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Energy Consumption of Drones for Delivery Usage: Case study in Dubai

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RIT

Energy Consumption of Drones for Delivery Usage: Case study in Dubai

By

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I devote my utmost gratitude and sincere thanks to my mother, father, and brothers, to whom I attribute all my successes in life.

Abstract

In the past couple of years, the dependency of delivery services on road vehicles has increased, compromising the efficiency of this service in urban areas. Aside from efficiency, another issue is the increase in greenhouse emissions, which jeopardizes the government's efforts to reduce dangerous gasses. Drone-based delivery has been highlighted as one of the most promising technologies in the field of delivery systems. This system could ease traffic congestion, expediting delivery efficiency, and in parallel, the use of electrified drones could help with decarbonizing the atmosphere. This study examines the use of drones for delivery in the city of Dubai and how this system could be helpful in the management of better delivery practices, the lightening of traffic congestion, and the contribution to better air quality. The project compares different delivery methods in the city in order to have a better understanding of the energy consumption of each delivery method.

TABLE OF CONTENTS

List of Figures

Tables

1. Chapter 1

1.1 Background

People all over the world are moving to living in cities for a variety of reasons, including the high chance of having better jobs, better educational opportunities, as well as to having access to better healthcare systems. Nowadays, the concept of ordering from a variety of websites has eased the lives of those who live in Dubai, and as Dubai is experiencing a boom in delivery services, this is also resulting in several issues. Congestion is one of the most common problems in cities, which is to be expected given the number of people who use transportation on a daily basis for a variety of reasons. Half of the planet's population now lives in urban areas and every year the amount of people grows, which causes many drawbacks that require solutions, the increased population size and needs of transportation also intensify poor air quality (Kuddus et al., 2020).

The number of deliveries every day keeps on increasing, which results in many factors that affect the city such as traffic, air pollution, greenhouse gas emissions, and the potential for global climate change. The United Arab Emirates has seen a significant increase in the number of people ordering online for same-day and next-day deliveries. Fast and same-day deliveries are the most popular types of deliveries that result in the highest level of customer satisfaction, but as the number of deliveries increases every day, this becomes more difficult for transportation services, whether they use cars or motorcycles. The main issue that delivery companies face is late delivery, which is compounded by other issues such as high delivery costs for consumers and rigid delivery schedules. Furthermore, as delivery congestion grows, the harmful effects on the environment are expected to grow unless solutions are created to reduce them (McKinsey, 2021).

A high number of deliveries require additional delivery vehicles; the increased number of vehicles will result in an increase in GHG emissions. Additionally, the increased congestion would also lead to an increase of nearly 25 percent in CO2 emissions (Lawton, 2021). The main purpose of this study is to learn whether the use of drones for delivery would be able to reduce carbon emissions while reducing traffic congestion.

Drones and lightweight vehicles, along with many other emerging technologies, can play an essential role in the city's environment in terms of delivery services. Drones can assist in delivering small packages to areas without causing or increasing congestion, which can cause delivery delays and negatively impact customer service. Common commercial drones that are used for parcel delivery are compact rechargeable batteries that contain a load capacity of around 2 kilo grams. Drones additionaly generate less CO2 since they are powered by battery, and their autonomous flying operation cuts delivery labor expenses (Viu-Roig & Alvarez-Palau, 2020).

Many e-commerce and logistics companies are excited about drone delivery for its enormous potential to deliver items at a fraction of the cost, time, and energy required today. Several drone delivery models and operating modes have been investigated, including several that have yet to be tested in the environment. Drone delivery technology such as storage, navigation systems, collision avoidance and recognition have advanced significantly, and since drones are considerably smaller than vehicles, they may cost less and require less energy per unit of distance travelled. Furthermore, as compared to regular diesel vehicles, most delivery drones require electricity which may be produced from clean energy sources. As a result, they may also emit fewer greenhouse gas emissions per unit energy spent (Di Puglia Pugliese et al., 2021).

1.2 Statement of the Problem

Due to the increased traffic and consequent consumed energy and emissions that result from the growing number of deliveries, this results in a significant strain on the environment. Carbon emissions are major causes to climate change, and transportation accounts for a huge amount of these emissions. Climate change has an effect onour ecosystems, and climate related threats will keep rising unless global house gas emissionsare controlled or minimized (Lin et al., 2022). The transportation sector is an important partof everyday life of every person living in the city, as well as a fundamental and necessary part of the city's economic growth. Together with the rising need for transportation in cities for different reasons such as delivery, the transport sector has resulted in significant useof energy and increased carbon emissions, while fostering economic progress and enabling human existence at the same time. Furthermore, as urbanization expands and the number of vehicles grows, co2 emissions caused by transportation continues to increase (Zhang, 2021).

Delivery transportation nowadays is going through a process of fast growth and need of change. The link connecting transportation development and co2 emissions may be addressed by precisely evaluating the causes of changes in CO_2 emissions in the transportation sector and looking for better alternatives (Lin et al., 2022). The delivery transportation sector in Dubai requires a sustainable and safe approach that could help with many problems other than emissions such as congestion and the safety of people in the transportation sector.

1.3 PROJECT GOALS

This research focuses on studying the energy consumption of drones with the aim of understanding the feasibility of the development of drone delivery. At the end of this study, the expected deliverables are as listed:

- A study of the energy consumption of drones for delivery purposes.
- A study of the feasibility of using drones for delivery in urban areas and the expected limitations.
- A comparison of energy consumption levels for different delivery services (ground-based and drone-based).

1.4 METHODOLOGY

The methodology that is adopted for this study implies the use of literature, analysis of case studies, collection of data, and considerations on the evidence of data. The literature researched is divided into two parts: first, a quantitative analysis that will present data about the drone delivery effects on the environment, and second, a systematic review that will present the major ideas of the literature's common topics.

The study's primary research methodology, on which it based its analysis and recommendations, called for the utilization of secondary data sources. The sources in this instance must have the most applicable information on current drone delivery procedures in urban cities because they were relevant to both the subject and the study's goals. As a result, the majority of the sources were recently released journals.

1.5 Limitation of the Study

The study includes some shortcomings that may require careful evaluation. For instance, it was difficult to determine the precise quantity of energy produced by the drone in the city of Dubai. Additionally, because the study was solely focused on the use of secondary data sources, there is a chance that some materials may be biased in their analysis and findings, which could potentially have an impact on this study. Additionally, because this study relied on secondary data sources, it was unable to analyze a scenario in real time and there was also a lack of studies done in Dubai.

2. Chapter 2

2.1 Literature Review

Cities are gradually relying on advanced technologies and the use of smart innovations to attain sustainable solutions as their population expands and the rely on new strategies and technologies are required for modes of transportation. The below studies demonstrate methods of drone delivery and their effects on the environment.

2.1.1 Using the rooftops of buildings for drone delivery

This study has proposed a model for drone planning and operations and using algorithms to study the feasibility of drone delivery on building's rooftops. Additionally, numerical tests with three different assumptions were carried out to validate the possibility of the suggested model and to evaluate the proposed model's performance. The first assumption was based on two drones and ten areas, the second was using four drones and twenty areas, and the third was using ten drones and fifty areas. The study suggests that in terms of functionality, rooftop drone delivery has possible benefits over other types of drone operations. Finding, following, and landing on the rooftops of buildings would be far simpler for drones than doing so with live targets like delivery vehicles.

Moreover, building roofs, especially flatter ones can serve as secure landing areas for drones. Based on light detection and distance as well as sensor input, actual categorization and selection of safer landing areas on roofs has also been studied. A camera was also used to execute perception of rooftop landing in some tests to assess the precision of rooftop drone delivery. The experimental findings indicate that the suggested model is practical, and that the proposed approach achieve great operation plans in terms of objective functionality gap and computing time. This model aims in contributing the implementation of drone delivery on the rooftops of buildings in cities as it is expected that the usage of drones will increase in the near future (Kim et al., 2020).

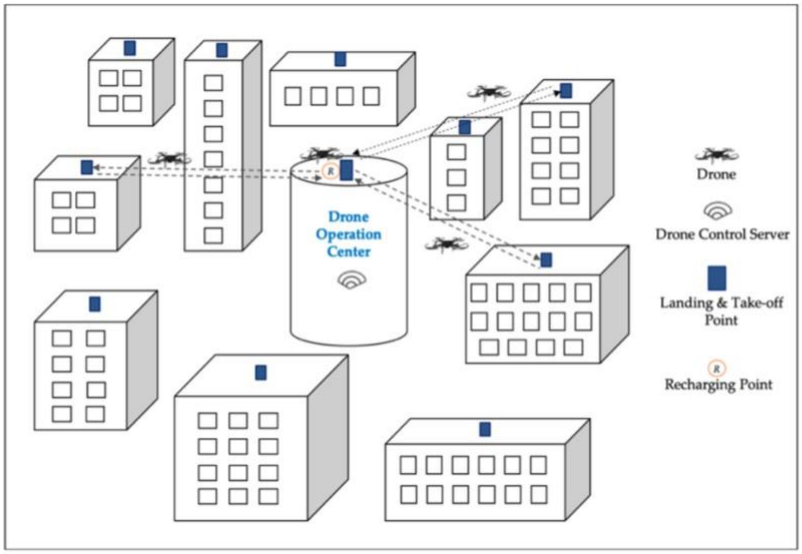

Fig1. Drone parcel delivery using the rooftops of buildings.

2.1.2 Greenhouse gas emissions of drones for package deliveries

The use of automatic vehicles (drones) for delivery of commercial packages is destined to be a thriving paradigm, reshaping the transportation sector's energy use dramatically. Based on assumptions, life-cycle GHG emissions per package delivered via drone and vehicle paths are compared. The research focuses on the package's ultimate delivery once it has been delivered to the storage facility. Emissions from batteries and fuel manufacturing are also included, along with combustion and energy generation for transportation and storage. The study shows that s mall sized drones have lower life- cycle emissions than traditional delivery vehicles driven by diesel and fossil fuel, and vans powered by gasoline. This study shows that while drones use much less energy per package/kilometer than delivery vehicles, the extra storage energy needed, and the additionalmiles traveled each package by drones considerably increase the life-cycle effects. The effects of package delivery by drones are often less than those of ground-based delivery in the majority of scenarios studied. The study findings show that drone delivery could cut greenhouse gas emissions and lower energy usage in the transport industry (Stolaroff et al., 2018).

2.1.3 Energy demands of different delivery services

An energy usage model for drone delivery is proposed in this study to define their energy consumption as a function of environmental parameters and flight mode. The model simulates the energy requirement of a fixed package delivery system that operates from a warehouse and delivers to a group of consumers. Accordingly, the drone energy use is contrasted to diesel and electrical truck energy demands serving the same consumers from the same warehouse. In most situations, the results show that changing to a drone-only package delivery system is not convenient from an energy standpoint. The study also shows that in urban regions where consumer levels are high and truck trips are comparably short, a stationary drone-based package delivery system consumes higher energy levels than a trucks. If climatic circumstances are reasonable, a drone package delivery system produces an energy demand like a package delivery system with electrical trucks in small areas with significant distances between consumers. Drones have some drawbacks in terms of energy efficiency when utilized as parcel couriers, according to the research presented in this study. Due to the fact that parcel delivery drones are built to travel long distances, they have a low energy efficiency when hanging, causing even brief periods of hanging to generate substantial energy demands, limiting a drone's operating range. (Kirschstein, 2020).

2.1.4 Energy Consumption Model of Drone Delivery in Urban Infrastructures

This paper proposes a new methodology that takes into account the size of the urban area and its unique characteristics in order to achieve an accurate estimation of the total energy consumed as well as the efficiency by a number of drones used for delivery. The suggested methodology provides data for decision-making issues connected to the right infrastructure, the drones specifications, and energy storage capabilities. A contrast with the traditional vehicles used for delivery under the same conditions are also conducted in the study, along with the applicable constraints. The findings acquired provide a decent understanding for assessing the energy usage of drone delivery systems, enabling the best dimensions of the supporting infrastructures in relation to the area serviced. The findings in particular highlight how despite the fact that drone delivery systems can potentially exceed traditional delivery services, the scope of practical operations is significantly constrained when population density and delivery service demands rises. Aerial logistics, for example, can be effective up to a range of around 9.5 km in rural settings, but this range drops to approximately 3.5 km in urban areas (Aiello et al., 2021).

	Drone	**d-Truck**	**e-Truck**
Speed (km/h)	29	20	20
Energy consumption (Wh/km)	30	1100	250
Max payload (kg)	2	1800	600
Range (km)	15	230	160

Table 1. Technical features of the vehicles considered.

The proposed strategic insight is that such structures must be designed with optimization in order to exceed the established ground distribution systems. The study also shows that, if urban supported infrastructures are well planned, drone delivery systems for last-mile deliveries can be a practical option for efficient and affordable parcel distribution. However, establishing such infrastructure can be challenging, especially in historic urban areas. As a result, there may be some questions about the applicability of this solution given that electric ground transport vehicles may quickly outperform drone delivery systems in so many practical scenarios and that drone delivery would always involve standby ground vehicles as a result of their limitations and their failure to perform in challenging weather conditions.

The study makes several recommendations for future research, such as the lifecycle evaluation of the infrastructure and services and the implementation of a new decision matrix to a multi-criteria strategic optimization model, while a significant flaw is the inaccuracy in anticipating the amount of business that will require delivery services that can be handled by drones. The methodology that is being suggested also makes use of several important assumptions, such as the demand forecasting strategy and the energy consumption model. There's a major limitation in the absence of comprehensive information regarding the number and density of parcel deliveries; the methodology so described might be improved by using a more sophisticated demand modeling approach. Regarding the issue of energy consumption, the proposed model only takes into account the energy needed for hovering in stationary situations and for horizontal motion, excluding the energy used by the on-board electronic equipment. The suggested approach can be expanded to many aerial vehicles by incorporating suitable energy consumption models (Aiello et al., 2021).

2.1.5 The Impact of Airspace Discretization on the Energy Consumption of Drones

In order to accurately examine the real effects of civil airspace discretization on the energy requirements of drones operating in dense urban environments, this study has introduced a new technological approach that evaluated the properties of a converged path in terms of total energy consumption and the effectiveness of the solution. The suggested framework combined all four subcategories that have an impact on the drone design specifications into a single model. These include kinematics, autonomy, costs, and airspace regulations. Overall, the findings and discussion present that airspace discretization has a significant impact on drones operation's ability to maximize energy efficiency. The digital-twin integration demonstrated its reliability for a precise path planning capability within the framework, particularly where constrained urban environments required a high accuracy 3D model of the barriers to successfully navigate the deployments while allowing comparisons of a wide range of discretization and path planning methods while also implementing airspace laws (ElSayed & Mohamed, 2022).

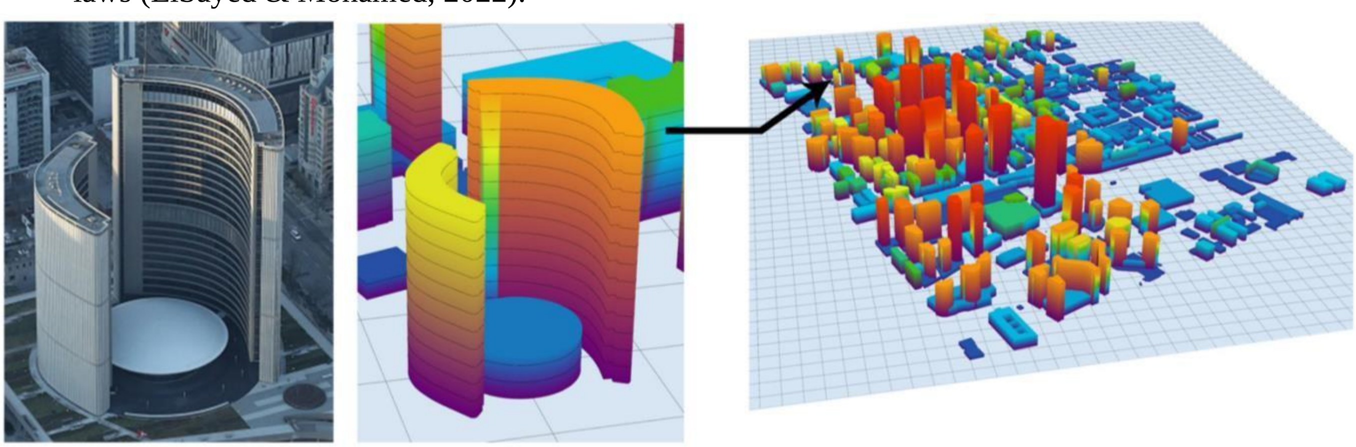

Fig2. 3D Digital-twin showing a building in Toronto city.

Both the standard Cartesian approach and the cutting-edge dynamic 4D discretization (Skyroutes) method are used to characterize airspace in the modeled case study. As a result, ten trips can be used to compare various routing and path planning methods. The findings reveal a difference in energy usage of up to 50%, highlighting the need of airspace discretization and planning for the development of drone's infrastructure, the reduction of greenhouse gas emissions, and the control of airspace. The suggested framework can be further improved to serve as a planning tool that helps specialists, air control managers, and lawmakers create a UAV system that will result in the environmental advantages of reduced greenhouse gases (ElSayed & Mohamed, 2022).

2.1.6 Vehicle-Assisted UAV Delivery Scheme Considering Energy Consumption for Instant Delivery

The focus of this study is the issue of vehicle-assisted drone delivery in instant delivery scenarios. Considering the effect of variations in the weight of the drones during the delivery time on energy consumption, a solution was presented to a new challenge wherea vehicle is supplied with numerous drones and the drones handle multiple customers at the same take-off. To limit the energy consumption during the drone delivery procedure, a UAV energy-consumption model was first created. Then, to estimate the UAV job allocations and route as well as the vehicle's operating path and to compute the minimum total duration, a vehicle-path planning model and a drone activity model were developed.

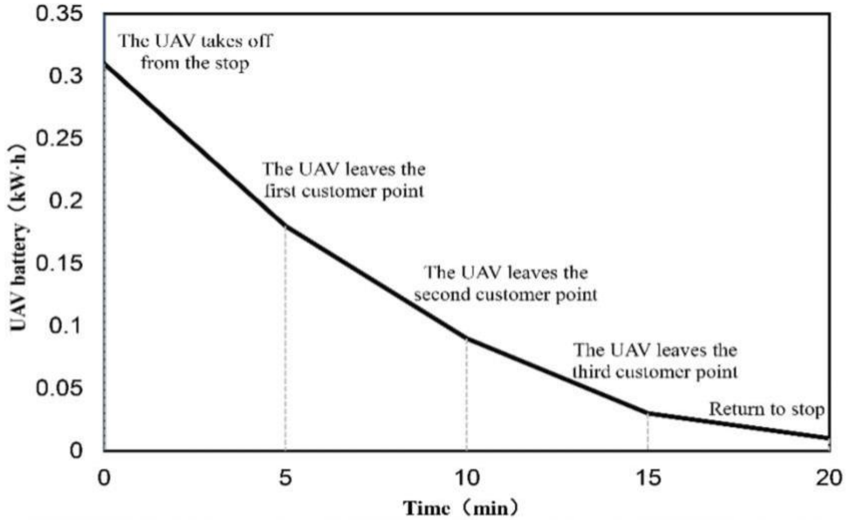

Fig3. Energy Consumption process of carrying three packages for delivery.

The problem was finally solved using a hybrid approach, which was supported by experimental trials and demonstrations of multi-scale calculations. The study's results showed that the recommended approach to the issue of vehicle-assisted drone delivery can increase the operational effectiveness of connected businesses that deal with same-day delivery by strategically placing vehicle stop zones together with UAV and vehicle delivery routes. It's found that the proposed method has a significant increase in efficiency when compared to the traditional solo vehicle delivery. The increase in efficiency rate R_{effect} ranged from 17% to 203.35%, with an average of 126.5% (Deng et al., 2022).

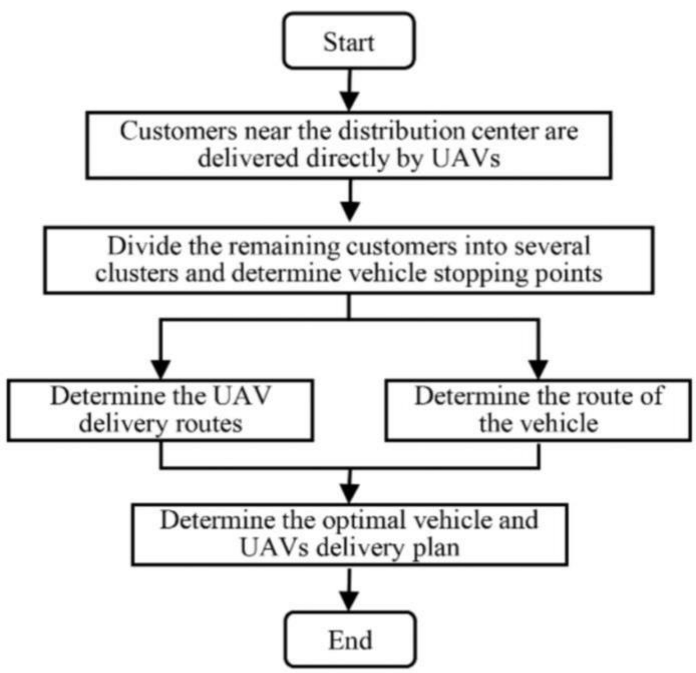

Fig4. Process of solving vehicle-assisted UAV delivery issues.

2.1.7 Last mile delivery by drones: an estimation of viable market potential and access to citizens across European cities.

This research proposes a modeling methodology for determining the possible ideal site of drone beehives based on the financial feasibility criteria, using high-resolution population and land-use data from across the EU. It calculates the approximate number of EU citizens who would gain access to last-mile drone delivery services under four different scenarios. The results of the analyses show that up to 7% of EU individuals could have access to these services under the scenario regarded as the most technologically realistic. The percentage rises to 30% when hypothetical technological advancements are taken into account.

In the most likely case (Scenario 1), drone deliveries from drone beehives might reach 40 million people (or 7.5% of the EU population), distributed over 13 different European nations. The citizens of the UK and Ireland (covering 20% of the population) would stand to benefit the most from this service. A contrast of the impacts of possible future developments in hardware (Scenario 4), which would allow for doubling the distribution range, and software (Scenario 3), which would allow for delivery to higher densities, shows that hardware investments would have a higher financial value and would cover a larger population (up to 27% of the European population).

2.1.8 Drone Delivery Scheduling Optimization Considering Payload-induced Battery Consumption Rates

This article examined a drone delivery application in which a number of drones were visualized delivering packages to consumers. Understanding the effects of drone battery consumption on the development of a drone-based package delivery system was given first priority. The number of loads carried and the travel time were two criteria examined in this article as factors impacting drone battery consumption. The study demonstrated that there is a linear relationship between the BCR and the load amount based on real studies utilizing drones. Two planning optimization models were suggested to locate the warehouse locations and delivery drone travel routes based on the linear statistical model.

The OP model was proposed to decide the distribution of clients to warehouses and flight pathways by integrating the drone battery duration as restrictions in the navigation optimization problem. The SP model was to locate the depot sites by optimizing a set covering issue. To decrease the computing time, the preparation procedure and other bound generating techniques were suggested. The numerical outcomes demonstrated that (1) up to 60% of the flight paths created without taking the battery consumption rate into account ultimately failed to finish the delivery flights because of insufficient battery life, (2) Switching the travel routes for the same group of clients would leave the battery with insufficient time to finish the deliveries (Torabbeigi et al., 2019).

2.1.9 An Optimization Approach to Minimize the Expected Loss of Demand Considering Drone Failures in Drone Delivery Scheduling

This research described a method for employing drones to deliver light packages to customers. The idea of reducing the predicted loss of demand was developed to find a more efficient flight path taking into account the risk of drone failure because drone failure during flights can result in unmet consumer demand. In order to find a flight schedule that follows to the minimum network expected loss of demand under the drone-specific restrictions of maximum flight time and payload capacity, a mathematical optimization model was developed. Using a range of test problem sizes, the performance of the model was examined and contrasted to the conventional make span model. The findings indicate that the model offered solutions that were, on average, 20.78% more dependable while only slightly increasing the time span by 2.43%. The numerical outcomes demonstrated that the shape parameter had a greater influence on the flight schedule than the size parameter (Torabbeigi et al., 2021).

2.2 Literature Review Summary:

The following characteristics and research gaps are discovered after a study of existing literatures on drone delivery:

1. The use of drones for residential delivery is the subject of growing academic research. Despite the fact that the potential economic advantages of drones are the main motivator, a lot of study is devoted to minimizing modeling of routing problems with

drones to reduce duration time. The most effective and economically sensible way to use drones for home delivery requires strategic evaluations.

2. Environmental considerations must increasingly be included in transportation planning. However, there aren't many studies looking at how drone delivery has an environmental impact (and mainly drone-only delivery). Additionally, there is a lack of knowledge of drone energy consumption as well as a wide range of drone energy usage models, which contributes to the research findings' varied conclusions regarding the energy and emissions efficiencies of drone delivery.

3. Although the majority of studies indicate that drones have the ability to reduce delivery costs and emissions, there is lack of agreement in the literature regarding the possible scale of cost and emissions reductions, as well as how these reductions rely heavily on crucial drone features and deployable settings.

3. Chapter 3

3.1 Project Description

E-commerce companies in Dubai have noticed a rise in both the number of demanding customers and the number of packages that need to be delivered each day. In this sense, the delivery method grew drastically, which has led to many drawbacks in the city, such as high energy consumption as well as increased traffic. For organizations in the quickly expanding and price-sensitive sectors, it is mainly predicted that drone-supported services will lead to decreased prices. The improvement of urban congestion is the main focus of this discussion.

Drones that deliver packages could ease traffic on already crowded cities and speed up air travel. Additionally, this shift would facilitate quicker ground transportation.

The project uses secondary data analysis to study the energy consumption of delivery drones in the city of Dubai. The project aims to evaluate if drones are able to lower energy consumption in the logistics world when compared to other delivery methods used nowadays. The purpose of proposing this project is to encourage the use of drones in the city of Dubai in order to lower the traffic and the GHG emissions, as well as to have a fast and reliable delivery system. Moreover, the use of drones for delivery has many advantages that would help advance the city and attract more people, including that drones are suitable for both long and short distances, drones are cheaper and faster than traditional ground vehicles, they have a short response time, they have easier access to remote areas, and they have much safer environmental impacts.

4. CHAPTER 4

4.1 PROJECT ANALYSIS

In recent years, many studies have been conducted in order to study the energy consumption of drone delivery in different scenarios and cases such as the following analyzed article in this section.

4.1.1 Drone flight data reveal energy and greenhouse gas emissions savings for very small package delivery

In the study by Rodrigues et al., testing of 188 drone flights at various speeds was conducted to create a practical energy model and a machine-learning system to evaluate energy during departures, flights, and landings of drone delivery. It was found that unmanned aerial vehicles (UAVs) used for last-mile deliveries will have an impact on the energy efficiency of the delivery process, demanding the development of new techniques for analyzing energy use and greenhouse gas (GHG) emissions. According to the calculations, a tiny electric drone with a load of 0.5 kg traveling across the United States would use about 0.08 MJ/km of energy and produce 70 g of CO_2 emissions per package. Only electric cargo bicycles emit fewer greenhouse gases per package as compared to drone delivery (0.33 MJ/package), which can be up to 94% less energy-intensive than other forms of transportation. When the total weight of the delivery is not the primary factor, the energy usage of a small drone with a load of 0.5 kg is equivalent to the most energy-efficient last-mile delivery methods.

Vehicle Class	Energy Consumption [MJ/km]	Fuel GHG emissions [g/km]	Upstream GHG emissions [g/km]	Battery GHG emissions [g/km]	Energy consumption [MJ/package]	GHG emission [g/package]
Medium duty truck	11.00	764.5	168.7		5.24	444.4
Small diesel van	4.90	340.6	75.2		1.41	119.5
Medium duty electric truck	3.74	681.4	82.4	24.5	1.78	375.4
Small electric van	1.63	296.1	35.8	14.1	0.47	99.4
Electric cargo bicycle	0.10	18.1	2.2	1.3	0.10	21.6
Quad-copter drone	0.05	8.5	1.0	0.8	0.19	41.1

Table 2. Energy Consumption and GHG emissions for different vehicles.

The study makes it clear that small drones could be a strategic edge to cut transportation emissions in major urban areas, for instance in delivery circumstances where small and light products with high added value are involved, such as medical deliveries, emergency parcels, and small gadgets. By substituting drones for diesel vehicles and electric vans, respectively, it was discovered that in these scenarios, drones may reduce energy usage by 94% and 31%, and GHG emissions by 84% and 29%, per package delivered. Additionally, it was observed that drones and electric cargo bicycles produced comparable or fewer greenhouse gases per shipment. Furthermore, the two key elements affecting the drone's relative energy consumption and environmental impacts are the delivery intensity, or the number of packages delivered per kilometer, and the fuel carbon intensity (Rodrigues et al., 2022).

4.2 COMPARISON OF ENERGY DEMANDS OF DRONE-BASED AND GROUND-BASEDPARCEL DELIVERY SERVICES

To compare both means of logistical transportation for the parcel, there is a need for data related to both types of transport, thus, all related factors will be taken into consideration, both type-specific data and general data. As an example, the standard ground-based delivery service utilizes three different vehicles for its process which are cars, trucks, and motorcycles, but they all share the same factors other than fuel type. For the drone-based delivery service, a significant percentage of industrial level drones that are required to carry such a payload for delivery utilize a high capacity lithium battery to perform the task. Other variables that are considered general variables are ones that apply to both types of services, which consist of fixed or control variables and variables such as CO_2 emission contributions and wastes.

4.3 ANTICIPATED BARRIERS

The expected problems involve the difficulty of modifying the current legal system to achieve a fair distribution of resources and regulatory gaps. A significant factor is the danger that drones could be used by terrorists and criminals. These problems include real-world issues with autonomous flying and airspace integration as well as challenges with battery capacity and data transmission. Invasion of privacy, safety issues, and noise levels are frequently considered as major issues. The difficulty of modifying current infrastructure or building new, digital and physical infrastructure in order to incorporate drones into urban space is the target of potential infrastructural obstacles.

The weather is yet another barrier to drone deployment. A drone would not be capable of functioning in the rain or snow due to the hurdles that would limit their operation, and even if it were able to, users would not choose to use this service in bad weather. In the case of the city of Dubai, Dubai experiences short and infrequent periods of rain, which makes the implementation of drone delivery more likely to be successful the majority of the time except when it's windy.

4.4 DECISION MAKING PROCESS

The study focuses on the designated location which is a warehouse located in Al Quoz area in Dubai at a distance of 10 kilometers from the point of delivery as shown in **Figure 4.** The resulted data would provide a clarification on which method is viable from two perspectives which are expenses and pollution. Furthermore, the path would be favorable towards the drone as it could go from point (A) which is the warehouse, directly to point (B) which is the delivery destination. In comparison, ground-based vehicles would require more duration and be subjected to human errors due to the driver, while the drone can be programmed to follow a route from location (A) towards location (B) and back to point (A) autonomously.

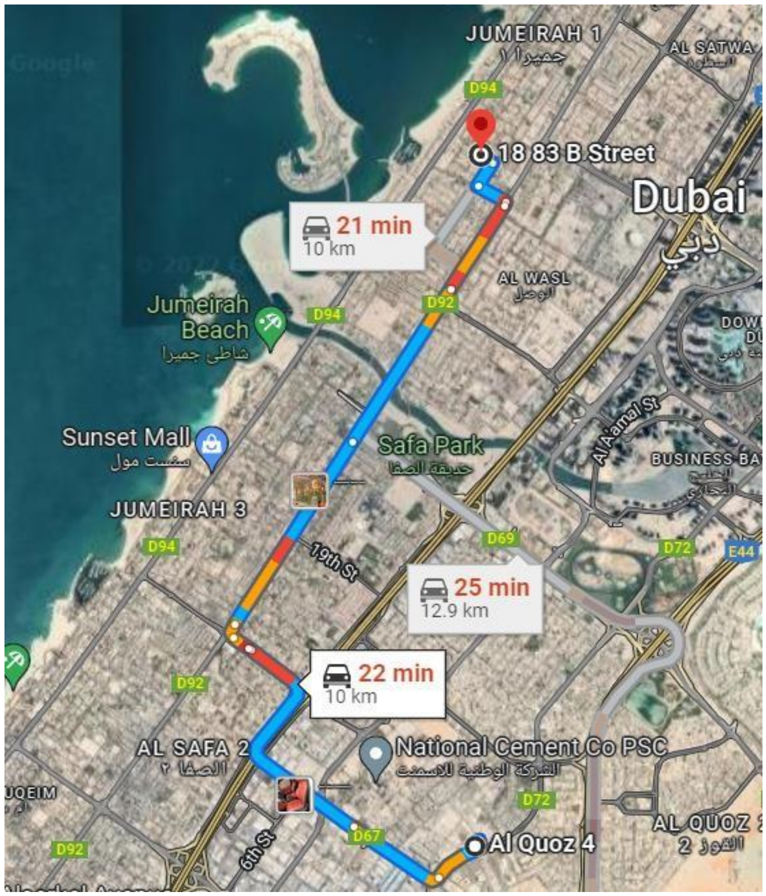

Fig 5. Distance from the warehouse to the delivery location.

4.5 THE RESULTS EXPECTED/ PROJECT DELIVERABLES

In the case of standard delivery methods, the first being a delivery truck that utilizes petrol. As shown in Figure 6, the miles per gallon of gasoline of a light truck is 17.50 mpg which is equivalent to 7.44 Km/l. To calculate the estimated Fuel consumption, the following formula was used:

$$Fuel = \frac{Distance}{Consumption}$$

As a result, the total fuel is 1.344 Liters. In order to calculate the cost, while taking into account that the current price of petrol in Dubai is 3.18 per gallon, the following equation was used (Benn, 2022):

$$Fuel\ Cost = (\frac{Distance}{Consumption}) \times\ Cost\ per\ gallon$$

The given result equals to 4.274 AED for this scenario. In order to calculate the total amount of CO_2 emissions, the total amount of fuel is multiplied by the amount of CO2 gasoline produces. For 1 L of gasoline, 2.3 kg of CO2 is produced. Furthermore, in the case of a delivery truck that utilizes petrol for 10 Km, 3.09 Kg of CO_2 is consumed.

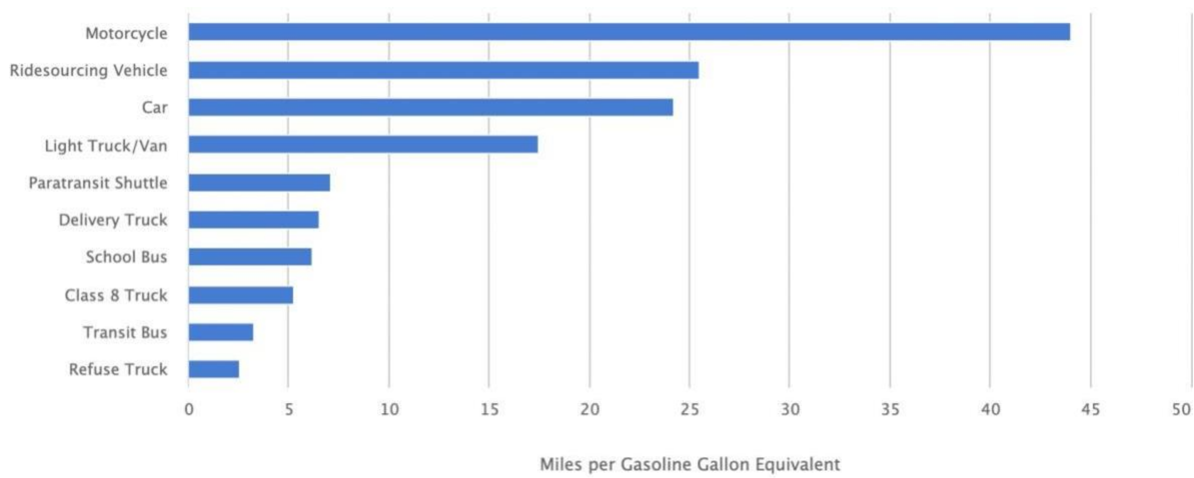

Fig 6. Average Fuel Economy by Major Vehicle Category.

In the case of motorcycle delivery, As shown in Figure 5, the miles per gallon of gasoline is 44 mpg which is also equal to 18.7 Km/l. The amount of fuel consumed is found to be 0.535 Liters. The fuel cost is 1.701 AED, and the CO_2 consumed is equal to 1.23 Kg.

In the case of drones, the distance from the chosen warehouse to the delivery destination is 8.08 kilometers as shown in Figure 6, and for the more frequently used small quad-drone that consumes 0.0089 Wh/m (Stolaroff et al., 2018), and would travel for 5 minutes and 29 seconds.

To calculate the total consumption, the following formula was used:

$$\boldsymbol{Total\ Consumption = Consumption_{meter} \times\ Distance}$$

The total consumption is 71.912 Wh. To calculate the cost of each flight, the following formula was used:

$$\boldsymbol{Total\ Cost = Total\ Consumption\ \times Energy\ Cost}$$

The cost of energy in Dubai is 23 fils/kWh (DEWA: Slab Tariff, 2022) and the total consumption was converted from 71.912 Wh to 0.071912 kWh. The results found states that the cost is 0.0165 AED per flight.

To calculate the total amount of emissions of the drone, we should consider the amount of emissions in Dubai which is 0.366 g/Wh (Climate change report DEWA, 2021), the following formula was used:

$$\boldsymbol{Total\ Emmisions = Emmissions_{g/Wh} \times Total\ Consumption}$$

Furthermore, the total emissions from the drone is 26.35 grams (0.02635 Kg).

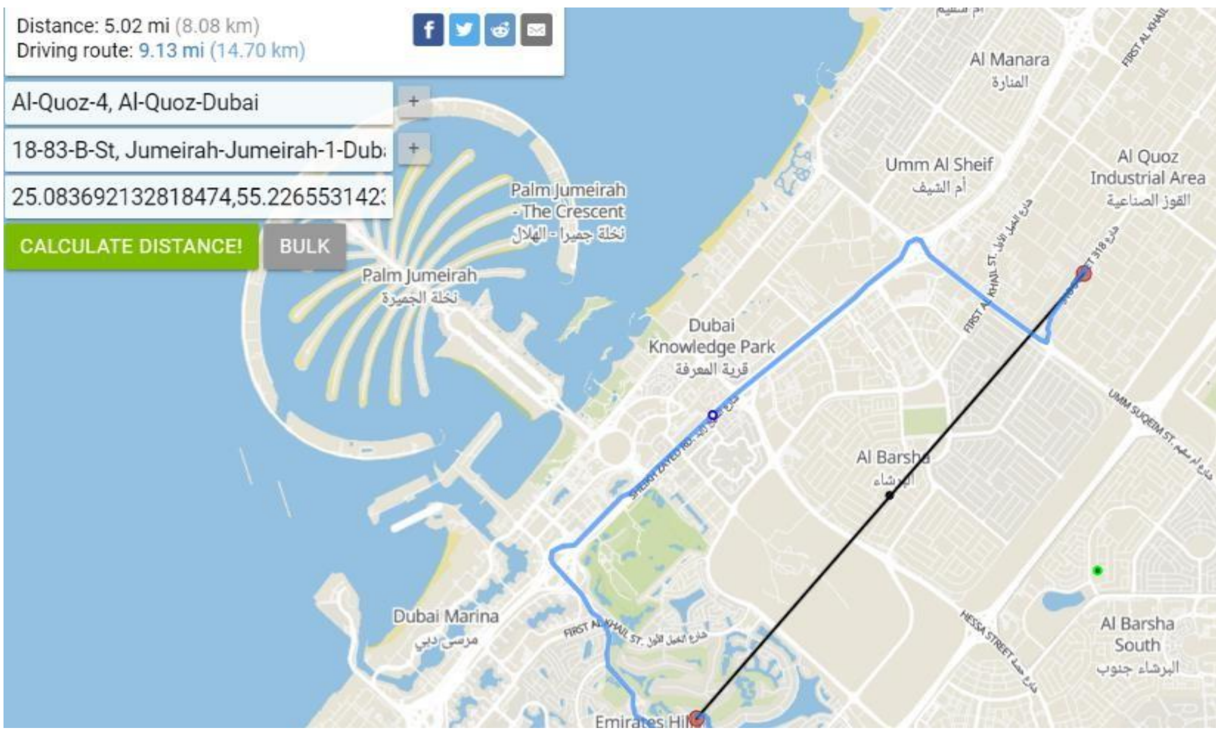

Fig 7. Distance from the warehouse to the delivery location in the case of drones.

The more industrial octa-drones which are capable of carrying a larger payload consumes 0.0739 Wh/m (Stolaroff et al., 2018), traveling for 8.08 kilometers and would take 4 minutes and 1 second costing 0.137 AED per flight. Moreover, the total consumption of the octa-drone is 587.112 Wh with total emissions of 215.134 grams (0.215 Kg) per trip.

Fig 8. Quad-drone.

- **Results:**

	Delivery Truck (Petrol)	Motorcycle
Distance	10 Km	10 Km
Miles per gallon	17.50 mpg (7.44 Km/l)	44 mpg (18.7 Km/l)
Fuel Consumtpion	1.344 Liters	0.535 Liters
Fuel Cost	4.274 AED	1.701 AED
CO_2 emissions	3.09 Kg	1.23 Kg

Table 3. Calculation results of Delivery Truck & Motorcycle.

	Drone	Quad-Drone
Distance	8.08 Km	8.08 Km
Time	5 minutes, 29 seconds	4 minutes, 1 second
Consumption	0.0089 Wh/m	0.0739 Wh/m
Total Consumtpion	71.912 Wh (0.071912 kWh)	587.112 Wh (0.587112 kWh)
Cost per Flight	0.0165 AED	0.137 AED
CO_2 emissions	0.02635 Kg	0.215 Kg

Table 4. Calculation results of Drone and Quad-Drone.

5. CONCLUSION

With the growth of electric mobility over the past decade, supply chain management researchers have become increasingly interested in the subject of transportation networks. Given that drone delivery services have demonstrated their usefulness in a number of different cases, the potential use of drones for urban delivery is an exciting opportunity to overcome the current challenges that cities all around the world are facing such as high emissions, traffic, and delayed deliveries. The objective of this study was to identify and compare the energy consumption of different delivery services which are both ground-based and drone-based. A literature review focusing on energy consumption of drones was also done, including a study of the feasibility of using drones for delivery in Dubai, United Arab Emirates. A case study in Dubai was considered while using secondary data in order to calculate the amount of emissions for each delivery method.

The findings of this study indicate that the drones have the least amount of emissions which is 0.02635 Kg and octa drones consume 0.215 Kg when compared to a petrol operated delivery truck which utilizes 3.09 Kg of CO_2, and a motorcycle which utilizes 1.23 Kg of CO_2. Drones may therefore be more energy-efficient. The study also shows that, drone delivery systems for urban delivery can be a practical option for efficient and affordable parcel distribution.

6. Future Work

The overall potential benefits of drones to the transportation sector in terms of greenhouse gas emissions are difficult to predict with certainty because autonomous vehicles' effects on GHG emissions are highly dependent on ongoing technological development and evolution, market response, and regulatory policies and actions. Given that long-term property adjustments, the impact of management, security, and equity, as well as the potential consequences of drones, are still unknown, it is questionable whether we can accurately forecast the long-term effects on GHG emissions. It is essential to build suitable methodologies, tools, and procedures in order to better understand the implications of GHGemissions for the deployment of drones at various levels. This can be accomplished by applying the appropriate system technique. Drone traffic management is a crucial component of understanding the drone delivery's industry future. There's a need in developing well-structured traffic management systems for drone delivery to be successful in urban areas as it will assist in coordinating and negotiating the usage of airspace by operators to prevent drone incidents.

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