# Abstract

In recent years, the logistics industry has witnessed rapid advancements, with drones playing an increasingly significant role in delivery applications. Fixed-wing unmanned aerial vehicles (UAVs) have emerged as a preferred choice for large-scale transportation due to their high payload efficiency, long-distance flight capabilities, and superior speed. However, the widespread adoption of commercial logistic-oriented fixed-wing UAVs is hindered by their elevated procurement and maintenance costs, extensive maintenance intervals, and unsuitability for small-volume, low-altitude transport tasks. To address these challenges, this study introduces the design, modeling, and control of an ultra-low-cost logistic delivery fixed-wing UAV.  
  
The proposed UAV is constructed primarily from cost-effective wood materials, with strategic use of lightweight laminates and minimal carbon fiber components. This design ensures adequate flight strength while being inexpensive, easy to manufacture, and maintain. The UAV is engineered to transport payloads of up to 1000 grams across predefined aerial routes at an altitude of 40 meters. Upon reaching the designated location, the UAV autonomously identifies the drop zone and descends to release the cargo, which is protected by a sponge-damping layer to mitigate impact forces during landing. The system’s energy-efficient design incorporates brushless motors, an APM 2.8 flight control, and M8N GPS for precise navigation.  
  
Key technical innovations presented in this research include:  
1. A streamlined wing design with a dual vertical H-tail, reducing fuselage vibration and enhancing stability. Aerodynamic optimizations result in a 10% to 20% reduction in volume factor compared to commercially available models.  
2. An autonomous projectile mechanism employing spring hinges for flexible and secure cargo drops.  
3. The development of precise control algorithms to enhance positioning accuracy and flight stability.  
  
The study delves into the aerodynamic performance, structural analysis, and energy management strategies required to optimize the UAV design. Finite element analysis and flow field simulations were employed to ensure the structural strength and aerodynamic efficiency of the wing and tail components. The wing design, based on the NACA 4412 airfoil, was selected for its high lift-to-drag ratio and low drag coefficient, suitable for low and medium-speed flights.  
  
Empirical findings from outdoor delivery trials demonstrate the UAV’s ability to execute accurate payload drops at targeted locations, confirming its potential as a cost-effective solution for small-volume, low-altitude deliveries. The research also highlights future applications of this design in military surveillance, environmental monitoring, and disaster relief operations.  
This investigation contributes to the growing discourse on leveraging ultra-low-cost UAVs in logistics and presents a viable pathway to address the economic and operational challenges of UAV-operated delivery systems. The results indicate that with continued technological advancements and exploration, fixed-wing UAVs can significantly enhance logistics efficiency and broaden their application scope across diverse sectors.