Prototype of Eco-Sustainable Cargo Drone: National and International Regulations and Cost-Benefit Evaluation for Potential Operational Startups

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SUMMARY

Cargo drone technology has disrupted traditional logistics, eliminating human-operated vehicles. Advancements in unmanned aerial systems have led to sophisticated drones equipped with advanced sensors, navigation capabilities, and obstacle avoidance mechanisms. These drones are employed in different sectors, from last-mile deliveries to critical medical supply transportation, showcasing their versatility and potential impact. However, regulatory frameworks pose challenges, particularly in urban environments. Complexities such as battery endurance and adverse weather performance remain significant hurdles. Despite these obstacles, substantial investments are being directed toward the research and development of cargo drone solutions. This study centres on an experimental eco-sustainable cargo drone prototype, highlighting its technical attributes. The investigation extends to dissecting regulatory intricacies, both domestically and internationally. Furthermore, the feasibility of establishing a startup based on this technology is evaluated. This research encapsulates the converging domains of drone technology, regulatory dynamics, and entrepreneurial opportunities.

Keywords: drones, UAV, prototype, international law, modern applications, opportunities, start up
Introduction

The development of drones for cargo transportation is representing a significant advancement in the logistics and transportation sector. Cargo delivery drones, which are unmanned aircraft designed to carry out deliveries from one location to another, are eliminating the need for human drivers or traditional vehicles (Barrile, Genovese, & Meduri, 2023; Barrile, et al., 2020a). This technology has garnered a lot of attention and has seen significant developments in various areas. In terms of technology and design, drones have become more sophisticated thanks to technological advancements. Improvements have focused on efficiency, reliability, and the ability to carry heavier loads over longer distances. Cargo delivery drones are equipped with advanced propulsion systems, navigation sensors, high-definition cameras, and obstacle avoidance systems, all aimed at ensuring safe and precise flights. These drones find applications in various sectors (Konert, Smereka, & Szarpak, 2019). For example, they are used for delivering parcels and lightweight goods directly to customers, especially in remote or hard-to-reach areas (Hwang, Kim, & Gulzar, 2020). Additionally, they are considered tools for delivering medical supplies in urgent times, particularly in places where conventional transportation methods struggle to reach. Some companies are also exploring the idea of using drones for supplying rural or isolated areas. In this context, sustainable eco-friendly drones for cargo transportation are emerging. They are designed with the environment in mind to minimize negative impacts during delivery operations. These drones incorporate technological solutions and specific designs to optimize energy efficiency (Barrile, et al., 2020b) reduce pollutant emissions, and contribute to a more sustainable logistics. However, the development of cargo delivery drones is constrained by regulations. Most countries have regulations that limit drone use, especially in densely populated urban areas. Despite advancements, there are still several challenges to overcome. Battery life is a significant limitation, particularly when covering long distances. Additionally, the reliability of drones in adverse weather conditions and their ability to handle emergency situations are critical aspects to consider (Barrile, et al., 2020c). Numerous companies, ranging from tech giants to startups, are investing in research and development of cargo delivery drones (Andersen, et al., 2020). Projects like Amazon Prime Air and Alphabet's Wing have received considerable funding to advance research and testing of this technology.

In this context, the current study focuses on the objective of illustrating the features of an experimental prototype of an eco-sustainable cargo transport drone. Emphasis is placed on issues related to Italian and foreign regulations concerning their flight, as well as on evaluating the feasibility of launching an Italian startup based on this technology.

Method

Companies, grappling with increasingly complex issues related to rising raw material costs as well as a shortage of drivers, look at eco-sustainable drones with great interest. They can lead to various advantages, such as reducing personnel costs, but also have implications for employment levels. Apart from recharging times, another aspect is that drones can operate 24/7, further enhancing delivery efficiency. Equally important are the distances covered: drones would not experience all the infrastructure-related challenges that ground or water transportation faces. Lastly, considering the nature of the power source for these aircraft – typically electric – the choice could also have implications for reducing CO2 emissions (Barrile, et al., 2020d; Barrile, Gelsomino, & Bilotta, 2017). Date the issues, in this regard, the current study has focused on a detailed feasibility analysis for the development of an eco-sustainable drone, the real behaviour of which has been simulated, yielding encouraging results. The eco-sustainable drone designed for cargo transportation has the following features:

- Frame made of biodegradable materials and coated with bioplastics;
- 6 motors with 700Kv;
- Lithium-Phosphate backup batteries;
- GNSS navigation system;
- Sensors enabling smooth flight;
- 8/12-inch three-blade propellers;
- Noise isolation system.
For so-called artisanal drones and all the prototypes developed in recent years, both in Italy and around the world, with a view to a more advanced and eco-sustainable use in the cargo transportation sector, the current regulatory framework of reference is, of course, the European Commission Implementing Regulation 2019/947/EU, along with the various transitional rules in effect (Bassi, 2019). The regulatory Italian framework, nowadays, proposes the following innovations: the elimination of the distinction between professional and recreational flights; the equal treatment of UAS (Unmanned Aircraft Systems) with traditional aircraft; the introduction of a "registration" system recognized at the EASA (European Union Aviation Safety Agency) level by the UAS operator; the requirement for UAS registration only when it concerns a certified aircraft intended for specific types of activities; the division of operational modes into three areas, based on progressive levels of risk (Figure 1):

- **Open**: Conducted with drones equipped with CE marking, weighing no more than 25 kg, under "visual line of sight" conditions, and at a maximum altitude of 120 m. No authorization or declaration is required from the operator, except when using the drone in controlled airspace. This category is further subdivided into three subcategories.
- **Specific**: Requires operational authorization from the national aviation authority or a prior declaration from the UAS operator.
- **Certified**: The risk level mandates prior operational authorization from the aviation authority, operator certification, possession of the specific license outlined in Regulation (EU) 2019/945 by the remote pilot, UAS registration (or recording) (in Italy, pursuant to Article 8 of the UAS-IT Regulation of January 4, 2021).

The European regulation includes a transitional period of three years (2020-2023), during which today's drones without the new CE marking can fly in the Limited Open categories. Starting from January 1, 2023, drones without CE class identification labels can only be used in Open Limited categories A1 (if weighing less than 250 g) or A3 (between 250 g and 25 kg) and in the specific category. The transitional regime will conclude on January 1, 2024.

![Figure 1. Flowchart showing the division of operational modes.](image)

As it concerns the international legislation (Brooks, 2014), the Federal Aviation Authority (FAA) has recently published new regulations for the execution of commercial services, including delivery operations, using small Unmanned Aircraft Systems (UAS), even during nighttime hours (the Final Rule amends Part 107 of Title 14 of the Code of Federal Regulations). By the end of 2020, drones and the world of delivery can begin a new season thanks to the United States Federal Aviation Administration (FAA), which has released rules concerning drones and their usage. This marks a significant step toward large-scale commercial drone use in the United States, undoubtedly providing a substantial boost to the industry beyond American borders. The regulations require that Unmanned Aircraft Systems (UAS) transmit identification or location data, permitting operators of small drones to conduct flights over people and vehicles, and also during nighttime, subject to specific conditions. The next significant step involves developing regulations for beyond-visual-line-of-sight operations. The interest in utilizing drones beyond the operator's line of sight is not limited to deliveries: Class I railroad BNSF Railway has submitted a petition to the FAA for a waiver to remotely operate up to 5 unmanned aircraft over long distances for railroad inspection and patrolling its private property.
Results

Starting from the concept of the prototyped environmentally sustainable drone, the real behavior of which has been simulated and has yielded encouraging results in simulations and taking into account the current national and international regulations, an idea was conceived to implement an innovative Startup. As it concerns the ecosystem of innovative Italian start-ups, it is a sector in which there are more and more success stories. However, the relatively small size of the ecosystem of Italian start-ups does not allow to reach those users and markets whose dynamism would allow greater prospects for growth and visibility. It is commonly believed that to reduce the gap with other countries, the ecosystem of innovative Italian start-ups needs to do more scale-up, that is, to develop through strategic agreements with large companies. In addition, there is a need for more acceleration programs, tax incentives and alternative financing practices such as crowdfunding.

There are many requests from companies for eco-sustainable technology, mainly in the field of transport sector. For this reason, the idea would be to establish a start-up focused on the development of an eco-sustainable drone. In particular, the innovation of our drone proposal will lie in the use of new biodegradable materials and bioplastics, less polluting batteries and blade shape with noise reduction, there will be a reduction in environmental, atmospheric and acoustic pollution that will have a rapid and substantial impact on the health of the entire planet and of the human being. Another advantage to keep in mind with this drone prototype is that the material it is made of self-generates and interacts perfectly with any surface and atmosphere. The main features are the following. Regarding the frame, as well as the main component of the drone, we have considered constructing it using entirely biodegradable materials. The exoskeleton of the frame would be composed of mycelium (fungi), which would then be coated with sheets of bacterial cellulose, rendering it waterproof. Additionally, to make it even more robust and capable of addressing the various complications that might arise during the journey, we have thought of enveloping the drone with an additional layer of bioplastic, made, for example, from corn starch. This bioplastic can deliver performance similar to traditional plastics but without environmental impact. Our drone will feature 6 motors with 700kv, striking the right balance to achieve strong performance even on long journeys. However, what will set our drone prototype apart from the competition is the power system. We have considered one of the most environmentally friendly solutions: solar panels.

On average, a small-sized cargo transport drone consumes 200 W of energy during flight. Assuming an average solar cell power of 3.5 W per cell and a solar panel efficiency of 20%, around 100 solar cells would be needed for a surface area of 2 square meters. This would provide the drone with autonomy ten times greater than that of the competition. Furthermore, it would be beneficial to implement "backup" batteries in case weather conditions prevent the panels from receiving the required energy. These would be ultra-lightweight batteries, specifically 6s LiPo models with a capacity of 2200 mAh. We aim to develop a fully autonomous drone capable of reaching various preset destinations without the need for remote piloting.

To achieve this, the drone must be equipped with sensors to detect obstacles and ensure a smooth flight. However, even more crucial is the GNSS system that will make the flight phase entirely autonomous. It will be equipped with three-blade propellers (8/10 inches) made of carbon, suitable for large-sized motors, with low rotational speeds to ensure the required delivery speed. We have also considered implementing a noise isolation system to minimize acoustic pollution. For instance, we're exploring a new technology to reduce drone noise using sound-damping nanofiber materials. The innovative start-up would therefore be focused on the prototype of a drone with these features, which will need to undergo further evaluations. However, even from the simulations conducted so far, it has shown encouraging results.

Conclusions

There is no doubt that the use of drones in many industries will facilitate tedious and dangerous processes. This will effectively improve flight safety, simplify approval procedures, facilitate
applications for home and business users, improve user experience, and support rapid business
development. This is a big step towards large-scale commercial use of drones, which will undoubtedly
give a significant boost to the transport sector on all continents. In conclusion, the establishment of a
startup focused on the development of eco-friendly cargo drones in Italy presents a timely and
promising attempt. The rising global emphasis on sustainable solutions aligns seamlessly with the
innovative concept of employing drones for environmentally conscious cargo transportation. Taking
into consideration the current regulations, this attempt not only promises to revolutionize the cargo
transportation sector within Italy but also holds the potential to reverberate globally, catalysing a
transformation toward greener and more efficient logistics solutions. Drones have opened new paths
in many areas and will continue to evolve. It must not forget that research, economy and society grow
together, and every investment of society has repercussions also on the economic world and in the
professions, generating a circular well-being that should benefit everyone.

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