Proceedings of CONF-FMCE 2025 Symposium: Semantic Communication for Media Compression and Transmission
DOI: 10.54254/2755-2721/2025.GL27350

Beyond High-Speed Rail: The Value of Electric Aircraft at Small Airports—A Study with Tow-Assisted System

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Abstract. While renewable energy is increasingly being integrated into various sectors, the aviation industry, particularly aircraft propulsion, has lagged behind due to significant technical hurdles. The electric airplane, though promising, is currently limited by the insufficient energy density of battery. Additionally, the rapid development of high-speed rail systems presents a formidable alternative, offering fast, eco-friendly travel options that challenge the dominance of short-haul flights. However, small-scale airports with electric aircraft can achieve the same effect with lower cost and have more benefits at the same time. This paper, using the literature review, discusses the benefits and offers a solution that might solve the battery problem. It is the tow-assist system that can help target plane overcome the most energy-consuming takeoff and climb phase and increase the cruise range. In conclusion, by leveraging such advanced new system and technology, the electric airplane and small-scale airport could become a common transport method for middle-range travel.

Keywords: electric aircraft, small-scale airports, tow-assist takeoff, regional aviation

1. Introduction

Unlike other forms of passenger transport, passenger aviation is dominated by the fossil fuel-based aircraft. The alternative electric airplane faces problems like low battery energy density and climate adaptability of battery cells, which challenge the maximum cruise range [1]. The high-speed railway system is also upgrading at a high speed. The service speed of the new type of vehicle is already close to cruising speed of a small regional airliner, and it doesn't need the time for check-in. While the construction cost of the high-speed railway system is an important element, the railway for a 350 km/h vehicle costs 20.6 million dollars per kilometer, which is enough to build a small-scale airport [2-3]. In this case, the small-scale airport has a cost advantage compared to the high-speed railway system. One of the problems the small-scale airport has is the lack of suitable models of airplanes and the small-size eclectic airplanes could be the perfect option. These electric aircraft not only offer a sustainable alternative by eliminating the need for traditional aircraft fuel, thereby reducing operational costs and environmental impact, but also enhance the airport's competitiveness with railway systems. Addressing the primary obstacle of limited cruise range in electric airplanes, advancements such as the next generation of batteries and high-capacity battery plane layouts are being explored [1,4]. An original tow-assisted system could also be introduced to solve this problem. The takeoff and climb phase of aircraft consume large amounts of energy in a short period and with

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a tug plane to help the electric plane to overcome that phase, the cruise range has a significant improvement [5]. With all the solutions, the small-scale airport can offer a convenient and affordable travel experience. Moreover, the combination of electric airplane and small-scale airport could enhance the robustness of grid by applying Vehicle-to-Grid (V2G) and disaster resilience [6-7].

This study aims to explore the potential of electric airplanes in small-scale airports, focusing on how tow-assisted systems can address the critical issue of limited battery capacity. The significance of this research lies in its potential to provide a sustainable and cost-effective alternative to high-speed rail for mid-range travel, while also contributing to the broader goals of reducing carbon emissions and enhancing the resilience of transportation infrastructure.

2. Mechanism of tow-assisted system for electric airplane

2.1. Definition of tow-assisted

The takeoff and climb phase consumes up to 45.21% of fuel out of the entire flight [5]. In this situation, an additional assist plane can tow the target plane to help it successfully navigate the takeoff and climb phase. After the target plane reaches the cruise altitude, it can turn on its own engines to fly toward the destination. For the assist plane, after its duty, it can land back at the airport again to prepare for next tow. For the tow-assisted plane, it could be specifically designed since it requires a large amount of energy to carry two airplanes into the cruise altitude. Also, I expect it is an electric plane too. Without the space needed for the passenger and cargo carrying more batteries is possible here; the wing with a high aspect ratio and airframe configuration like a blended wing-body could be used to reduce the drag [8].

In another case, the assist plane could also be another plane that has passengers in it. For example, there are two flights that take off at a similar time. Also, one of the destinations is shorter than the other and the designed range of plane. Then that plane with a closer destination can be the assist plane to transfer part of its energy to another plane to help it reach a further destination. Also, the fossil fuel-based airplane can also achieve this tow-server since, for the same reason, it can also reduce the consumption of fuel for any kind of plane after some modification. This system can reduce the pollution caused by traditional passenger aviation [9].

2.2. Benefits of assist airplane for the small-scale airport

The small-scale airports have the main problems, like the lack of funding from both the government and companies and suitable models of airplane [3]. Looking forward, the electric airplane could have a high chance to get the government subsidy like electric vehicles, if there are practicable solutions. The issue of suitable aircraft models can be readily addressed by designing new electric airplanes specifically tailored to operate within a tow-assist system. This approach not only meets the unique demands of small-scale airports but also ensures compatibility with the new system. After the early stages of the application of this new system, without using expensive fossil fuel, in the countries that have relatively cheap prices for electricity, a lot of cost can also be saved. If it is an economical solution, more small-scale airports can be built with this system.

Also, the tow-assisted system itself can be an attractive point for passengers. In China, many people are unaware of the existence of light plane operations and are eager to try them out for the unique experience they offer. The introduction of a novel and intriguing system is likely to pique public interest. With the advertisement on social media, more people will know about this option for travel.

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3. The value of electric airplane and small-scale airport

3.1. The financial benefits

The first obvious benefit of electric airplanes and tow-assisted systems is that it can reduce the cost of jet fuel, especially in the region where electricity is available at a low price. The relatively low price to build the small-scale airport also makes it easy for people to get their cost back.

As the adoption of electric airplanes increases, the batteries used in these aircraft can participate in V2G systems, similar to electric vehicles (EVs), which have already proven to be a viable solution [6]. Electric planes offer several unique advantages. For example, electric planes can be designed to have bigger batteries, allowing for integration with airports' schedules [10]. The time spent connected to the grid can be considered downtime for the aircraft, providing owners with an opportunity to earn additional income. Moreover, if the batteries are modularized and can be taken out of the plane, joining in this system is even more reasonable and more productive, which takes a lot of benefits from the already existing grid system.

3.2. The social benefits

Small-scale airports can play a crucial role during disasters. particularly in the aftermath of events like earthquakes [11]. When land transportation is damaged and repairs are delayed, aviation becomes essential for transporting cargo and injured individuals in the initial and critical stages of disaster response. Additionally, airports service as the information collection and sharing center and refueling and maintenance base for the helicopters and other aircrafts. After the Great East Japan Earthquake, due to the severe damage to the Sendai Internation Airport, the relatively regional airport became more important and took the response of relief efforts. More small-scale airports can improve its robustness furthermore.

Considering the features of electric aircraft, their batteries can also serve as backup power sources in emergencies. It is also reasonable to build some small-scale solar panels or wind turbines around the airport operating a lot of electric aircraft. Some of the light aircraft can take off and land on unpaved roads or even grassland, which makes it close to the landing ability of helicopter, which has been widely used after earthquake.

The combination of small-scale airports and electric aircraft also can offer an affordable transport option for the relatively rural area. For example, in Japan, local railways that connect distant regions to major cities like Tokyo are facing financial difficulties, leading to plans for closures. Due to the low birth rate and the tendency for the young generation to concentrate on the main cities, there are fewer passengers using the local railway. As a result, communities are becoming more reliant on bus systems and private cars, but the bus network has not expanded to meet growing demand. In this case, small-scale airports can be introduced here to reduce the stress on the traffic system. The light electric aircraft can handle the relatively low population in those areas and offer a time-efficient way of travel.

4. The challenges of electric airplanes and tow-assist systems

The first step in advancing electric aviation is the development of electric airplanes themselves. Safety is paramount, especially given that electric engines are not yet widely used in passenger aviation. This necessitates a complete redesign of safety standards. Many potential passengers may hesitate to fly in electric aircraft due to safety concerns, particularly before sufficient flight data has

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been collected. While this presents a significant technical challenge, many technologies used in electric vehicles (EVs) can serve as a foundation for the motors and batteries in electric airplanes. Current advancements already enable the creation of motors powerful enough for aviation applications.

For the pilots operating the tow-assist planes that help another plane to climb, specialized training is essential. It typically takes years to train a pilot that can operate an airplane safely and every small-scale airport will need at least one pilot to operate the tow-assist plane. If the pilot of tow-assist plane only will not operate other types of airplanes, a special license could be set for this kind of pilot. Alternatively, to streamline the process, they could be required to hold the same license as other pilots.

After the first stage of the tow-assist system, some large airplanes might also take the tow service. In this case, only one tow-assist plane is possible, which is not enough to help large airplane to climb; two planes need to work together. This scenario would demand a high level of skill from all three pilots involved and could present significant risks. Thus, for this situation, a large tow-assist plane needs to be developed, or this system should give up the large airplane.

5. Conclusion

This paper shows the potential value of the combination of electric airplane and small-scale airport. While designing batteries with sufficient energy density remains a challenge, this paper offers a novel tow-assist system that addresses the range limitations of electric aircraft. This system effectively conserves energy during the most fuel-intensive phases of flight: the takeoff phase and climb phase. After the first try of this system, it also could be applied to those large fossil fuel-based airplanes. Furthermore, although high-speed rail systems present strong competition for travel, the synergy of electric airplanes and small-scale airports offers an affordable and convenient alternative.

However, this research has its own limitations. First, all the works in this research are based on literature review and model on paper, lacking experimental data and results come from the simulation software. And a lot of technical details in the two-assist system remain unclear, like the safety protocols, dispatch method in airport and the accurate number of energies that could be saved by this system. Those data require future computational fluid dynamics (CFD) simulations and scaled prototype testing. Additionally, whether passengers would accept this system and the integration with V2G also needs future surveys and research.

Despite these challenges, the future of electric aviation appears promising. The combination of electric airplane, tow-assisted takeoff and small-scale airport can not only solve the problem of cost, cruise range and sustainability but also enhance regional mobility and disaster resilience. The future research should focus on the technical standards, methods to regulate this system and training of pilots and ground crews. With the new ideas and policy support in the future, this intergrated system could significantly impact regional air travel.

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