OPERATIONAL FEASIBILITY TO INTRODUCE THE EVTOL IN SÃO PAULO CITY USING THE EXISTING INFRASTRUCTURE OF HELIPADS AND HELIPORTS

by

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Abstract

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Title: **Operational Feasibility To Introduce The EVTOL In São Paulo City Using The Existing Infrastructure Of Helipads And Heliports**

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This work studied the existing infrastructure in São Paulo and the project of the new EVTOLs under development, finding feasibility to take advantage of the facilities, recommending that potential investors and operators in the aviation sector consider the discussion of the necessary adaptations in the 308 helipads and heliports analyzed for the introduction of operations. EVTOL with Brazilian authorities and manufacturers using as a guide the FAA ENGINEERING BRIEF #105 issued September 21, 2022.

The São Paulo city area, considered the financial center of Brazil, has an intense helicopter operation at existing helipads, with more than 1300 trips per day, which qualifies it as a natural candidate to have an EVTOL operation.

We collected the current operation data from the National Civil Aviation Agency (ANAC) and the infrastructure data from the Airspace Control Department (DECEA). This study analyzes the current helipads infrastructure and the current helicopter operations, and with 308 helipads/heliports capable to support the operational specifications from the vehicles analyzed, we verify that São Paulo has operational feasibility to support the EVTOL, it may happen replacing the Helicopters or even increasing flights over the city with EVTOL adoption.

In parallel with the operational feasibility, we carried out a study on the impacts on the reduction of pollutant emissions, a matter of great concern in the airline sector. We demonstrated

a very significant impact for the environment considering the replacement of helicopters by electric aircraft, as a consequence we found a huge market for future EVTOL operators called generation of carbon credits.

The predictions revealed that in a comparison scenario where helicopters would fly the same average as EVTOLs (6.5FH/Day) it is possible to generate €891.580 (European Union - compliance market, in a prediction of ten years/per vehicle.

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Chapter I

Introduction

The objective of the study is to analyze the operational feasibility to introduce the electrical vertical take-off and landing (EVTOL) vehicle in the city of São Paulo and the metropolitan area using the existing helipads and helicopters infrastructure.

Electric vertical take-off and landing aircraft can take off and land vertically, like a helicopter, without the need for a runway. Unlike conventional helicopters, which rely on internal combustion engines and mechanical transmissions to drive their large main rotors, EVTOL aircraft typically have multiple smaller propulsion units driven by electric motors. (Elan Head, 2021)

The focus is on aircraft with the capability to carry at least four passengers along with one pilot for, at least, 50 kilometers.

Project Definition

The Urban Air Mobility (UAM) part of Advanced Air Mobility (AAM) is an air transportation concept of autonomous or piloted aircraft initially designed to perform transportation of passengers and cargo by electric vehicles capable of Vertical Take-Off and Landing (EVTOL).

Considering that São Paulo City has the biggest helicopter fleet in operation worldwide, its become Brazil's one of the most exciting markets in the world for vehicles with vertical takeoff and landing operations. (Verena Brahler and Solveig Florke, 2011)

In the city of São Paulo, considered Brazil´s financial center, in accordance with our research, considering the data provided by ANAC and DECEA was possible validate that there are 400 registered helicopters, with 700 in the state. These vehicles fly over 1,300 trips per day. This places São Paulo ahead of cities like New York and Tokyo. (Verena Brahler and Solveig Florke, 2011)

Another important point for this research is that São Paulo is known worldwide for its chaotic traffic. In 2014, it set a new record with a traffic jam stretching more than 344 kilometers, 214 miles, during rush hour. (Myra, 2021)

This research project explore finding an efficient and carbon cleaning solution related to urban traffic problems in São Paulo considering the introduction of EVTOL operations using the existing infrastructure of helipads and heliports.

Problem Statement

Is São Paulo City like Los Angeles shaping up to become one of the first major battleground in the potentially lucrative air taxi market? (Tom Patterson, 2021)

Already, industry players such as Embraer and Lilium have partnered with community leaders who are setting the table for electric vertical takeoff and landing (EVTOL) aircraft. And while it's not the only city on the run, experts say São Paulo like Los Angeles is ideally positioned to be the proving ground for what could be a trillion-dollar industry by 2040. (Tom Patterson, 2021)

Initial air taxi routes could connect Guarulhos and Congonhas airports with smaller airports like Campo de Marte near the center of São Paulo city. Eventually, they could include established heliports and helipads, and then, ultimately, to lead to newly constructed vertiports.

Here is a great contribution of this study to the EVTOL Market, we analyze the existing infrastructure of heliports, and helipads in São Paulo City and define de possible routes between them, with that, it is possible to estimate the EVTOL operations, define which one can be operated in which routes, in this way concluding it is feasible or not introduce the EVTOL operation in São Paulo City.

The EVTOL has the potential to transform the way of transportation for people in urban regions that are clogged with traffic jams like São Paulo. Some models of this vehicle also provide technical specifications that will enable short trips between cities and/or regional trips of equivalent distances.

To address the problem identified for this research project we plan to survey the available EVTOL projects that:

- Can carry at least four passengers by 50 kilometers.
- Have more than 100 orders.
- Are funded with a minimum $ 100 million dollars.
- Provide aircraft specifications like passenger capacity, range, payload, maximum take-off weight and landing size limitations.

In addition, we plan to assess current helipads available at São Paulo City for take-off and landing and their operations limitations, and then compare the information about those helipads with the selected EVTOL projects specifications.

This research project evaluates the criteria described above regarding the current EVTOL models available in the market and after that was selected five models that can operate in São Paulo City in the existing infrastructure. To do our analyses comparing the service of the EVTOLs in São Paulo with the actual Helicopter operations, we also collect the number of hours that helicopters are flown per year in São Paulo City to predict hypothetical scenarios of EVTOL operations. The idea related to this study is to demonstrate the operational opportunities in the market for EVTOL and the benefits it can bring for companies and customers, so, we do not expect in the short period that this operation will replace the helicopters, but it will create new demands.

Goals and Scope

Our research focuses on identifying how many helipads and heliports exist in São Paulo Cite with infrastructure capable of supporting the EVTOL operational specifications related to the five selected EVTOL models of this research.

We calculate the routes between each defined helipad or heliport and after that was define the percentage of routes that each EVTOL can attend considering the technical specifications provided by each EVTOL manufacturer. The same calculation is done for helicopters to obtain a comparison between these kinds of vehicles. The database from DECEA, the Brazilian Air Traffic Authority, with the airports, heliports and helipads currently installed in the region with size and weight limitations is used as source to correlating with the design of existing and proposed aircraft.

In terms of cost, we compare the acquisition cost of each kind of EVTOL selected with an equivalent helicopter to define the better option in terms of benefit-cost, it may be very important to understand the attractiveness that each kind of vehicle can bring for future demand.

Sustainability is another factor to influence public acceptance in a city like São Paulo. Compared to conventionally powered aircraft, EVTOL reduce or eliminate CO_2 emissions, an essential fact for integrating future transportation systems, we expect to demonstrate the impact on the environment related to a hypothetical scenario of EVTOL operation and the benefits related to the avoided CO_2 emissions that these kind operations can bring for companies and as consequence for environment.

Contributions Expected

The EVTOL is a potentially transformative industry. The promise of this new urban air mobility (UAM) yet hinges on some new technologies, processes, certifications, infrastructure, and regulations to be implemented in the areas to be operated by them. Also, another important point to be considered is public acceptance requirements are a challenge, the reason is quite simple, safety. Before becoming a reality in the market, the EVTOL manufacturers together with the local authorities need to prove to the people that this new concept of aircraft is safe for those that are flying as well as for those on the ground. Many of which have yet to be clearly defined. (Elan Head, 2021)

In this study, we look to demonstrate the opportunities that São Paulo City brings for this new kind of aircraft considering the existent helipads and heliport infrastructure, and also demonstrate for those who may be interested, the cost-benefit relationship of acquiring an EVTOL versus an equivalent helicopter considering the carbon credit generation. The sustainability and traffic alleviation for big cities is a main drive for introduce the EVTOL operations, it is directly linked with or resource that intend demonstrate the results related the CO_2 emissions avoid removing cars from the chaotic traffic from São Paulo by using EVTOLs.

The into-service consolidation and the future of EVTOL aircraft will be enabled by rapid advancements in next-generation electric motors, and computing technology but mainly by a new design of batteries that could bring different levels of safety, longer ranges, and new performance parameters for this vehicle.

Uber Elevate estimated that a fully electric air taxis would have near-term operating costs of around $ 700 per hour, at least 35 percent less than a comparably utilized single-engine helicopter. (Elan Head, 2019)

When combined with ridesharing APPs that will allow passengers to book flights by seat, the EVTOL can become an affordable form of transportation for many more people than compared with helicopters today. Their low operating costs promised also can make them attractive for some other missions currently being performed by helicopters, such as organ transport, service hyper-relevant for society.

In conclusion, our expectation is to provide for the reader, data that demonstrate how feasible operationally and economically may be operating the EVTOL in São Paulo City and in the same way how important it can be for the local environment. Once providing this clear perception related to the EVTOL operation, we also hope that this study can contribute to other researchers around the world.

Definitions of Terms

ANAC - The Agency is responsible for the regulation, inspection and certification of aircraft, companies, manufacturers, aircraft maintenance organizations, aerodromes, schools and civil aviation professionals. The government agency works to ensure civil aviation safety and security and to improve the quality of services, fostering a competitive market.

DECEA – The Department of Airspace Control (DECEA) is responsible for the management of all the activities related to the safety and efficiency of the Brazilian airspace control. Its mission is to manage and control the air traffic in the Brazilian sovereign airspace as well as to guarantee its defense.

EASA - Agency of the European Union with primary responsibility for Civil Aviation Safety carries out certification, regulation, and standardization, performs investigation and monitoring.

FAA – The Agency issues and enforces regulations covering manufacturing, operating, and maintaining aircraft, certifies airmen and airports that serve air carriers, conducts research on and develops systems and procedures needed for a safe and efficient system of air navigation and air traffic control.

List of Acronyms

AAM - Advanced Air Mobility

ANAC - Agência Nacional de Aviação Civil

DECEA -Departamento de Controle do Espaço Aéreo

EASA - European Union Aviation Safety Agency

ECTOL - Electric Conventional Take Off and Landing

ESTOL - Electric Short Take Off and Landing

EVTOL - Electric Vertical Take Off and Landing

FAA - Federal Aviation Administration

GAMA - General Aviation Manufacturers Association

SAE - International Society of Automotive Engineers

UAM - Urban Air Mobility

VFS - Vertical Flight Society

Chapter II

Review of Relevant Literature

Introduction

This research is being developed using material, information and concepts of a future transportation environment that is in development in many parts of world. After exploring other alternatives for the present opportunities, challenges, and risks of this new form of transportation, we choose to make our research analyzing the ecosystem of the São Paulo City.

The reason for choosing São Paulo City is that the largest operation number of helicopters worldwide is concentrated in São Paulo, and certainly, a study that demonstrates the operational feasibility of EVTOLs in this city can bring important information to the aviation industry worldwide.

A New Paradigm

For many years, we have dreamed about the possibility of take out of the garage a vehicle that could not only run, but also fly around, like the old fiction of Jetson´s series. We finally appear that we are having the real opportunity for this old dream to become a reality through the introduction of a new transport modal called EVTOL. Considering that this new and advanced transport model is heavily dependent of new technologies in the areas of structures, electric engines, electronic controls and new automated and autonomous navigation systems, some information’s are still classified as being intellectual property of the companies that are developing the new devices. Will be interesting to see how the public will react to this new way of transportation, even the ones that will not use it, for example, the ones that have flying fear, but will see that strange aircraft flying over its head and knowing that there is people inside.

Advanced Air Mobility Ecosystem

This new Advanced Air Mobility industry can be divide it in 6 parts to have an individual view and perspectives of the ecosystem as follows:

1. Aircraft EVTOL vehicles.
2. Regulatory.
3. Airspace.
4. Infrastructure.
5. Rise of Vertiport.
6. Public Acceptance.

1. Aircraft EVTOL vehicles

Considering that actually we can find a long and numerous list of proponents for this new market it is reasonable to understating that not all of them will succeed. Considering the main categories of EVTOLs analyzed in this study, was possible identify the follows different models and architecture:

The simplest are wingless multicopter, these models appear like a big and oversized drone. The other ones are lift-plus-cruise models that use one or more thrusters' propellers for cruise and separate thrusters for vertical lift.

The most complex models are the vectored thrust, that use the same thrusters for both lift and cruise, the complexity of this architecture is that is needed change the orientation of the thrusters in flight. It is very important at this moment to really understand the different types of architectures used in these new models because they are tailored for the specific use and application that is envisioned for each model. What we are talking here is that some models appear to be simple, others appears to be of medium complexity and others appears to be very complex models.

2. Regulatory

The time when EVTOL aircraft will actually take to the skies for commercial operations is now yet not clear, because not even the regulations are established, the most manufactures and Airline operator that are ordered EVTOLs around the world have been talking about start operations test between 2024 to 2025. Different regulatory approaches may determine where urban air mobility operations launch first. Embraer revealed it had formalized the process for obtaining a type certificate for its EVTOL aircraft with the Civil Aviation Agency of Brazil (ANAC). For these operations become a reality, first communities will want assurances that noise from urban flights is acceptable (Vascik and Hansman, 2017b). Regulators and air navigation service providers (ANSPs) will require that flights remain safe, orderly, and efficient, while minimizing impact on airline and air traffic management (ATM) (International Civil Aviation Organization (ICAO, 2016). Operators of small drones will want access to low-altitude airspace, while fleet operators will need equitable access to urban corridors. General aviation (GA) pilots of fixed-wing aircraft and helicopters will want to fly above urban areas with the freedom they enjoy currently. The urban airspace needs to accommodate the needs of all these stakeholders (Embraer X, 2019).

At an interview Roberto Honorato, ANAC´s airworthiness superintendent explains its significance, “It is an important moment that demonstrates the company´s commitment to exploring the future of urban air mobility.

Before start operations, the process aims to achieve the best safety standards to allow EVTOL access to global market. From the regulation perspective, there is much work to be done concerning aircraft technology and the definition of the entire ecosystem. Brazil has the conditions and engagement to deal with this challenge.” (Mike Stones, 2022)

Currently, the FAA has no clear timeline or direction on when it will finalize a permanent certification process for EVTOL. But there are many USA government efforts to accelerate this process. On August 3, 2022, the US Air Force signed the cover letter for a Department of the Air Force “Report to Congressional Committees” on this report details the overview, approach, milestones, and future plans for the AFWERX Agility Prime program (Vertical Flight Society, Sep, 2022). This new approach is accelerating and adopting dual-use technologies in the Department of the Air Force, specifically for the transformative vertical lift and electric Vertical Takeoff and Landing (EVTOL) industry. The committee recognizes that the U.S. Air Force’s Agility Prime program is working towards its goal of ensuring a robust domestic market for electric vertical takeoff and landing (EVTOL) aircraft, as well as introducing the Department of Defense to zero emissions aviation (Vertical Flight Society, Sep, 2022).

3. Airspace

One of the big problems to be solved related to EVTOL operations is the safety and reliability of the flight. The point is how to manage the low airspace that is the space that this new vehicle is designed to use, considering that in the future autonomous operations are envisioned, the number of EVTOLs ordered by Airlines and other companies worldwide have been demonstrate how big could be this market, and for Brazilian market its not different, the information’s retrieved from the EVTOL manufacturers website and from Brazilian Airlines demonstrate huge number of aircraft to be introduced in the low airspace in the next decade, will be hundreds of EVTOL aircraft sharing the same narrow defined low airspace over the cities, and São Paulo should be the first one.

Automated traffic management systems that facilitate a high number of aircraft sharing urban skyways will require significant public and private investment, commitment and collaboration. Looking at São Paulo City low airspace environment, already crowded by a huge number of helicopters operations, the regulation of this for the operation of the EVTOL together with helicopters will be very tough and challenge situation. The White Paper Flight Plan 2030 (Embraer X) describes an urban air traffic management (UATM) solution that will enable the UAM industry to evolve to a future where EVTOL flights are a mainstream mode of transportation. Embraer X believes that an urban traffic management solution must provide shared situation awareness for all stakeholders, enable equitable airspace access, minimize risk, optimize airspace use, and provide flexible and adaptable airspace structures.

4. Infrastructure

Flight Plan 2030 presents a concept for the design and management of low-altitude urban airspace that will allow UAM to evolve over the next decade (Embraer X, 2019), UAM infrastructure requirements and customer demands provide an opportunity to build new businesses and create new jobs. The development of sky ports, or vertiports, across a wide metropolitan area will be critical to the growth of the UAM industry; the number and location of TOL pads will drive the number of UAM flights that a city can accommodate. Sky port operators will provide EVTOL fleets with battery swap or recharging services and deliver transit services to UAM passengers. Fleet operators will be responsible for managing fleets of EVTOLs that fly across cities. They will also interact with Sky port operators and booking platforms that receive requests for passenger rides or cargo movements. If necessary, fleet operators will assign a pilot to operate a flight. These are but a few of the new opportunities that will be enabled by the growth of a UAM industry (Embraer X, 2019). Many stakeholders are looking at the adequate infrastructure that will be needed to extract all the benefits that are being expect from the EVTOL use in a big city like São Paulo.

Our research is focused on defining the operational feasibility of the EVTOL operation in São Paulo City using the already existing infrastructure that the helicopters use today, so this is a way that it can happen without too much investment, maybe only improvements.

In the future is envisioned specific and tailored infrastructure to take all the advantages the EVTOL can bring to a city like São Paulo.

5. Rise of the Vertiport

The Vertiport will be a special infrastructure designed to better handle the EVTOL operations with all the facilities and amenities to optimize the customer experience.

According to Chapman Taylor upon introduction, the service will focus on a route from the airport to city destinations, using the many rooftop landing opportunities that already exist in São Paulo along with adaptable potential sites, such as multi-level car park structures. In time, the hub base will be augmented by the connection of these point to point locations, supporting a wider city connection.

6. Public Acceptance

Other UAM proponents talk about democratizing aviation, where the cost of taking an electric aircraft from downtown locations to the local airport costs an amount similar to ground transportation.

According to the Chapman Taylor studies the flight from Campo de Marte in northern São Paulo to Guarulhos International Airport can take as little as 10 minutes, costing around 211 reais ($63), plus 30 reais ($9) for the car ride from house to helipad, or about twice what the trip would have cost by cab alone. The same trip in a cab, however, could take an hour, or even two, in rush hour traffic.

While this might ultimately be the case, it is more likely that package delivery will be the initial way in which the vast majority of people are able to benefit from the urbanization of aviation. As is widely accepted many cite noise as the main reason why helicopter flights have been driven out of urban settings over the recent decades, and recent registered tests with EVTOL, under NASA control, clearly demonstrated they will be quieter.

Conclusion

The building and introduction of the Advanced Air Mobility Ecosystem, the concept that includes Urban Air Mobility have been worked around the world by the private sector together with the local authorities, but due to the challenges related to the definitions and roles for low airspace operations, certifications and regulatory issues and also infrastructure and technological problems that will involve the number of vertiports and helipads available to make operations really viable, until know, there is no any country that has confirmed a target that the first EVTOL and AAM/UAM ecosystem will be implemented and certified. USA government programs like the AFWERX Agility Prime, a program office at the Air Force Research Laboratory (AFRL), that connects innovators across government, industry and academia has defined Key Milestones for 2023 that will accelerate the EVTOL test phases (Vertical Flight Society, Sep, 2022). Also in 2021, Embraer and BAE Systems unveiled plans to collaborate on the development of EVTOL as a potential defense variant. This agreement reinforces the confidence of leading aerospace organizations in these vehicles and its adaptability for purposes other than urban air mobility. Actions to regulate this type of transport also already are being developed in Europe (Bae Systems Jul 2022).

EASA (European Union Aviation Safety Agency), for example, has already published rules for the operation of EVTOLs in cities on the Old Continent (EASA Jun,2022). The measure is the first regulatory action for this type of transport. According to EASA, the goal is to develop "a new urban air mobility ecosystem" to safely integrate certified aircraft. By the end of September, the regulations, which cover the areas of airworthiness, crew licensing, and air operations, will be available for public consultation.

We understand that the challenge is significant, in the next phase of the aerospace infrastructure development, aimed at creating an entirely new system of passenger and cargo transportation, the urban air traffic management (UATM) solution that will enable the UAM industry to evolve to a future where EVTOL flights are a mainstream mode of transportation is the main challenge as it depends on a paradigm shift that will involve a complete change in the operational rules of low airspace, a region where the airspace will be shared between drones, regular and business aviation, helicopters, and EVTOLs (Embraer X, 2019). The market guide for this scenario is the Flight Plan 2030, a document in which EVTOL manufacturers and stakeholders disclose their action and development plans regarding the effective implementation of the operating ecosystem involving EVTOLs.

Chapter III

Methodology

Data Source FALA.BR

In Brazil, the Federal Law 12527, of November 18, 2011, regulates the access to information provided by the government. This law allows any Brazilian citizen to request information about the judicial, legislative, and executive branches, in all spheres of government, federal, state, and municipal. The general rule is to grant access, but it is possible to restrict access provided there is a legal justification.

In the case of the Federal Government, one of the instruments used to gain access to information is the website https://falabr.cgu.gov.br/, known simply as FALA.BR. At this address, it is possible to request information that is under the control of the federal government, and such requests have a protocol number and control of responses. This tool has been used in this work to get the data needed if it was not already available via some government website.

Geographical Area

This study covers the area of the São Paulo metropolitan region (figure 01), that covers, in addition to the city of São Paulo, the cities defined by State Law No. 1139 of June 16, 2011 (Law, 2011), composed of 38 municipalities, as follows:

I - North: Caieiras, Cajamar, Francisco Morato, Franco da Rocha and Mairiporã;

II - East: Arujá, Biritiba-Mirim, Ferraz de Vasconcelos, Guararema, Guarulhos, Itaquaquecetuba, Mogi das Cruzes, Poá, Salesópolis, Santa Isabel and Suzano;

III - Southeast: Diadema, Mauá, Ribeirão Pires, Rio Grande da Serra, Santo André, São Bernardo do Campo, and São Caetano do Sul;

IV - Southwest: Cotia, Embu, Embu-Guaçu, Itapecerica da Serra, Juquitiba, São Lourenço da Serra, Taboão da Serra, and Vargem Grande Paulista;

V - West: Barueri, Carapicuíba, Itapevi, Jandira, Osasco, Pirapora do Bom Jesus and Santana de Parnaíba.

Figure 01 – Cities that are part of the São Paulo Metropolitan Area.

Helipads

The data on helipads are registered with the Departamento de Controle de Espaço Aéreo (DECEA). This is an agency subordinated to the Brazilian Air Force, which is part of the Federal Government. The website https://aisweb.decea.mil.br/ has public information about the helipads open to the public and based on this information we collected the names, cities, coordinates, dimensions in meters, and maximum capacity in metric tons. For São Paulo State there are 609 Helipas, and for the metropolitan area, there are 308 Helipads.

To calculate the distances between the helipads an estimation of the differences between latitudes and longitudes was used. For simplicity we took as reference the Sé Cathedral (Catedral da Sé, in Portuguese), which is in the center of the city of São Paulo, at the coordinates 23.551S and 45.634W, and calculated the distance in km between two points, one with 0.5 degrees below and the other with 0.5 degrees above, using the site https://www.nhc.noaa.gov/gccalc.shtml. Obtaining the values shown in Table 01.

Table 01

Distance using latitude and longitude

Point 1		Point 2		Difference	Distance
Latitude	Longitude	Latitude	Longitude		
23.051S	45.634W	24.051S	45.634W	01° Latitude	111 km
23.551S	45.134W	23.551S	46.134W	01° Longitude	102 km

The number of available routes between two helipads is calculated using the combination formula:

$$R = \frac{n!}{2 \times (n-2)!}$$

With 308 helipads, n = 308, and R = 47278 possible routes between the Helipads in the Metropolitan Area.

To calculating the distances in kilometers for each route the formula below has been used

$$D_{AB} = \sqrt{\left((LatA - LatB) \times 111\right)^2 + \left((LongA - LongB) \times 102\right)^2}$$

To calculate the values a Microsoft Excel Spreadsheet using Power Query data transformation tool was used.

The histogram below illustrate the distribution about the number of the possible routes per 5 km distance interval, and 80% of the routes are below 28.5 km.

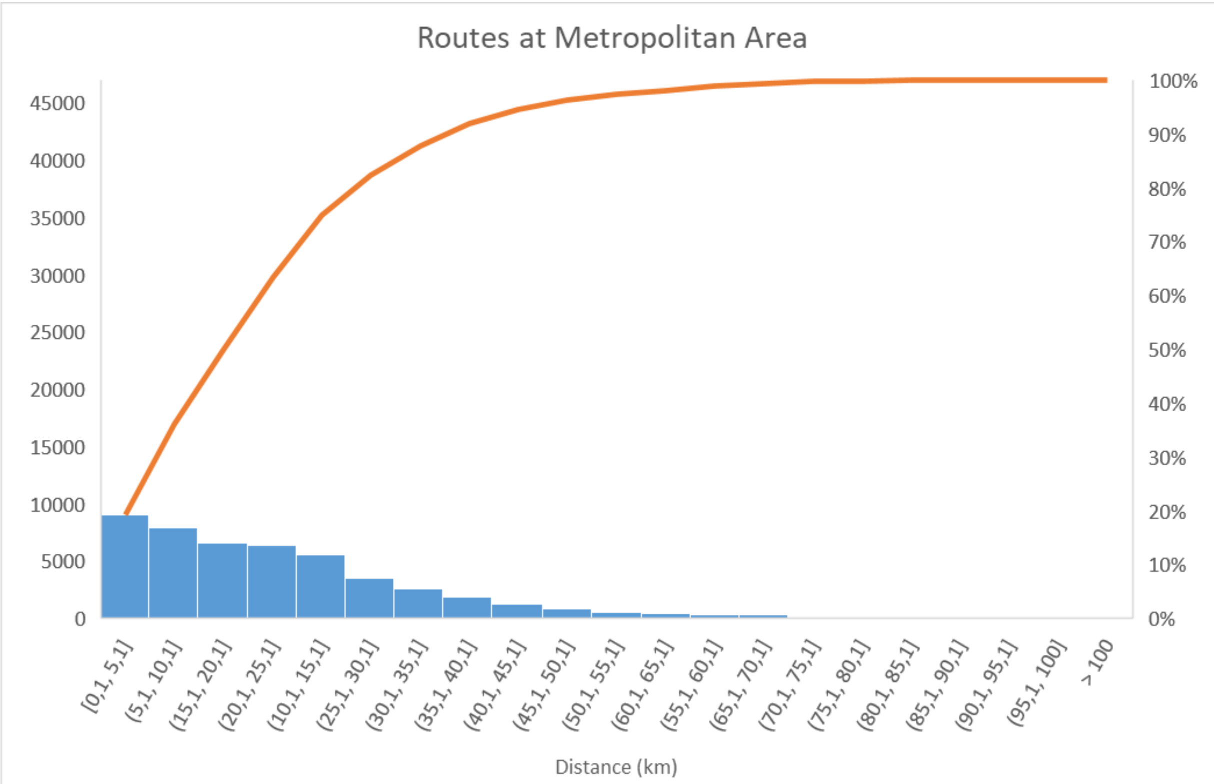

Figure 02 – Distribution of possible routes at metropolitan area at intervals of 5 km.

Note: as an acceptable simplification the routes calculated here does not avoid restricted airspace for Congonhar Airport (CGH) and does not follow the corridors established in São Paulo City for Helicopter by DECEA.

Electric Vertical Takeoff and Landing (EVTOL)

The EVTOL models that meet this study's criteria were surveyed using published data from open capital companies as relevant facts in the Investors Relations Area. The technical specifications are those that has been published by the manufacturer over its own website. Map of São Paulo City and Metropolitan Area used in this study of operational feasibility of EVTOL Operations.

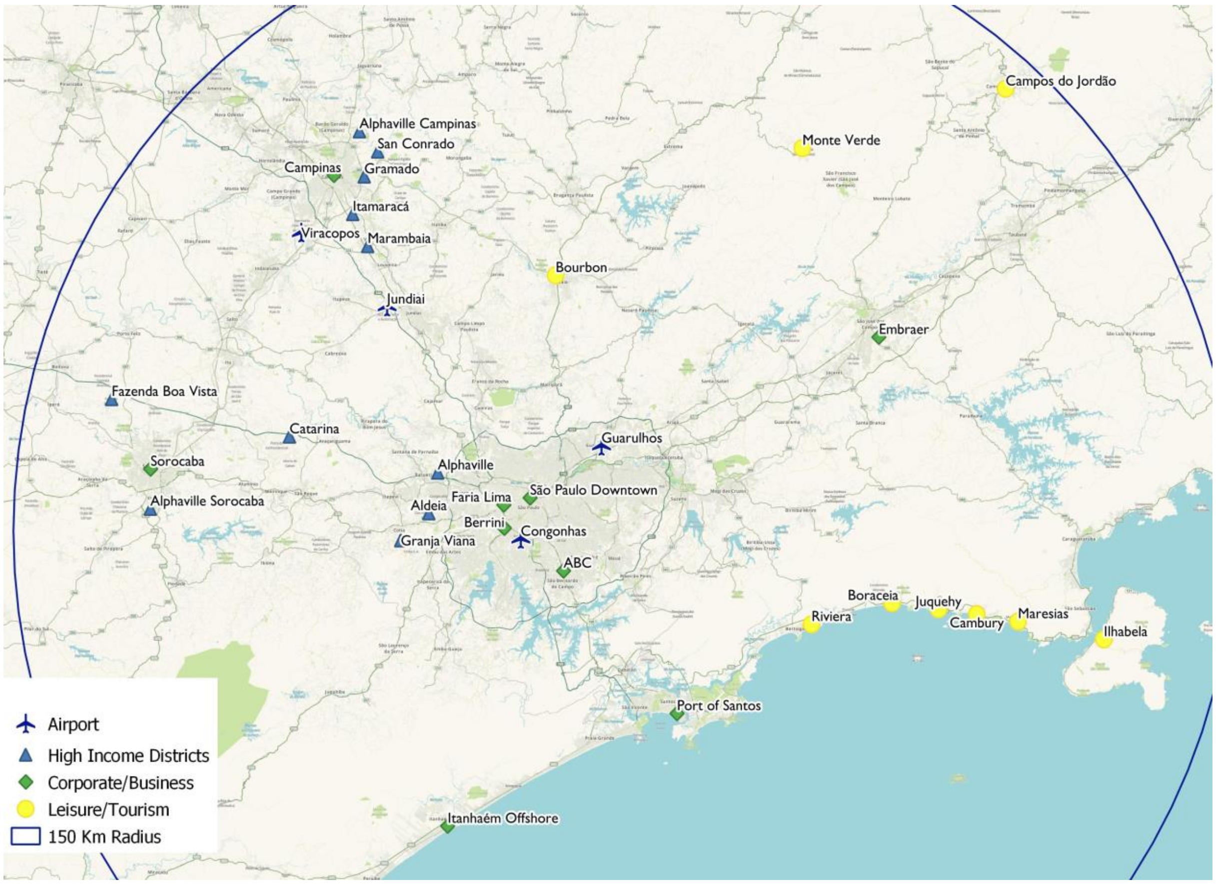

Figure 03 – Distribution of possible routes at metropolitan area at intervals of 50 km.

Table 02

EVTOL Specifications

MODEL	**RANGE (nm)**	**DIMENSION (m)**	**WEIGHT (tonnes)**
JOBY S4	150	10,7	1,815
Eve	60	15,2	1,000
Archer	60	12,2	3,175
VX4	161	15	3,175
Lilium	155	13,9	3,175

The estimated cost of acquisition for each EVTOL is

JOBY S4……………………….……….US$ 1.3 MM

Eve…………………………..……….US$ 3.0 MM

Archer……………………..………….US$ 5.0 MM

VX4………………………….……….US$ 4.0 MM

Lilium…………………………..…….US$ 4.5 MM

Helicopters

The source to identify the helicopters were those data published in August 2022 by the Brazilian Civil Aviation National Authority (Agência Nacional de Aviação Civil, or ANAC, in Portuguese) at its website https://www.gov.br/anac/pt-br/sistemas/rab/relatorios-estatisticos.

As described in International Civil Aviation Organization (ICAO) Doc 8643, the first character of the aircraft type means:

L	landplane
S	seaplane
A	amphibian
H	helicopter
G	gyrocopter
T	tilt-wing aircraft

So, as a first filter, the column CD_CLS was used and filtered only lines in that column starting with H to select only Helicopters. To avoid bringing to the analysis aircraft that are no longer in the country, or that have been disassembled, it was used as a second filter the column CD_INTERDICAO, in which removed the aircraft with class M, which means canceled registration, and the option R, which means registration number reservation, as described in Annex 1.

As a third filter was used the column UF_OPERATOR, which filtered only aircraft with operators registered in the state of Sao Paulo. With these first 3 filters, it was obtained the value of 595 helicopters registered in the state of São Paulo.

As the database provided by ANAC does not contain the information about the city, we consulted the website of the Brazilian Government, https://servicos.receita.fazenda.gov.br/servicos/cnpjreva/cnpjreva_solicitacao.asp, where it is possible to check the data for the company that is operating the helicopter, creating a new column with the city of each operator. It was observed that 112 helicopter operators are individuals, so it is not possible to identify the city.

Filtering the data only with the cities that are part of the Metropolitan Area, 371 helicopters were identified to be operating by companies established in these cities.

The main manufacturers were Airbus, Robinson, Leonard and Bell.

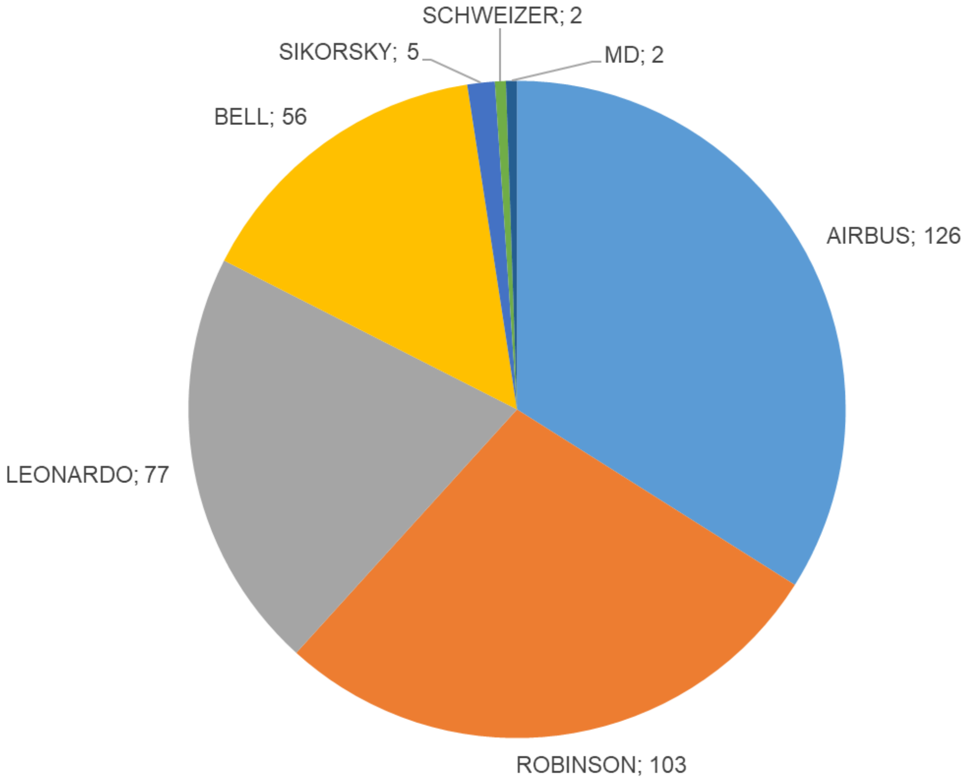

Figure 04 – Number of helicopters registered at São Paulo Metropolitan Area by manufacture.

To simplify the analysis several models and variants were grouped as described below.

Table 03

Helicopter Models Grouped

DS_MODELO	**MODEL**	**DS_MODELO**	**MODEL**	**DS_MODELO**	**MODEL**
206B	206	A119	AW119	EC 135T1	H135
206L-3	206	AS 350 B2	AS350	EC 135T2+	H135
206L-4	206	AS 350 B3	AS350	EC 155 B1	H155
269C-1	269	AS 350 BA	AS350	EC 225 LP	H225

369HS	369	AS 365 N2	AS365	EC135 P3	H135
407	407	AS 365 N3	AS365	H160-B	H160
429	429	AW109SP	AW109	HB-350B	AS350
430	430	AW119MKII	AW119	R22	R22
47G	47	AW169	AW169	R22 ALPHA	R22
505	505	BK 117 D-2	H145	R22 BETA	R22
600N	600	BK117 D-3	H145	R44	R44
A109AII	AW109	EC 120 B	H120	R44 II	R44
A109C	AW109	EC 130 B4	H130	R66	R66
A109E	AW109	EC 135P1	H135	S-76A	S-76A
A109S	AW109	EC 135P2+	H135	S-76C	S-76C

With the models grouped were possible to better organize the models as shown in figure 05.

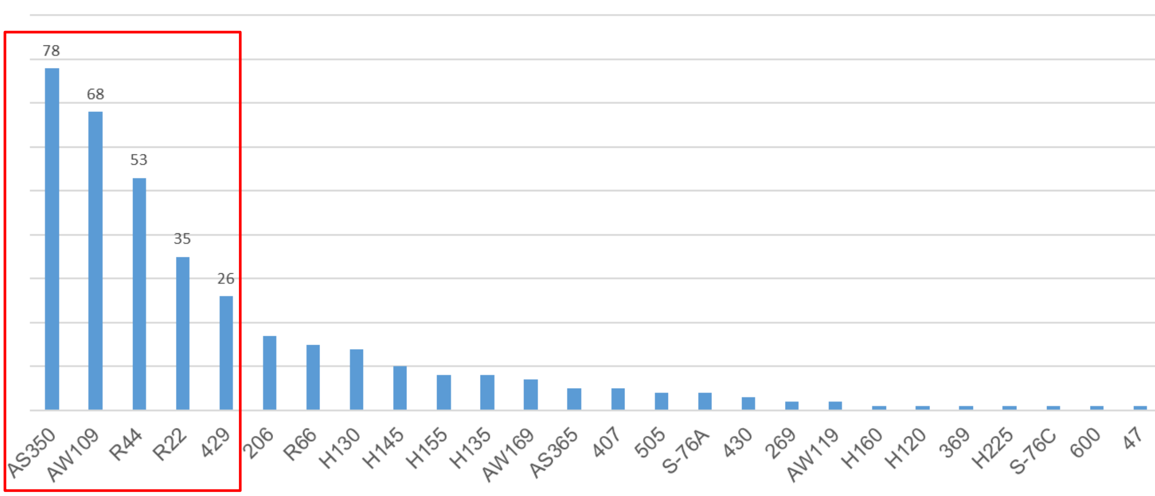

Figure 05 – Models of the helicopters registered at São Paulo Metropolitan Area

In a further analysis, all helicopter without a valid airworthiness certificate were removed from the list by selecting in the field CD_INTERDICAO, only those with N, which means normal situation (Annex 01). The total number of airworthy helicopters were 268 helicopters.

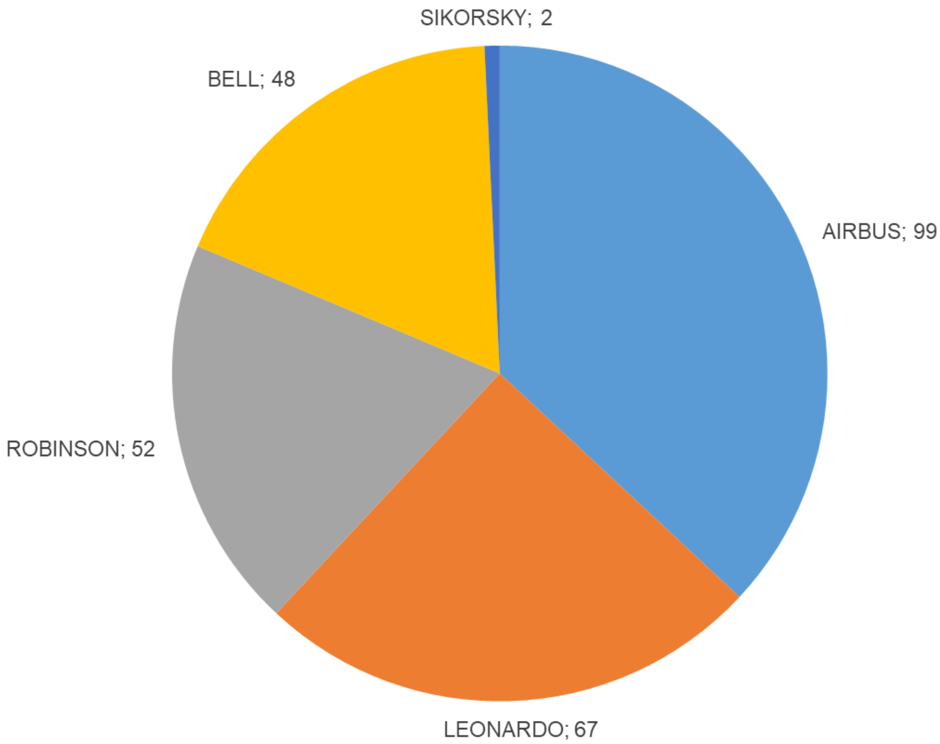

Figure 06 – Number of helicopters with a valid airworthiness certificate registered at São Paulo Metropolitan Area by manufacture.

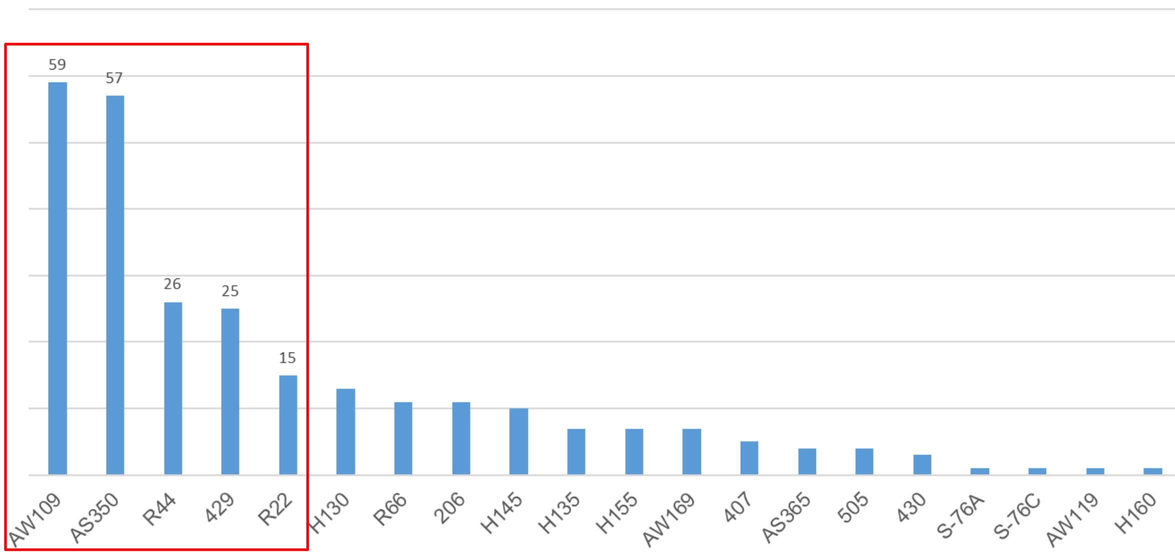

Figure 07 – Models of the helicopters with a valid airworthiness certificate registered at São Paulo Metropolitan Area

With the data gathered, the Leonardo AW109, Airbus Helicopter AS350, Robinson R44, Bell 429 and Robinson R22 were selected as comparison case for EVTOLs.

The center of the city of São Paulo is at 780m sea level (Topographic, 2022), or 2560 ft. The average daily temperature in São Paulo is 22.5°C (Climate, 2022). In the manufacturers' data, there are several graphs to find the speed and fuel consumption, and the one that came closest to the altitude and temperature conditions of the city of São Paulo was chosen. The recommended cruise speed was used, and where this option was not available the maximum endurance was used. The helicopter was considered in the maximum weight.

As long as the helicopter cannot be refueled in the vast majority of the Helipads, the range was divided by two to count for a return to refill and the results are shown in the Table 04.

Table 04

Helicopters specifications

MODEL	RANGE (nm)	DIMENSION (m)	MTOW (tonnes)	FUEL CONSUMPTION (kg/hour)
R22	105	8,8	0,621	25
R44	135	11,7	1,134	47
AS350	180	12,9	2,37	136
429	206	13,1	3,402	188
AW109	228	13,0	2,85	176

The Helivalue website (https://www.helivalues.com/) was visited on Sep, 28th 2022, to compare costs for acquisition of a new helicopter, with the current variant of the model available, and presented the values below:

- R22 Beta II…………………………..……..…US$ 325,000
- R44 Raven II…………………...……..…US$ 500,000
- Airbus AS350B3e……………………..……US$ 2,400,000
- AW109SP Grand New..............................US$ 5,900,000
- Bell 429..US$ 6,855,000

Comparison between EVTOL and Helicopter

To use one of the 47278 possible routes the vehicle should have a range equal or larger than the distance between the two helipads.

As explained before, in this study the range was considered half of the real range for helicopters. For the EVTOLs all range was considered, as long as, will be easier to recharge an electric vehicle than a liquid fuel vehicle. This is a assumption that may change when more information is available about this subject.

Beside the range the weight of the vehicle cannot be above any of the helipads maximum weight and the bigger dimension of the vehicle cannot be bigger that the smaller dimension of any of the two helipads.

Table 05

Percentage of routes achievable for each vehicle

Helicopters						EVTOLs			
R22	R44	AS350	AW109	429	S4	Eve	Vx4	Lilium	Archer
100%	99%	97%	97%	65%	99%	97%	65%	65%	64%

Helicopter Flight Hours

For the estimates on helicopter flying hours in São Paulo, we used as a data source the Airworthiness Verification, which is a mandatory annual task for all helicopters registered in Brazil. If this task is not performed, the aircraft automatically loses its airworthiness status (RBAC 91, 2021).

When the helicopter operator or the responsible Workshop, performs such a check, they need to fill out an online registration on the website of the National Agency of Civil Aviation (ANAC).

FALA.BR was used to officially request the hours registered in the years 2018, 2019, 2020, 2021, and 2022 for all helicopters registered in the city of São Paulo. This information can be found in Annex 2. After organizing the data was obtained the values in Table 5.

Table 06

Flight Hour between years

	Interval of Years			
Helicopter Type	2018□2019	2019□2020	2020□2021	Average /Year
H1P	21557,62	13834,08	10621,2	15338
H1T	25456,01	22885,99	21386,17	23243
H2T	17207,54	17232,54	18811,61	17751

Table 07

Helicopter Fuel burned in São Paulo Last 3 Years

Helicopter Type	Average flight hours per year	Fuel consumption (kg/hour)	Fuel (tonnes)
H1P	15338	36 (1)	552
H1T	23243	126 (2)	2929
H2T	17751	172 (3)	3053

Notes: (1) average between R22 and R44 fuel consumption (2) AS350 Fuel Consumption (2) average between AW109 and 429 fuel consumption

Carbon Emissions

To do the calculation of how much carbon emissions can be avoided using the EVTOL operations, was necessary do the calculation related the amount of fuel burned by an equivalent helicopter when compared with the EVTOL model selected for this study, using the same leg with the standardized load and number of passengers. The equation to do CO_2 emissions calculation was designed using the standards from IATA RECOMMENDED PRACTICE -RP 1726 that provide the methodology to develop a Carbon Emissions Calculator.

Due to the kind of aircraft used and the parametrization defined to do the calculations related this study, we abbreviated the standard equation below:

CO_2 per pax = 3.16 * (total fuel * pax-to-freight factor)/(number of y-seats * pax load factor)

For:

$$CO_2 = \sum M_f \times FCF_f$$

As defined in the Methodology ICAO Carbon Calculator_v11-2018, to converting fuel mass to per passenger CO_2 emissions Fuel burn per passenger is multiplied by a CO_2 emissions factor of 3.16. In this case, also is necessary converting volume to mass using density values.

If the amount of fuel used is determined in units of volume (e.g., liters), must convert this volume to mass by using either of the two options consistently when applying to fuel data:

Option 1: Adjusted Density Value - adjusted density means density expressed as kg/liter and determined for the applicable temperature or region for a specific measurement. Option 2: Standard Density Value - a standard density value of 0.8 kg/litre must be applied.

In our study we choose use the Option 2, the standard density value of 0.8 kg/litre for Jet A/A1 and 0.72 kg/litre for aviation gasoline.

Where:

CO_2 = CO_2 Emissions (in tons);

M_f = Mass of fuel used (in tons)

FCF_f = Fuel conversion factor, equal 3.16 (kg CO_2/kg fuel).

Table 08

CO_2 emission yearly by Helicopter in São Paulo Last 3 Years

Helicopter Type	Fuel (tonnes)	FCF_f	CO_2 Emissions (tonnes)
H1P	552	3,16	1,744
H1T	2,929	3,16	9,256
H2T	3,053	3,16	9,647
		Total CO_2 Emissions per year (tonnes)	20,647

Carbon Credit

As established by CORSA, and adopted in the Carbon marketplace, 1 CO_2 TON is equal to 1 Carbon Credit.

As the main benefit for environment considering the EVTOL operations is the “ZERO” CO_2 emissions, we can assume that a company that operate EVTOL will be available to generated Carbon Credit. As defined by Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), the global roles related to neutralize emissions bring the obligations for companies create the carbon offsetting programs, and as consequence the carbon markets turn CO_2 emissions into a commodity by giving it a price. So, currently it become a big industry and the companies can save or make money with that.

Using the historical flight hours data collected from the DECEA related to the helicopters in operating in São Paulo City, and applying this simplified equation, was possible establish the amount of fuel burn by helicopters in the routes between helipads and heliports defined in this study. Also, with these data was possibly create a hypothetical scenario to predict the equivalent CO_2 issued amount maybe avoid using the EVTOL steady of helicopter in the São Paulo Atmosphere. Once defined the number of flight hours to be operated by EVTOL in place of the helicopter, is possible found the number of fuel burned to avoided, applying the equation $CO_2 = \Sigma M_f * FCF_f$ we found the total o CO_2 emission avoided.

Applying the equation below it is possible to found out the Generated Value (Gv) by the CO_2 emissions avoided.

$$Gv = CO_2 * Cv$$

Where:

Gv = Total amount in USD selling the carbon credits

CO_2 = Total amount of CO_2 Emissions amount (in tonnes)

C v = Carbon Credit Value

In accordance with the information's available in the specialized websites like (carbon credits.com), there are two ways to sale of carbon credits within the carbon marketplace:

1. Regulated market - set by “cap-and-trade” regulations at the regional and state levels.
2. Voluntary market - where businesses and individuals buy credits (of their own accord) to offset their carbon emissions.

CarbonCredits.com Live Carbon Prices	Last	Change	YTD
Compliance Markets			
European Union	€66.25	+3.05 %	−17.41 %
California	$26.85	-	−16.15 %
Australia (AUD)	$30.75	-	−39.71 %
New Zealand (NZD)	$78.00	−0.64 %	+13.95 %
South Korea	$19.09	+10.00 %	−15.90 %
China	$8.08	−0.86 %	+6.05 %
Voluntary Markets			
Aviation Industry Offset	$3.96	-	−50.50 %
Nature Based Offset	$8.18	−1.09 %	−41.90 %
Tech Based Offset	$1.96	-	−61.42 %

Figure 08 – Carbon Credit Value by market (Source: carboncredit.com)

Table 09

Possible Carbon Credit Value Generated by replacing Helicopter for EVTOL in São Paulo

Market		Fuel (tonnes)	Price	Value
Compliance	European Union	20,647	66.25	€ 1,367,864
Compliance	Australia	20,647	30.75	US$ 634,895
Coluntary	Aviation Industry Offset	20,647	3.96	US$ 81,762

Chapter IV

Conclusions

In this chapter our focus in on describe our four prime conclusions related this research. Each conclusion will provide the literature analysis, data gathering methods, and results related to the operational feasibility of electrical vertical take-off and landing aircraft (EVTOL) operation in São Paulo City and other benefits identified during the study. Our conclusions include the results generated by the implementation of the EVTOL operations. An important result founded in this research is related to sustainability, the reductions related to CO_2 emissions and the benefits for companies considering the carbon credit is a point to be considered on the evaluations related to the implementations of the operate EVTOL.

Considering the commitment assumed by 195 countries on December 12, 2015, during COP 21 (21st United Nations Conference on Climate Change), the Paris Agreement, with a goal of reducing the emission of greenhouse gases, the EVTOL utilization bring a big opportunity for help in this globally transformation. In this sense, the main goals of the Brazilian government established in that agreement were the reduction of greenhouse gas emissions in 37% by 2025 when compared with 2005 rates, and 43% until 2030. The results of this study related to the numbers of CO_2 emissions also demonstrate that the introduction of EVTOL at São Paulo can contribute to the CO_2 emissions reduction goals of the country, and also can provide financial results to the companies considering the Carbon credit generation.

This study generated valuable data for currently aviation scenario considering the EVTOL utilization at São Paulo city and we will present the four main conclusion points raised as follows:

- ➢ The current infrastructure of helipads and heliports from São Paulo City is capable of supporting the operational specifications of EVTOL vehicles analyzed in this research.
- ➢ Financial results related to Carbon Credit generated by EVTOL operations
- ➢ Relationship between the Helicopter and an equivalent EVTOL (Cost Benefit Analysis).
- ➢ The EVTOL utilization can bring traffic congestion alleviation for São Paulo City

- **First Conclusion: The current infrastructure of helipads and heliports from São Paulo City is capable of supporting the operational specifications of EVTOL vehicles analyzed in this research**.

- **Data Gathering:** The data source used to identify the number of helipads was the website https://aisweb.decea.mil.br and the data used for identify the number of helicopters in the metropolitan area of São Paulo City was taken from ANAC website in August 2022 at https://www.gov.br/anac/pt-br/sistemas/rab/relatorios-estatisticos.

- **Results:** The analysis demonstrated that the metropolitan area of São Paulo City has a total of 371 helicopters registered and just 268 in airworthy conditions, in the moment of this analysis. Also, we confirmed that exist 308 helipads in the same area with infrastructure to support the EVTOL operational specifications relative to five EVTOLs selected in this study. This number of helipads create a scenario with 47278 possible routes between them.
- **Conclusion:** The current infrastructure of helipads and heliports from São Paulo City is capable of supporting the operational specifications of EVTOL vehicles analyzed in this

research, the technical specifications and limitations analysis of each vehicle and helipad demonstrate that the EVTOL operations can cover in 64% to 99% of the possible routes currently operate by similar Helicopters.

- **Second Conclusion: Financial results related to Carbon Credit generated by EVTOL operations.**

- **Data Gathering:** The number of flight hours operated by helicopters was request to ANAC using the FALA.BR portal. We used these values to estimate our calculations by the standards from IATA RECOMMENDED PRACTICE -RP 1726. The information's related to the carbon credit value was retrieve from the specialized website carboncredits.com.

- **Results:** The five helicopter models selected for this study totalized 182 aircrafts in operation in São Paulo, and these aircrafts has burned 19602 tonnes of fuel in last 03 years, quantity equivalent to 61942 tonnes of CO_2 emitted in the environment. Considering an equivalent fleet of EVTOL to this sample fleet selected (182 aircrafts), flying an average of 19000FH per year, we estimate that it is possible to generate the follows values of carbon credit per year considering the current carbon credit market:

    - € 1.367.884 (European Union - compliance market)
    - $634.905 (Australia - compliance market)
    - $81.763 (Aviation Industry Offset – Voluntary Market)

In a conservative scenario, with a prediction of 10 years the EVTOL fleet can reach approximately 431vehicles. considering 6,5FH as daily average, will be possible to generate the values below of carbon credit when considered the same operation with helicopters, in a standardized prediction of fleet introduction of 20% of EVTOL units per year:

- €114.466.828 (European Union - compliance market)
- $53.129.886 (Australia - compliance market)
- $6.842.093 (Aviation Industry Offset – Voluntary Market).

- **Conclusion:** The potential carbon credit generation found in this study demonstrate that there is a huge opportunity to future EVTOL operators make money using the standards of the market for sustainability related to carbon credit.

- **Third Conclusion: Relationship between the Helicopter and an equivalent EVTOL (Cost Benefit Analysis).**

- **Data Gathering:** Literature Analysis and manufactures information's data.

- **Results:**. Comparing the purchase value t between the vehicles capable to perform similar flight missions, the results demonstrate that AW109 and Bell 429 helicopters have a purchase value between 354% to 427% higher the EVTOL JOB S4, and 31% to 52% higher than Lilium, the EVTOL most similar in terms of performance and number of passengers transported. In terms of carbon credit, considering a prediction of 10 years with an average of 6,5FH/day, an EVTOL operator can generate approximately:

- € 891.580 (European Union - compliance market)
- $413.828 (Australia - compliance market)
- $53.293 (Aviation Industry Offset – Voluntary Market).

The figure 13 in the conclusion details related to equivalency of vehicle purchase value versus carbon credit generation demonstrate the benefit that may be reach by operator operating the EVTOL (10 years period), in this analysis the EVTOL JOBY S4 may reach until 67% of the purchase value in carbon credit in the compliance market of the European Union, and the others vehicle between 13 to 30% in the same market.

Once the helicopter has a higher purchase value than the similar EVTOLs and in terms of operation and maintenance cost the premise is that these new kind of vehicle will offer a lower cost than helicopters, and in additional the EVTOL will allow return of investment related to the carbon credit generation, we creating the cost-benefit ranking below using the technical specifications, purchase value, and flight mission that each one is possible to perform:

Table 10

EVTOL Classification by purchase value and flight Mission

1°	JOBY S4
2°	Lilium
3°	EVE
4°	VX4
5°	Archer

Table 11

Helicopter Classification by purchase value and flight Mission

1°	AW109
2°	Bell 429

- **Conclusion**: In accordance with our calculations and analysis, the EVTOL was considered the vehicle with better cost benefit characteristic, costing up 427% less than an equivalent Helicopter, with possible return of investment by carbon credit around 67% for JOBY S4 model.

- **Fourth Conclusion: The EVTOL utilization can bring traffic congestion alleviation for São Paulo City**

- **Data Gathering**: The number of passengers in transit on Congonhas Airport was retrieved from website https://aviacaobrasil.com.br/, From ENERGY.GOV (Office of Energy Efficiency & Renewable Energy), was retrieve the data related to Cars CO_2 emissions, the Brazilian Gross Domestic Product (GDP) historical data was retrieved from Instituto Brasileiro de Geografia e Estatística (IBGE).

- **Results:** Analyzing the total number of passengers in transit in the Congonhas (CGH) Airport in the last 20 years was noticed that from 2000 to 2019 the number doubled in size (Around 10M for 23M). After COVID-19 Pandemic, in 2021 the number dropped to the level of 10M again. The calculations showed that on average the number of passengers in transit at CGH Airport grew 5,93% per year. Standardizing 5,93% as the rate of growth, considering that only 70% of the total passengers in transit will take a car

(Uber or personal car) to drive to the airport our to return home, and considering that only 5% of the 70% of total passengers that needs a car will be able to pay for the EVTOL Fares, the predictions performed, considering the interval 2025 through 2034, demonstrate that the EVTOL operation can reduce up to 8,6% (in average) of total cars in the traffic of the São Paulo City. Its means 559.075 fewer cars on streets on an annual average and 5.665.120 fewer cars in a prediction of 10 ten years. As consequence, the total number of CO_2 emissions avoided by reducing the number of cars in traffic in São Paulo can reach a Annual/average of 5.179.622 (tonnes) and a total of 52.266.079 (tonnes) in ten years.

- **Conclusion:** The introduction of the EVTOL operations in São Paulo City can generate a traffic congestion alleviation considering 8,6% less cars on the street and as consequence related to the number of cars to be removed from streets it's also become a sustainability action generating benefits for environment due to the amount of CO_2 emissions to be avoided in the period of ten years (52.266.079 (tonnes).

Conclusion

Considering the helicopter operations rules by similarity for EVTOLs and analyzing the technical specifications and limitations from five EVTOLs (EVE, Archer, JOBY S4, Lilium and VX4) part of this research, was possible conclude that the existing infrastructure (308 helipads) from São Paulo city is capable to support the EVTOL operations. These vehicles will be able to cover 64 to 99% of the 47278 possible routes created by number of helipads and heliports found.

The cost benefit analysis from these vehicles, showed that JOBY S4, Liium and EVE are the tree best vehicle classified taken in considerations technical specifications that make possible diversify the flight missions, purchase cost, and return of investment related to carbon credit generation versus purchase vehicle price. The carbon credit generation also revelated a huge market for future EVTOL operators, the predictions revealed that in a comparison scenario where helicopters would fly the same average as EVTOLs (6.5FH/Day) it is possible to generate €891.580 (European Union - compliance market, in a prediction of ten years/per vehicle. And for a fleet of 431 vehicles this number can reach €114.466.828 (European Union - compliance market).

Finally, this research also concludes that the introduction of the EVTOL operations in São Paulo City can generate a traffic congestion alleviation of 8,6% in average. Its mean less cars on the street, as consequence it's become a sustainability action, generating benefits for environment due to the amount of CO_2 emissions that could be avoided. In the period of ten years the number may reach (52.266.079 (tonnes).

With the results raised, we conclude that the EVTOL operations in São Paulo opened a new market door. This market will start with a big demand to be attended in a short-term perspective as well as open a new market called carbon credit that may be "the best bet for the future".

Conclusion Details

- **First Conclusion: The current infrastructure of helipads and heliports from São Paulo City is capable of supporting the operational specifications of EVTOL vehicles analyzed in this research.**
- Was identified 112 individual operators that is no possible to confirm the operational area. Or understanding is that is possible that these aircrafts have been operate in São Paulo city area, which would make a total of 380 aircrafts in operation (268 in airworthy conditions + 112 individual operator). Due this reason, for predictions calculations of fuel burn and CO_2 emissions was used the total number of registered helicopters in São Paulo City (371 Aircrafts).
- To do the calculations, the first point was answering the question about which vehicle can serve which route? the technical specifications of each EVTOL were analyzed and then the data were crossed with the dimensions and maximum supported weight of each helipad and heliport in the city of São Paulo (308 in total). Considering the actual rules of ANAC for Helipads certification and Helicopters operations and applying it for similarity for the five EVTOLs analyzed in this study we have:

Table 12

Percentage of routes achievable for each Helicopter

Helicopters				
R22	R44	AS350	AW109	429
100%	99%	97%	97%	65%

Table 13

Percentage of routes achievable for each EVTOL

EVTOLs				
S4	Eve	Vx4	Lilium	Archer
99%	97%	65%	65%	64%

- Considering the information's provided in the Engineering briefing report (EB N° 105) issued by FAA on September 21, 2022, document that provides interim guidance for the design of vertiports for aircraft with vertical takeoff and landing (VTOL) capabilities, considering the requirements related to Relationship and Dimensions of TLOF, FATO, and Safety Area for EVTOL operations, in case of ANAC adopt a similar rule like FAA, in accordance with the requirements described in the Engineering report (EB N° 105), would be necessary do adaptations of Charging and Electric Infrastructure as well as Marking, Lighting, and Visual Aids, before start EVTOL operations. This rules also can change *the number of vertiports raised in this research.*

- **Second Conclusion: Financial results related to Carbon Credit generated by EVTOL operations.**
- To start the predictions related the possible carbon credit to be generate by EVTOL operations, the first step was establishing a standard for that. As demonstrated in the methodology, we selected a sample of helicopters from São Paulo fleet.

As described in the table xx below, we calculate the numbers of flight hours operated by this helicopters sample fleet. In this case were selected 182 aircrafts filtered by model in a period of 03 years of operation. With that was possible to calculate the total of fuel burn and as consequence the total of CO_2 emitted in the environment.

Table 14

Helicopter fuel burned in São Paulo (3 years period) – (182 aircrafts)

Helicopter Type	Average FH/Year	Period years	Total FH	Fuel consumption (kg/hour)	Fuel Burned (tonnes)
H1P	15338	3	46014	36 (1)	1657
H1T	23243	3	69729	126 (2)	8786
H2T	17751	3	53253	172 (3)	9160
Total Average FH/Year	18777			Total Fuel Burned (Kg/hour)	19602

After that was calculated the annual CO_2 Emissions by helicopter (sample of 182 aircrafts), using the standards from IATA RECOMMENDED PRACTICE -RP 1726 and recommendations from CORSA, we created the table below:

Table 15

Annual CO_2 emission by Helicopter in São Paulo (Average 3 years period) - Sample of 182 aircrafts

Helicopter Type	Number of Aircraft	Total Fuel Burned (tonnes)	FCF_f	CO_2 Emissions (tonnes)
H1P	66	1657	3,16	5235
H1T	59	8786	3,16	27763
H2T	57	9160	3,16	28944
Total of Aircrafts	182		Total CO_2 Emissions Average 3 years period (tonnes)	61942
			Total CO_2 Emissions Average Per Year (Tonnes)	20647

To find the future average of fuel burn and CO_2 Emissions that can be avoid using the EVTOL, was considered the following points:

- The prediction for EVTOL operations is short turn around-around time (10-15 mim), short flight duration (10-15 mim), and High Frequency (20 – 30 flights per day).
- The average between 20 and 30 is 25 flights per day, considering the turn around and flight duration we have legs of 30 mim. Converging 30mim to decimal and multiplying per 25 (number of flight/day), we found approximately 13FH/day. Being conservative, the calculations will consider 50% of this prediction of operation (6,5FH/ Day in average).
- Using the average flight hours per year from helicopters (3 years period), was applied the conversion factor to 6,5FH, being possible to estimate the total of flight hours and fuel burned that would have been burned by the helicopter sample fleet selected in a operating rate of 6,5FH/day.
- Following the rules above was created the table below related to Helicopter Fuel burned in São Paulo (3 years period flying 6,5FH/Day) - (182 aircrafts)

Table 16

Helicopter Fuel burned in São Paulo (3 years period flying 6,5FH/Day) - (182 aircrafts)

Helicopter Type	Average flight hours per year	Period (in years)	Total FH	Fuel consumption (kg/hour)	Fuel Burned (tonnes)
H1P	154440	3	463320	36 (1)	16680
H1T	138060	3	414180	126 (2)	52187
H2T	133380	3	400140	172 (3)	68824

Total Average FH/Year	141960		Total Fuel Burned (Kg/hour)	137690

- Commercial operations in cities for EVTOL are expected to start around 2025 (ITA, 2022), considering an introduction of 84 EVTOL in São Paulo (20% of predict helicopter fleet in 2025) in the first year after certification of the AMM/UAM, and keeping the same rate of fleet growth (20% per year), in relation to the future helicopter fleet size, the table 17 below demonstrate the total of CO_2 emission that can be avoided if the EVTOL is introduced in the market.

Table 17

Annual CO_2 emission by Helicopter in São Paulo (Average of 6,5FH/Day)

Helicopter Type	Number of Aircraft	Total Fuel Burned (tonnes)	FCF_f	CO_2 Emissions (tonnes)
H1P	66	16680	3,16	52707
H1T	59	52187	3,16	164910
H2T	57	68824	3,16	217484
Total of Aircrafts	182		Total CO_2 Emissions Average 3 years period (tonnes)	435101
			Total CO_2 Emissions Average Per Year (Tonnes)	145034

- As a conservative prediction, considering the currently helicopter fleet of São Paulo (371 aircrafts) and applying a scalation equal to 3% per year for 10 years, will be possible predict the helicopter fleet size. The period of 10 years was estipulate considering the long-time predictions as well as considering the information's relative the market expectations for AMM/UAM be completed designed and certified. Considering the future helicopter fleet size, the table xx below demonstrate the total of CO_2 emission that can be avoided if the EVTOL is introduced with a constant rate of 20% per year in relation of the helicopter fleet size prediction.

Table 18

Total CO_2 Emissions to be avoided with EVTOL Introduction flying 6,5FH/Daily (10 Years from 2025)

(Count from 2025)	Helicopters fleet Growth (3% per Year)	QTY of EVTOL introduction in the market (Percentage relative the SP helicopter Fleet)	Total CO2 Emissions avoided Average per Year (Tonnes)
2025	418	84	66560
2026	430	100	79872
2027	443	120	95846
2028	456	144	115015
2029	470	173	138018
2030	484	208	165622
2031	499	249	198746
2032	514	299	238495
2033	529	359	286194
2034	545	431	343433
CO_2 Emissions to be avoid in 10 Years (Tonnes)			1727801

After determining the number of CO_2 emission per period, the table 19 below demonstrate the possible carbon credit generated for period.

Table 19

Potential Carbon Credit Using EVTOL instead of Helicopter fleet sample (182 aircrafts) – (Annual Average)

Market	CO_2 (tonnes) = 1 Carbon Credit	Price	Value

Compliance	European Union	20647	66,25	€ 1.367.884
Compliance	Australia	20647	30,75	$634.905
Voluntary	Aviation Industry Offset	20647	3,96	$81.763

Carbon Credit to be generate by use EVTOL instead of Helicopter fleet sample (182 aircrafts) - (3 Years Period)

Market		CO_2 (tonnes) = 1 Carbon Credit	Price	Value
Compliance	European Union	61942	66,25	€ 4.103.652
Compliance	Australia	61942	30,75	$1.904.714
Voluntary	Aviation Industry Offset	61942	3,96	$245.290

Carbon Credit to be generated by Introduction of EVTOL flying 6,5FH/Daily with a growth rate of 20%/Year in comparison with current São Paulo Helicopter Fleet (10 Years period)

Market		CO_2 (tonnes) = 1 Carbon Credit	Price	Value
Compliance	European Union	1727801	66,25	€ 114.466.828
Compliance	Australia	1727801	30,75	$53.129.886
Voluntary	Aviation Industry Offset	1727801	3,96	$6.842.093

- **Third Conclusion: Relationship between the Helicopter and an equivalent EVTOL (Cost Benefit Analysis).**
- Considering that the main characteristic of EVTOL vehicles is safety, mainly related to the high-tech navigation systems and the number of engines available that provide much more redundance in terms of trust and flight stability for EVTOL, to do the financial comparation with helicopter, was necessary exclude the single engines helicopters from the analyses and was considered just 02 models that offer a power plant system with 02

engine and also the models that have more robust and modern navigation systems. The helicopter model selected was:

- AW109SP Grand New
- and Bell 429.

Even knowing that the EVTOL will have a lower maintenance cost than the helicopter, there is no open data about it, so, it was not taken in consideration in the calculations. Once defined the vehicles to be compared, was performed the cost comparison between the helicopters and EVTOL selected and then calculated the percentage relative the helicopter purchase value vs EVTOL as demonstrate on results of figures below:

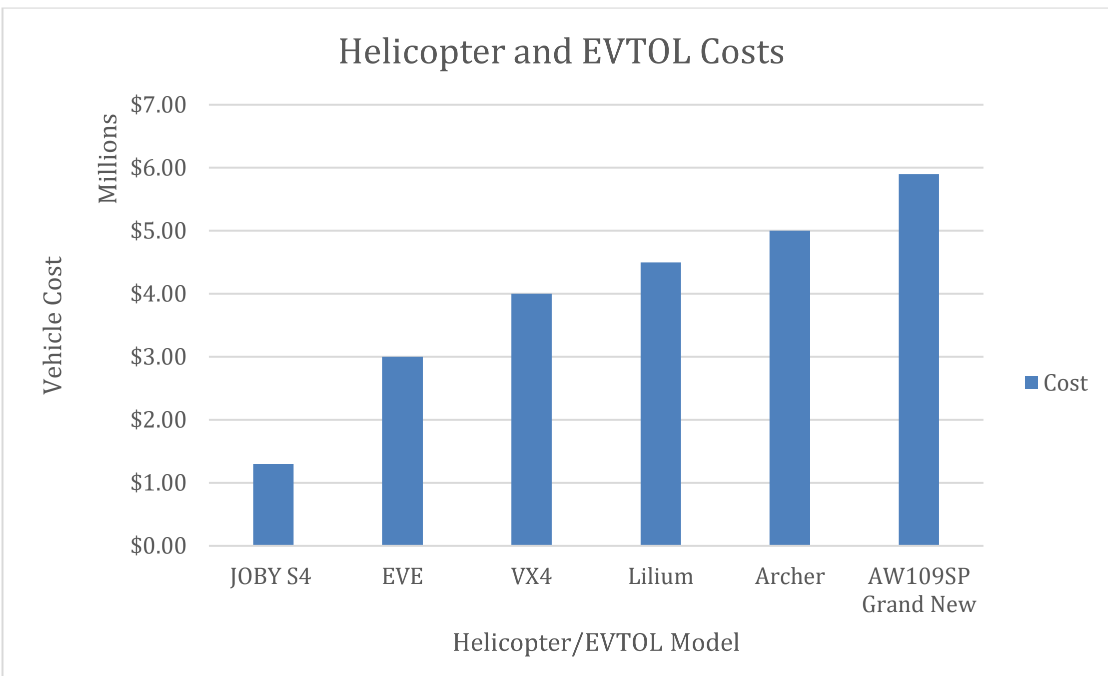

Figure 09

Helicopters and EVTOL Purchase Values

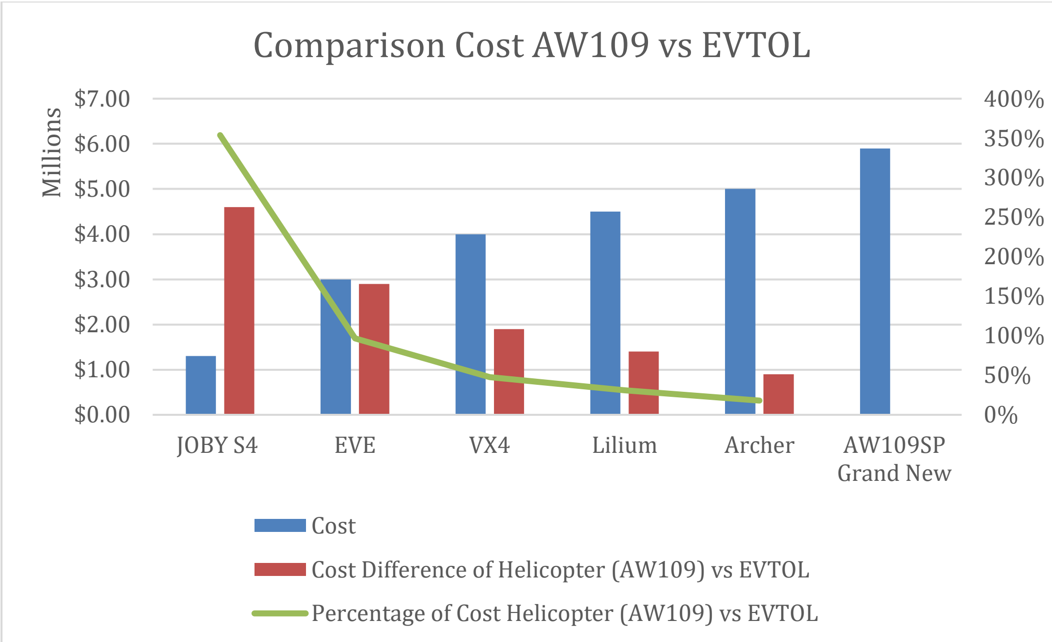

Figure 10

Comparation purchase value between the helicopter AW109 vs EVTOL

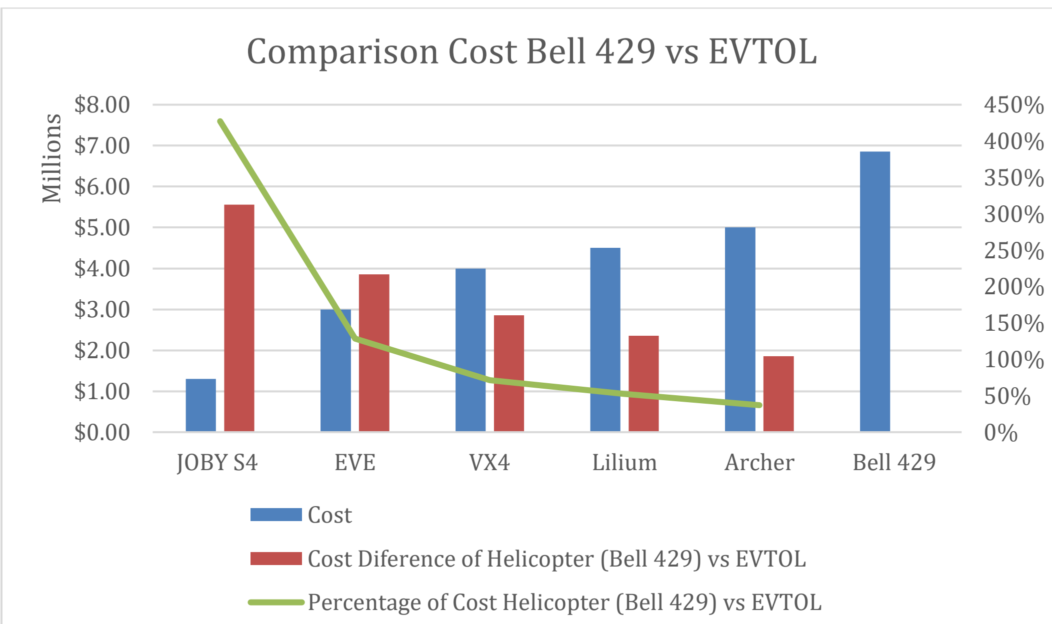

Figure 11

Comparation purchase value between the helicopter Bell 429 vs EVTOL

The Final point considered is that the EVTOL have been developed to fly in high frequency (20 – 30 flights per day – 10 to 15 min each leg, totalizing an average of 6,5

FH/Day), it means that this vehicle would fly a few more times per day that the current daily average from the helicopter have been flying. Using the hours flown data of helicopters provided by ANAC by FALA.BR portal, was identified the average of flight hours per aircraft, the calculations demonstrate a average of 1FH/day as demonstrate in the table 20.

Table 20

General Daily FH per Helicopter

Helicopter Type	N° of Aircraft	Average /Year	Annual FH Average per Aircraft	Monthly FH Average per Aircraft	Daily FH Average per Aircraft	General Daily FH per aircraft
H1P	66	15338	232	19	0,6	1
H1T	59	23243	394	33	1,1	
H2T	57	17751	311	26	0,9	

- To understand the flight mission profile that each vehicle is capable to perform, and to understand better each technical characteristic and performance data, was created the table xx and xx below to do the vehicle classifications and after that be possible to create a ranking of better cost benefit.

Table 21

EVTOL technical specifications and purchase price classification

Model	Range (nm)	DIM. (m)	Weight (tonnes)	Price (millions)	Price (class)
Eve	60	15,2	1	3	Low
Archer	60	12,2	3,175	5	High
JOBY S4	150	10,7	1,815	1,3	Medium
Lilium	155	13,9	3,175	4,5	High
VX4	161	15	3,175	4	High

Table 22

EVTOL technical classification

Range (class).)	Speed (class)	Dim. (class)	Wight (class)	Pilots (class)	Pax (class)
Low	Low (96 km/h)	High	Low	1	4
Low	High (241 Km/h)	High	high	1	4
High	High (322 Km/h)	Medium	medium	1	4
High	High (280 Km/h)	High	high	1	6
High	High (241 Km/h)	High	high	1	4

Table 23

Helicopter technical specifications and purchase price classification

MODEL	RANGE (nm)	DIMENSION (m)	MTOW (tonnes)	FUEL CONSUMPTION (kg/hour)	PRICE (millions)	PRICE (class)
429	206	13,1	3,402	188	6,85	High
AW109	228	13	2,85	176	5,9	High

Table 24

Helicopter technical classification

RANGE (class)	SPEED (class.)	DIMENSION (class)	WIGHT (class.)	PILOTS (class.)	PAX (class.)
High	High (280 Km/h)	High	High	1	7
High	High (289 Km/h)	High	High	1	7

The analyses demonstrated that all EVTOL vehicles are capable to attend the short flight missions up to 60nm, the vehicle with the lower cruse speed is the EVE. For long rage flight missions up to 150nm just JOBY S4, Lilium and VX4 are capable to attend these flights with similar performance like the helicopters analyzed here as demonstrate in the figure 12. Finally, the purchase value of each vehicle was compared with the purchase value of the helicopter and the figure 12 below illustrate these differences.

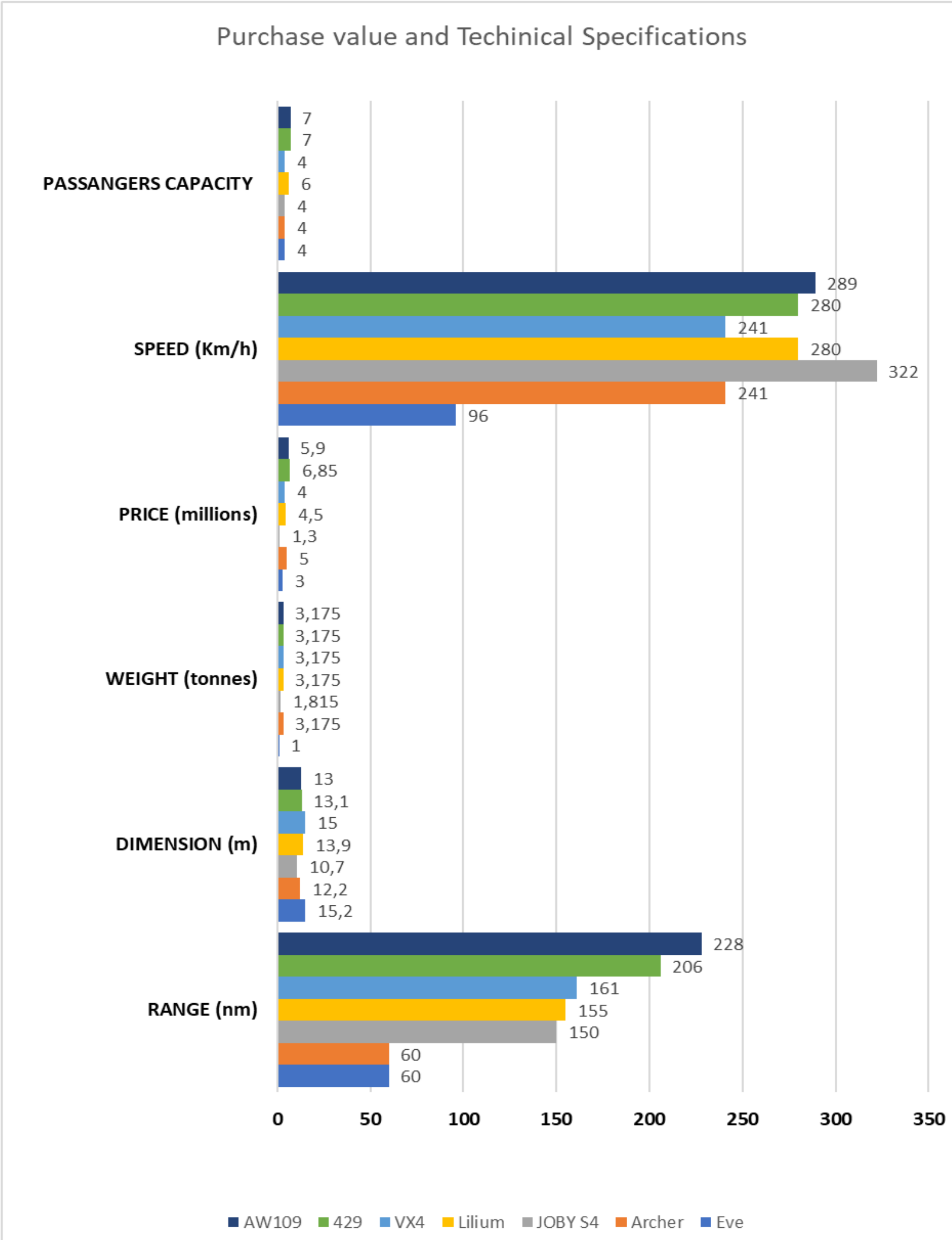

Figure 12

Purchase value and Technical Specifications comparison

Considering the average of 6,5FH/Day (number of flight hours estimated to be operated by EVTOL) was estimated the possible fuel to be burned by an equivalent helicopter, with the numbers reached relative the fuel burn, was calculated the quantity of CO_2 emissions to be avoid, see table 25.

Table 25

Total CO_2 prediction considering helicopter FH average of 6,5FH/Day

	QTY Vehicle	Period (Year)	Annual FH Avg.	Total FH (10 Years)	CO2 Emission	Fuel Burned (tonnes)	Fuel consumption (kg/hour) Avg. 429 and AW109
Helicopter Average 1FH	1	10	311	3114	1791	567	182
Helicopter Average 6,5FH	1	10	234 0	23400	13458	4259	182
EVTOL Average 6,5FH	1	10	234 0	23400	0	0	
				Total CO_2 Emissions Avoided	13458		

With the total o CO_2 emissions predict, we calculated the possible carbon credit to be generated by this estimate operation, the results are illustrated in table 26 below:

Table 26

Carbon credit to be generated by a EVTOL considering 6,5FH/Day

Market		CO_2 (tonnes) = 1 Carbon Credit	Price	Value	Value (US Dollar)	Conversion Tx U$ to Euro (10,Octuber/2022)
Compliance	European Union	13458	66,25	€ 891.580	$864.832	$0,97
Compliance	Australia	13458	30,75	$413.828		
Voluntary	Aviation Industry Offset	13458	3,96	$53.293		

To understand the benefit of the carbon credit value predicted, was crested an equivalency of this possible credit value between the vehicle purchase value, and the results is illustrated below.

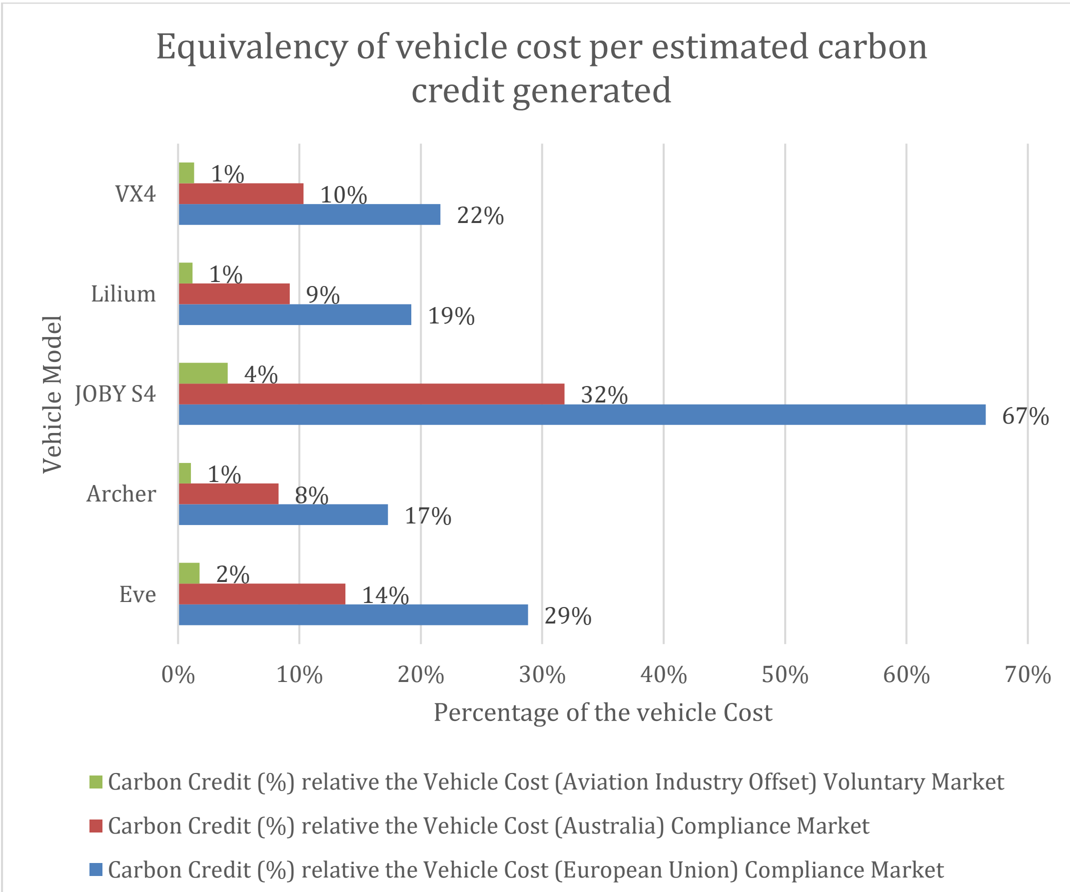

Figure 13

Equivalency of purchase vehicle value vs Carbon credit to be generated

The return of investment (ROI) and the payback analysis was not demonstrated in the study because there is no how to estimate the correctly EVTOL fares before the certifications process and operational requirements that also involve pilots training be finished, these two drives usually bring a lot cost for the industry, a situation that for sure will change the fares.

Fourth Conclusion: The EVTOL utilization can bring traffic congestion alleviation for São Paulo City

- After collected the data relative the number of passengers in transit on CGH Airport and the Brazilian GPD, was performed a correlation between them (Pax. in Transit Growth and Brazilian GPD Growth percentage) to understand if exist any relationship, the R^2=0,079 demonstrate that the correlation is week and p-value = 0,1 indicated that there is no statistical significance, therefore, the GPD growth is not the main drive that influence the CGH Airport passengers' variation.

Table 27

Simple Linear regression statistics data

Regression statistics	
Multiple R	0,079
R Square	0,006
Adjusted R Square	-0,049
Standard Error	10,791
Observations	20,000

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	13,218	13,218	0,114	0,740
Residual	18	2096,071	116,448		
Total	19	2109,290			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 0%*	*Upper 0%*	*Lower 0%*	*Upper 0%*
Intercept	5,479	3,214	1,705	0,105	-1,274	12,233	-1,274	12,233
PASSENGERS	0,294	0,872	0,337	0,740	-1,539	2,126	-1,539	2,126

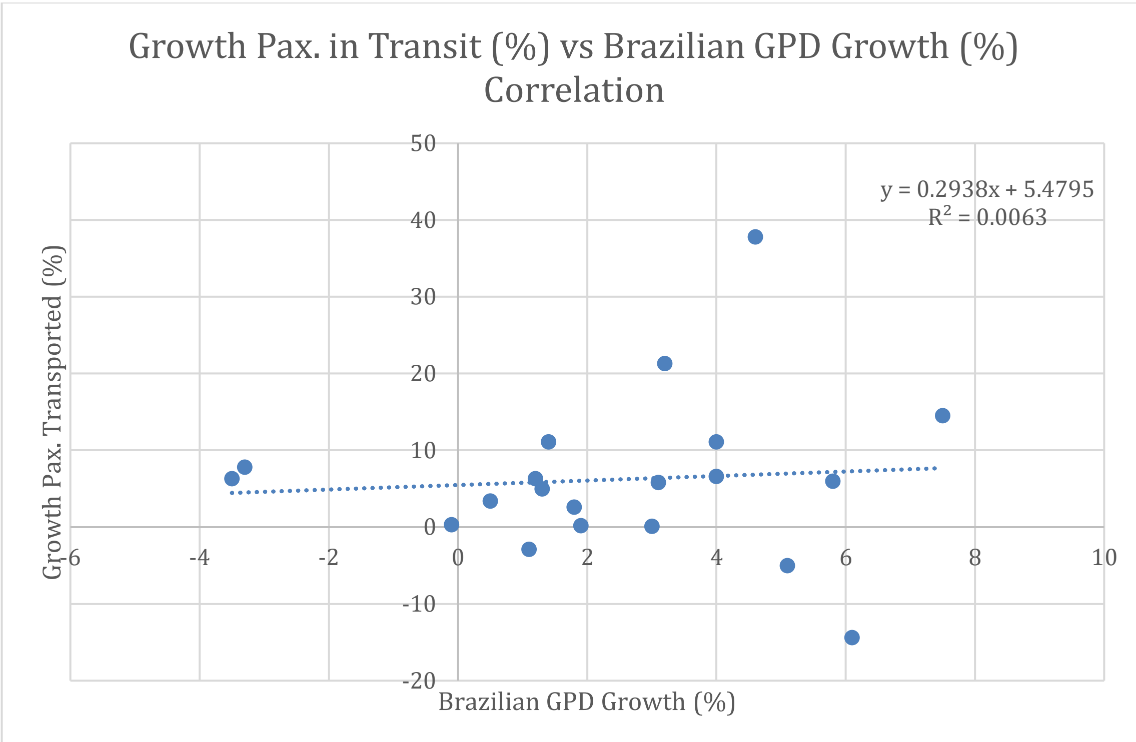

Figure 14

Growth Pax. in Transit (%) vs Brazilian GPD Growth (%) Correlation

- Once the correlation is week, was created the table 28 to calculate the average/year related (Pax. in transit Growth and Brazilian Gross Domestic Product (GDP) percentage).

Table 28

Pax. in transit Growth and Brazilian Gross Domestic Product (GDP) average calculation

Year	Total Pax. Congonhas	Pax. Transported Growth (%)	Total Pax. Congonhas (Millions)	GPD Growth (%)
2021	9.654.827	37,86%	10	4,6
2019	23.570.800	6,32%	24	1,2
2018	22.170.416	2,65%	22	1,8
2017	21.597.291	5,04%	22	1,3
2016	20.560.913	7,83%	21	-3,3

2015	19.068.522	6,33%	19	-3,5
2014	17.933.435	3,48%	18	0,5
2013	17.330.436	0,12%	17	3
2012	17.310.065	0,23%	13	1,9
2011	17.270.572	11,17%	17	4
2010	15.535.626	14,58%	16	7,5
2009	13.559.340	0,36%	14	-0,1
2008	13.510.726	-5,03%	14	5,1
2007	14.226.840	-14,43%	14	6,1
2006	16.626.636	6,63%	17	4
2005	15.593.189	21,37%	16	3,2
2004	12.847.331	6,01%	13	5,8
2003	12.118.715	-2,91%	12	1,1
2002	12.482.270	5,84%	12	3,1
2001	11.793.713	11,13%	12	1,4
2000	10.612.845		11	4,4
	Average	Average		Average
	15.593.189	5,93%		3

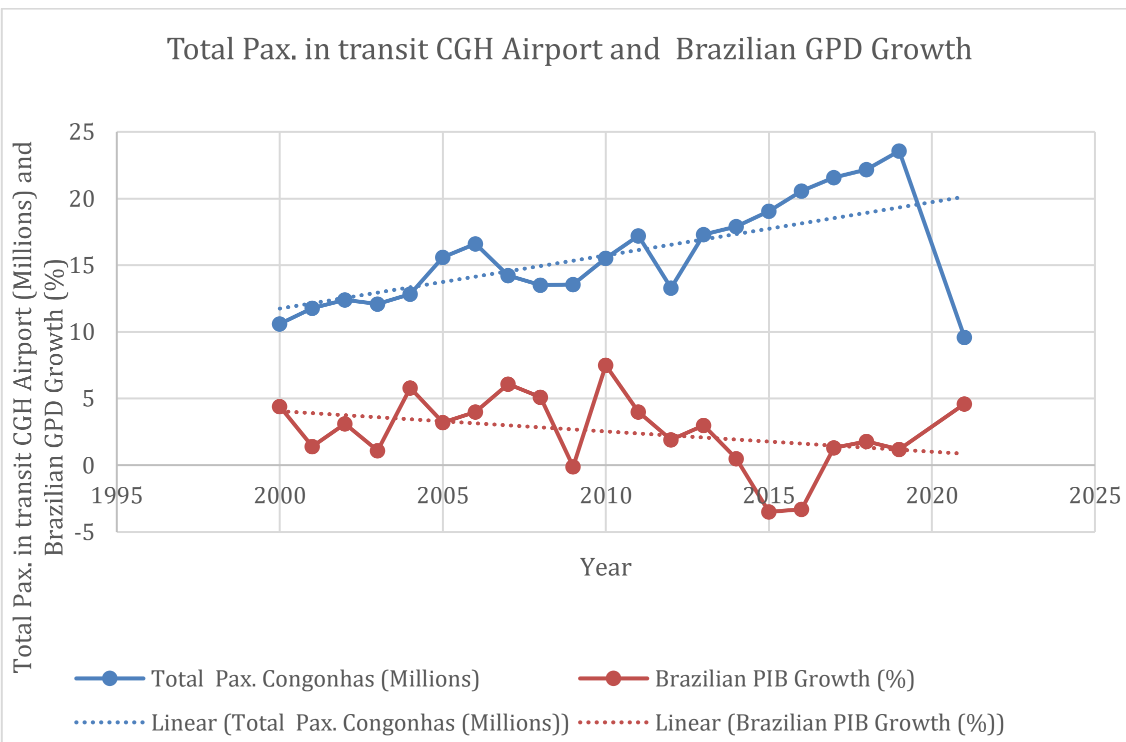

Figure 15

Behavior of Total pax. in transit in CGH Airport and GPD growth percentage

- Defined the averages cited above, we predicted the number of Passengers to be in transit at CGH Airport in next years, the number of passengers to be transported by EVTOL, the number of EVTOL necessary to attend this possible demand and the number of cars to be removed from traffic introducing the EVTOL operations. The following standardization was applied in the calculations:
    - Only 70% of the total Passengers in transit will need a car, this 30% excluded from the calculation, was considered the number of people that leave or get in the CGH airport using a shared vehicle (Uber or a personal car) as well as the people that will use public transportation. In this way, was considered that 70% of the passengers use an individual car to go or back from CGH Airport.
    - Of this total (70%) we also established that only 5% of this total people will be able to pay for EVTOL fares.
    - Was standardized a load average for EVTOL of four people per vehicle.

The table 29 below demonstrate the results found:

Table 29

Total cars to be removed per year from São Paulo City Traffic Using EVTOL Operations

Year	Pax to be in transit (Year)	70% Pax (daily)	5% under 70%	Qty EVTOL	Cars to be removed/day	Cars to be removed/year
2025	12.154.536	23.634	1.182	295	1.182	431.317
2026	12.874.692	25.034	1.252	313	1.252	456.873
2027	13.637.518	26.517	1.326	331	1.326	483.942
2028	14.445.541	28.089	1.404	351	1.404	512.616
2029	15.301.439	29.753	1.488	372	1.488	542.989
2030	16.208.049	31.516	1.576	394	1.576	575.161
2031	17.168.376	33.383	1.669	417	1.669	609.239
2032	18.185.603	35.361	1.768	442	1.768	645.336
2033	19.263.100	37.456	1.873	468	1.873	683.572
2034	20.404.438	39.675	1.984	496	1.984	724.074
					Total	5.665.120

Annual Average	559.075

- To demonstrate the average of cars to reduced using the EVTOL operations, was used the data related to São Paulo fleet cars (historical data) available on IBGE website, was created the table 30 and figure 15 illustrated below to define the Car fleet growth Average (last 15 years).

Table 30

São Paulo fleet car percentage growth

Year	Car fleet (last 15 years)	Growth Percentage
2006	10.294.811	
2007	11.014.104	1,07%
2008	11.753.856	1,07%
2009	12.536.177	1,07%
2010	13.334.875	1,06%
2011	14.108.047	1,06%
2012	14.880.771	1,05%
2013	15.643.415	1,05%
2014	16.319.980	1,04%
2015	16.834.630	1,03%
2016	17.247.124	1,02%
2017	17.719.258	1,03%
2018	18.230.138	1,03%
2019	18.753.364	1,03%
2020	19.089.286	1,02%
2021	19.305.526	1,01%
	Car fleet Growth Average (last 15 years)	1,04%

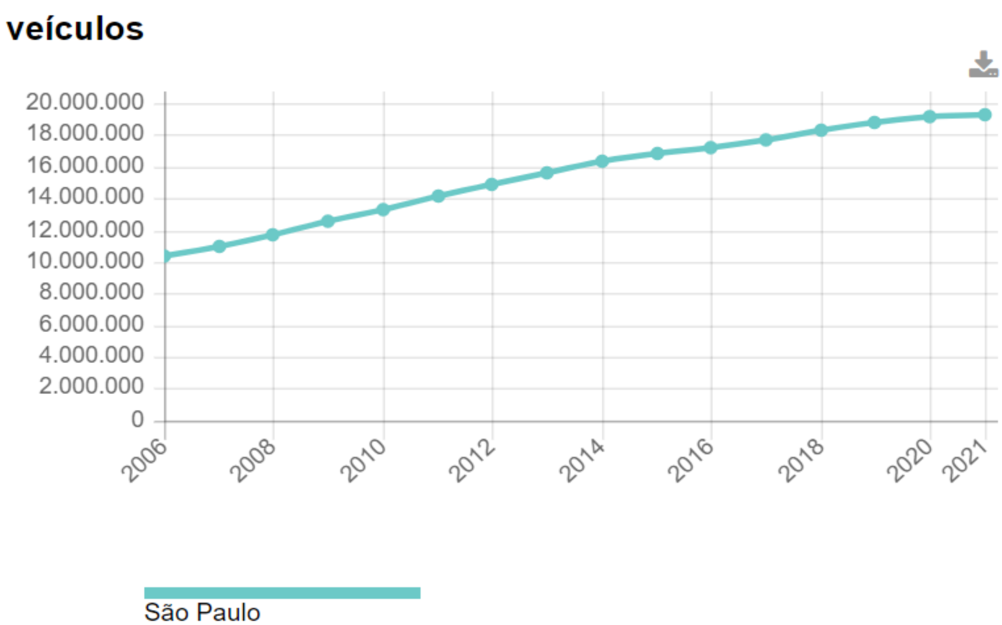

Figure 16

São Paulo fleet car growth

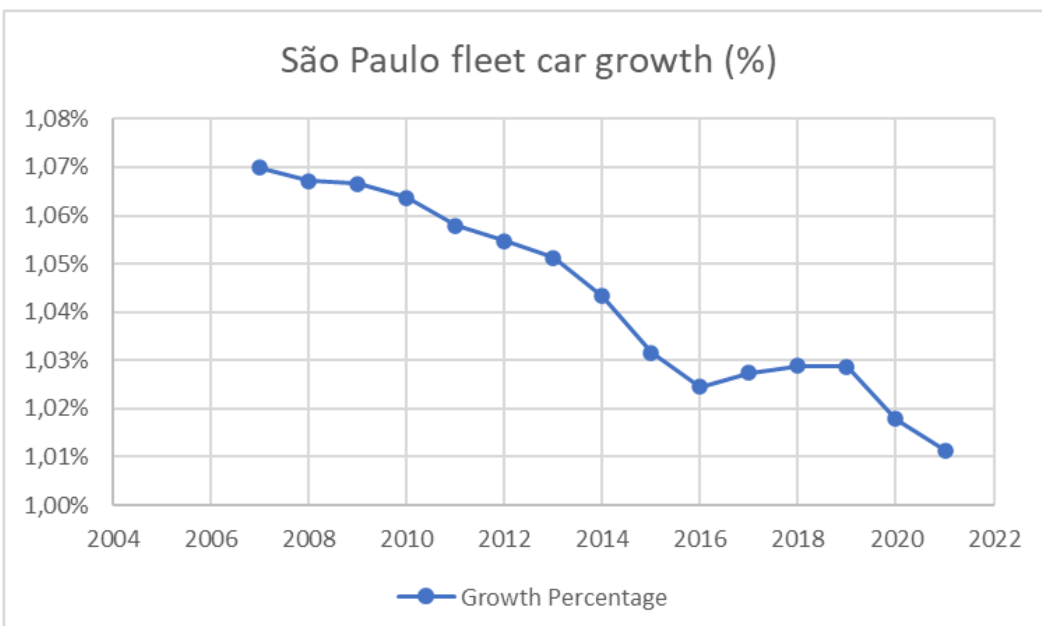

Figure 17

São Paulo fleet car percentage growth

- Using the rate of 1,04% car growth per year was predicted the total number of cars per year and comparing with the number of cars to be removed from São Paulo traffic using the EVTOL operations was calculated the percentage of cars reduced using EVTOL.

Table 31

Percentage of Cars to be reduced in São Paulo City Traffic Using EVTOL

Year	Cars Growth/year (1,04% rate)	São Paulo City (Number of Cars)	Number of Car Reduced Using EVTOL	Percentage of Cars Reduced Using EVTOL
2025	84.627	6.129.447	431.317	7,0%
2026	85.812	6.215.259	456.873	7,4%
2027	87.014	6.302.272	483.942	7,7%
2028	88.232	6.390.504	512.616	8,0%
2029	89.467	6.479.971	542.989	8,4%
2030	90.720	6.570.691	575.161	8,8%
2031	91.990	6.662.681	609.239	9,1%
2032	93.278	6.755.958	645.336	9,6%
2033	94.583	6.850.541	683.572	10,0%
2034	95.908	6.946.449	724.074	10,4%
			Average	8,6%

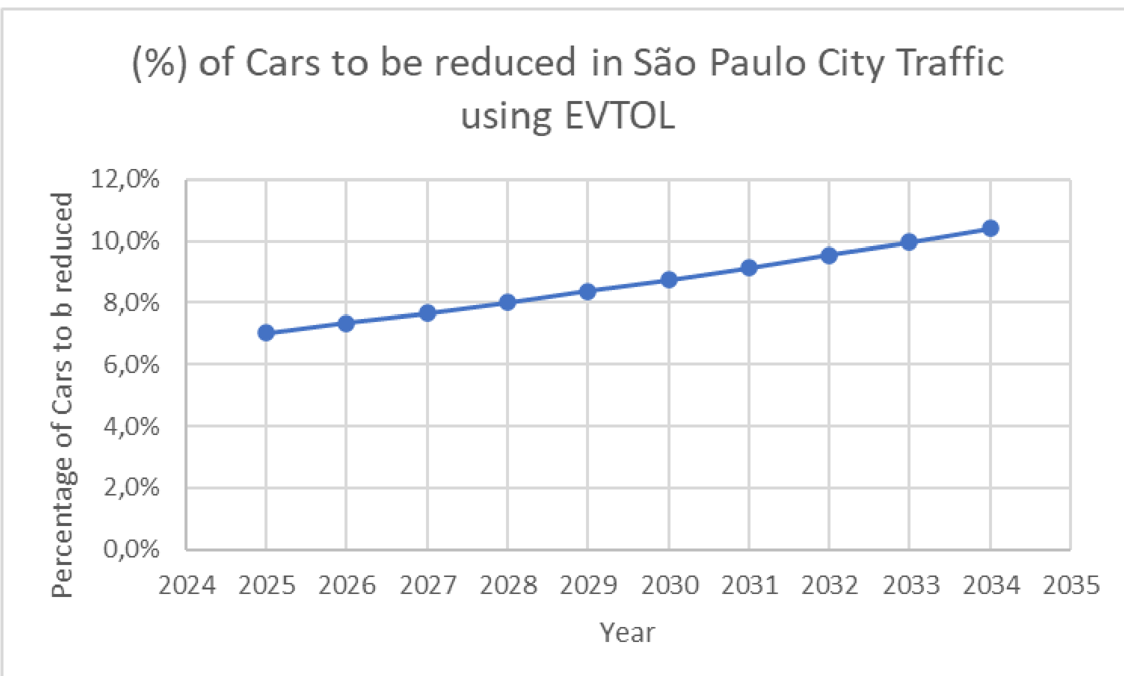

Figure 18

Percentage of car to be removed from São Paulo City traffic

- With the data raised by calculations demonstrated in the tables above, the table below was created to understand the total CO_2 emissions that could be avoided by removing the number of cars predicted..

Table 32

Amount of CO_2 Emissions by Cars to be avoided by using EVTOL in São Paulo City

Model Year	CO_2 Emissions (g/mi)	CO_2 Emissions (g/Km)	CO_2 Emissions (Tonnes/Km)	Avg. CO_2 Reduc. (%)	CO_2 Emissions (Tonnes/Year) per Car	CO_2 Emissions (Tonnes/Year) x N° Cars
2021	348,2	560,44	0,0005604	1,00		
2022	344,8	554,86	0,0005549	1,00		
2023	341,3	549,34	0,0005493	1,00		
2024	337,9	543,88	0,0005439	1,00		
2025	334,6	538,46	0,0005385	1,00	10	4.180.485
2026	331,3	533,11	0,0005331	1,00	10	4.384.115
2027	328,0	527,80	0,0005278	1,00	10	4.597.663
2028	324,7	522,55	0,0005225	1,00	9	4.821.614
2029	321,5	517,35	0,0005174	1,00	9	5.056.473
2030	318,3	512,20	0,0005122	1,00	9	5.302.772
2031	315,1	507,11	0,0005071	1,00	9	5.561.068
2032	312,0	502,06	0,0005021	1,00	9	5.831.945
2033	308,9	497,06	0,0004971	1,00	9	6.116.017
2034	305,8	492,12	0,0004921	1,00	9	6.413.926
					Total	52.266.079
					Annual Avg.	5.179.622

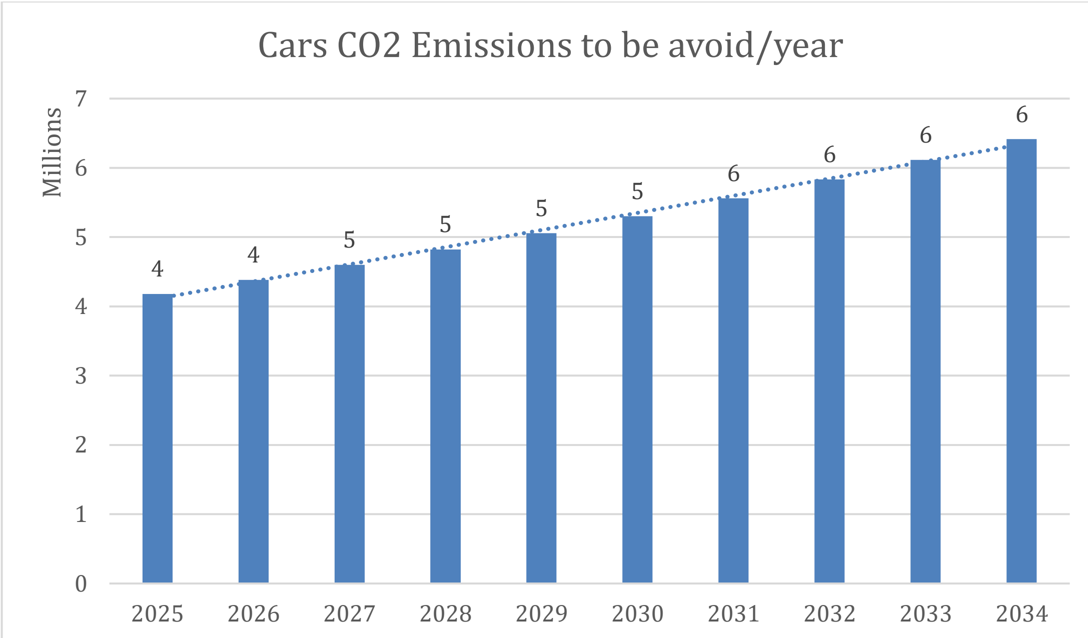

Figure 19

Amount of CO_2 Emissions by car to be avoided by using EVTOL in São Paulo City

Chapter V

Recommendations, Future Research, and Lessons Learned

In this study we analyzed the helipads data and helicopters registered in the city of São Paulo and the metropolitan area and we identify that the existing infrastructure of helipads and heliports is capable to attend the operational specifications regard to the five EVTOL analyzed.

Considering the results found for the delimited study, in which we were successful in demonstrating the feasibility, we propose some recommendations for future studies aiming at a complete solution for the operation of this type of vehicle in the metropolitan region of São Paulo, thus making it possible to enjoy all the advantages described throughout our work.

- **Recommendation 1**

We recommend that the potential investors and operators of the aviation industry as well others like UBER, consider discussing the necessary adaptations in the 308 helipads and heliport analyzed in this study (existing infrastructure in São Paulo Cite and metropolitan area) for introduction of EVTOL operations with the Brazilian authorities and manufacturers using as guide the FAA ENGINEERING BRIEF #105 issued on September 21, 2022.

- **Recommendation 2**

We recommend for all potential operators and major Brazilian Airlines to perform financial analyzes and create a business plan to implement EVTOL operations in São Paulo City (after 2025), considering the predicted demand for the sector and keep focus in the possible carbon credits generations by CO_2 emissions avoid.

- **Recommendation 3**

Based on better economic results to purchase a EVTOL steady of an equivalent Helicopter, we recommend for the potential companies of the industry to analyze the return of investment for this market and then analyze the possibility to invest on the EVTOL vehicle.

- **Recommendation 4**

Considering the benefits that EVTOL operation can bring in terms of traffic alleviation for São Paulo City and metropolitan area as well as the benefits for environment caused by the CO_2

emission to be avoid, we recommend that the government of state work together the potential EVTOL operators to help in the implementation of the EVTOL operation in São Paulo.

Recommendation Details

- **Recommendation 1**

For EVTOL operations become a reality in Brazil, a series of adaptations must be made to the current Brazilian legislation, which currently does not include this type of electric vehicle in the current regulations. According to lawyers specialized in the aviation sector, the EVTOL must face the same regulatory process as the already known VTOL (Vertical Take Off and Landing) aircraft, which implies several certifications of the performance and safety of aircraft components and their operating conditions. and which culminate in the final approval of the authorities of each jurisdiction. In Europe, the EASA (European Union Aviation Security Agency) already has issued a proposed new regulatory framework for public consultation, its cover the technical domains of airworthiness, air operations, flight crew licensing and rules of the air.

In addition to the operational certification of the vehicle, EVTOL must establish a new panorama for the control of urban air traffic management (UATM) solution, that will enable the UAM industry to evolve to a future where EVTOL flights are a mainstream mode of transportation.

Some EVTOL models are already in the process of being certified by the ANAC (EVE from Embraer is the first in this run). Every aircraft under development requires adaptations of certification protocols and new methods of evaluating the performance of the incorporated equipment. This certification is a constantly evolving process in which the use of new technologies challenges certifiers to design ways to assess critical aspects of the new aircraft's performance.

Most experts say that the operational challenges of spreading the transport offer based on EVTOL will be great worldwide. Not only will traffic regulation and control be tested, but operating conditions will be challenging. The major regulatory frameworks for air navigation will provide the fundamental principles, but the conditions to be faced with unprecedented volumes of traffic on certain routes and locations will require the improvement of all elements: from monitoring and control of traffic to the discipline of operators and users.

In this way the Automated traffic management systems that will facilitate the management of the high number of aircraft sharing urban skyways will be part of this ecosystem, but for it become real will require significant public and private investment, commitment and collaboration from all involved sectors.

An important discussion within the regulatory issue, according to concept of operations (Conops), is the characteristics of a proposed system from the point of view of the person who will use that system. The Brazilian regulatory environment is already being updated in debates carried out by Decea (Department of Airspace Control) via internal studies and Conops. However, it will be necessary to update a series of legislation related to aeronautical activity and operations.

Considering all details relative the development of the AMM/UAM system described above, is important for Brazilian industry keep the discussion and the development of studies that involve this ecosystem together the aviation authorities, helipads and heliports administrators as well as with the EVTOL manufacturers. Is important that these discussions include flight safety issues and the sustainability benefits related to operations such carbon credit that will be generate by CO_2 emissions avoided.

- **Recommendation 2**

Due to the Paris agreement occurred on December 12, 2015, during COP 21 (21st United Nations Conference on Climate Change), the worldwide counties have assumed the commitment to reducing the emission of greenhouse gases. The gols established aggressive results until 2030, and for Airlines that are a very problematic industry in terms of CO2 emissions have a big challenger in the hands. Even time more the airlines have been looking for aircrafts more efficient in fuel burn, but unfortunately the engines and aircrafts currently available in the market even being more efficiency is not enough to reach the established levels of CO2 emissions to the future.

In this sense the carbon credit industry born, the international carbon trading markets have been around since the 1997 Kyoto Protocols. A carbon market allows investors and corporations to trade both carbon credits and carbon offsets simultaneously. This mitigates the environmental crisis, while also creating new market opportunities (Carbon credit.com). These emissions fall into one of two categories: Carbon credits or carbon offsets.

- Carbon credits also called carbon allowances, could be considered like permission slips for emissions, which are usually bought from the government. When a company buys a carbon credit, they gain permission to generate one ton of CO2 emissions. The flows relative to the carbon revenue are from companies to regulators. If the companies end up with excess credits, they can sell them to other companies.

- On the other hand, carbon offsetting is trading carbon revenue between companies. When one company removes a unit of carbon from the atmosphere as part of their normal business activity, they can generate a carbon offset. Other companies can then purchase that carbon offset to reduce their own carbon footprint. Note that the two terms are sometimes used interchangeably, and carbon offsets are often referred to as “offset credits”.

Once a company is unable to reduce their CO2 emissions to the necessary level, the rules of carbon credit market and sustainability allow companies purchase carbon offset from other to reduce their own carbon footprint. In this sense the environment will have the benefits from the company more efficient and substantiable. Other actions like tax credit in the Inflation Reduction Act to incentivize greater production of sustainable aviation fuel (SAF) are being in discussion in the recent policy action at the EU level and in the UK.

- **Recommendation 3**

As demonstrated in this work, the cost of an EVTOL is projected to be lower than a conventional helicopter, in addition to having a benefit in its operation in terms of fuel cost and pollutant emissions. Thus, it is likely that this type of aircraft, in addition to opening a new market, will bring about strong changes in the market for existing helicopters, $1.5 trillion market for Urban Air Mobility by 2040 is predicted by Morgan Stanley.

We therefore recommend that companies and individuals operators in this sector analyze careful the possibilities to introduce these kinds of new vehicles in fleet. As shown, in addition to being cheaper equipment, they promise bring a gain in the operation by carbon offsetting. Obviously, it is necessary to consider the type of operation, observing the limits of autonomy, among others.

- **Recommendation 4**

As demonstrated, the benefits of this operation will reach society as a whole. In addition to the benefits of reducing pollutants, already demonstrated, it will bring a direct benefit to city traffic. Nowadays, the traffic in the city of São Paulo is chaotic. Public authorities, in order to control this problem, implement actions such as the rotation of license plates, which consists of prohibiting the circulation of vehicles one day a week depending on their license plate. This action has been implemented for many years and theoretically reduced 20% in city traffic. The operation of EVTOL can be effective in reducing traffic since a part of the population will use this service with some frequency, migrating the streets to the skies of the city.

The public power can buy this idea by speeding up the adaptation of laws and the infrastructure necessary for this project to get off the ground, bringing its benefits to the entire population.

Future Research

- This was a restrict study, we considered the technical and operational information's from the helipads and vehicles analyzed considering the legislation currently applied for helicopters, being necessary to analyze the changes to be made in the helipads for adaptations of charging and electric infrastructure as well as marking, lighting, and visual aids, as well as the area for the parking of the vehicles for EVTOLs.

- It is necessary to study the public acceptance of this new type of transport in Brazil. Considering that the EVTOL can bring a big number of vehicles flying over the people heads, is important for market understand the level of public acceptance about it. In NYC there was a study in this direction that resulted in a poor acceptance of the population.

- It is necessary to analyze the parking areas for the system's passengers, who can arrive by car, taxi, or other means of transport.

- We were unable to find relevant information regarding future maintenance costs, being necessary to predict this cost in the future studies.

- Low Airspace management rules is the challenger for EVTOL become a reality, studies that can demonstrate how the government, aeronautic authorities and the industry have been working to solve this problem may be very relevant.

Lessons Learned

- During the study, we collected data from all helipads in the metropolitan region of São Paulo, including geographic position, type and dimensions, as well as information on all helicopters that use these helipads with the appropriate flight hours. This information may be of great interest to the scientific community for future studies.

- The use of EVTOL has demonstrated be an important solution for the market related to the benefits for populations in terms of sustainability considering the CO2 emissions that may be avoided as well as the possibility of traffic alleviation for big cities. And also, the EVTOL operations demonstrate that can be an important source of revenue generation for companies looking for carbon credits.

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Annex 01 - Data Set Metadata: Brazilian Aeronautical Register

Available at https://www.anac.gov.br/acesso-a-informacao/dados-abertos/areas-de-atuacao/aeronaves/registro-aeronautico-brasileiro/5-registro-aeronautico-brasileiro, retrieved on Sep 6th, 2022.

Metadados do conjunto de dados: Registro Aeronáutico Brasileiro

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publicado 09/09/2021 11h47, última modificação 15/10/2019 16h35

Caracterização do conjunto de dados

Área temática:

Aeronaves

Conjunto de dados:

Registro Aeronáutico Brasileiro

Nome da área de contato:

Registro Aeronáutico Brasileiro

E-mail de contato da área:

rab@anac.gov.br

Periodicidade de atualização:

mensal

Descrição:

Os dados de aeronaves têm objetivo de alimentar informações sobre a evolução da frota aérea brasileira e sua composição.

Esses dados arquivados são requeridos por:

- Instituições nacionais (órgãos censitários e de planejamento, entre outros)
- Internacionais - como IRCA (Registro Internacional da Aviação Civil) - iniciativa apoiada pela ICAO de colher informações e partilhá-las entre os membros da ICAO
- Pesquisas acadêmicas

Particulares no interesse de prospectar possíveis oportunidades de mercado.

Visão geral:

Em conformidade com:

- Resolução no 293, de 19 de novembro de 2013 - Capítulo I do Registro Aeronáutico Brasileiro - Art. 2o Inciso XXIII

    - Assegurar a publicidade, autenticidade, inalterabilidade e conservação de documentos inscritos, averbados, autenticados e arquivados;

- Regulations and Procedures for the International Registry da ICAO em Section 10 STATISTICS 10.1
    - The Registrar shall maintain updated registration statistics and shall publish them in an annual report. This report shall be electronically accessible to any person.
    - 10.2 The registration statistics under Section 10.1 shall consist of:
        - (a) Transactional volumes and revenues subdivided in each case by registration type and geographic distribution; and

(b) Other compilations of non-confidential information requested by the Supervisory Authority.

Metadados

Campo	**Descrição**

MARCAS	Conjunto alfanumérico reconhecido internacionalmente composto de marcas de nacionalidade e matrícula – No Brasil usamos apenas letras: ▪ As marcas de nacionalidade brasileira perfazem o seguinte conjunto de duas letras: PP – PR – PT – PS e PU. ▪ As marcas de matrícula são atribuídas por ocasião da Reserva de Marcas e são constituídas, no Brasil, das últimas três letras. ▪ O Registro disponibiliza no sítio da ANAC as opções disponíveis para reserva, obedecidas as limitações descritas no próprio sítio eletrônico.
PROPRIETÁRIO	Nome ou Razão Social do Proprietário registrado da aeronave
OUTROS PROPRIETÁRIOS	Nome ou Razão Social dos demais proprietários da aeronave
UF	Estado da Federação da residência declarada pelo Proprietário
CPF_CNPJ	Identidade de Pessoa Física ou Jurídica do Proprietário
OPERADOR	Nome ou Razão Social do Operador registrado da aeronave
OUTROS OPERADORES	Nome ou Razão Social dos demais Operadores da aeronave

UF	Estado da Federação da residência declarada pelo Operador
CPF_CNPJ	Identidade de Pessoa Física ou Jurídica do Operador
MATRÍCULA	Número atribuído pelo Registro em uma sequência cronológica quando da matrícula da aeronave na emissão do CM (Certificado de Matrícula).
NÚM. SÉRIE	Número de série atribuído pelo Fabricante – único para cada aeronave
CATEGORIA	Classificação das aeronaves de acordo com a natureza do Operador (Privado ou Público) e com o tipo de operação como instrução, aero agrícola, transporte de passageiros, etc.
TIPO CERT	Treinamento e habilitação para pilotos para determinados modelos de aeronaves.
MODELO	Modelo de produto aeronáutico, reconhecido mediante certificação pela ANAC.
NOME FABRICANTE	Nome do Fabricante da Aeronave
CLASSE	Classificação baseada em características como: Tipo de Pouso, Tipo e Número de motores – prevista no RBAC 21
PMD	Peso Máximo de Decolagem

TIPO_ICAO	Agrupamento de modelos de aeronaves que geram os mesmos impactos na operação de um aeródromo.
TRIP. MÍN.	Tripulação mínima
PAX MAX	Número máximo de passageiros
ASSENTOS	Número de assentos
ANO FAB	Ano de Fabricação da aeronave
VAL CAV	Data de validade do Certificado de Verificação de Aeronavegabilidade
VAL CA	Data de validade do CA
DATA CANC	Data de cancelamento da Matrícula da Aeronave
MOTIVO	Motivo do cancelamento da Matrícula
CD_INTERDICAO	Situação de Aeronavegabilidade (Normal, suspensa, etc.)
MARCA NAC 1	Marcas Nacionais anteriores – se houver
MARCA NAC 2	Marcas Nacionais anteriores – se houver
MARCA NAC 3	Marcas Nacionais anteriores – se houver
MARCA EST	Marcas estrangeiras anteriores

DESCRIÇÃO DO GRAVAME	Descrição de restrições de Direitos Reais sobre a aeronave

CD_INTERDICAO

Situação de Aeronavegabilidade

R	RESERVA DE MARCAS
N	SITUAÇÃO NORMAL
S	CERTIFICADO DE AERONAVEGABILIDADE SUSPENSO
C	CERTIFICADO DE AERONAVEGABILIDADE CANCELADO
V	CERTIFICADO DE AERONAVEGABILIDADE VENCIDO
X	AERONAVE INTERDITADA
U	AERONAVE ULTRALEVE (SITUAÇÃO NORMAL)

Z	AERONAVE EXPERIMENTAL (SITUAÇÃO NORMAL)
P	AERONAVE COM SITUAÇÃO PUNITIVA EM VIGOR
M	MATRÍCULA CANCELADA

MOTIVOS DAS SUSPENSÕES DE AERONAVEGABILIDADE

1	AERONAVE AVARIADA POR ACIDENTES OU INCIDENTES
3	PENDÊNCIAS JUDICIAIS
4	SITUAÇÃO IRREGULAR NO RAB
6	SITUAÇÃO TECNICA IRREGULAR
7	NÃO CUMPRIMENTO DE NCIA (NOTIFICAÇÃO DE CONDIÇÃO IRREGULAR DE AERONAVE
8	CVA VENCIDA

Annex 02 - FALA.BR ticket for helicopter flight hours

Plataforma Integrada de Ouvidoria e Acesso à Informação
Detalhes da Manifestação

Dados Básicos da Manifestação

Tipo de Manifestação:	Acesso à Informação
Esfera:	Federal
NUP:	50001.015163/2022-26
Órgão Destinatário:	ANAC – Agência Nacional de Aviação Civil
Órgão de Interesse:	
Assunto:	Acesso à Informação
Subassunto:	
Data de Cadastro:	19/08/2022
Situação:	Concluída
Data limite para resposta:	12/09/2022
Canal de Entrada:	Internet
Modo de Resposta:	Pelo sistema (com avisos por email)
Registrado Por:	Órgão
Tipo de formulário:	Acesso à Informação
Serviço:	
Outro Serviço:	

Teor da Manifestação

Resumo:	Estudo EVTOL
Teor:	Boa Noite Estamos fazendo um Projeto de Conclusão de Curso pela Embry Riddle e pretendemos avaliar a viabilidade da operação de EVTOL na cidade de São Paulo. Para tal precisamos do registro de Horas Totais lançados na Inspeções Anuais de Manutenção nos anos de 2019, 2020 e 2021 dos helicópteros registrados na cidade São Paulo. Caso não consigam isolar somente São Paulo, pode ser os dados brutos, que nossa equipe vai trabalhar para retirar o que precisamos. Atenciosamente Antonio
Proposta de melhoria:	
Município do local do fato:	
UF do local do fato:	
Local:	

Não há anexos originais da manifestação.

Não há anexos complementares.

Plataforma Integrada de Ouvidoria e Acesso à Informação
Detalhes da Manifestação

Não há textos complementares.

Não há envolvidos na manifestação.

Campos Adicionais

Não há campos adicionais.

Dados das Respostas

Tipo de Resposta	Data/Hora	Teor da Resposta	Decisão
Resposta Conclusiva	23/08/2022 10:28	Prezado Senhor, Em atendimento à sua manifestação, segue anexa a extração das horas lançadas em DIAM para aeronaves de asa rotativa cujo operador está registrado na cidade de São Paulo. Somente estão listados os helicópteros com lançamento de DIAMs válidas. Destacamos que o lançamento de DIAM não obedece a datas fixas. Assim, as colunas de ano representam o ano de emissão da DIAM, podendo ocorrer em qualquer data do ano. Aproveitamos para apresentar o canal de comunicação Fala.BR, que passou a centralizar pedidos de informação, prestação de serviço, reclamações e denúncias. O objetivo é dar mais qualidade e eficiência no tratamento das demandas, acompanhado de menores prazos para resposta. O tempo médio de atendimento é de 2 dias úteis. Para acessá-lo, entre no site anac.gov.br, selecione Fale com a ANAC e, depois, Solicitação OU entre direto pelo link https://falabr.cgu.gov.br/Login/Identificacao.aspx?idFormulario=1&tipo=5&ReturnUrl=%2fpublico%2fManifestacao%2fRegistrarManifestacao.aspx%3fidFormulario%3d1%26tipo%3d5%26origem%3didp%26modo%3d. O assunto utilizado pode ser "Serviços Públicos", ou outro pertinente. Por fim, ressaltamos que manifestações relacionadas a esta demanda deverão ser encaminhadas em até 10 dias, sendo apreciadas em 1ª instância pelo chefe da unidade organizacional responsável e, em 2ª instância, pela autoridade máxima da Agência ou autoridade por ela designada. Atenciosamente, Agência Nacional de Aviação Civil - ANAC www.anac.gov.br	Acesso Concedido

Denúncia de descumprimento

Não há registro de denúncias de descumprimento.

Plataforma Integrada de Ouvidoria e Acesso à Informação
Detalhes da Manifestação

Dados de Encaminhamento

Não há registros de encaminhamento.

Dados de Prorrogação

Não há registros de prorrogações.

Annex 03 – Helicopter Fuel Consumption

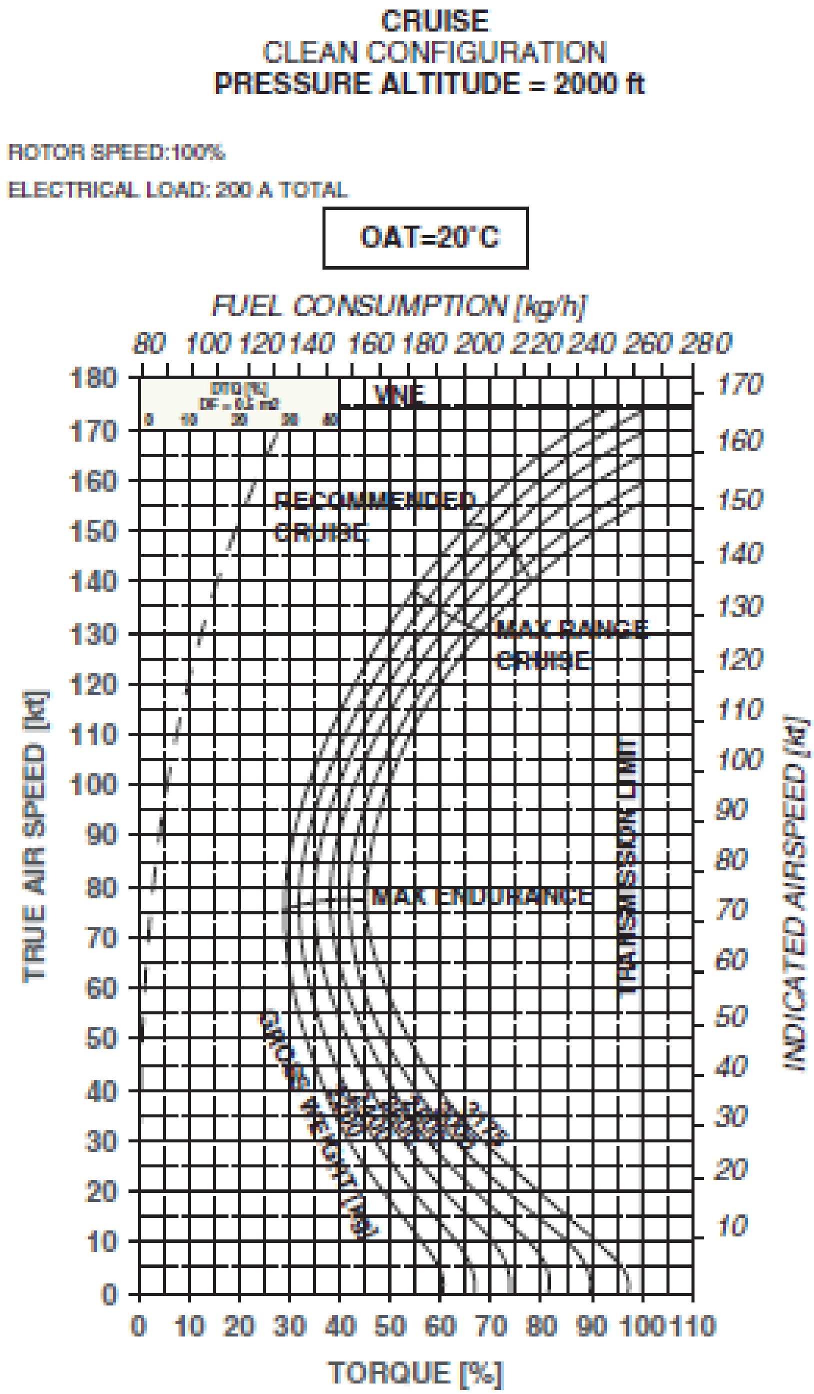


Figure 20 - AW109 Fuel Consumption and speed graph (RFM AW109, 2011)

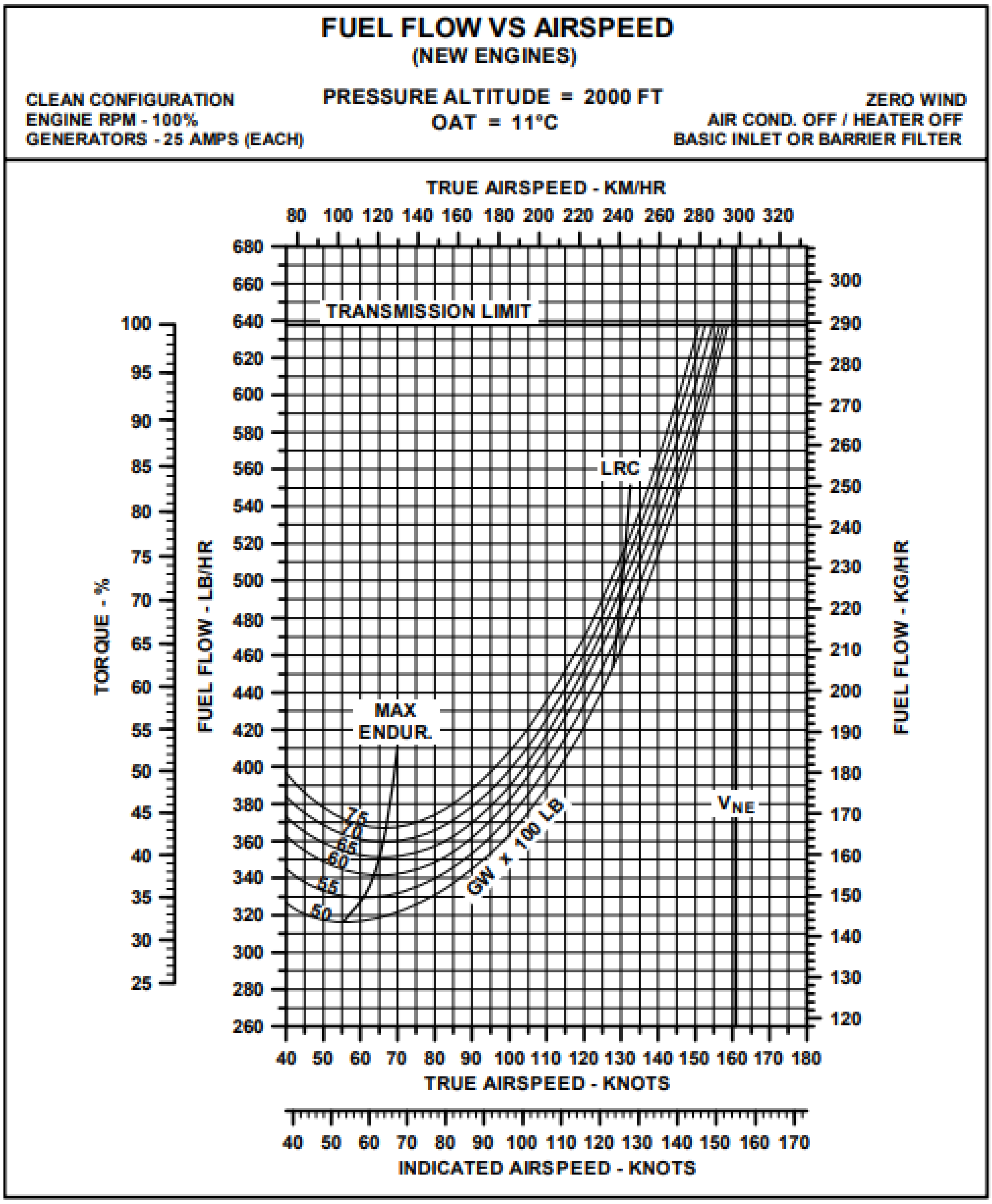


Figure 21 – Bell 429 Fuel Consumption and speed graph (RMD 429, 2013)

Annex 04 – Helicopter Dimensions

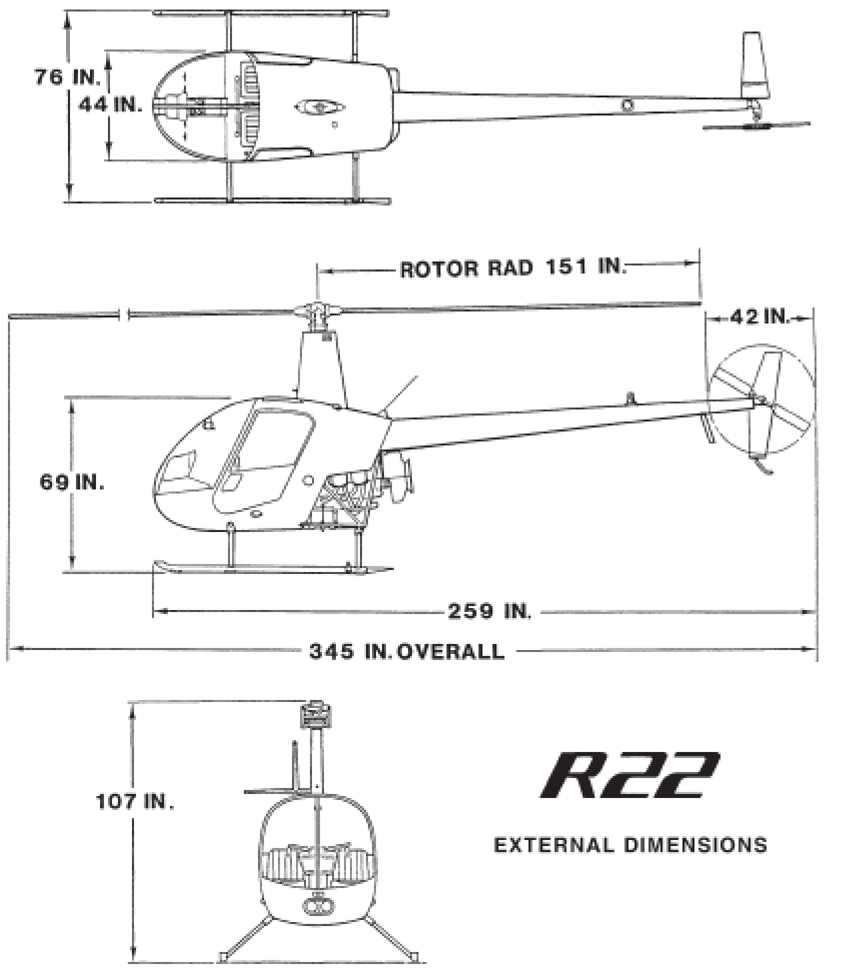


Figure 22 – R22 External Dimensions (POH R22, 2020)

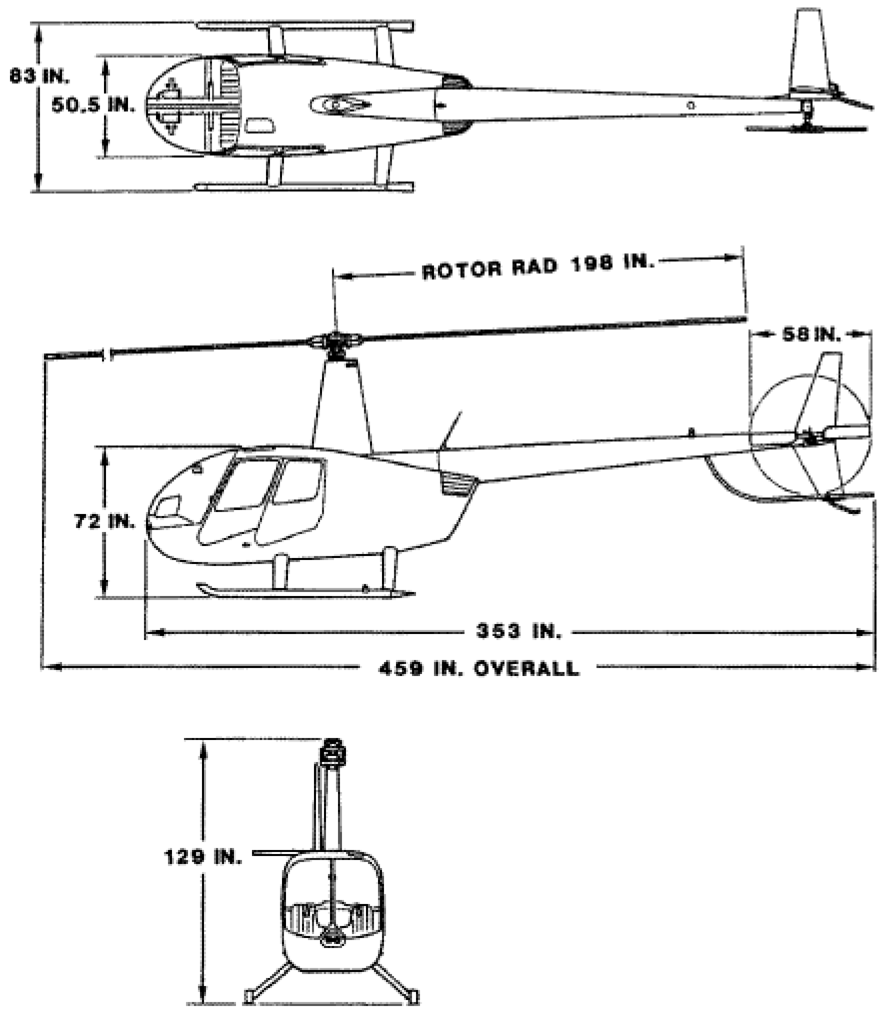


Figure 23 – R44 Dimensions (POH R44, 2021)

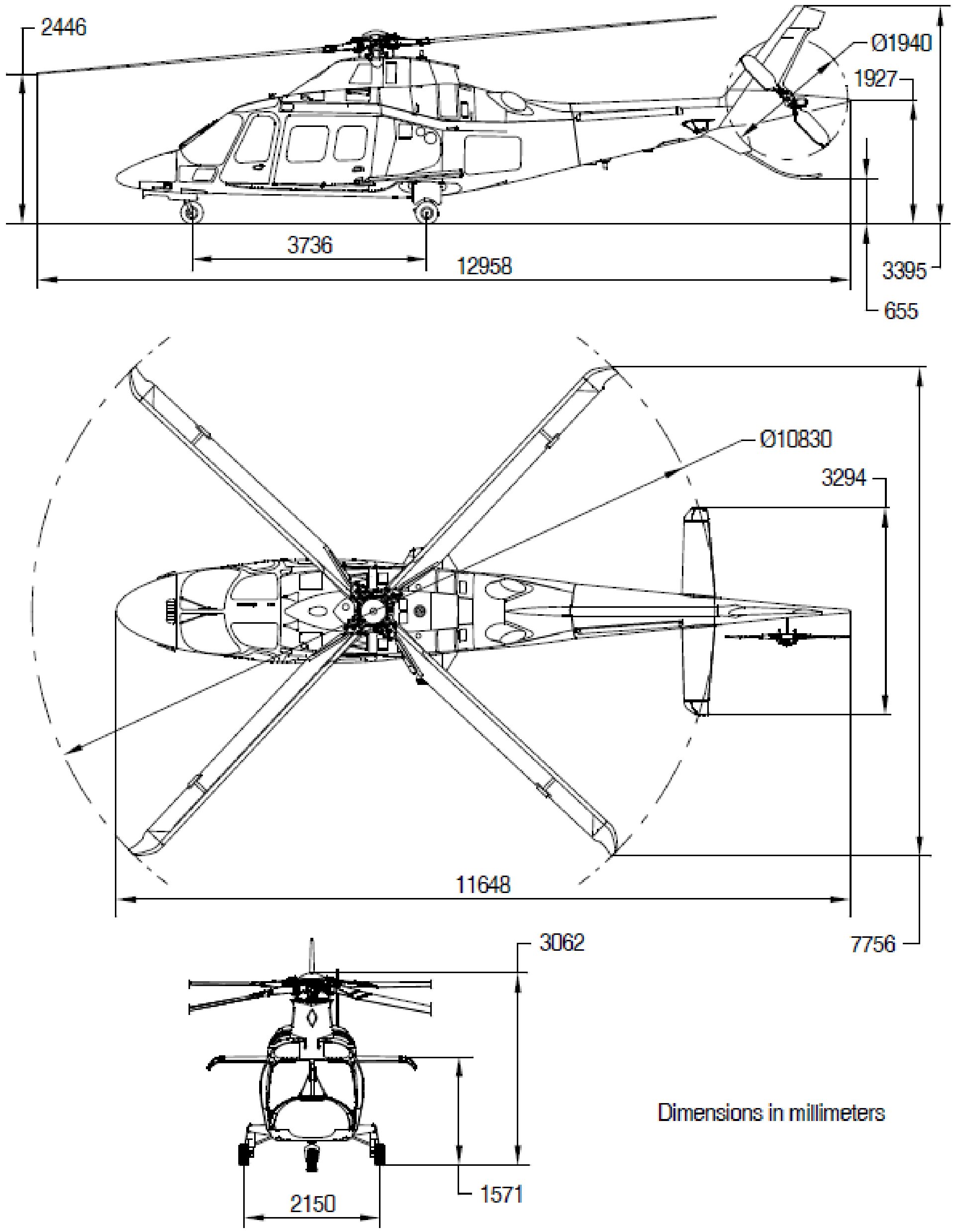


Figure 24 – AW109 Dimensions (RFM AW109, 2011)

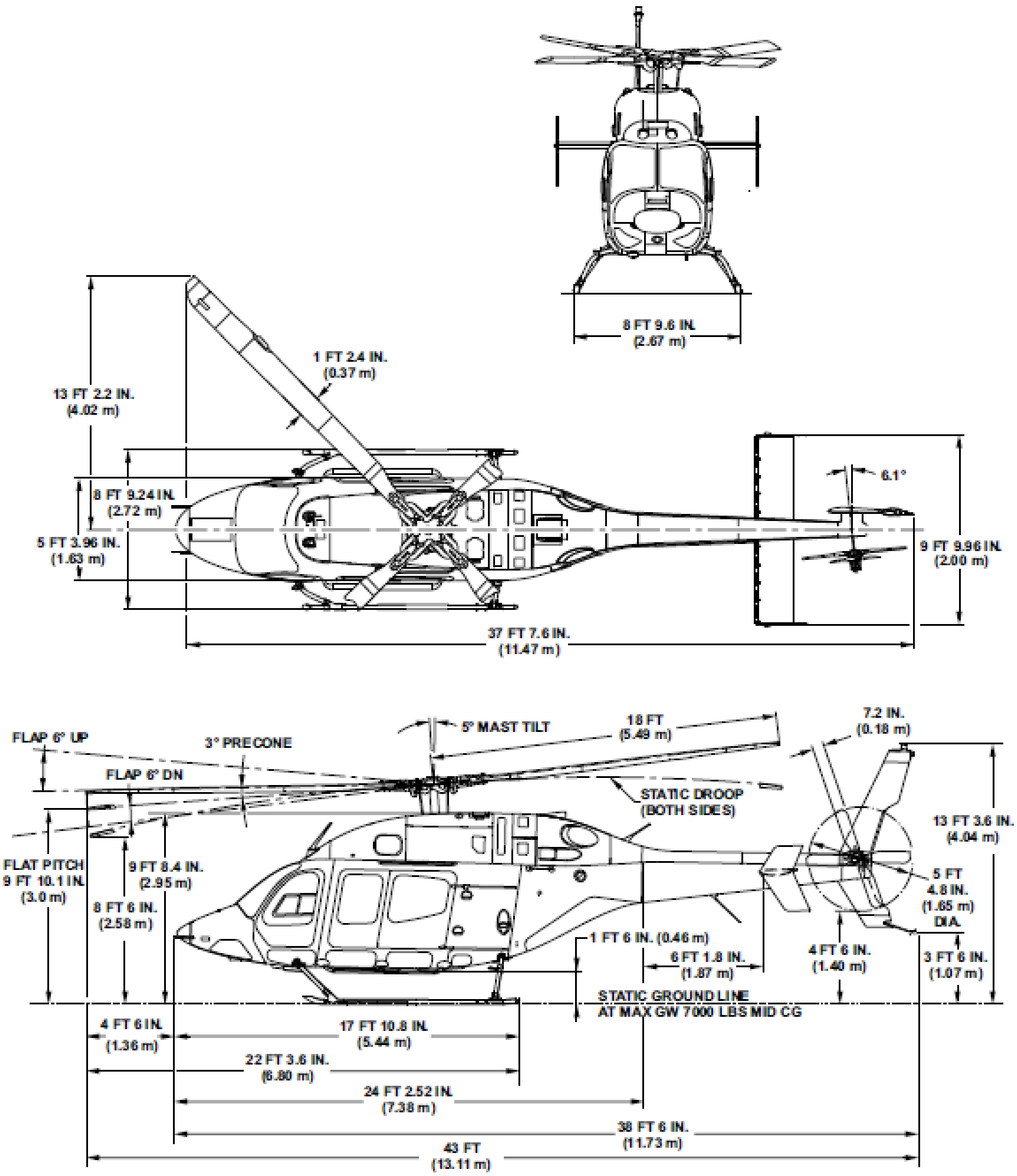


Figure 25 – 429 Dimensions (RMD 429, 2013)

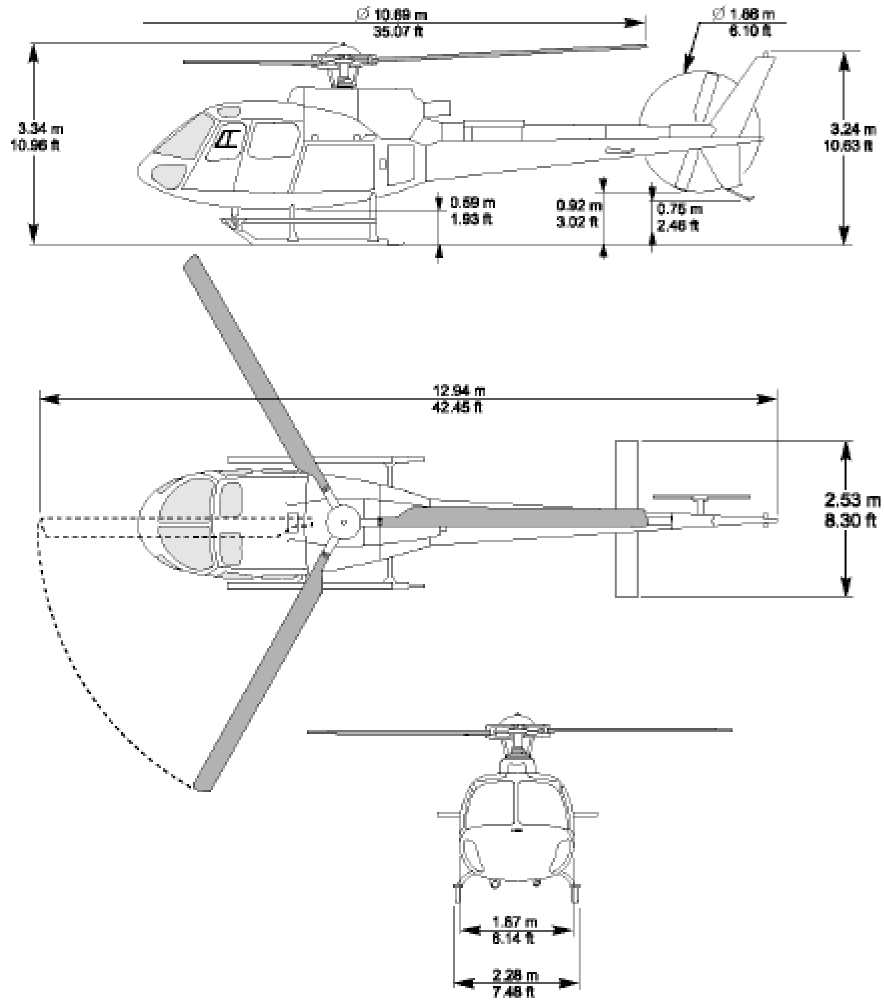
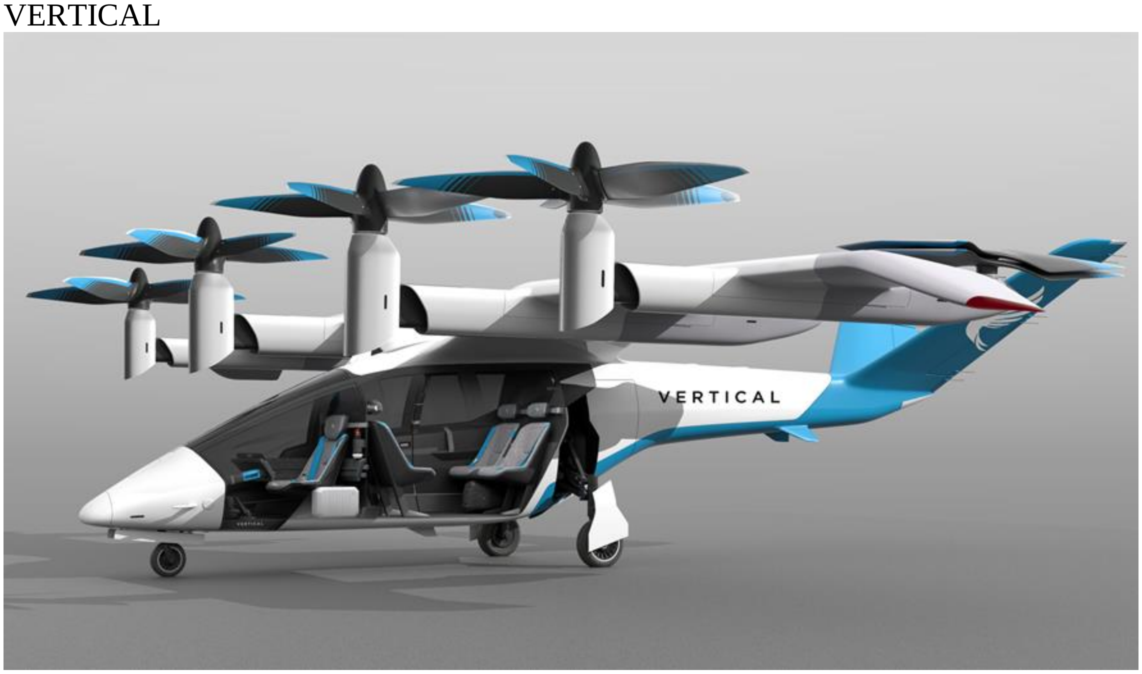


Figure 26 – AS350 Dimensions (TD AS350, 2009)

Annex 05 – EVTOL Aircraft Images

LILIUM

VERTICAL



ARCHER

JOBY

EVE