Air budJet: a VTOL virtual operator company in Portugal

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Abstract

Creation of sustainable transportation service for a new and virtual airline company that uses VTOL aircraft in order to increase mobility and flexibility in Portugal.

This study started with the VTOL concepts, peripherally and accessibility, and business models and plans reviews. The air service characterization was then carried out using localization and trajectory optimization algorithms, thus allowing to elaborate two applications (software): one for clients to book their flights and another that compiles flight's data booked by clients and optimizes flights routes/trajectories.

With this study, it is possible to depict the viability of the economic-financial results of the new virtual company and the application development results with the optimized trajectories.

The development of this air service will increase accessibility and mobility in all regions of Portugal and companies that cannot afford the costs of executive aviation, too. In order to facilitate the booking of the flights, an application was created for the client in order to optimize the company costs related to this air service, and thus to make the cost of a trip more appealing; a second application was elaborated that optimizes the trajectories of the aircraft.

Keywords

VTOL Aircraft; Business Model and Plan; Peripheral Regions; Network Optimization

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1 - Introduction

In the last decades, there has been a migratory increase from peripheral areas to large urban areas, a behavior conditioned by natural and human factors. It is, in fact, on the coast that most of the cities are located, becoming true poles of attraction and population establishment, for the job offer, generated by the intense commercial and industrial activity and by the many services and facilities that are provided to its population. New transport networks were built (not only at the road level but also at sea and air) that allowed these centers to become ones of attraction and fixation of companies (which activity and contacts became facilitated). Increased population in large cities, because of business growth and increased employment, contributes to increased road traffic, air pollution, noise, road accidents, travel time within cities, among other factors. On the other hand, there are, however, companies that by specific factors are attracted to the regions away from the large urban centers – the peripheral regions. In the absence of transport networks as big as the ones offered at large urban centers, firms located in peripheral regions are faced with the obstacle of distance to external markets. A new means of transportation has been developed in recent years and promises to reach the market very soon, Vertical Take-Off and Landing aircraft (VTOL), that will revolutionize the concept of aviation in the world. These aircraft will be essential to develop a new concept of executive aviation. Thus, in this work, we present a possible solution that will improve the mobility and speed of movement of companies located in large urban centers and peripheral regions.

The main objective of this paper is to present a virtual company that operates VTOL aircraft, ensuring the technical and economic viability of the resulting business plan. There is also a set of sub-objectives that we want to accomplish: to calculate the ideal location of VTOL parking bases, to design two applications for flight booking and to optimize the trajectories, and to create a model and a business plan for a sustainable service of VTOL.

2 - State of the art

Vertical take-off and landing aircraft (VTOL)

The development of technology is progressing rapidly, especially technology linked to the aircraft industry and the development of passenger drones and "traditional flying cars". These vehicle concepts have been developed since the 1980s and there are already several prototypes, most of which can take off and land vertically. A VTOL vehicle is an aircraft that takes off, flies and lands vertically, with no runways needed. For this project, the definition of VTOL excludes any type of helicopter. Although traditional helicopters operate in the same way, most are poorly energy efficient. Many companies are currently focused on electrical or hybrid-electric designs with VTOL capabilities. These vehicles, popularly called "flying cars" or passenger drones, are designed to [1]:

- Accommodate between two and five passengers or the equivalent load weight;
- Be highly energy-efficient, with low or zero emissions;
- Be quieter than a traditional helicopter.

Despite the technological progress and many potential applications of these aircraft, there are several challenges to be considered such as regulation, certification, infrastructure, and air traffic management.

Regulation: From the regulatory standpoint, the Federal Aviation Administration (FAA), as other equivalent agencies around the world, and transportation regulatory agencies need to assess the requirements for these types of transportation: Is a pilot license required? What airspace can these occupy? What are the airworthiness requirements of the vehicle? There has been progressing since the FAA has already begun discussing certification options with some manufacturers and believes that initially these vehicles should be manned, then autonomously assisted and then converted into a fully autonomous aircraft at a later stage [1].

Technology: In terms of technology, there are several considerations for manufacturers of VTOL's [1]:

- In a GPS denial environment, these vehicles would need sensors on board, such as radar, optical and geolocation sensors. Although these technologies exist and are being used in autonomous cars, they would have to be enhanced to provide the long-range sensing and recognition capabilities required to handle the multidirectional and convergence speeds associated with autonomous flight;
- These vehicles would require advanced technologies, such as artificial intelligence and cognitive systems, to enable advanced detection and prevention capabilities. Machine learning can be essential as operations go from piloting to autonomous: a vehicle would need to learn from the pilot's actions for thousands of operating hours to become fully autonomous over time;
- Energy management is crucial: carry a load of energy enough to carry passengers or cargo, maintain a margin of safety and recharge for the next flight. While battery technology is improving rapidly to increase passenger and cargo capacity and extend the ranges of passenger drones, it needs to improve further, or alternatives will have to be found.

Infrastructure: A broad network of vertiports would require new infrastructures or modify and prepare existing infrastructures such as heliports, roofs of large public buildings and unused land. To create a truly unified traffic management system, it may be necessary to install additional infrastructure along predefined flight corridors to assist in high-speed data communication and geolocation [1]. Figure 1 illustrates an example of integrating a VTOL transport network into the urban environment and the infrastructure used.
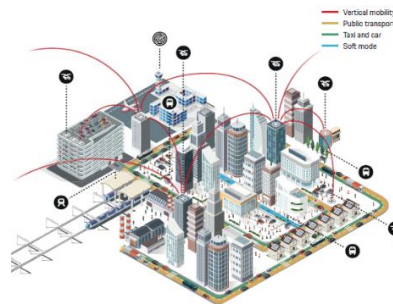

Figure 1: Example of integration of a VTOL transport network in urban areas. Source: [2].

Air traffic management: A robust air traffic management system would have to ensure safe and efficient VTOL operations, which would meet the requirements of the FAA and the European Aviation Safety Agency (EASA).

Safety: For VTOL's adoption of passenger scale, operators of these vehicles would need to demonstrate a near-perfect safety record, covering both mechanical integrity and safe operations.

Peripherally and accessibility

Geographic approach of periphery: From the geographical point of view, the periphery can be considered as the location beyond the range that limits an area, precisely at the maximum distance from the respective geographic center. However, and regarding regional development, the periphery should also reflect the distance to the most relevant economic activity/activities in the region, country, or even a group of countries [3]. In this sense, the periphery is marked by both the physical configuration of the territory and the geographic distribution of economic activities within it. That is: from the relationship with regional development it is observed that the periphery is synonymous with relative accessibility - or inaccessibility, to the economic activity, as it is distributed geographically throughout the territory [3].

Economic approach of periphery: The conditions of relative centrality or periphery influence the industrial sector, both regarding investment decision-making and regarding competitive efficiency. In other words, variations in the periphery degree are reflected, in the direct ratio, in distance costs. The simplest way to assess distance costs in peripheral regions is to analyze

the costs incurred by companies in, for example, transporting products to the market and accessing services and/or materials. These costs are lower for businesses located in the center. Transport costs are not the only costs attributable to the distance in peripheral regions, considering technological advances in recent years, telecommunication and access to information costs are further examples of what these regions must endure at higher levels than in central regions. Increased economies of scale (coupled with progress towards full European integration) also end up influencing the Center-Periphery relationship in areas such as industry growth and regional economic development. Central location, as it facilitates contact with broader market areas, leads - as a rule, to economies of scale in production, lower product costs, and significant sales increases. Companies located in central regions may also incur higher costs related, for example, to labor or value of space, against those in the periphery [3].

Accessibility: The concept of accessibility is intrinsic to the periphery. Accessibility translates the relevant opportunities for interaction between companies and industries, distributed and confined to a given space. Reflecting the costs inherent to the distance in monetary terms, access time to the information, organizational adjustments, and other terms end up marking the differences between the region's degrees of economic activity. The term accessibility closes (at least) two concepts: location and market potential (or economic), any significant enough so that it does not go unnoticed in the approach to the theme that we intend to do [3].

Market Potential: Simplistically, the designation of market potential is closely linked to the concept of population density [3]. If we look at the distribution of the main urban centers in Portugal (or if we look more closely at the population density of the country), easily we can conclude that a large part of the population is concentrated on the coast (except for the Alentejo coast). Moreover within a territorial band covering Lisbon, Sintra, Vila Nova de Gaia and Oporto councils [4]. Outside this central nucleus, a considerable number of regions (Cascais, Loures, Braga, and Matosinhos) with high population emerge. Outside this ring, in turn, we find other critical territorial spaces that assume specific relevance in the national context, such as Amadora and Almada [4]. This irregular distribution of the Portuguese population is conditioned by natural and human factors. However, more than natural factors, human ones are currently those that best explain the regional asymmetries observed in population distribution [5]:

- **The job offers:** generated by the intense commercial and industrial activity and by the numerous services and equipment available to the population;
- **The existence of a dense transport network on the coast:** reinforced by port and airport intense activity, is a factor of attraction and fixation of numerous national and international companies that see, in this way, their activity and contacts facilitated, also contributing to fixing the population.

When we look closely at the map of the distribution of purchasing power *per capita* by the municipality and compare it to the population density map by the municipality (Figure 2), we conclude that wealth seems to be concentrated in the central regions.
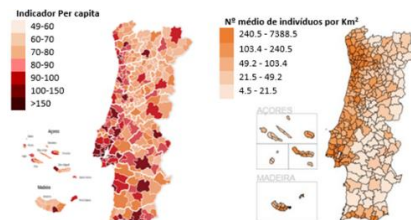

Figure **2**: Distribution of Purchasing Power *per capita* by Municipality (left) [6] and population density map by the municipality (right). Source: [7].

Location and Access Time: Until very recently, and with due regard to transport network failures and bad quality of roads, road distance was a tool used to assess market potential in any region, especially on the (economic) cost of market access. Currently, the distance has been relegated to a secondary plan, considering the time of access. The occurrence of this change is due not only to the increase in the quality of the networks but also to the progressive use of various modes of transport and to the variety of goods which have been transported.

Moreover, the access time, we verified the change that this parameter would operate in the traditional model of accessibility based solely on distance. Let us see: specific peripheral regions (island regions, for example) in an analogous situation can benefit compared to others located in continental spaces; especially if island populations use the airplane as a general mean of transport. At the same time, many regions located on the mainland do not have any aerodrome locally open to commercial traffic, being completely dependent on ground means of transport to meet their communication needs, and considerable time is required to travel - by road or by railway. However, this does not allow us to infer that island spaces have (always) good accessibility. They depend on a single mode of transport, with infrequent connections, and on a limited range of destinations [3]. Thus, to evaluate the relative centrality/periphery of a region, we should keep in mind: the volume of economic activity maintained with other regions, including the markets with which goods and services are transacted, sources and opportunities for acquiring raw materials and components, and access to specific information and business activity support services; and regional accessibility face of the economic activity regarding distance costs.

Business models and plan

Business model (BM) concept is relatively new, making its first peek at the beginning of this millennium, during the araising of *e-commerce* transactions. Driving forces such as outsourcing and offshoring procedures, better economic perception and substantial financial restructuration have also boosted BM notions [8]. There is no overall established theory defining business models. Instead, there are several designations proposed by different authors. According to Osterwalder and other authors, a BM is how an organization creates and delivers value to customers, delineating the business logic necessary to generate profit. In other words, BM is commonly associated as the company's blueprint, revealing how an organization does business and interacts with other entities to generate profit. To sum up, a BM is a collection of organizational roles, system functionalities, and detailed mechanisms descriptions and relationships among parties [8]. A business plan describes what the new activity intends to fulfill. They usually have two different uses: inside and outside the company. Inside the company, the plan helps to develop a "roadmap" with the steps to follow while the plan and strategies are implemented. Outside the company, it gives to the stakeholders and potential investors the business opportunity that the company strives for and how it plans to do so [9]. To prepare a business plan, it is necessary to conduct at least three main studies [10]:

- **Market Study:** where a comprehensive and sectoral analysis, a market analysis, a strategic analysis and finally a marketing plan are carried out;
- **Technical Study:** where a production plan or operations and human resources and organizational plan are drawn up;
- **Economic-Financial Feasibility Study:** where an economic-financial plan and a sensitivity analysis are made.

3 - Methodology

Traveling salesman problem

The Traveling Salesman Problem (TSP) is the name that usually occurs to a series of real problems that can be modeled in terms of Hamiltonian cycles in complete graphs. The TSP considers a set of cities - in one of which the salesman leaves (city-based or depot). He must visit all the cities or a subset of them, and the goal is to optimize one or more objectives (distance traveled or the associated costs). TSP is defined in directed and non-directed graphs [11]. The different heuristics procedures to solve the TSP are:

- The Nearest Neighbor Rule (NNR);
- The cheapest cost insertion rule;
- The Lin's r-optimal heuristic;
- Christofide's Heuristic.

The NNR was chosen for this work because it delivers minimal distance traveled. We applied this algorithm in the company application to calculate the minimum cost route, complementing the Clarke and Wright algorithm.

Clarke and Wright algorithm

The problem of determining optimal routes consists of determining routes to be performed by vehicles that, departing from a single location, the depot, will serve the other locations, the customers, with the required quantities of a good and so that the total cost is minimal. The capacity limitations of each vehicle will have to be respected and it is assumed that each locality is served once by a single-vehicle. The management objectives usually relate to the minimization of cost/distance or fleet size. Much of the literature on vehicle routing has been concerned with problems having the following features [12]:

- A single commodity is to be distributed from a single depot to customers with known demand;
- Each customer's demand is served by one vehicle;
- Each vehicle has the same capacity and makes one trip;
- The total distance traveled by each vehicle cannot exceed a specified limit;
- Each customer must be serviced within a specified time window;
- The objective is to minimize the total distance traveled by all vehicles.

The Clarke and Wright algorithm was applied in the application to calculate what was the best routes to take when a VTOL aircraft leaves a vertiport parking spot to transport passengers.

The compensation heuristics

In a location problem, we intend to install equipment in order to best serve a set of communities whose location is known. To solve a problem of location and multiple-choice we use the Compensation Heuristic, which has the following characteristics:

- We admit installing/constructing the equipment/service in all possible locations;
- We determine the costs associated with the movement of each customer to all possible equipment;
- We focus on the set of equipment/movements with lower cost;
- We compare the cost to move each customer from the equipment determined with each one of the other equipment;
- If any cost/change is compensating (a negative value), we admit installing this new equipment too.

We use compensation heuristic to determine the ideal location for the installation of a vertiport parking spot.

4 – Case study

Service characterization

The company: Since the objective of this study is to create an air transport service optimized to operate in peripheral and central regions, this section presents a (fictional) aviation company and the personalized services provided by companies located in Portugal. The company has two objectives. The first one is to revitalize transport in peripheral regions (hard to reach places, where travel time to an urban center and international airports is more than 2 hours), increasing the accessibility of these regions and offering greater flexibility to the companies located there. The second one is to revitalize urban transport in the metropolitan areas of Lisbon and Porto by creating an air transport network in a 100 km area around these cities, allowing users to escape from road traffic and thus save time on their journeys. Therefore, *Air budJets* is an aviation company that offers executive flights of small distance (between 100 and 300 km) and very short distance (less than 100 km). The next examples can help to understand these services:

- **For the first service:** a car trip from Castelo Branco airfield to Lisbon airport takes about 2 hours (120 minutes) with 277 km. If this trip is made on *Air budJets*, we can see that the distance from the trip will decrease to about 188 km (a decrease of 89 km) and will take about 20 minutes, depending on the aircraft used (a reduction of about 100 minutes). Figure 3 shows the routes for this example.
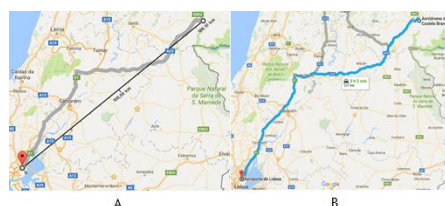
Figure 3: Travel between Castelo Branco and Lisbon Airport by *Air budJets* (A) and by Car (B). *Source:* Google Maps.

- **For the second service**: a car trip from Seixal to Lisbon airport takes about 32 minutes with 29 km. If this trip is made by one of *Air budJets* VTOL aircraft, we can see that the distance from the trip will be reduced to about 15 km (a decrease of 14 km) and would take about 5 minutes, depending on the aircraft to be used (a reduction of about 27 minutes). Figure 4 shows the routes for this example.
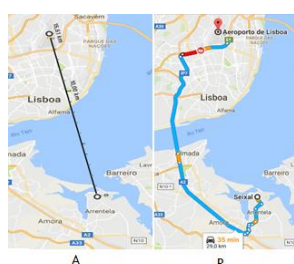

Figure 4: Travel between Seixal and Lisbon Airport by *Air budJets* (A) and by Car (B). *Source:* Google Maps.

Vehicle: German enterprise called Lilium Aviation is working on a 100% electric short-haul private jet that may, at last, fulfill the promise of the flying car. The company was founded in 2015 by a group of four engineers and doctoral students from the Technical University of Munich and developed in a European Space Agency-funded business set up. The company's aircraft concept promises flight without the flight infrastructure. It will require an open space of just 225 square meters — about the size of a typical back garden, to take off and land. The Lilium Jet can cruise as far as 300 kilometers at very brisk 300 kilometers per hour and reach an altitude of three kilometers, and it recharges overnight from a standard household outlet [13]. The Lilium Jet (Figure 5) consists of a rigid winged body with 12 flaps. Each one carries three electric jet engines. Depending on the flight mode, the flaps tilt from a vertical into a horizontal position. At take-off, all flaps are tilted vertical, so that the engines can lift the aircraft. Once airborne, the flaps gradually tilt into a horizontal position, leading the aircraft to accelerate. When they have reached complete horizontal position, all lift necessary to stay aloft is provided by the wings as on a conventional airplane [13].

Figure 5: Lilium Jet aircraft (Lilium GmbH, 2018). Source: [13].

The beauty of this system is its simplicity. In comparison to existing concepts, Lilium Jets require no gearboxes, no foldable or variable pitch propellers, no water-cooling, and no aerodynamic steering flaps; just tillable electric engines [13]. The Lilium Jet has the highest possible structural efficiency. As it can provide differential thrust from the engines in cruise flight, no stabilizing tail is necessary. The design of the electric engines ensures a very low drag coefficient in cruise flight, leading to a higher speed and range. The energy consumption per seat and kilometer thereby becomes comparable to an electric car, but the jet is 3 times faster. The Lilium Jet uses an integrated high-lift system. The objective is to increase the lift of the wings even at low speeds to save energy. While hovering is very energy-consuming, as an aircraft must provide thrust equal to its own weight, the dynamic lift of wings consumes much

less energy to stay aloft. So, it is important to create as much dynamic lift from the wings as possible, even at very low speeds [13]. As the engines always maintain attached flow on the surface of the flaps, the Lilium-Jet is highly maneuverable in any flight condition. It can do climbing, curves and high-rate sinking in any phase of a transitional flight. This feature is highly important when flying in narrow corridors in urban areas or for avoiding unexpected objects during a transition flight [13].

Trajectories: As previously stated the first *Air budJets* service aims to increase urban mobility within major cities. Therefore, to determine the advantages that the VTOL aircraft have in relation to the other transport modes, distance data were collected between several locations in three regions of Portugal: Lisbon, Porto, and Coimbra.

Location of *Air budJets* bases in each region: To land and take off the Lilium VTOL aircraft requires a space of 15m by 15m minimum, or 225m^2. In addition, it will be necessary to build facilities to store the aircraft, recharge the batteries or exchange passengers. For this, 3 different types of infrastructure were defined [14]:

- Vertiport parking spot: with the ability to land and take off, it allows the recharge of the batteries or exchange and still parks several aircraft;
- Vertiports: they have space to land and take off, allows the recharge of the batteries or exchange;
- Vertistops: they only have the space to land and take off, to leave passengers or goods.

By applying the compensation heuristic to each of these regions we determine the ideal location for the installation of a vertiport parking spot. The optimization of transport networks is fundamental to increase the efficiency of complex transport systems. Given several possible locations for vertiports and vertistops (locations where VTOLs can land and take off), choosing their location from a subset of these possible locations will have specific implications on installation and transportation costs. This choice will also be influenced by the total number of the population served by the VTOLs and their suitability over other means of transport. Thus, with the compensation heuristic, it was possible to determine that the best location of *Air budJets* base/vertiports parking spots for the regions of:

- Lisbon was Almada;
- Oporto was Penafiel;
- Coimbra was Coimbra.

Optimization of *Air budJets* routes: Since it is intended to connect by air the previous sites of the three Portuguese regions, it is necessary to optimize the routes that the aircraft will use to reduce the cost associated with their displacement. For this purpose, two applications have been developed: one for the client to enter the data of his trip, namely the place of departure, arrival, day and time and if he wants to share the flight or prefers to do the direct flight; and another application that checks if there are two or more customers who want to travel in a short time and do not mind sharing the flight. For the sharing flights, it calculates the best route using the Clarke and Wright heuristics and, if necessary, the heuristic of the traveling salesman. This application will facilitate the elaboration of the routes. That is, is possible to calculate all the possible routes, the associated costs and the time spent. As previously mentioned, the second service will allow trips of distances up to 300km. From cities located on the periphery of Portugal, it is possible to connect a large part of the western territory in Spain. Thus, the cities of Bragança, Covilhã, Évora and Vila Real de Santo António (V.R.S.A) will serve as points of connection among the regions of Porto, Coimbra, and Lisbon with other cities in Portugal, and several cities in Spain. This will also allow a greater speed of access between the respective cities of the periphery with the central cities of Portugal and important cities of the western region of Spain. The mapping of the connection routes between Lisbon, Porto, and Coimbra with Bragança, Covilhã, Évora and V.R.S.A and the western region of Spain is shown in Figure 6.
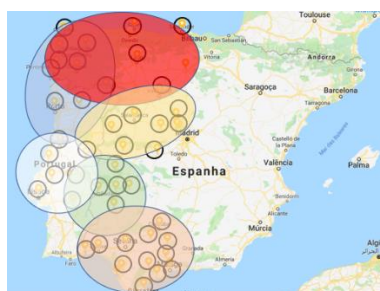
Figure 6: Mapping of routes with a distance greater than 100km from *Air budJets*. *Source:* own elaboration.

In turn, the second service of *Air budJets* will be short-haul flights (up to 300 km): this will allow difficult-to-reach and localized regions at great distances and large travel times to have greater mobility and faster access to services essential for their development. To recharge the aircraft to be able to return to the respective vertiport parking spot, all locations that are more than 150 km from vertiports parking spot have the possibility of recharging the batteries and back. To determine the cities with vertiports, the distances between all the cities were calculated and in order not to exceed the value of 300 km of VTOL autonomy.

Business model

We have filled out the information required to produce an *Air budJets* business model canvas, as in Figure 7.

Customer segments: This component of canvas defines the different groups of people or organizations that a company seeks to reach and serve [15]. Customers are fundamental to the survival of companies and so to better satisfy them a company needs to group them into distinct segments, each with common needs.

Value propositions: The value proposition component describes the set of products and services that create value for a specific Customer Segment [15]. With a combination of customer-driven elements, values can be quantitative (e.g. price, service speed) or qualitative (e.g., design, customer experience). The value propositions are mainly represented by mobility, speed, low price, straight transport, accessibility, and convenience.

Channels: Communication, distribution and sales channels make up the company's interface with customers. Channels are the point of contact for customers and play an important role in their overall experience [15]. The channels will consist of awareness, commercials, website, application, and events.

Customer relationships: The customer relationship component describes the types of relationships a company establishes with specific customer segments. A company should clarify the type of relationship it wants to establish with each customer segment. Customer relationships will be made through dedicated personal assistance, automated services such as a website and an app.

Key resources: This building block states the most crucial assets to make the business model function, this is, the resources for the company to create and offer a value proposition, reach markets, maintain relationships with customer segment and earn revenues. Human resources include pilots and co-pilots, loadmasters, technicians, maintenance personnel and ground crew.

Key activities: They are the most important actions that a company must perform to operate successfully. Like key resources, they are needed to create and deliver the value proposition, reach out to markets, maintain customer relationship, and make a profit. Key activities are essential to keep aircraft airworthy, keep routes optimized and aircraft distribution balanced.

Key partnership: This building block illustrates the partner and suppliers' network necessary to make this business feasible. The key partners block shows how relevant it is for a company to form partnerships to improve their business models and reduce risk. Thus, this study must take in consideration VTOL's manufacturers, marketing companies, takeoff and landing places.
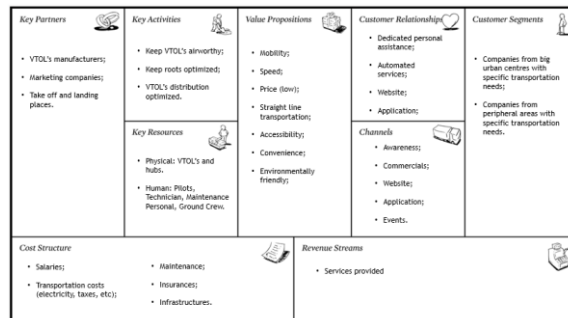
Figure 7: Business model canvas filled. Source: own elaboration.

For the preparation of the business plan of *Air budJets*, a programmed excel document was used, made available by Professor António José Pires, from Institute for Small and Medium-Sized Enterprises and Innovation (IAPMEI), to assist in the creation of this business plan. Because this excel has a very large size, this is not included in this paper. As necessary inputs we consider the revenue streams and the cost structure, which include the vehicle operation, vehicle acquisition cost, vehicle life, piloting and avionics costs, infrastructure burden, vehicle maintenance costs, chargers, and indirect operating costs. As such, we assumed assumptions, the necessary inputs and finally the outputs and related results. A small part of the necessary variables to create a business plan are shown in table 1.

Table 1: Some variables from the business plan. *Source:* own elaboration.

Inputs / Activity year	2026	2027	2028	2029	2030	2031
Income: Services	4 064 640	4 485 600	5 692 800	6 589 200	6 760 320	6 913 920
Energy (Electricity)	366 796	372 297	377 882	383 550	389 303	395 143
Maintenance of VTOL's	256 307	260 152	264 054	268 015	272 035	276 116
Aircraft (paid in 12 years)	12 126 413	-	-	-	-	-
Batteries (payable in 5 years)	563 687	-	-	-	-	-
Infrastructures (paid in 25 years)	3 690 000	-	-	-	-	-
Other Costs	4 687 213	1 017 109	1 017 671	1 018 216	1 018 768	1 017 362
Financing / Year of activity	2026	2027	2028	2029	2030	2031
Investment = Fixed Capital + FMN	20 755 226	0	0	0	0	0
Cash flow	0	2 319 625	2 301 939	3 157 764	3 502 443	3 529 932
Associated interest rate	8,85%	---	---	---	---	---
Results / Year of activity	2026	2027	2028	2029	2030	2031
Services provided	4 064 640	4 485 600	5 692 800	6 589 200	6 760 320	6 913 920
EBITDA	2 257 431	2 583 301	3 780 388	4 575 322	4 827 223	4 970 247
NET INCOME FOR THE PERIOD	-437 727	-111 856	1 067 227	1 674 558	1 970 017	2 177 489

5 – Discussion of the results
App's development
As mentioned earlier, the technology associated with this service is sustained in the development of two applications: the application of the client and the application of the company. When the client initializes the application, a first page is opened (Figure 8) where he can choose the type of flight: private or shared flight.
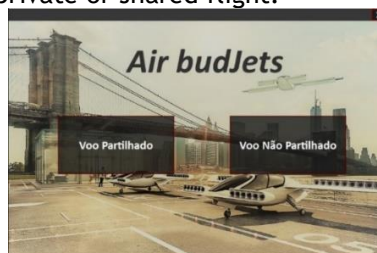

Figure 8: Client's application: first page - private or shared flight. *Source:* own elaboration.

Private flight (Figure 9) allows a direct flight with the number of passengers that he wants, choose the date and time of flight and the places of departure and destination. The shared flight allows a shared flight, provided that the total number of passengers is less than 4, where it is possible to choose between one of the already marked flights or to choose a new flight. After choosing the type of flight, he will be asked to fill out a form with data related to the flight.

Figure 9: Client's application: Form - Private Flight. Source: own elaboration.

After fulfilling the requirements, it is then possible to book the flight by clicking the reserve button; all data is stored in a database. In the case of being a shared flight (Figure 10), the presentation is different as it can be seen in Figure 10. When the fields are filled in, a table is displayed showing the flights already reserved for that destination, and if the client wishes, he can choose to select that flight, sharing it with the one who booked it, thus reducing the cost of the flight. If he doesn't want to do that, the customer can fill out the form with the data that he wants and book a new flight. In turn, this new flight will be visible in the table of reserved flights. With the collection of all flights marked (inputs), the company's application goes into operation. This application can be divided into two parts, the business part, and the user part. The part of the application business is the part that applies the algorithms of optimization of trajectories and optimizes the optimal trajectory. On the user side, as shown in Figure 11, one can see from the upper right a list showing all reserved flights. As we fill in the information of the date, time and place of departure, this list is filtered according to the submitted information, appearing only flights with these characteristics. Finally, in the lower part of Figure 11, one can see the information on the optimized trajectories. Showing, in the end, the result of the shared flights already optimized, is possible to visualize the optimal trajectory.

Figure 10: Client's application - form for a shared flight. Source: own elaboration.
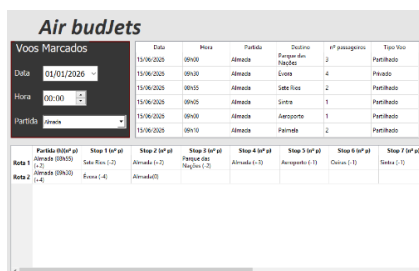

Figure 11: Company application. Source: own elaboration.

Business Plan

The income statement is the report that shows us the details of income and expenses over a certain period of time. It gives us the information if the company during that period had profit or loss. Looking at the results of the 5-year period, we observe that although we have a negative net result during the first two years of activity, i.e. the company will suffer losses in these two years of activity, it is expected that from then these values will be positive, that is, the company will profit in the third, fourth and fifth year of activity. We can see that there will be a positive evolution over the years, which reinforces the importance of this project. From the project's point of view, we can see that the cash flow available to be distributed among all the holders of company financing sources has a growing tendency, being negative in the first year of activity, but positive in the following. The WACC is used for two important functions in financial management: to calculate the value of the company when used as the discount rate of future cash flows, and to evaluate the viability of new projects, operating as "minimum rate" to be exceeded to justify the investment. The updated flows refer to the cash flow in the company cash, that is, to the amount of cash received and spent by a company during a defined period of time, in this case annually; in the example of *Air budJets* we have a negative updated flow in the first year and positive in the following. In turn, the cumulative updated flows are negative up to 5 years of activity, going from positive to negative in that year. The sum of all inflows and outflows of money over the life of an updated project for the present moment is given by the VAL, totaling 3 815 286€. The Internal Rate of Return (IRR) is an indicator used to measure the profitability of investment projects. The higher the IRR, the greater the project's profitability. As the IRR is superior to the WACC, the project is viable [16]. Finally, we note that the payback period is 5 years.

Comparison between actual transportations and Air budJets transportation

By examining all cases, travel times would be greatly reduced if transportation was done on a VTOL aircraft. It should be noted that:

- In the case of VTOL's, we considered the time of taking off and landing, as such, we assume 3min of duration;
- Cruising speed of 240 km / h for distances exceeding 20 km, and 150 km / h for distances up to 20 km; the maximum speed of 300 km / h was not considered;
- The price per place is considered if the vehicles are at their maximum capacity, i.e. 4 passengers in the taxi, 5 people in the car, 4 passengers in VTOL.

Within the examples of travel/travel possibilities, there is some information that should be highlighted due to their characteristics. The following example was chosen because they showed a journey from the periphery to the coast within Portugal.

Table 2: Example of a trip from Covilhã to Lisbon airport. *Source:* own elaboration.

Departure City	Arrival City	Transport type	Km	Time	Price	Price per seat
Covilhã	Aeroporto Lisboa	Train + Subway	-	3h55	18,80 €	18,80 €
		Bus + Bus	273,57	4h23	18,20 €	18,20 €
		Car (consumption: 5l/100km)	271	2h30	51,35 €	10,27 €
		Taxi	271	2h30	258,25 €	64,56 €
		VTOL (Year 1)	215,23	00h57	170,03 €	42,5 €

6 – Conclusion

It was possible to create two applications (APPs), one that allows the customer to book the flights and another for the company to register the flights and optimize those that are possible. The economic-financial study of the business plan shows great profitability and the sustainability of the business developed. The sum of all inflows and outflows of money over the life of an updated project for the present moment is given by the VAL, totaling € 3 815 286. We can also see, that the payback period, that is, the period that the project takes to generate earnings is 5 years. In the development of the application, some difficulties arose due to the quality of the computers on which we developed the software, making the whole process of

compiling and testing the software slower. Consequently, it was not possible to test the software for most of the locations we wanted, and thus the simulation was done only in the Lisbon area. When comparing the transport done by a VTOL aircraft with other means of transport, the travel time is much lower when done by a VTOL, being the price quite competitive when compared to a taxi, but much higher than the other modes of transportation. such as the bus, train or personal car.Due to the current work and acquired knowledge and experience, it's believed that the next steps in this work should cross the following research lines:

- Increase *Air budJets'* operating area throughout all the Iberian Peninsula and other locations around South (Mediterranean) and West Europe region;
- Improve application by adding other (or replacing the referred) route optimization algorithms;
- Optimize the business plan with the use of more aircraft and more vertiports/vertistops to decrease the price per km

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