of previous improvements, as developing new battery technology is beyond the purview of the design project.

Additional technical limitations present themselves due to the absence of a currently active Unmanned Aircraft System Traffic Management (UTM) system, with which the proposed drones are to integrate with. A functional UTM system will enable the real-time identification, tracking, and navigation of autonomous drones across a city, similar to current air traffic control systems detecting and advising commercial aircraft navigation. Implementing the communications hardware both on the aircraft and across an urban environment will be costly and difficult, and thus is a difficult problem to overcome. However, a bureaucratic issue regarding drone flight is currently the largest barrier to the deployment of a functioning UAS in the near future. Current FAA regulations place many restrictions on drone flight than make such a system impossible to implement, namely the ban on autonomous flight. Drones must be piloted by a human, and, the drone must never leave the naked-eye sightline of the person operating the drone. Such a restriction makes the widespread adoption of package delivery drones impossible, as flying within the proposed 10-mile radius would require fully autonomous navigation. Additionally, even in small-scale applications, even flying behind an obstacle would invalidate the line-of-sight condition, making flying between large buildings in cities impossible without the pilot traveling alongside the drone. A new Federal Aviation Authority initiative regarding the deployment of a UTM system has been proposed, however this system is not likely to be available before 2021 at the absolute earliest (Barbeau and Javob, 2017). Given the generally slow pace large government bodies have in rolling out new technologies, a proper UTM apparatus will not likely be ready before 2030 (FAA, 2019), which is consequentially when battery technology and market demand enables a profitable drone performance and operation condition, as can be seen in the figure below (UAM Study, 2018).

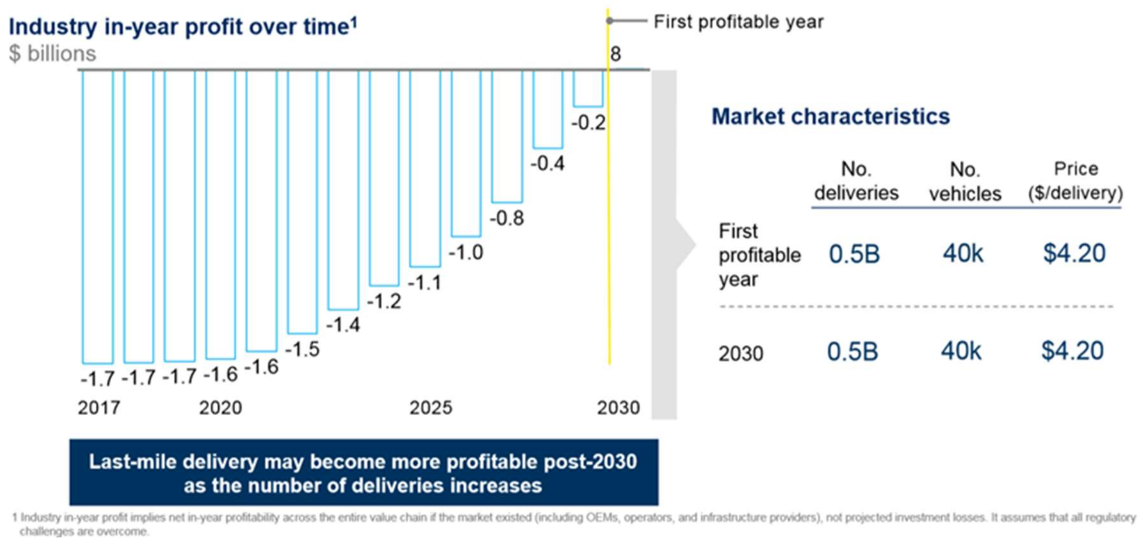

Figure 1: Industry in-year profit for Unmanned Aerial Systems (UAM Study, 2018)

When completed, this project will be submitted to NASA ARMD in a contest with other universities from around the country. The winning system design will achieve the previously stated design objectives, while simultaneously developing a business case, reducing noise, and ensuring safety. Designs will make use of currently available technical data to provide justification for claimed performance figures, as well as incorporating projections for likely technical developments within the near future.

STS Topic - Socioeconomic Impacts of Urban Rail Transportation

Urban public transportation in the United States is in a state of failure. City residents lack proximate access to services, schedules of operation are inconvenient, and transit infrastructure is decaying. Rail transportation represents a major component of mobility to residents in and around cities, and its successful operation is essential to both companies and employees. Additionally, traveling by rail is one of the cleanest forms of transit available, far surpassing automobiles (BBC, 2019). Social mobility and economic growth are also enhanced by having a good transportation system. Failing to implement a well-functioning rail transportation network will negatively impact a city's populace, environment, and commercial wellbeing.

The benefits provided to a society by a successful rail transportation network are numerous. First, it enables people to have a more convenient way of moving from point to point. Trains do not suffer from the congestion and stress often encountered when driving, and provide a far more pleasant overall experience (Time, 2014). Second, taking public transit can increase productivity. Riders can do work or prepare for their day ahead of them on their journeys, as they are not occupied by having to drive a car. Employees are also less mentally fatigued after taking the train relative to a rush-hour commute (Wener & Evans, 2011), therefore being more effective at work. A third benefit is that of residential cost savings. Commuters travelling from suburbs into cities can benefit greatly from taking the train. The costs of parking, gasoline, and automotive maintenance incurred by driving are far higher than rail fare. Finally, rail transportation is a far cleaner form of transportation than the automobile. As urban areas can often feature high levels of atmospheric pollutants, cutting down on these in any way possible is a benefit. Particularly for individuals travelling alone, they can reduce their carbon footprint by 75% through taking the train, as shown in the figure below (BBC, 2019). Using more rail transportation can help to combat climate change, both on a local and global level.

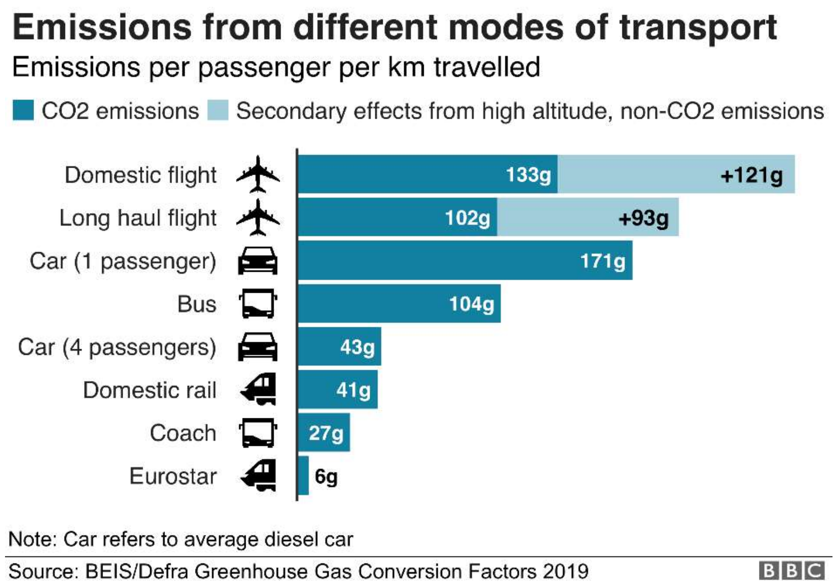

Figure 2: Emissions produced per kilometer travelled on different modes of transport (BBC, 2019)

New forms of technology are also enabling a more successful and productive rail transportation infrastructure. Advancements made in electric train technology make their construction and operation less expensive. New regulations placed on diesel locomotives and multiple-unit trains require them to meet stringent emission standards, bringing their pollution per passenger-mile (how many pollutants are generated by moving one person one mile) index to levels 50% lower than automobiles (BBC, 2019). More space efficient bi-level carriages are being introduced to US railways as well (SEPTA, 2017), enabling significant weight and space savings on rail networks operating on thin budgets. Additionally, new developments in signaling technology, such as the mandated implementation of Positive Train Control, have made metro and commuter rail systems far safer and time efficient, through the setting of automatic speed control and being able to run more trains per hour in congested corridors. These improvements in urban rail transportation all serve to provide a more time and fiscally efficient system.

These are all benefits that can be experienced with a well-developed public transit network. Without a sufficient system in a city, many negative effects are felt by those living there. Social mobility is hampered, as people have a more difficult time accessing jobs outside of their immediate surroundings (House of Commons, 2013). The stresses and time costs from vehicular commuting also decrease worker productivity, which decreases economic output or both companies and localities. Pollution levels are also increased with more people driving rather than taking the train, as many are driven away by the inconvenience of a poorly funded and run system.

The primary method of analysis used will be the theory of Technological Determinism, a major concept in the field of Science, Technology and Society (STS). Technological Determinism is the idea that "societal development is shaped by technology rather than the other way around; the course of history itself is driven by technology" (Seabrook, 2019). This theory was initially put forward by Thorstein Veblen in his 1899 book *The Theory of the Leisure Class*. Veblen's main point was that items are a mark of social status. This theory has changed since its inception, as the Marxist revolutionary fervor which led to its inception has died down. The most prevalent modern proponent of Technological Determinism is Merritt Roe Smith of the Massachusetts Institute of Technology. His research in on this topic is mostly on the history of technology innovation and social change. This definition of Technological Determinism, particularly Soft Determinism is much more applicable to the analysis of urban rail networks, such as claiming that people use less rail transit because they find the current state of the technology inadequate to suit their needs (Smith, 1994).

Other STS theories that will be referenced include Political Artifacts and Technological Momentum. Rail networks can be seen as Political Artifact, as they may by constructed in areas which have strong lobbying power and not built in the areas which could benefit the most from them. A Political Artifact or Technology is defined as an object or system having an innate power to it, as its creation was politically motivated, or that the technology itself can govern politics (Winner, 1980). A scholar of this field of STS is Langdon Winner, a professor at the Rensselaer Polytechnic Institute. Technological Momentum is another theory that will aid in researching this issue. This theory, proposed by technology historian Thomas P. Hughes, states that society is both shaped by and shaping of technology (Hughes, 2004). These theories can assist in looking at the political motives and societal changes that rail network implementation and development can produce.

Research Question and Methods

How does the implementation of an urban rail transit network impact the socioeconomic and ecological status of a city and its residents? In order to answer this question data pertaining to economic growth, social mobility, and pollution will have to be collected and analyzed. Papers analyzing the growth of cities before, during, and after the construction of rail networks will be studied. These case studies will come from different time periods to gain perspective on what methods worked at different times, and from different countries, to see how to build effectively in different cultural environments. The cost to taxpayers to fund and construct rail lines will also be investigated. Environmental data concerned with air quality and climate change indices will be used in this analysis as well. Information regarding the pollution generated by construction and manufacturing of rail infrastructure relative to automotive will also be gathered and examined. Finally, population growth and migration trends will be studied to see the social effects of rail networks.

Conclusion

The overall goal of the projects above is to improve urban transportation. The desired end result of the technical project is the creation of a successful urban package delivery drone. This drone will be able to coordinate with existing shipping infrastructure, be environmentally friendly, and spur the development of new aircraft, battery, autonomy, and network communication technology. UAS drone technology will seek to replace or augment existing urban package delivery methods that are costlier and more pollutive. The technical project is part of a larger NASA design competition between universities to design urban package delivery systems, and the team with the best design will win the contest. The submitted designs will be used to influence the direction of the urban air mobility and package delivery fields for the foreseeable future. The purpose of the STS thesis is to analyze the socioeconomic and environmental impacts that rail transit infrastructures have on cities. The successes and failures of different systems, as well as modern developments, will be illustrated. Existing research on the positive and negative effects of rail transit will be examined. The desired outcome of this research will be to encapsulate how to best implement a rail transit network in a city in today's society while considering the aspects of society, economy, and environment. Both of these projects will aid in the improvement of the movement of people and goods in urban environments in a sustainable, effective, and productive manner.

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