UNIVERSIDADE DA BEIRA INTERIOR
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Air budJets: A VTOL virtual operator company in Portugal

(Versão corrigida após defesa)

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Para a minha família,

“When Henry Ford made cheap, reliable cars, people said, 'Nah, what's wrong with a horse?' That was a huge bet he made, and it worked”

Elon Musk

Agradecimentos

Em primeiro lugar, agradeço ao Professor Jorge Reis Silva que desde muito cedo me acolheu no NIT e encaminhou-me ao longo desta etapa académica.

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Abstract

The aeronautical industry is evolving very rapidly mainly due to the development of technology. These technological advances have allowed the Man to develop projects that are very ambitious as is the case of "flying cars".

This concept has been developed since the '80s, but only now have arisen prototypes capable of satisfying this dream. With this, the appearance of VTOL aircraft, aircraft capable of taking off and landing vertically, without needing any runways to do so. For this project, helicopters are not considered as VTOL aircraft because they are not very energy efficient. Many companies have developed VTOL aircraft, with design and consequently characteristics very different from each other, but having in common being hybrid or fully electric aircraft.

For this study, a "fictitious" airline company was created using VTOL aircraft. The service characterization was then carried out, where using localization algorithms and trajectory optimization, we were able to elaborate an application (software) that treats the data of the flights to the marked ones by clients to optimize the routes/trajectories of the flights. Then the elaboration of a model and a business plan was made, and it is possible to observe the viability of the economic-financial results of the new (fictitious) company.

Keywords

VTOL aircraft; Business model; Business plan; Peripheral regions; Mobility; Network optimization; Operational performance.

Resumo

A indústria aeronáutica está a evoluir muito rapidamente sobretudo devido ao desenvolvimento da tecnologia. Estes avanços tecnológicos têm permitido ao Homem desenvolver projetos há muito ambicionados como é o caso dos “carros voadores”.

Este conceito tem vindo a ser desenvolvido desde os anos 80, mas só agora surgiram protótipos capazes de satisfazer este sonho. Com isto o aparecimento de aeronaves VTOL, aeronaves capazes de descolar e aterrar na vertical sem necessitar de quaisquer pistas para o fazer. Para este projeto não são considerados aeronaves VTOL os helicópteros pois estes são pouco eficientes energeticamente. Muitas empresas têm desenvolvido aeronaves VTOL, com *design* e consequentemente características muito diferentes entre si, mas que tendo em comum serem aeronaves híbridas ou totalmente elétricas.

Para este estudo foi então criada uma empresa “fictícia” de transporte aéreo que utiliza aeronaves VTOL. Foi então feita a caracterização do serviço, onde utilizando algoritmos de localização e de otimização de trajetórias, fomos capazes de elaborar uma aplicação (software) que faz o tratamento dos dados dos voos já marcados por clientes para otimizar as rotas/trajetórias desses voos. Depois a elaboração de um modelo e de um plano de negócios foi possível observar a viabilidade dos resultados económico-financeiros da nova empresa (fictícia).

Palavras-chave

Aeronaves VTOL; Modelos de negócios; Plano de negócios; Regiões periféricas; Mobilidade; Otimização de rede; Desempenho operacional.

Resumo alargado

Introdução

Esta secção da dissertação de mestrado serve para explicar e demonstrar resumidamente o trabalho efetuado.

Em primeiro lugar é feito o enquadramento da dissertação, consecutivamente é explicado o caso de estudo e por fim são apresentadas as conclusões e as perspetivas de trabalhos futuros.

Enquadramento da dissertação

O aumento da população nas grandes cidades, como resultado do crescimento dos negócios e consequentemente o aumento da empregabilidade, contribuiu para o aumento do tráfego rodoviário, poluição do ar, ruído, acidentes rodoviários e tempo de viagem dentro das cidades.

Por outro lado, há muitas outras empresas que, por fatores específicos, são atraídas para as regiões afastadas dos grandes centros urbanos - as regiões periféricas. Nestas regiões a ausência de redes de transporte como as oferecidas nos grandes centros urbanos, constituem um obstáculo às empresas localizadas nas regiões periféricas.

O aumento da competitividade empresarial, a globalização e a internacionalização das empresas são tendências crescentes, sendo por isso necessário fazer um grande número de viagens. Assim, a flexibilidade, a mobilidade e a velocidade são características fundamentais exigidas às empresas.

Um novo meio de transporte que tem vindo a ser desenvolvido nos últimos anos e que promete chegar ao mercado muito em breve, são as aeronaves Vertical Take Off e Landing (VTOL) e que irão revolucionar o conceito de aviação no mundo. Essas aeronaves serão essenciais para desenvolver um novo conceito de aviação executiva. Assim, neste trabalho, apresentamos uma possível solução que melhorará a mobilidade e a conectividade entre empresas localizadas em grandes centros urbanos e regiões periféricas.

Objetivos

O objetivo desta dissertação é criar uma empresa virtual que opere aeronaves VTOL, garantindo a viabilidade técnica e económica do plano de negócios resultante. Há ainda um conjunto de sub objetivos que pretendemos cumprir: calcular a localização ideal das bases de estacionamento VTOL, projetar duas aplicações para a marcação de voos e efetuar a otimização das trajetórias, e criar um modelo e um plano de negócios para um serviço sustentável de VTOL.

Caso de estudo

No caso de estudo da dissertação apresentamos a caracterização do serviço, o modelo de negócio e o plano de negócio.

Na caracterização do serviço apresentamos uma empresa fictícia/virtual que operará as aeronaves VTOL, apresentando os seus serviços. Mostramos ainda as características do veículo que esta poderia operar – Lilium jet. Apresentamos ainda as trajetórias que inicialmente iriam existir, os locais para onde voaria e onde iria localizar cada base de estacionamento. Neste subcapítulo do caso de estudo apresentamos a lógica, através de dois fluxogramas, do funcionamento das duas aplicações projetadas, uma aplicação para o cliente reservar os seus voos e outra para a empresa otimizar as trajetórias.

Na parte do modelo de negócio descrevemos e preenchemos os vários blocos do canvas de Osterwalder. No plano de negócios apresentamos as estruturas de custo e as fontes de receita e preenchemos um exemplo de um plano de negócios, projetado para os 5 primeiros anos. Este caso de estudo foi desenvolvido tendo em conta a sustentabilidade da empresa que idealizamos e, claro, a carteira do cliente.

Principais conclusões

Nas conclusões deste estudo apresentamos os resultados do projeto das duas aplicações, analisamos o plano de negócios com um especial enfase nos custos, receitas e lucro. Depois apresentamos uma comparação entre as aeronaves VTOL e outros meios de transporte.

No desenvolvimento das aplicações, a aplicação do cliente mostra uma primeira página com a possibilidade de escolher o tipo de voo, privado ou partilhado. Consoante a escolha, a página que possibilitará a marcação do voo será diferente.

Caso o cliente prefira um voo não partilhado, terá de preencher os dados referentes à partida e ao destino, como o país, distrito, localidade, nº de passageiros, data e hora.

Caso escolha um voo partilhado o formulário de preenchimento será diferente. É mostrada uma lista com todos os voos que tenham escolhido partilhar o voo, sendo possível ao cliente “reservar um lugar” nesse voo ou caso não haja nenhum do seu interesse reservar um novo, que por sua vez será acrescentado àquela lista.

A aplicação da empresa aplica os algoritmos de otimização de trajetória do Caixeiro viajante e de Clarke e Wright (Clarke, G. and Wright, J.W,1964), mostrando no fim os voos nas suas trajetórias otimizadas e os outros que não sofreram otimização.

Na análise do plano de negócios, analisamos os *inputs* e os *outputs* deste. Daqui destacamos que ao longo de 5 anos, e como mostra a tabela 4.4, no capítulo 4, embora tenhamos um resultado líquido negativo durante os dois primeiros anos de atividade, ou seja, a empresa sofrerá perdas nesses dois anos, espera-se que a empresa lucre no terceiro, quarto e quinto anos de atividade. Podemos ver que haverá uma evolução positiva ao longo dos anos, reforçando a importância deste projeto.

Por fim comparando o transporte feito por uma aeronave VTOL com outros meios de transporte é visível que o tempo de viagem é muito menor quando feito por um VTOL, sendo o preço bastante competitivo quando comparado com um táxi, mas bastante superior aos restantes modos de transporte, como o autocarro, o comboio ou carro pessoal.

Perspetivas de investigação futuras

Para que este projeto possa num dia tornar-se real é preciso que muito trabalho e mais estudos sejam feitos ou completados. Alguns destes são:

- Enquadramento legal destas aeronaves no setor aéreo;
- Estudos sobre o controlo específico de tráfego aéreo;
- Desenvolvimento e melhoria da aplicação do cliente, criando a versão mobile da mesma;
- Criação ou aplicação de algoritmos de otimização de trajetórias mais inteligentes;
- Estudar a aplicação destes serviços noutros países.

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List of acronyms

VTOL	Vertical Take Off and Landing
SATS	Small Aircraft Transportation System
EPATS-STUDY	European Personal Air Transportation System – Study
IRR	Internal Rate of Return
EU PART OPS	European Union Part Operations
FAA	Federal Aviation Administration
EASA	European Aviation Safety Agency
NASA	National Aeronautics and Space Administration
eVTOL	Electric Vertical Take Off and Landing
SWOT	Strengths Weaknesses Opportunities and Threats
TSP	Travelling Salesman Problem
NNR	Nearest Neighbor Rule
TBO	Time Between Operations
HR	Human Resources
WACC	Weighted Average Cost of Capital
V.R.S.A.	Vila Real Santo António
BN	Business Volume
IAPMEI	Instituto de Apoio às Pequenas e Médias Empresas e à Inovação

Chapter 1- Introduction

1.1 Motivation

Increasing business competitiveness, globalization and the internationalization of companies are growing trends, being often necessary to make a great number of trips. Thus flexibility, mobility, and speed are fundamental characteristics required from companies nowadays.

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. Among the natural factors, the climate, soil relief, and fertility, which, when favorable, facilitate the practice of agriculture and promote the development of transport and communications are the ones who influence most this distribution.

But more than natural factors, human factors are currently the best explanation for the regional asymmetries observed in population distribution. 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.

Over the last years, we have witnessed a major development of large urban centers. New transport networks were built (not only at the road level but also at sea and air) that allowed these centers to become centers of attraction and fixation of companies (which activity and contacts became facilitated).

Increased population in large cities, as a result of business growth and increased employment, contributes to increased road traffic, air pollution, noise, road accidents, travel time within cities, among other factors.

In 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. These companies represent great importance to the local and national economy since they export a large part of their production. Many of these exportations' contracts imply a large amount of business travels to the countries to which they export or may export.

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. It should be noted that distance is not measured with measures of length but rather with measures of time. Therefore, a place is more (or less) distant depending on the time it takes to get there.

Thus, the major problem that companies located in these regions have is the time they take to travel to international airports, where sometimes the time they take to get to the airport is longer than the travel time from the airport to the destination.

Currently, the fastest, more flexible and more practical mode of transport is undoubtedly business aviation.

Business aviation is a segment of general aviation that explores a niche market of air transport with very specific characteristics. This transportation mode came to meet the demand for private flights, often in different routes than those used by civil and military aviation.

Business aviation can be also defined as a sector of aviation which concerns the operation or use of aircraft by companies for the carriage of passengers or goods as an aid to the conduct of their business, flown for purposes generally considered not for public hire and piloted by individuals having, at the minimum, a valid commercial pilot license with the instrument rating.

The increasing need for speed and predictability led to a worldwide constant increase in business aviation. Large companies from all regions of the world, at different stages of economic and business cycles, require the use of business aviation to properly position themselves to capture value as market conditions evolve.

Unfortunately, this transportation mode is not accessible to all, its high costs do not allow that many companies and individuals make use of it.

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) 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.

1.2 Object and objectives

The objects of this dissertation are the VTOL, the periphery and level of accessibility of regions, the business model and the business plan.

The main objective of this dissertation is to create 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 routes, and to create a model and a business plan for a sustainable service of VTOL.

1.3 Dissertation structure

The first chapter of this dissertation is the study introduction, which is divided into three sub-chapters, the motivation, the object and objective, and the structure of the dissertation.

The development of this dissertation starts with a state of art review where the following concepts are approached: small aircraft transport systems, VTOL, peripherally and accessibility and business models.

The third chapter is dedicated to the methodologies used to make the network optimization and the selection of the best location, that will be used to sustain the case study. These methodologies are the traveling salesman problem, the Clarke and Wright algorithm, and the compensation’s heuristics.

In the fourth chapter, the case of study is presented and analyzed. That is, the characterization of a new transportation service is made, and its business model and business plan are developed. To help to understand how this new service works, two software applications are developed and presented: one directed to clients and another one that manages the entire service (manages the client's requests, optimizes routes according to booked flights, among other features).

The fifth chapter addresses the discussion of the results and the seventh chapter contemplates the dissertation synthesis, the final considerations and the prospects for future work regarding business transportation.

The flowchart of Figure 1 represents the methodology applied in this dissertation.

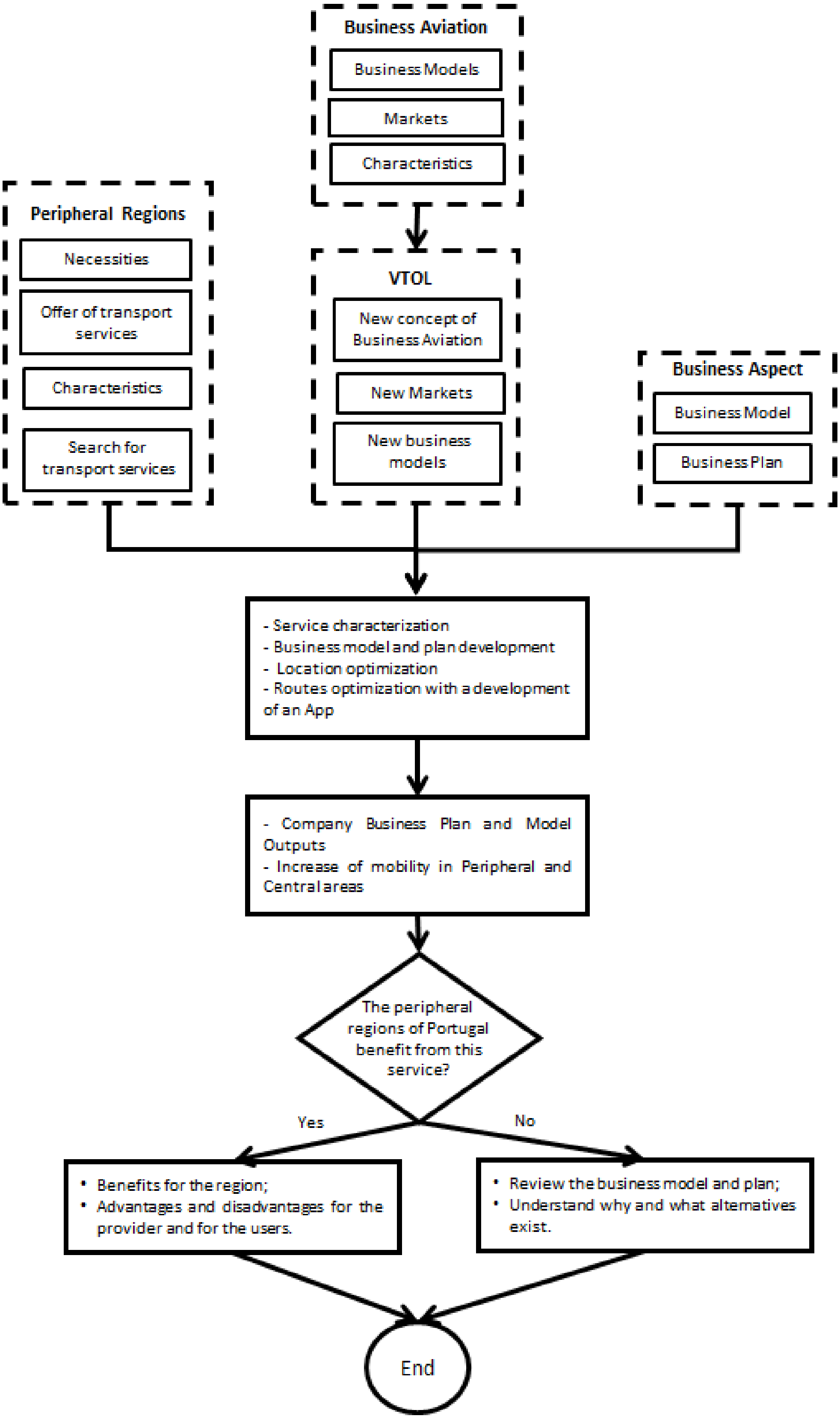


Figure 1: Dissertation methodology (own elaboration).

Chapter 2- State of the art

2.1 Introduction

This chapter provides a general state of the art and literature review concerning the small aircraft transport system, vertical take-off, and landing aircraft, the peripherally and accessibility, the business models and mobility servicing. The bibliographic review on all these topics is fundamental for the interpretation of a problem that exists and how it can be overcome.

It begins by approaching small aircraft transport systems (SATS) where we talk about their accessibility, their affordability, and their market potential. Obviously, the impact on the environment and safety cannot be bleached topics when we talk about the SATS.

The concept, the development, and the regulation of VTOL is described, and the mobility advantages that these aircraft will bring are also mentioned.

A review of the state of art on peripheral regions and accessibility is described, where a geographic and economic approach of the periphery is made and the concepts of market potential, location and time of accessibility access are analyzed.

The concepts of the business model and business plan are also approached.

Finally, a brief conclusion is made regarding this chapter.

2.2 Small aircraft transportation system (SATS) concept

Some regions are not served by air transport or high-speed trains which results in a substantial need for road travel for short to medium distances. The Small Aircraft Transport System (SATS) aims to answer the specific needs of business and other users of these regions, filling a gap between surface transport and regular mass air transport. Using small aircraft and local and regional airports/airfields will allow access to more communities in less travel time.

The main idea of this system “is to shift a part of medium/long distance passenger car trips to small aircraft to improve the efficiency of passenger transport, relieve the congestion on roads and thus reduce the environmental impact” (Krzysztof, 2009:2). Considering the travel cost and the value of time saved by air travel, SATS will offer an attractive alternative to travel by car for distances greater than 200 kilometers.

2.2.1 Accessibility

According to Krzysztof Piwek “The FP6 project EPATS-STUDY (European Personal Air Transportation System - Study) showed that the currently available airport infrastructure (2570 airports and airfields in Europe) is sufficient to provide easy access to all European communities. About 60% of the European population is living within 20 kilometers from the nearest regional airport, whilst for 95% of the European population, the nearest regional airport is within fewer than 40 kilometers. The existing airport infrastructure will be sufficient (SATS will use satellite CNS and satellite-based landing aids)” (Krzysztof, 2009:2).

2.2.2 Affordability

Calculations show that small aircraft transportation is cost effective compared to road traffic over distances greater than 200 kilometers. Using modern mass-produced small aircraft based on advanced technology and an intelligent transport business model, SATS will be affordable, and once full maturity is reached, costs will be similar or less than car travel (Krzysztof, 2009).

2.2.3 Impact on the environment

The environment remains the main policy area where further improvements are necessary. The impact of different modes of transport on the environment is usually assessed by costs externalities measurements. Many types of research were made to compare road and air transport. In all cases, the impact of air transport on the environment is much friendlier than in the case of road transport; it concerns noise pollution, local air pollution, traffic congestion, crash and others (Krzysztof, 2009).

2.2.4 The market potential of SATS

EPATS-STUDY showed that small aircraft transportation is beneficial for business travel in Europe, especially in southern France, Spain, Portugal and Italy, as well as in Eastern Europe, adding a new relevant market towards the current business aviation market which is currently more mature between London and Milano (Krzysztof, 2009).

2.2.5 Business aspect

The business cases are generated by straight forward choices but have complex operational characteristics. Operational characteristics and elements of the business cases include (Krzysztof, 2009):

- **Totally on-demand:** the passenger is free to choose the final airport destination and the flight time. He always flies without other non-related passengers;
- **Semi-on-demand:** the passenger is bounded in his departure and destination airport choice, but can choose its own flight time;
- **Per seat on-demand (net-centric case):** the passenger is free to decide his final departure and destination airport; other non-related passengers may accompany the original passenger to the same destination. Consequentially the passenger can choose a flight time interval for departure, whereas the operator decides the ultimate intermediate departure time of all passengers. The higher the interval the lower the charter price;
- **Aircraft fleet:** passengers are free to choose different aircraft type according to their demands.

The structure of the SATS network, planning, and service management are aimed at reducing empty flight seats, increasing fleet effectiveness and fuel efficiency, to minimize transportation costs (Krzysztof, 2009).

2.2.6 Safety

Using professional pilots for small transport aircraft operating both under Parts 91 and 135 of EU PART OPS, SATS will have a far lower accident rate than road transport. The challenge to SATS is to reach safety levels like those of current commercial air transport (Part 121 or EU OPS air carriers). Improved small aircraft will be based on new technologies that facilitate pilot situation awareness and flying in poor weather which will help to reach the projected safety levels (Krzysztof, 2009).

2.3 Vertical takeoff and landing aircraft (VTOL)

2.3.1 Concept and development

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 have the ability to 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 considered to be 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 (Lineberg, R. et al, 2018):

- 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.

There are three broad categories of VTOL vehicles for urban mobility, each with distinct characteristics and potential uses (Lineberg, R. et al, 2018):

- **Passenger Drones:** a passenger drone is expected to be an electric or hybrid-electric quadricopter (although some may have more than four rotors) that can be used to move people or cargo between established points. These vehicles can be piloted manually, remotely piloted or fully autonomous;
- **Traditional flying cars:** a traditional flying car would be a vehicle in which the driver/pilot can drive the vehicle in the car configuration up to an airport, reconfigure the vehicle's airplane mode and then fly to a destination airport. Currently, this aircraft would need to be operated by a licensed pilot but could become fully autonomous and driverless over time;
- **Revolutionary vehicles**: a combination of passenger drones and a traditional flying car, would be fully autonomous vehicles that can start or stop anywhere. These vehicles

have advanced VTOL capability and therefore can land and take off from virtually anywhere as they may not need an established airport. These would probably be piloted by a licensed pilot initially but could become totally autonomous over time.

In Figure 2 we have some examples of the major manufacturers of these aircraft and the proposed models.

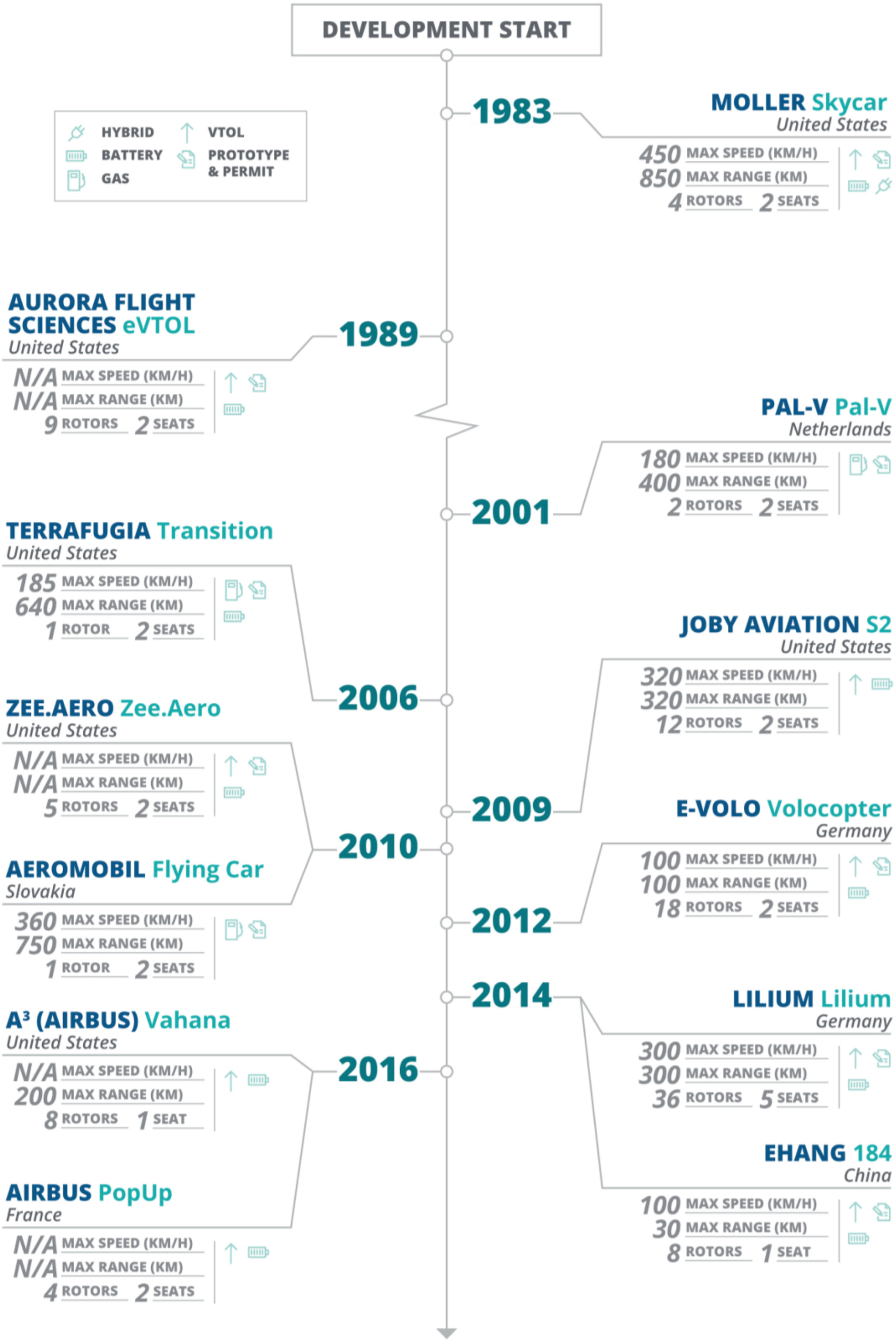
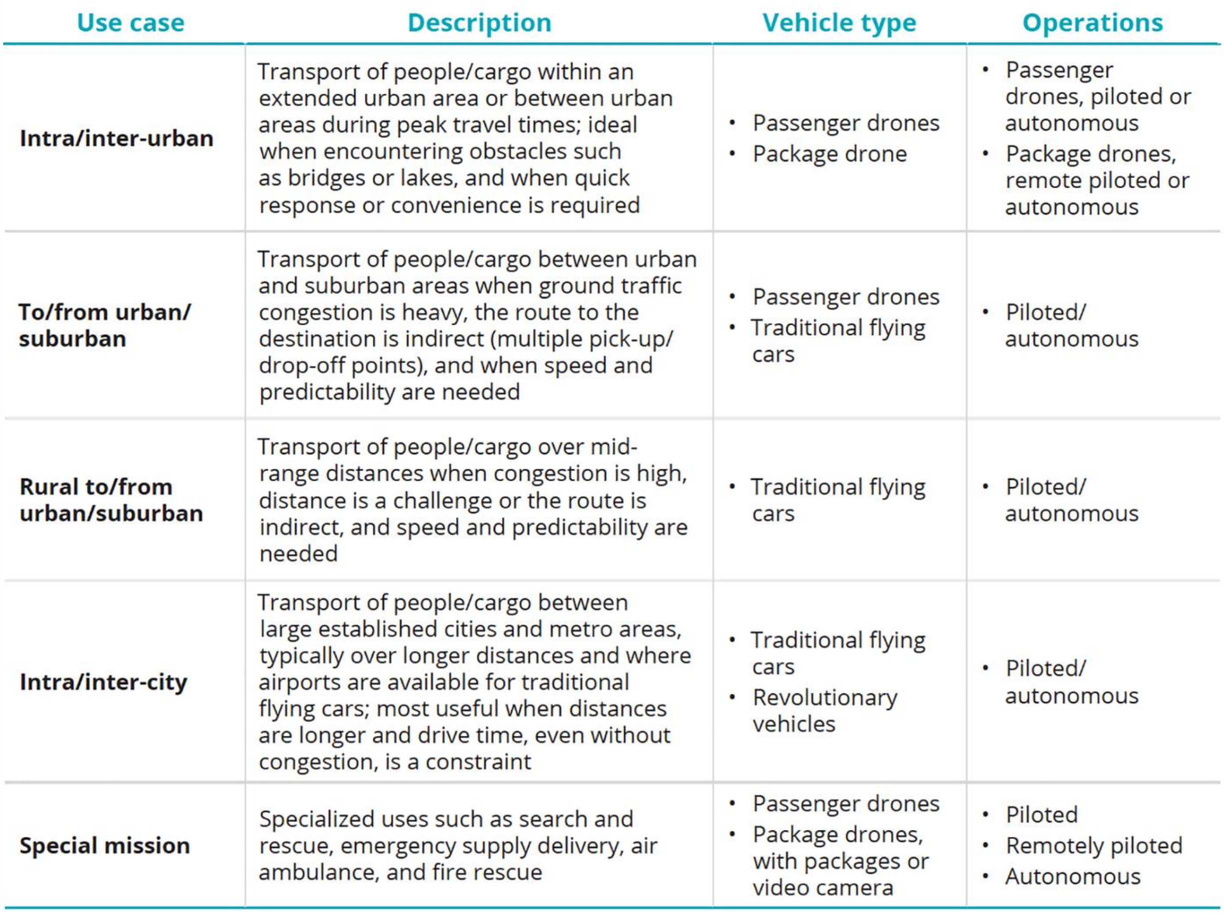


Figure 2: Specifications for some VTOL models in development (Lineberg, R. et all, 2018).

Many of these manufacturers have already gone through the design phase, and most of them are currently in the prototype and testing phase, with most manufacturers expecting to start delivering models by 2020 (Grandl, G. et all, 2018).

There are numerous potential applications for these new urban mobility vehicles as can be seen in Table 1.

Table 1: Applications for VTOL aircraft (Lineberg, R. et all, 2018).



Use case	Description	Vehicle type	Operations
Intra/inter-urban	Transport of people/cargo within an extended urban area or between urban areas during peak travel times; ideal when encountering obstacles such as bridges or lakes, and when quick response or convenience is required	• Passenger drones • Package drone	• Passenger drones, piloted or autonomous • Package drones, remote piloted or autonomous
To/from urban/ suburban	Transport of people/cargo between urban and suburban areas when ground traffic congestion is heavy, the route to the destination is indirect (multiple pick-up/ drop-off points), and when speed and predictability are needed	• Passenger drones • Traditional flying cars	• Piloted/ autonomous
Rural to/from urban/suburban	Transport of people/cargo over mid-range distances when congestion is high, distance is a challenge or the route is indirect, and speed and predictability are needed	• Traditional flying cars	• Piloted/ autonomous
Intra/inter-city	Transport of people/cargo between large established cities and metro areas, typically over longer distances and where airports are available for traditional flying cars; most useful when distances are longer and drive time, even without congestion, is a constraint	• Traditional flying cars • Revolutionary vehicles	• Piloted/ autonomous
Special mission	Specialized uses such as search and rescue, emergency supply delivery, air ambulance, and fire rescue	• Passenger drones • Package drones, with packages or video camera	• Piloted • Remotely piloted • Autonomous

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.

2.3.2 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 (Lineberg, R. et al, 2018).

2.3.3 Technology

In terms of technology, there are several considerations for manufacturers of VTOL's (Lineberg, R. et al, 2018):

- 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 sufficient to carry passengers or cargo, maintain a margin of safety and recharge for the next flight. While battery technology is improving rapidly in order 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.

2.3.4 Infrastructure

Infrastructure restrictions include proper take-off and landing zones, parking lots and battery recharging stations. 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. All these changes in infrastructure would require the collaboration of stakeholders and local urban planning authorities (Lineberg, R. et al, 2018).

Figure 3 illustrates an example of integrating a VTOL transport network into the urban environment and the infrastructure used.

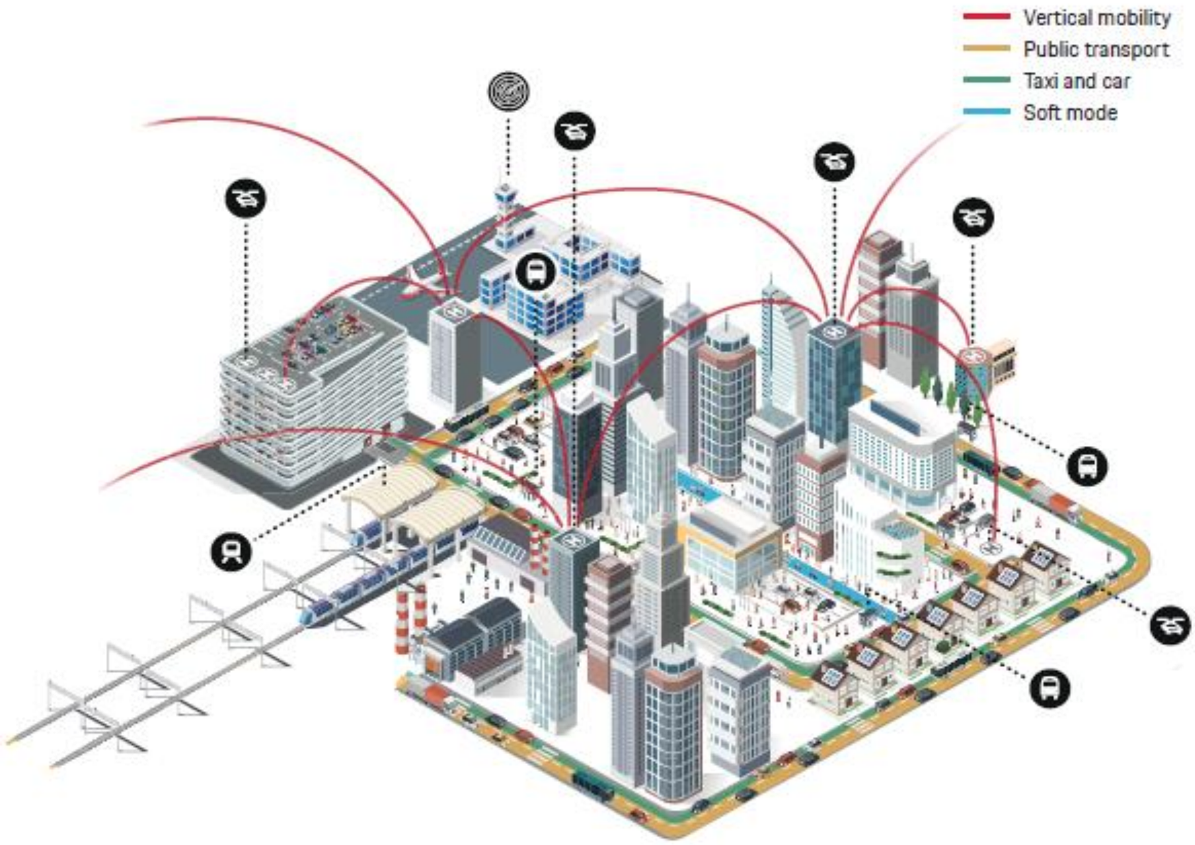


Figure 3: Example of integration of a VTOL transport network in urban areas (Grandl, G. et all, 2018).

2.3.5 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). To this end, industry leaders and manufacturers are likely to agree on a reliable traffic management framework that integrates with other modes of transportation, especially in urban areas. In the United States, progress has already been made, with Uber and the National Aeronautics and Space Administration (NASA) recently signing a space saw agreement for the management of low-altitude autonomous vehicle traffic (Lineberg, R. et al, 2018).

2.3.6 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 (Lineberg, R. et al, 2018).

As we have seen in autonomous cars, any accident can attract significant attention and slow down the pace of use. While facilitating mechanical integrity is easier, VTOL operations in suburban and urban areas may represent unique challenges (Lineberg, R. et al, 2018).

2.3.7 Psychological barriers

To other considerations, people also need to overcome any psychological barriers they may have associated with the idea of flying on an aircraft without a pilot, as these vehicles will eventually be autonomous.

In addition, for passenger drones and flying cars to be widely accepted, they would probably have to be ubiquitous and as versatile as a car - people should be able to take the vehicle to a store or take it to the beach and should be able to cover longer distances safely. Psychological barriers can be overcome if manufacturers and regulatory authorities ensure that these vehicles are as safe as an aircraft, and vehicles have well-documented safety records (Lineberg, R. et al, 2018).

2.3.8 Advantages of vertical mobility

Getting stuck in traffic is a worldwide phenomenon that has serious negative consequences in terms of wasted time as well as increased fuel consumption, higher emissions, and loss of quality of human life. The infrastructure provided by cities, to channel ever-increasing traffic flows, has reached its limit or is about to hit, often due to lack of funding, available space or both (Grandl, G. et al, 2018).

The increase of populations in the big cities, causes the population to spend more and lose more time along the way. Despite the worsening of road congestion, cities do not lose their attraction. The United Nations (UN) estimates that by 2050, 70% to 80% of the world's population will be urbanized, bringing with it new challenges and opportunities for more efficient and sustainable mobility solutions. Some of these solutions consist of leaving the traffic jams behind and literally raising a flight (Grandl, G. et al, 2018).

Saving time in transport - or avoiding traffic jams in the ground is the basic condition for this market to develop.

At the same time, the hub-to-hub architecture requires passengers to be transferred, which can be time-consuming. In most cases, vertical mobility will only gain against other modes of transport when passengers can save at least 20% of total travel time, despite transfers (Grandl, G. et al, 2018).

Customers already have a wide variety of modes in which VTOL's will have to find their space. At one end of the spectrum are fixed-line modes, such as subway, train or commercial airlines, which are expected to range from A to B. At another extreme are individual means of transport such as cycling, taxi or personal car. A perfect mobility-on-demand experience via personal flight will allow customers to quickly set up their itinerary, order their flight, catching ground transportation for a vertiport, board the electric VTOL (eVTOL) flight and, once landed, have a waiting service to travel the last kilometers to the final destination, as shown in Figure 4.

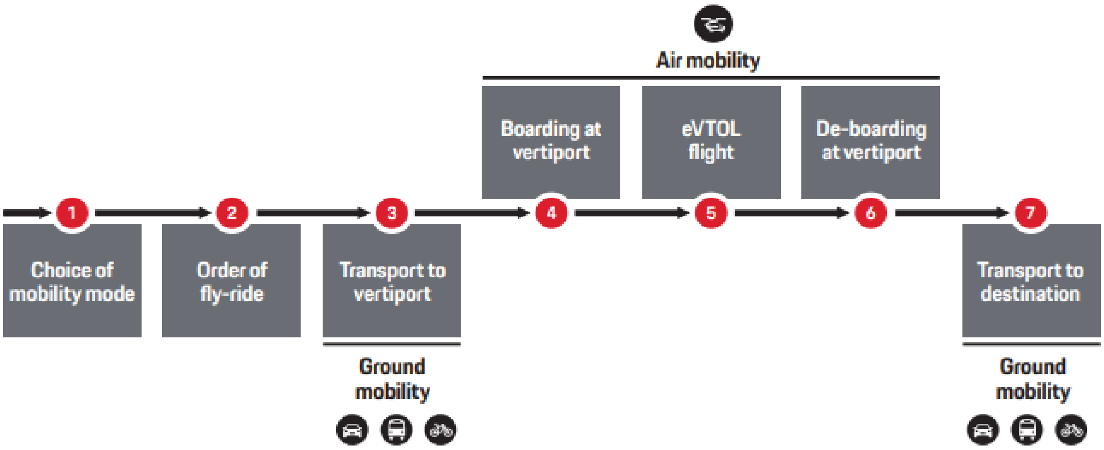


Figure 4: Combination of a VTOL service with land transport (Grandl, G. et all, 2018).

2.4 Peripherally and accessibility

The concept of peripherally is related to something (or someone) located in the periphery, that is in the limits or the circumference - in relation to a "center" (Silva, 2005).

2.4.1 A geographical approach of the periphery

From the geographical point of view, the periphericity can be considered as the location beyond the range that limits a certain area, precisely at the maximum distance from the respective geographic center. However, and in terms of 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.

In this sense, periphericity 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 periphericity is synonymous with relative accessibility - or inaccessibility - to the economic activity, as it is distributed geographically throughout the territory (Silva, 2005).

2.4.2 Economic approach of the periphery

The conditions of relative centrality or periphericity influence the industrial sector, both in terms of investment decision-making and in terms of competitive efficiency. In other words, variations in the degree of periphericity 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, taking into account technological advances in recent years, telecommunication and access to information costs are further examples of what these regions have to 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. Clearly, firms located in central regions may also incur higher costs related, for example, to labor or the value of space; conversely, those of the periphery (Silva, 2005).

2.4.3 Accessibility

The concept of accessibility is intrinsic to the concept of peripherality. Accessibility translates the relative opportunities of 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 of them important enough so that it does not go unnoticed in the approach to the theme that we intend to do (Silva, 2005).

2.4.4 Market potential

In a simplistic form, the designation of market potential is closely linked to the concept of population density (Silva, 2005).

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) we can easily conclude that a large part of the population is concentrated on the coast (with the exception of the Alentejo coast), within a territorial band covering Lisbon, Sintra, Vila Nova de Gaia and Oporto councils (INE, 2012).

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 important territorial spaces that assume certain relevance in the national context, such as Amadora and Almada (INE, 2012).

This very irregular distribution of the Portuguese population is conditioned by natural and human factors. Among the natural factors that most influence this distribution can be (Queirós, 2013):

- **The climate:** the milder and more humid climate of the coast has always been a factor of attraction for the Portuguese population since it favors the development of various human activities;
- **The relief;**
- **The fertility of the soil:** the fertile plains of the coast have always attracted the population, helping to fix it, as it facilitates the practice of agriculture and promotes the development of transport and communications.

But more than the natural factors, the human factors are the ones that best explain the regional asymmetries observed in population distribution. It is in fact on the coast that most of the cities are located, true poles of attraction and population fixation, for (Queirós, 2013):

- **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 the intense port and airport 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 **5Erro! A origem da referência não foi encontrada.**), we conclude that wealth seems to be concentrated in the central regions.

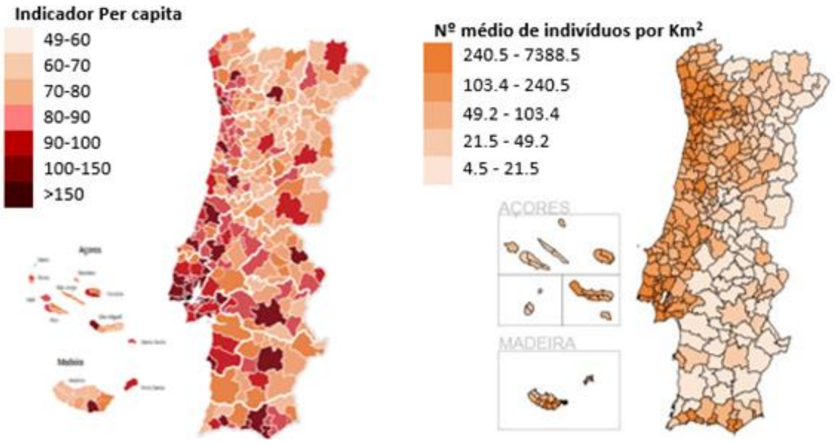


Figure 5: Distribution of Purchasing Power *per capita* by Municipality (at Left) and population density map by the municipality (at Right), in Portugal. (INE, IGP, & PORDATA, 2017; INE & PORDATA, 2016)

2.4.5 Location and access time

Until very recently, and with due regard to network failures and quality, 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, taking into account 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. Taking into account the access time, we verified the change that this parameter will operate in the traditional model of accessibility based solely on distance. Let us see: certain peripheral regions (insular regions, for example) in an analogous situation can benefit compared to others located in continental spaces; especially if insular populations use the airplane as a regular 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 terrestrial means of transport to meet their communication needs, and considerable time is required to travel - by road or by railroad. However, this does not allow us to infer that insular spaces have (always) good accessibility. As a general rule, they depend on a single mode of transport, with infrequent connections, and on a limited range of destinations (Silva, 2005).

2.4.6 Study framework

As we have previously shown, the determination of the peripherality of a region imposes not only the geographic and economic analysis of the region but also an analysis of its level of accessibility. According to the national economic and geographic context, and looking at the accessibility that each region has, we can define as peripheral regions the Portuguese interior regions and as central the Portuguese coast regions, mainly the regions of Lisbon and Oporto.

Thus, for this study we consider as central districts: Viana do Castelo, Braga, Oporto, Aveiro, Coimbra, Leiria, Lisbon, Santarém, Setúbal and Faro. Consequently the districts considered peripheral are: Vila Real, Bragança, Viseu, Guarda, Castelo Branco, Portalegre, Évora and Beja.

Peripheral districts of Portugal:

The districts that we consider peripheral, although they have a small business fabric, compared to the central districts, are of great importance in the regional and national economy. In spite of the disadvantages that companies in these regions have to compare to companies in the central regions, such as the quality of transport networks, there are advantages that are important not to forget, such as cheaper labor and the lower spaces cost.

There are many companies that, in peripheral areas, export a large part of their production. Many exports involve a large amount of business travel to the countries to which they export or may export. The major problem that companies located in these regions have is the time they take to travel to international airports, with examples of traveling time to the airport being longer than the travel time from the airport to the international destination. To eliminate this problem, it would be important to improve the quality of the transport network serving these areas. Since air transport, more specifically the fastest and most flexible executive aviation service, the creation of an air transportation service in the peripheral areas would not only lead to an increase in the companies' quality of transport but could also create a possible increase of the establishment of new companies.

2.5 Business models

The business model concept is relatively new, making its first peek at the beginning of this millennium, during the internet boom and the emerging of e-commerce transactions. Driving forces such as outsourcing and offshoring procedures, better economic perception and huge financial restructuration's also boosted business model notions (Silva, 2014).

There is no overall established theory defining business models, instead, there are several designations proposed by different authors. Some examples of new business models that emerged at the beginning of the millennium and that have changed the way business is done are:

- The Business Model for Disruption: In terms of money flow, disruptive entrepreneurs spend investors' funds until they get big enough to figure out how to generate revenue on their own, some examples of this business model users are Facebook, Twitter and Pinterest (Berry, 2012).
- The Circular Shift, from Singular to Circular. Value is created in re-use and reduction of waste and a value proposition customer are willing to pay for (Pijl, P.2019).
- OGSM: The OGSM is developed by Marc van Eck and Ellen van Zanten of Business Openers into the *Business plan on 1 page*. Translated in several languages all over the world. The foundation of Business plan on 1 page is the OGSM - Objectives, Goals, Strategies and Measures (dashboard and actions) (Story, 2015).
- Business model canvas: As Osterwalder defines, "A business model describes the rationale of how an organization creates, delivers, and capture value" (Osterwalder, 2010:14).

The business model is how an organization creates and delivers value to customers, delineating the business logic necessary to generate profit. This view is shared by several authors such as Osterwalder. Osterwalder sees business models as a collection of organizational roles, system functionalities, detailed mechanisms descriptions and relationships among parties. He introduced a detailed analysis of business models in a simplified format with the nine-block canvas proposition. According to him, the business model is commonly associated as the company's blueprint, revealing how an organization does business and interacts with other entities in order to generate profit (Osterwalder, 2010).

2.5.1 Osterwalder business model

The essence of business models is to create value for companies, customers and society. Osterwalder created an ontology for business models description, exploiting synergies and avoiding conflicts among the involved agents.

Osterwalder develops and proposes the nine blocks canvas. The business model canvas consists of nine interrelated building blocks, showing how a company or organization plans to make a profit. This canvas can be used to design business models but can also function as a diagnostic tool, helping in planning scenarios. The nine building blocks consist in (Osterwalder, 2010):

- **Customer segments:** define which clients or group of people the company intends to reach and serve with their products or services. This block is usually the starting point of designing a business model;
- **Value proposition:** describes a variety of products and services, or a combination of both, that an organization could do, creating added value to a specific customer segment;

- **Channels:** represents how an organization reaches its customer segments, delivering value propositions. Customers reach the company's products and services through communication, distribution and sales channels;
- **Customer relationships:** type of relationship that an organization wants to have with their customer segments;
- **The revenue streams:** the cash flow generated by offering a product or service to customer segments. This can be generated through asset sales, usage fees, renting or leasing;
- **Key resources:** the required assets to practice a certain business model. Through customer segments, profiting with this operation these resources allow a company to create and offer value propositions into the market;
- **Key activities:** for a business model to work, a company must produce or provide key activities to their customers that combined with key resources must offer a value proposition, reaching customer segments through channels;
- **Key partnerships:** creating strategic partnerships with important suppliers and partners enables business model's optimization, reducing risks and acquiring resources;
- **Cost:** this building block describes the most important induced costs of running a business model. To create revenues, a company must support the running costs of making and delivering products.

We chose the Osterwalder business model because this model fits well in the type of business that we intend to develop. Figure 6 shows how these blocks are organized and interconnected.

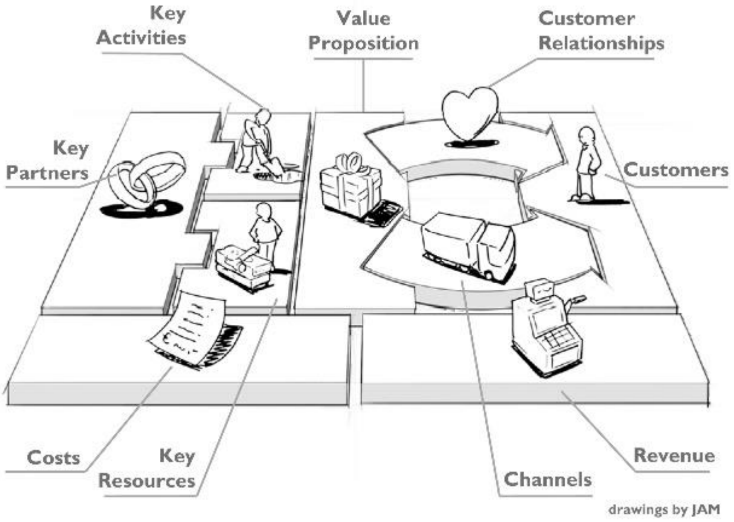


Figure 6: Osterwalder nine blocks canvas (Osterwalder, 2010).

2.6 Business plan

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 (B. Neto, C. Carvalho, and J. Silva, 2010).

In order to prepare a business plan, it is necessary to conduct at least three main studies (Pires, 2017):

- **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.

2.6.1 Market study

Surrounding environment analysis:

In the surrounding environment analysis, we can divide the surrounding environment into two means (Pires, 2017):

- **Contextual environment means:** it covers the political-legal context, the economic context, the socio-cultural context and the technological context of the country or region;
- **Transactional environment means:** constituted by the customers, the suppliers, the community and the competitors.

Market analysis:

In market analysis, the geographic area of influence (company's area of activity), the market's size and the prospects for this market (forecasting the evolution of demand) are analyzed and defined. This allows knowing not only who the customers/consumers are, the products/services, the motivation of the purchase, the size of the market, the distribution channels and the price level, but also who is the competitor, the competing products/services, market shares, distribution markets and the price and conditions of sale (Pires, 2017).

One of the most used exercises in market analysis, whether to open a new business or to define a new strategy, is Porter's Five Forces analysis that aims to evaluate the attractiveness of each specific segment, diagnose where the main competitive pressures are from and assess how strong and important each of them is. Figure 7 evidences that the five forces of this model are the supplier power, the buyer power, the competitive rivalry, the threat of substitution and the threat of a new entry (Porter, M., 1979).

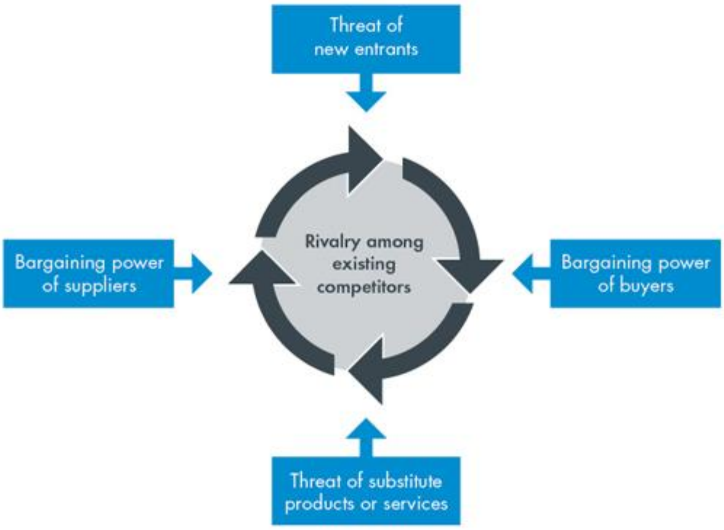


Figure 7: Porter’s five forces model (Porter, M., 1979).

Strategic analysis:

A company's strategic analysis clarifies what a company's goals, mission, and vision are, and helps the organization to make more assertive decisions, study and understand the scenario, understand its market position, and indicate how positioning and performance of the company should be.

Through Strengths, Weakness, Opportunities, and Threats (SWOT) analysis, a diagnosis is made about the company and the market where it is inserted. Created in the matrix to facilitate its elaboration, the SWOT analysis is simple and practical and measures the strengths, weaknesses, opportunities, and threats (external or internal) allowing to adopt an appropriate strategy (Pires, 2017).

Marketing plan:

The marketing plan defines how to sell the product/service that the company produces or sells. Thus, the following policies are presented (Pires, 2017):

- **Product/service:** a clear definition of the product/service that produces and/or sells;
- **Price:** definition of price and sale conditions;
- **Distribution:** definition of the distribution/sale channel;
- **Communication:** definition of the product/service dissemination way to the market.

Technical study

The organizational and Human Resources (HR) plan is the presentation of the organizational structure and planning of the HR which consists in (Pires, 2017):

- The presentation of the teamwork (number of employees, functions, and structure);

- Specifying jobs, necessary tasks, and necessary skills;
- The workers' remuneration and benefits;
- The HR policy (recruiting, selecting and hiring staff) and staff training program.

The production/operations plan consider several criteria in the (Pires, 2017):

- The decision of the location of the company (facility’s needs);
- Definition of how the manufacture of products or the provision of services is performed;
- Explanation of each of the stages of the production/service process;
- Choice of machinery, equipment, raw materials, subsidiary materials and technology to adopt;
- Schedules the project, the activities and the seasonality of the activities.

Economic-financial feasibility study

The economic-financial plan of a company begins with an investment plan, where it is necessary to define (Pires, 2017):

- **Incorporated fixed capital:** such as studies and projects, constitution expenses, patents, trademarks and licenses and training of personnel;
- **Fixed tangible capital:** such as land, buildings and facilities, machinery and equipment, cargo and transport materials, social and safety equipment.

This represents assets of a company, i.e. equity or net worth and non-equity or liabilities, which are the resources needed for a company to start and develop its activity. To finance its activity, a financial plan is drawn up which describes the financial resources needed by the company.

The sensitivity analysis consists of the construction of alternative scenarios, based on critical variables of the project, namely the sale price, the quantity of supply, changes in cost structure, changes in interest rates, inflation rate, among others (Pires, 2017).

2.7 Conclusion

Through the state of the art, we can see that the reality of mobility in Portugal is very different between regions. We have seen that on the coast the transport networks are more developed than in the interior of the country, making the interior regions of difficult and time-consuming access. In addition, in large cities, it is very common to have road congestion because of the high use of personal/private transport.

The use of small aircraft and/or VTOL aircraft will contribute to increased mobility and flexibility in Portugal. As we can verify there is no air transport network in Portugal that is able to meet the needs of companies located in peripheral and central regions.

In order to elaborate a model and business plan for the creation of a fictitious company with an air transport system through VTOL aircraft, it was important to make the state of art of these two concepts.

Chapter 3- Methodology

3.1 Introduction

Operational research translates the study and development of optimization models that support decision making. Within the extended universe of optimization models, there is a specific group of management models, called mathematical programming models, that allow determining under what conditions a given objective can be maximized or minimized given the existence of a set of limitations (Hill, M. M., and dos Santos, M. M., 2015).

The models of mathematical programming, in turn, include the linear programming models, these models are deterministic, that is, they translate a clear and unique reality, leaving no room for approximations, estimates, expected values or probabilities of occurrence (Hill, M. M., and dos Santos, M. M., 2015).

In many situations of our professional activity, whether business or not, we are faced with the need to achieve well-defined goals. However, these objectives are generally conditioned by certain limitations, in particular, the availability of the resources available to us for use. These types of situations are classic problems of linear programming. Its resolutions involve the development of an adequate process, which allows finding the maximum profit solution, according to the preferences of the manager or the shareholder of the company (Hill, M. M., and dos Santos, M. M., 2015).

3.2 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 (Arenales, M. et al, 2007).

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.

Before formulating the TSP, let's begin by introducing some basic concepts of combinatorial optimization (Arenales, M. et al, 2007).

Definition 1.1

A graph G = (V, A) is a system formed by sets V and A, where V = {v1, ..., vn} is the set of n vertices/nodes of the graph and A = {a1, ..., ap} ⊂ V × V the set of edges/arcs of the graph. When A is a set of ordered pairs, the graph is said to be oriented. If none of the elements of A is an ordered pair, the graph is said to be non-oriented.

Definition 1.2

The degree of a vertex v ∈ V, deg (v), is given by the number of edges in G connected to it. When the graph is oriented, it is called the degree of input, indeg (v), and degree of output, outdeg (v) the number of arcs entering and leaving v, respectively.

Definition 1.3

A path between two vertices vi, vj ∈ V, is a sequence of vertices and arcs < u_1, (u_1, u_2), u_2, ..., u_k > checking:

(i) $u_i \in V$, $i \in \{1, \ldots, k\}$,
(ii) $(u_i, u_i+1) \in A$, $i \in \{1, \ldots, k-1\}$,
(iii) u_1 = vi e $u_k = v_j$.

Definition 1.4

We call the path to a path in which no vertex (and hence no arc) is traversed more than once except possibly the initial and terminal vertex that may coincide, that is if $u_i = u_j$ so i = j or i = 1 and j = k. In this case, where $u_1 = u_k$, we have a cycle.

Definition 1.5

We call the Hamiltonian cycle a cycle that contains all the vertices of the graph, that is, a path of length |V| that passes through each and every vertex once.

Formulation

$$\begin{cases} x_{ij}=1 & \text{, if the arc (i,j) is the optimal TSP tour (Hamiltonian Circuit)} \\ & x_{ij}=0 \quad \text{,otherwise} \end{cases}$$

Considering the distance (or cost) associated with the arc from city i to city j, the total cost of the route is given by $\sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij}$

$$
P_A \left\{
\begin{array}{ll}
\min \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} & (1) \\
subject\ to \quad \sum_{i=1}^{n} x_{ij} = 1 \quad , i = 1, \dots , n & (2) \\
\sum_{j=1}^{n} x_{ij} = 1 \quad , j = 1, \dots , n & (3) \\
\sum_{i \in S_t} \sum_{j \in S_t} x_{ij} \leq |S_t| - 1 \quad \forall S_t \subset V : 1 < \ |S_t| < n - 1 & (4) \\
x_{ij} \in \{0,1\} \quad \forall \ i, j \in V & (5)
\end{array}
\right.
$$

Thus, the constraints (2) guarantee that from vertex i only an arc goes to some vertex j and the constraints (3) guarantee that a vertex j is accessed only by an arc coming from some vertex i. We thus have the assurance that the traveling salesman passes through all the cities once and for all. The constraints (4) guarantee that the solution does not contain several disjoint cycles covering all vertices instead of a single cycle.

The NNR was chosen for this dissertation as it delivers the minimal distance travelled.

3.2.1 The Nearest Neighbor Rule (NNR)

A node is chosen and the lesser edge incident on this vertex. This edge determines another vertex. From each new vertex, one chooses the edge of smaller weight, between the edges that are incident in this vertex and in a vertex that has not yet been chosen. In the end, it returns to the initial vertex to close the circuit. Test all possible circuits, facing each node as a possible starting vertex.

The following example illustrates a more practical application of the method.

Example: Considering five different points with the distances (in km) between them as represented in Table 2.

Table 2: Distance between points (own elaboration).

Points	A	B	C	D
A	-	4	2	1
B		-	13	9
C			-	8
D				-

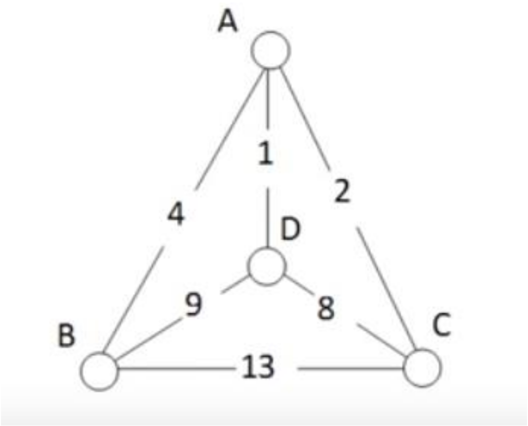


Figure 8: Distance between points (own elaboration).

Choosing, randomly, to start in point A, according to the Nearest Neighbor Rule one must check the closest distanced point - which is city D.

Then, starting from point D the next closest point is point C. When getting to point C the user goes to point B and then returns to point A to close the cycle. In Figure 9 is represented the application of the NNR to this case.

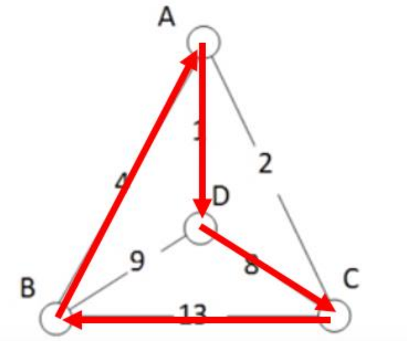


Figure 9: Representation of NNR (own elaboration).

Following the rule above, the salesman travels a total of 26 km (Figure 10).

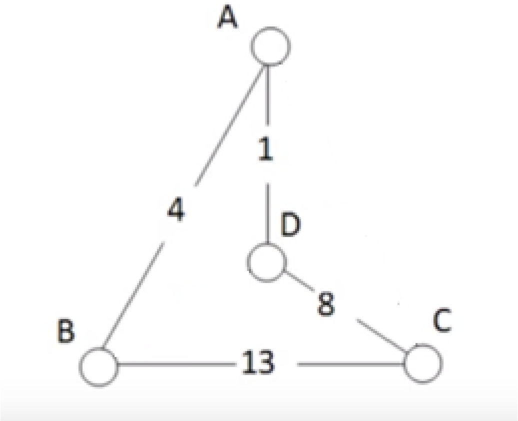


Figure 10: Solution for the placement of a depot in city 1 (own elaboration).

Based on NNR it is necessary to experiment all the points as depot-based to search for the best solution. Following we have the results for each one:

- **Start in B:** associated distances (in km) = 26 km;
- **Start in C:** associated distances (in km) = 26 km;
- **Start in D:** associated distances (in km) = 25 km.

Analyzing the results, start in point D would be ideal as he represents the shortest path. The final path is represented in Figure 11.

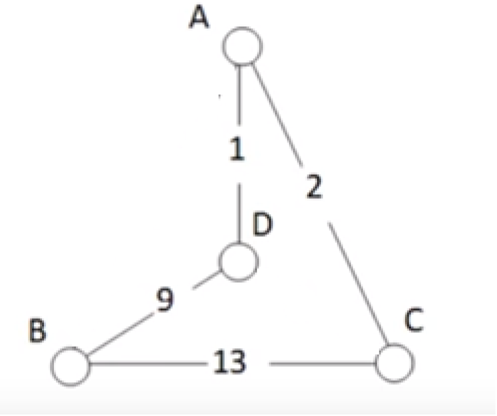


Figure 11: Final path when applied the NNR (own elaboration).

3.3 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 (Caccetta, L. and Hill, S. P., 2001):

- 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.

Formulation

We denote the depot by 1 and the set of clients' locations by C = {2,3, ..., n}. Thus, the graph G = (V, E) representing the vehicle network has V= {1,2, ..., n} and the arcs associated with the connections between the vertexes that represent the clients E= {(i,j):i,j ∈ V, i < j}.

We adopt the following notation:

- **K:** set of identical vehicles
- **Q_i:** vehicles' capacity
- **q_j:** cargo
- **P_j**: distribution points
- **P_0:** depot/warehouse
- **$C_{i,j}$**: cost/distance between points (vertexes)
- **K:** vehicle

For i, j ∈ V, our decision variables are defined as

$$x_{ij} \begin{cases} 1 \text{ if the vehicle k runs the (i,j) arc,} & \forall\, k \in K,\ \forall\, (i,j) \in E \\ \qquad\qquad 0 \text{ otherwise} \end{cases}$$

In the case of $Q_i \geq \sum q_j$ the problem is no longer a Clarke and Wright Algorithm one, but a Travelling Salesman Problem instead.

The equations associated with the resolution of this algorithm are (Arenales M., et all,2007):

$$\text{minimize} \sum_{k \in K} \sum_{(i,j) \in E} c_{ij} x_{ijk} \qquad (6)$$

Equation (6) minimizes the total routing cost/distance.

$$\textit{subject to} \sum_{k \in K} \sum_{j \in N} x_{ijk} = 1,\ \forall\ i \in C \qquad (7)$$

$$\sum_{i \in C} d_i \sum_{j \in N} x_{ijk} \leq Q,\ \forall\ k \in K \qquad (8)$$

Constraints (7) and (8) indicate that to each customer (i) a single vehicle (k) is designated and that in the total route cost the vehicle cannot exceed the (Q) vehicle's capacity.

$$\sum_{i \in N} x_{ihk} - \sum_{j \in N} x_{hjk} = 0, \qquad \forall\ h \in C, \forall\ k \in K \qquad (9)$$

$$\sum_{i \in N} x_{ihk} - \sum_{j \in N} x_{hjk} = 0,\ \forall\ h \in C, \forall\ k \in K \qquad (10)$$

$$\sum_{i \in N} x_{i,n+1,k} = 1, \ \forall \ k \in K \qquad \textbf{(11)}$$

$$\sum_{i \in S} \sum_{j \in S} x_{ijk} \leq |S| - 1, S \subset C, 2 \leq |S| \leq \left[\frac{n}{2}\right], \ \forall k \in K \qquad \textbf{(12)}$$

The (9), (10) and (11) constraints assure that each vehicle (k) starts its path at the depot (vertex 0) only once and that only leaves the (h) vertex if and only if it enters that same vertex and returns to the depot.

The last constraint (12) guarantees the non-existence of sub-routes.

The following example best explains this algorithm.

Example:

Considering A as a deposit and that a vehicle must attend cities B to F, the red numbers (Figure 3.5) stand for the demand of each city, and that there is only one vehicle with a capacity of 5 people. Thus Table 3 depicts the costs (distances) from the deposit to each city.

Table 3: Costs of traveling from each city to another(own elaboration).

	A	B	C	D	E	F
A		28	21	14	17	28
B			47	36	25	37
C				26	37	30
D					15	37
E						39
F						

Figure 12 illustrates the costs of traveling from each city to the deposit.

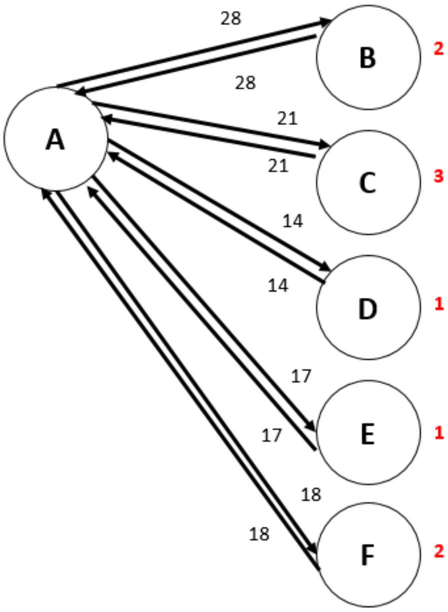


Figure 12: Costs of traveling from each city to the deposit (own elaboration).

The algorithm calculates how much is the saving to joint the depot (always) with each (every possible) pair of cities in the same route.

For this example, the equations and the related costs/distance savings obtained are as follows:

C_{BC} = 28+21-47 = 2

C_{BD} = 28+14-36 = 6

C_{BE}= 28+17-25 = 20

C_{BF}= 28+18-37 = 9

C_{CD}= 21+14-16 = 9

C_{CE} = 21+17-37 = 1

C_{CF}= 21+18-30 = 9

C_{DE}= 14+17-15 = 16

C_{DF}= 14+18-31 = 1

C_{EF}= 17+18-29 = 6

The largest cost reduction is grouping cities B and E, and as demand for both (3) is lower than the vehicle capacity (5), then this link is reliable. As it is still possible to add a new connection, according to this algorithm we add the city D, getting the vehicle crowded (5 passengers). This way you cannot add another city. In this way, the remaining cities E and F, together with the deposit A, form a circuit/route.

Figure 13 depicts the result.

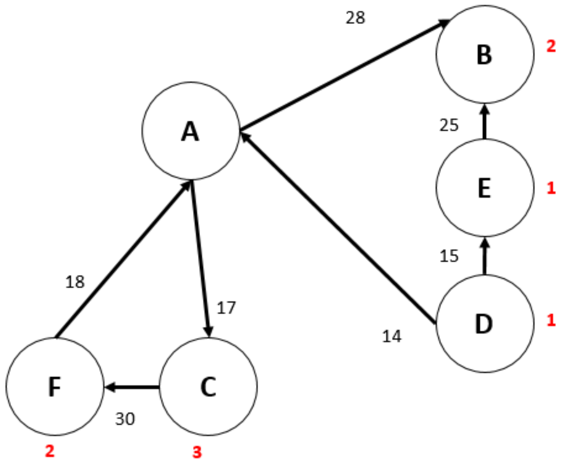


Figure 13: Results from implementing the Clarke and Wright algorithm (own elaboration).

The subcircuit cost involving the depot and cities B, E and D means 82 km, the subcircuit cost involving the depot and cities F and C mean 65 km. Thus, the total cost will be 147 km. If the application of the algorithm resulted anywhere in a set of more than two cities and the depot, with is the case, then it could also be used the TSP/NNR (for example).In this case applying the NNR, the result is the same as shown in Figure 13.

3.4 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 in (c) with each one of the other equipment;
- If any cost/change is compensating (a negative value), we admit installing this new equipment too.

Formulation

We adopt the following notation:

- ***s:*** total number of types of facilities (or services);
- ***n:*** total number of possible locations;
- ***mk:*** number of facilities of type k, to be leased ($k = 1, 2, \ldots, s$);
- a_{ik}: number of individuals residing at location i ($i = 1, 2, \ldots, n$), which require service type k ($k = 1, 2, \ldots, s$);
- d_{ij}: distance between location i ($i = 1, 2, \ldots, n$) and the location j ($j = 1, 2, \ldots, n$).

For i, j our decision variables are defined as

$$x_{ij}\begin{cases}1 & \text{if the individuals in the location i (i=1,2,..., n) and service requester k(k=1,2, ..., s),}\\ & \text{are assigned to the location j (j=1,2, ...,n), where a type of installation k is located,}\\ & \text{0 otherwise}\end{cases}$$

The equations associated with the resolution of this algorithm are (Nunes, 2002):

$$\text{minimize} \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij} \sum_{k=1}^{S} a_{ik}\, x_{ijk} \qquad (\mathbf{13})$$

The objective function (13) minimizes the sum of the distances multiplied by the respective searches.

$$\textit{subject to} \sum_{k=1}^{S} x_{ijk} \leq 1, i = 1,2, \dots, n; j = 1, 2, \dots, n \qquad (\mathbf{14})$$

Constraint (14) ensures that customers requiring different types of services cannot obtain these services in the same installation.

$$\sum_{j=1}^{n} x_{ijk} = 1, i = 1, 2, \dots, n;\ k = 1, 2, \dots, s \qquad (\mathbf{15})$$

Equation (15) ensures that each service of each customer will be serviced by exactly one installation.

$$x_{jjk} \geq\ x_{ijk}\ , i = 1,2, \dots, n; j = 1, 2, \dots, n;\ k = 1, 2, \dots, s \qquad (\mathbf{16})$$

The equation (16) avoids the possibility of assigning individuals residing in a location i and requesting a type of facility k, to a location j, where there is no such facility.

$$\sum_{i=1}^{n} x_{ijk} = m_{k},;\ k = 1, 2, \dots, s \qquad (\mathbf{17})$$

$$x_{jjk} = 0,1\ , i = 1,2, \dots, n; j = 1, 2, \dots, n;\ k = 1, 2, \dots, s \qquad (\mathbf{18})$$

The constraints (17) specify the number of facilities that should be designated in the n possible locations and the constraints (18) indicates the binary variables.

Example:

Considering:

- **m**: the number of customers;

- **n**: the number of possible locations for the installation of the equipment (or services);
- **d:** the cost of moving the customers to the places where the equipment is installed;
- **c:** the cost of installing the equipment in the locations.

Thus, considering:

- m (clients) = 6;
- n (locations) = 4;
- f (installation cost) = [3 2 2];
- D (distances) is represented in Table 4.

Table 4: Table of costs of distances and installation of equipment (own elaboration).

		Installation (n)		
		1	**2**	**3**
Clients (m)	**1**	6	6	5
	2	6	8	0
	3	8	6	3
	4	6	0	6
	f	3	2	2

To find the permissible solution for the compensation heuristics:

- **Location in 1** = 3 + (6+6+8+6) = 29
- **Location in 2** = 2 + (6+8+6+0) = 22
- **Location in 3** = 2 + (5+0+3+6) = 16

We allowed to build the equipment in 3.

Change customers from 3 to 1:

- C_1 = 3 + (6-5) = 4
- C_2 = 3 + (6-0) = 6
- C_3 = 3 + (8-3) = 8
- C_4 = 3 + (6-6) = 3

Change customers from 3 to 2:

- C_1 = 2 + (6-5) = 3
- C_2 = 2 + (8-0) = 10
- C_3 = 2 + (6-3) = 5
- C_4 = 2 + (0-6) = - 4

As C4 ≤ 0 then compensates for changing from 3 to 2.

The permissible solution is shown in Figure 14. The total cost (C_T) adds up to the cost of installing the equipment with the cost of travel, in this example:

$$C_T = (2 + 2) + (5 + 3) = 12$$

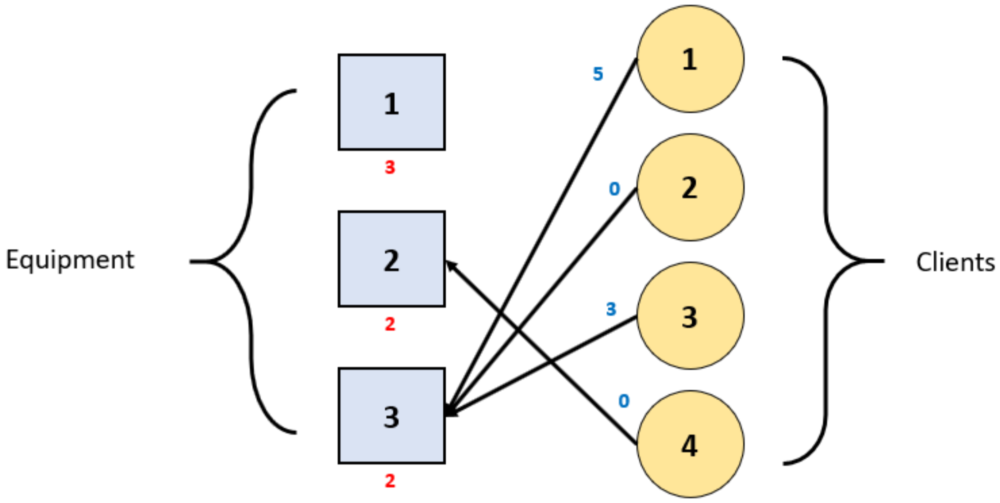


Figure 14: Permissible solution using compensation heuristics (own elaboration).

3.5 Conclusion

Combinatorial optimization problems arise everywhere, and certainly in all areas of technology and industrial management. A growing awareness of the importance of these problems has been accompanied by a combinatorial explosion in proposals for their solution.

The compensation heuristics, the traveling salesman problem and the Clarke and Wright algorithm are the tools we will need to solve the problem of the case study. Although these have different applications in different scenarios, they can be implemented together in order to optimize a route and a location problem with multiple choice.

Chapter 4 – Case study

4.1 Introduction

The need for man to move more and more quickly has been the main driver of the advancement of technology associated with the means of transport and their networks. Mobility is an intrinsic factor for economic, social and scientific development and so in this chapter, we present a concept that will revolutionize the way we currently move.

The case study of this work consists of the creation of an aviation service using VTOL aircraft, besides the creation of the service and the elaboration of a business model and plan; also two applications were developed that will facilitate the flight marking and the optimizations of the routes, calculating the lowest cost and price, the shortest distance and time of each trip.

4.2 Service characterization

4.2.1 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 (yet 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.

***Air budJets* services:**

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), using VTOL aircraft between any locations that have the proper characteristics to land this type of aircraft.

- **Flights of very short distances (less than 100 km);**
- **Short-haul flights (between 100 and 300 km);**

The next examples can help to understand these services:

- **For the first 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 27 minutes). Figure 15 shows the routes for this example.

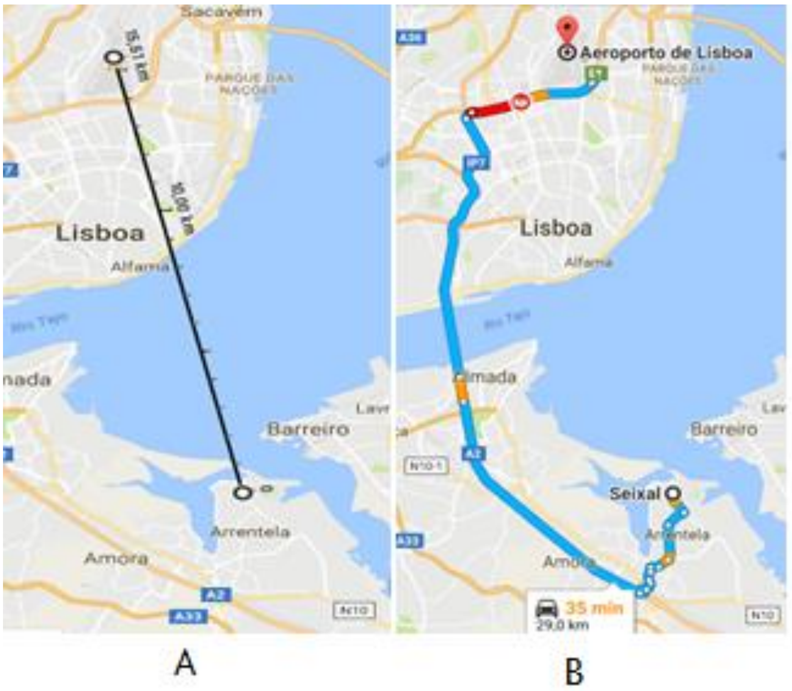


Figure 15: Travel between Seixal and Lisbon airport by *Air budJets* (A) and by car (B) (own elaboration).

- **For the second 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 100 minutes). Figure 16 shows the routes for this example;

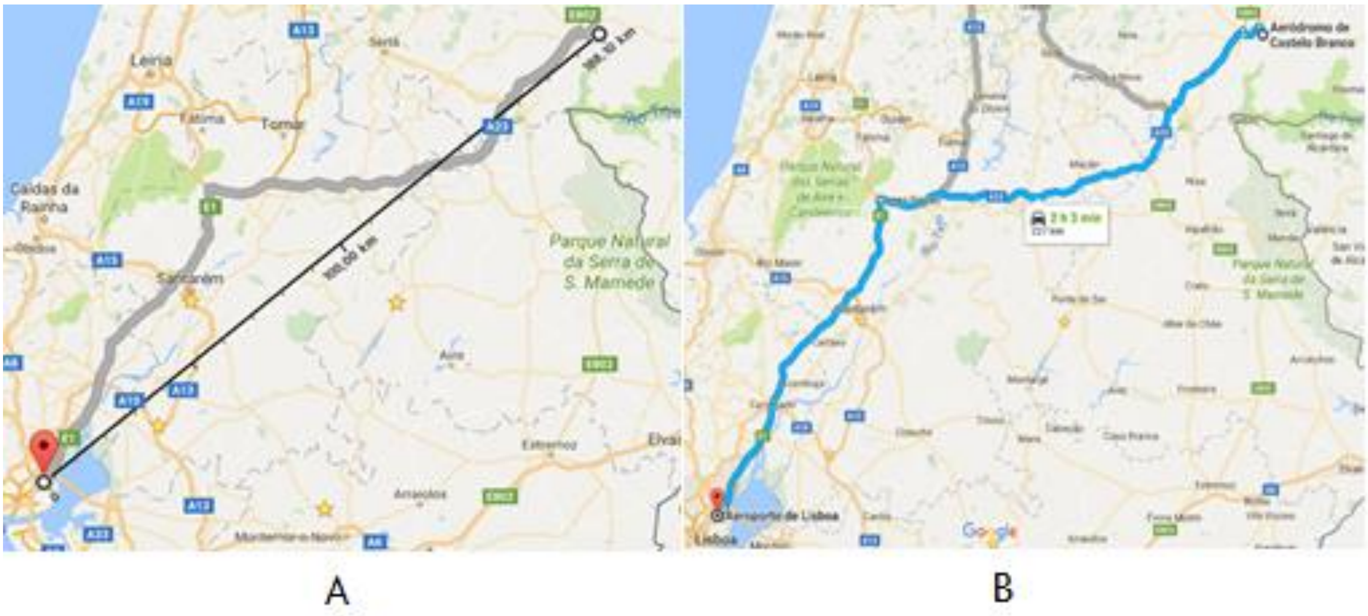


Figure 16: Travel between Castelo Branco and Lisbon airport by *Air budJets* (A) and by car (B) (own elaboration).

4.2.2 Vehicle:

A 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 (Lilium GmbH, 2018).

The Lilium Jet (Figure 17) 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 (Lilium GmbH, 2018).

Figure 17: Lilium Jet aircraft (Lilium GmbH, 2018).

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 (Lilium GmbH, 2018).

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 (Lilium GmbH, 2018).

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 (Lilium GmbH, 2018).

Engines:

The electric jet engines (Figure 18) work like turbofan jet engines in a regular passenger jet. They suck in air, compress it and push it out the back. However, the compressor fan in the front is not turned by a gas turbine, but by a high-performance electric motor. Therefore, they run much quieter and completely emission-free (Lilium GmbH, 2018).

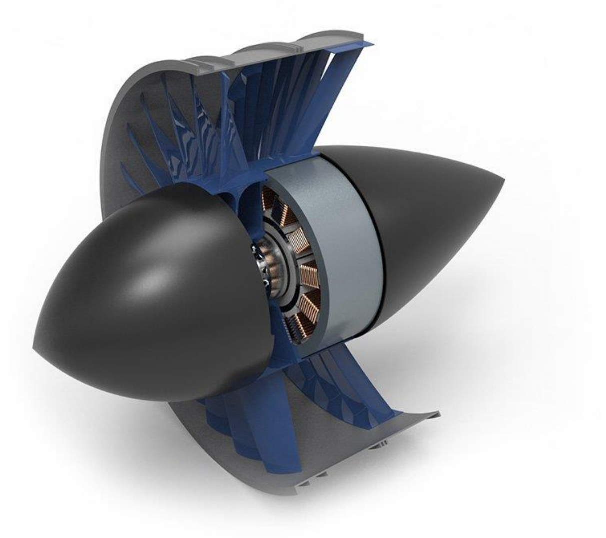


Figure 18: Electric jet engines (Lilium GmbH, 2018).

The Lilium Jet engines have only one moving part - the central shaft of the rotor holding both the fan in the front and the magnets of the electric motor. This ensures the highest reliability in operation and low maintenance costs of the propulsion system. The high redundancy of the system allows large inspection intervals to keep costs much lower than for helicopters or reciprocating engines (Lilium GmbH, 2018).

The large open rotors of a helicopter induce vibrations into the cabin. The whole vehicle vibrates in the frequency of the rotor blades passing. The Lilium Jet's electric jet engines, however, run smoothly. This ensures a quality passenger experience during the entire flight. Likewise, a big advantage of electric jet engines is their low noise signature for people on the ground (Lilium GmbH, 2018).

Safety:

In order to make these aircraft safety levels higher than road transport and similar to current air transport, it is necessary to take measures to ensure that these aircraft have such safety levels. Therefore, Lilium Aviation has the following characteristics in its Lilium Jet aircraft (Lilium GmbH, 2018):

- **Ultra-redundancy**: Lilium Jet is equipped with small independent components, so that, for example, a single engine failure does not have consequences for the aircraft's safety or stability. The system can still do a vertical landing with a loss of multiple engines. This philosophy of redundancy has been applied to all flight systems. Figure 19 helps to understand this concept;

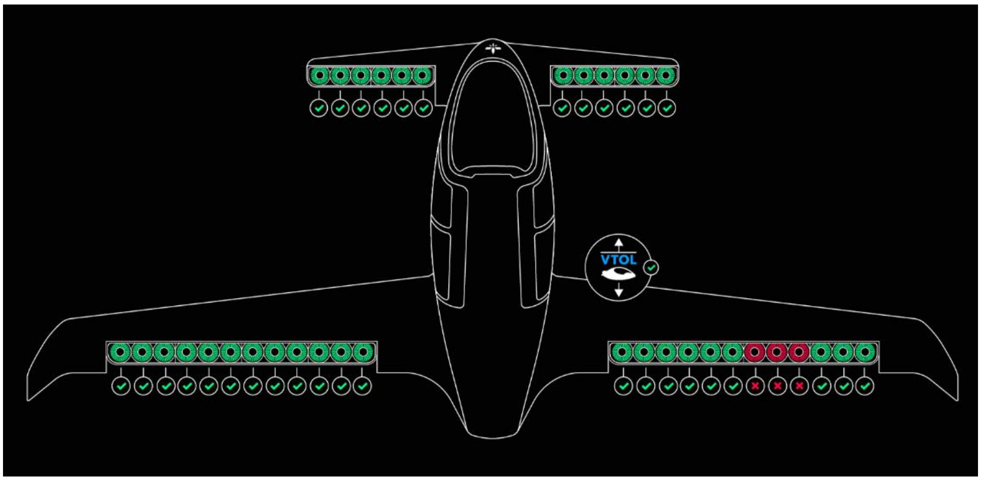


Figure 19: Example of Ultra-Redundancy (Lilium GmbH, 2018).

- **Flight envelope protection:** the Lilium Jet is a full fly-by-wire system. This means a set of fully redundant computers are flying the airplane and controlling all functions of the engines and actuators always. The pilot commands high-level directions with a joystick, which the computer puts into action. This makes flying a Lilium Jet as easy as steering a toy quadcopter. Furthermore, the system has a built-in flight envelope protection: meaning that even if the pilot requests a dangerous maneuver, the computer does not exceed safety limits of speed, roll, and pitch;
- **Shielded engines:** electric jet engines also excel in safety. The duct around the fan is designed to contain the loss of a fan blade at full power. If an engine fails, for example, due to the ingestion of a foreign object, it is guaranteed that this event does not cause the adjacent engine to fail as well. The only way to prevent a cascade effect, in case of a blade loss event, is by using shielded engines;
- **Failsafe batteries:** the Lilium Jet's battery pack is comprised of several thousand Lithium-Ion cells like those in electric cars. It is designed to fully contain a thermal runaway of several cells while still delivering enough power to the propulsion system. To achieve this, it is built with many independent parallel strings of cells ensuring multi-redundancy also on the energy supply;

- **Parachute**: (represented in Figure 20) in case all precautions won't help, and a regular landing is impossible, there is still a safety net. Every Lilium Jet is equipped with a full aircraft parachute – bringing the jet safely down to the ground if necessary. The cabin is water-resistant in case of descending onto the water.

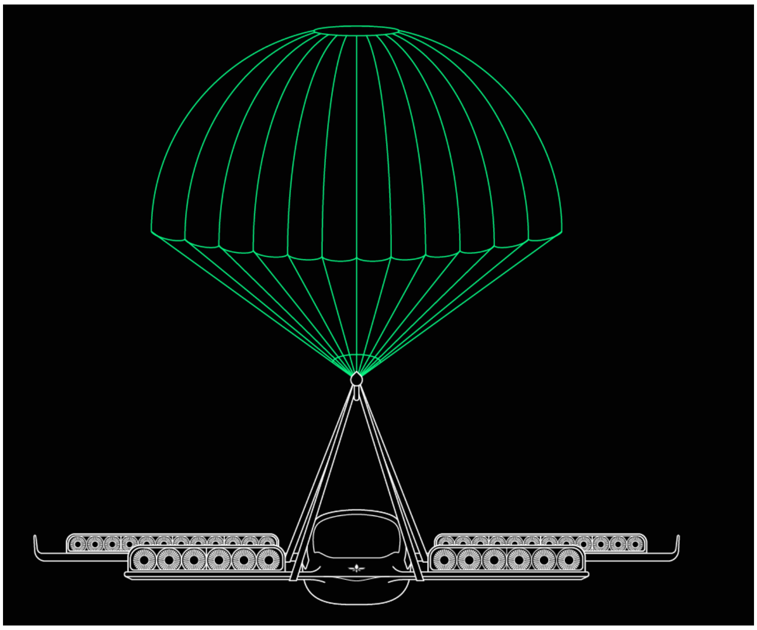


Figure 20: Example of the use of the parachute (Lilium GmbH, 2018).

Comfort:

The Lilium Jet features elegant gull-wing doors. This enables easy boarding and exit - it also lets everyone literally slide into the comfortable seats the way we would in a premium car. Once in the jet, passengers can easily store their luggage under their seat or in the trunk behind them. There is enough legroom even for tall passengers, and the huge panoramic window ensures an almost 360° view (Lilium GmbH, 2018).

4.2.3 Overall characteristics:

Table 5 contains the most important specs for the Lilium Jet - which must be used for our case study.

Table 5: Detailed technical data from Lilium Jet (adapted from (Lilium GmbH, 2018).

Capacity	**5 people**
Length	Not available
Wingspan	Not available
Height	Not available

Max gross take-off Weight	640 kg
Propulsions	36 ducted fans
Cruise Speed	300 km/h
Endurance	300 km
Power type	Electric/batteries

4.2.4 Routes:

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. In Figure 21 we observed the location of these regions.

Figure 21: Regions of Portugal used for the study (own elaboration).

Table 7 and Table 8 contain the straight-line distance between several places within each of these three regions. These places/locations are possible important ones, and may be replaced by others, or even it is possible to add others to these sets. The information was collected directly through the Google Maps web page.

Table 6: Distances between each point in the Lisbon region in a straight line in km (own elaboration).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Airport		23.0	18.1	26.9	21.0	5.07	3.66	14.1	30.8	37.3	16.3	11.8	15.8
2. Vila Franca de Xira			40.1	47.2	37.8	28.1	22.7	33.7	43.7	57.7	28.1	34.5	36.3
3. Oeiras				9.4	13.1	13.6	20.3	20.6	38.4	33.4	29.5	12.3	19.8
4. Cascais					12.3	22.8	29.5	30.2	47.1	39.5	38.9	22.6	29.1
5. Sintra						19.7	24.7	31.2	48.7	46.7	36.8	23.4	30.5
6. Sete Rios							6.9	11.8	29.7	33.5	17.2	7.2	12.6
7. Parque das Nações								12.1	27.6	36.1	12.6	12.1	14.2
8. Barreiro									18.2	24.3	10.2	7.7	2.7
9. Palmela										22.1	16.3	25.5	18.6
10.Sesimbra											30.9	26.2	21.9
11.Montijo												16.8	12.9
12.Almada													6.9
13.Seixal													

Table 7: Distances between each point in the Oporto region in a straight line in km (own elaboration).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Airport		50.2	37.8	37.4	47.37	49.4	31.9	12.2	15.7	27.9	38.5	41.7	25.1
2. Viana do Castelo			38.4	52.8	61.6	78.7	71.4	63.1	67.5	81.4	89.6	63.7	59.0
3. Braga				16.7	23.6	42	39.7	46.3	49.9	63.3	71.2	26.8	29.3
4. Guimarães					9.2	26.3	26.6	42.3	45.6	57.2	62.8	11.6	19.2
5. Fafe						21.8	29.3	50.6	51.3	63.7	65.8	9.7	25.9
6. Amarante							19.5	46.7	47.4	55.6	54.2	14.7	24.8
7. Penafiel								30.3	29.2	37.2	37.3	19.6	10.7
8. Porto									4.7	17.4	27.1	42.6	25.2
9. Vila Nova de Gaia										13.9	21.8	43.7	24.2
10. Espinho											11.1	55.6	38.9
11. Santa Maria da Feira												57.15	42.0
12. Felgueiras													17.7
13. Paços de Ferreira													

Table 8: Distances between each point in the Coimbra region in a straight line in km (own elaboration).

	1	2	3	4	5	6	7	8
1. Pombal		31.6	32.5	16.4	58.3	39.3	48.2	29.9
2. Figueira da Foz			32.8	20.6	68.6	51.7	30	12.5
3. Coimbra				21.4	33.6	16.9	23.9	25.4
4. Soure					52.9	31.8	32.7	14.1
5. Arganil						20.4	49.9	55.8
6. Lousã							40.9	40.7
7. Cantanhede								21.5
8. Montemor-o-Velho								

4.2.5 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 225m2. 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 (Holden, J., & Goel, N., 2016):

- **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. This calculation is given in Annex 1.

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 also their suitability over other means of transport.

Thus, it was possible to determine that the best location of *Air budJets* base/vertiports parking spots for the regions of:

- **Lisbon:** Almada;
- **Oporto:** Penafiel;
- **Coimbra:** Coimbra.

4.2.6 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 in order 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.

The flowchart explaining the application methodology for the client is shown in Figure 22, and Figure 23 explains the methodology of the application that the company will use to optimize the routes.

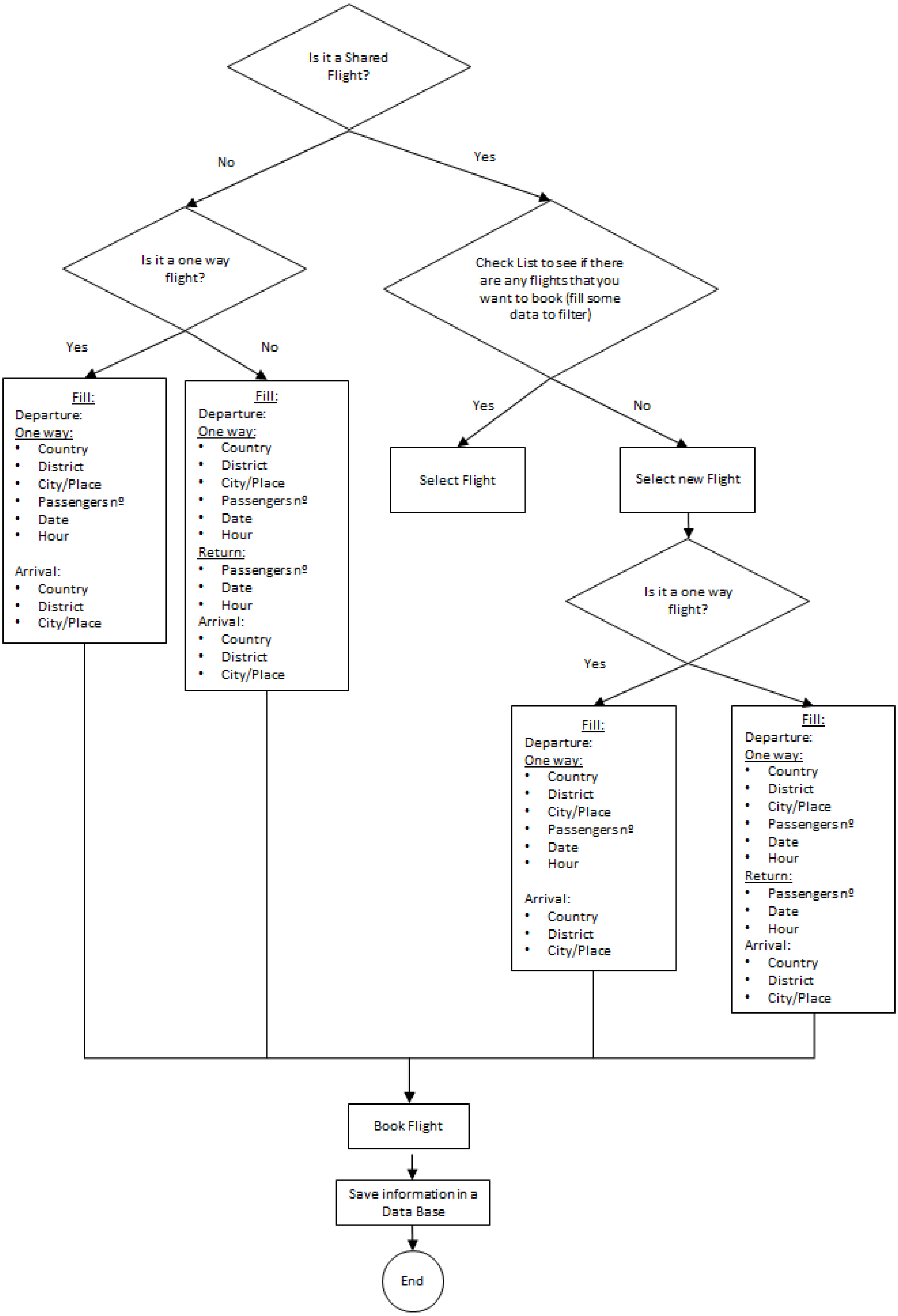


Figure 22: Client APP flowchart (own elaboration)

After entering data, the flight is reserved, and the information entered by the customer/passenger will be stored. The application that will help the company in the process of optimizing routes and costs will compare the records of the information introduced and verify if there is a possibility of sharing a flight between passengers (if they choose to have shared flight preference, and the total number of passengers is less than 4); then a shared flight proposal is sent to the customer, with the information of departure time and estimated time of arrival.

The sharing criterion still has attention to flight time, i.e. one flight is only considered compatible with sharing with another if the flight hours range is less than 30min in small flights and 3h in long-range flights.

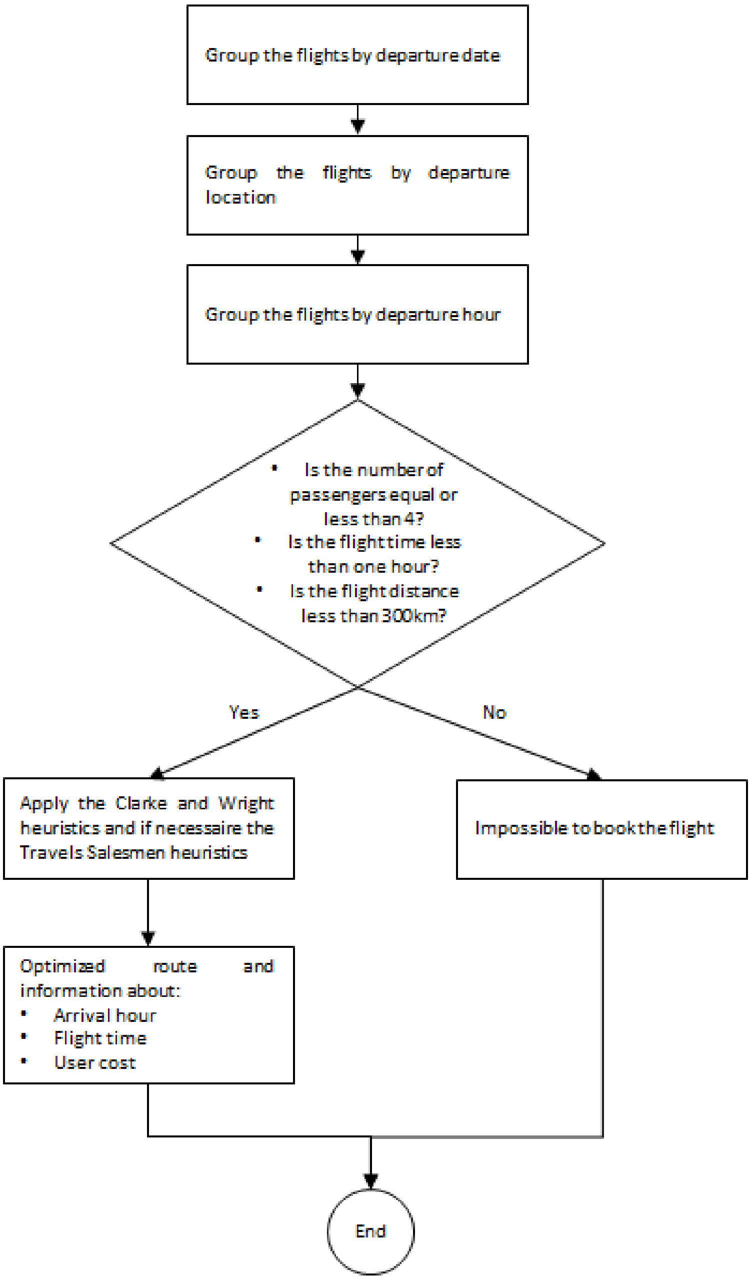


Figure 23: *Air budJets* routes optimization app basic flowchart (own elaboration).

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 between the regions of Porto, Coimbra, and Lisbon with other cities of Portugal, and several cities of 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 24.

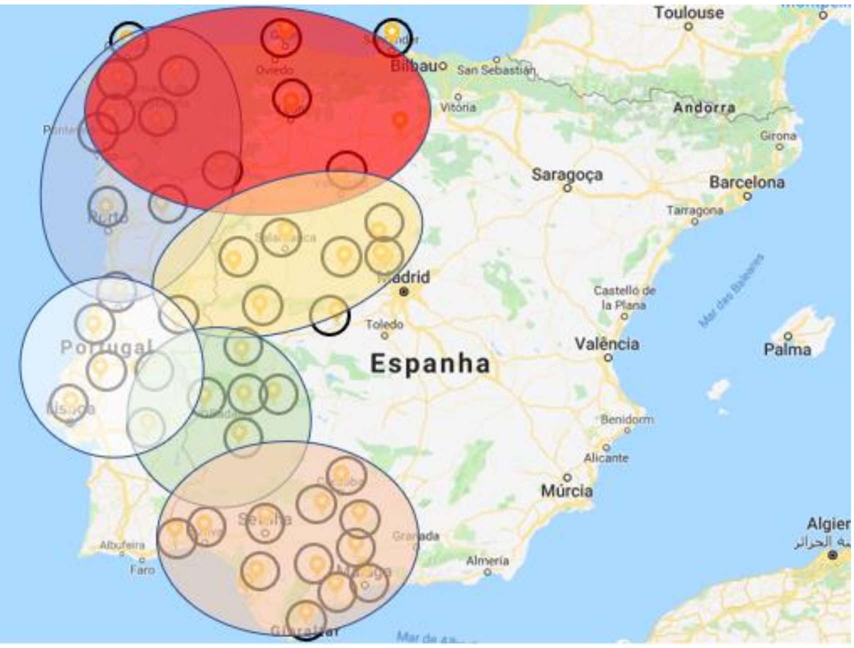


Figure 24: Mapping of routes with a distance greater than 100km from *Air budJets* (own elaboration).

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.

Table 9 indicates the distances between the bases of the regions of Coimbra, Oporto, and Lisbon to the outlying cities of Bragança, Covilhã, Évora, and V.R.S.A., and the distances between them and their respective connections in Portugal and Spain too.

Table 9: Distances between the various Portuguese and Spanish cities (own elaboration).

Vertiports parking spots	Connections	Distance (km)
Oporto (Penafiel)	Bragança	144,7
	Covilhã	123,1

	Coimbra	103,62
	Ourense	116,67
	Vigo	122,9
	Pontevedra	140,0
	Santiago Compostela	189,2
	Corunha	241,6
	Lugo	212,0
	Aveiro	69,6
Coimbra (Coimbra)	Covilhã	78,7
	Aveiro	54,0
	Oporto	103,62
	Leiria	60,0
	Santarém	110,0
	Lisbon	180,0
Lisbon (Almada)	Covilhã	228,7
	Évora	109,2
	Santarém	75,1
	Leiria	122,3
	Coimbra	180,0
Bragança	Ourense	111,9
	Vigo	168,0
	Pontevedra	168,9
	Santiago Compostela	189,2

	Corunha	214,3
	Lugo	149,4
	Gijón	209,1
	León	125,2
	Santander	280,5
	Burgos	258,3
	Valadoli	170,2
	Collado Villalba	263,5
	Segóvia	241,4
	Salamanca	129,6
	Porto	144,7
	Vila Real	98,5
	Viseu	162,6
	Covilhã	179,8
Covilhã	Viseu	54,7
	Lisbon	228,7
	Oporto	123,1
	Bragança	179,8
	Cidade Rodrigo	88,17
	Salamanca	172,4
	Ávila	243,5
	Talavera de la Reina	225,4
	Mérida	174,3

	Badajoz	165,4
	Don Benito	201,7
	Segóvia	280,8
	Guadarrama	287,8
	Cáceres	128,4
	Plasencia	122,3
	Portalegre	109,0
	Évora	196,2
Évora	V.R.S.A.	156,3
	Beja	62,7
	Portalegre	90,3
	Covilhã	196,2
	Lisbon	109,2
	Huelva	170,8
	Zafra	131,2
	Córdoba	284,3
	Jerez	260,8
	Écija	271,8
	Plasencia	223,7
	Badajoz	94,6
	Cáceres	161,8
	Sevilha	213,7
	Mérida	141,8

	Don Benito	182,7
V.R.S.A.	Évora	156,3
	Huelva	42,7
	Sevilha	129,1
	Jerez	128,5
	Córdoba	241,2
	Marbella	238,9
	Gibraltar	216,2
	Málaga	266,4
	Antequerra	252,6
	Lucena	261,2
	Cádiz	133,7
	Écija	212,2
	Ronda	207,1

Cities with vertiports parking spots, that is, vertiports with the capacity not only to recharge the batteries of the aircraft but also to park them, are the following:

- Penafiel;
- Coimbra;
- Almada;
- Vila Real de Santo António;
- Évora;
- Covilhã;
- Bragança.

In order to recharge the aircraft to be able to return to the respective vertiport parking spot. So, all locations that are more than 150 km from vertiports parking spot have the possibility of recharging the batteries and back.

In order 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, the following cities with vertiports were selected:

- Corunha;
- Ourense;
- Gijón;
- Santander;
- Burgos;
- Valladolid;
- Salamanca;
- Segóvia;
- Guadarrama;
- Mérida;
- Córdoba;
- Jerez;
- Plasencia;
- Sevilha;
- Talavera de la Reina.

4.3 *Air budJets* business model

As described in the characterization of the service, we intend with this study to create a company that, through the use of VTOL's aircraft, increase mobility with passenger transportation.

Based on Figure 6, we have filled out the information required to produce an *Air budJets* business model canvas, as in Figure 25.

Customer segments:

This component of canvas defines the different groups of people or organizations that a company seeks to reach and serve (Osterwalder, 2010). 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.

In Figure 25, the customer segment is filled with the target customers that this business wants to achieve.

Value propositions:

The value proposition component describes the set of products and services that create value for a specific Customer Segment (Osterwalder, 2010). 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 described in Figure 25 and 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. Channels serve a variety of functions, including broadening customer insight into the company's products and services, helping customers evaluate a company's Value Proposition, enabling customers to purchase specific products and services, and providing customer support after purchase (Osterwalder, 2010). 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. Relationships can range from personal to automated. Customer relationship can be driven by customer acquisition, customer retention, and increased sales.

Customer relationships will be made through dedicated personal assistance, automated services such as a website and an app.

Key resources:

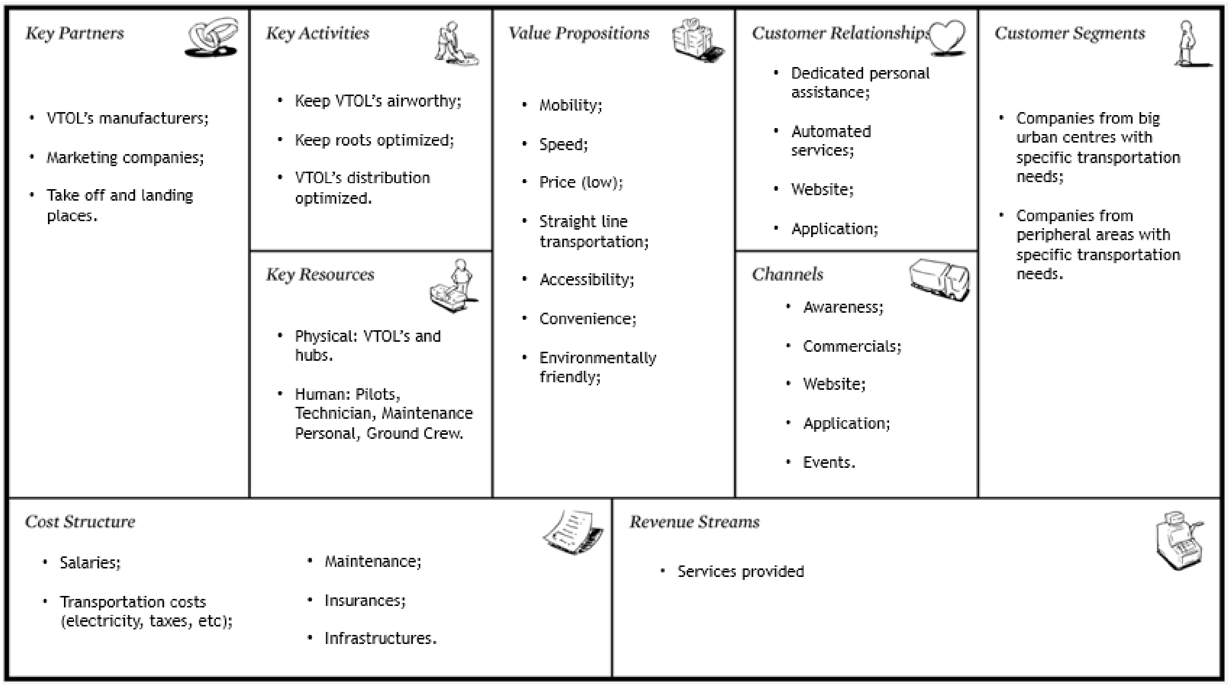
This building block states the most crucial assets to make the business model function, this is, the resources for the company to create and offer a value proposition, reach markets, maintain relationships with customer segment and earn revenues. They can be characterized as physical, human, intellectual, and financial. In this business model, the resources are mainly physical and human, and thus both resources are detailed in Figure 4.11; the physical resources contain vehicles and infrastructures so that VTOL's and hangars were included here. 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. And, just like key resources, key activities differ depending on the type of business model. 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.



Key Partners

- VTOL's manufacturers;
- Marketing companies;
- Take off and landing places.

Key Activities

- Keep VTOL's airworthy;
- Keep roots optimized;
- VTOL's distribution optimized.

Key Resources

- Physical: VTOL's and hubs.
- Human: Pilots, Technician, Maintenance Personal, Ground Crew.

Value Propositions

- Mobility;
- Speed;
- Price (low);
- Straight line transportation;
- Accessibility;
- Convenience;
- Environmentally friendly;

Customer Relationships

- Dedicated personal assistance;
- Automated services;
- Website;
- Application;

Channels

- Awareness;
- Commercials;
- Website;
- Application;
- Events.

Customer Segments

- Companies from big urban centres with specific transportation needs;
- Companies from peripheral areas with specific transportation needs.

Cost Structure

- Salaries;
- Transportation costs (electricity, taxes, etc);
- Maintenance;
- Insurances;
- Infrastructures.

Revenue Streams

- Services provided

Figure 25: Business model canvas filled (own elaboration).

4.4 Business plan

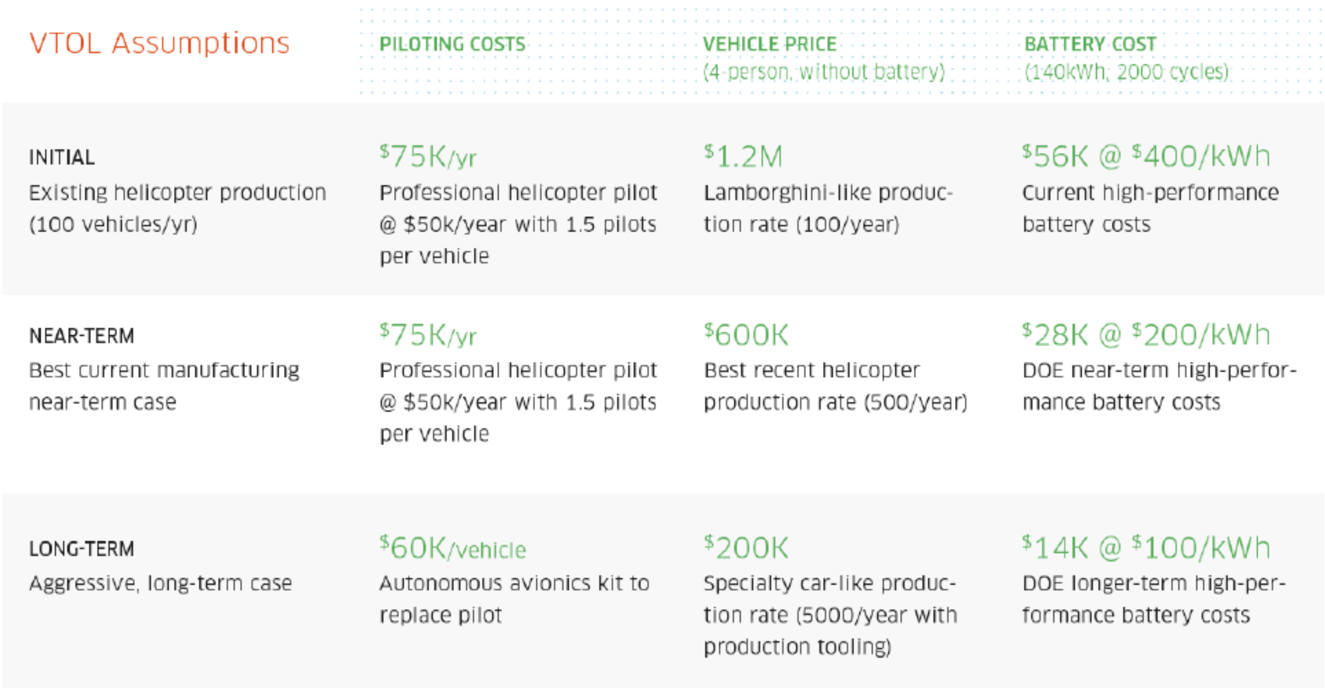
4.4.1 Cost structure

It was developed a set of attributes that define a VTOL for the purposes of our model and the assumptions surrounding those attributes. In our business plan, we assume that a VTOL includes:

- **Capacity:** 5-place capacity (including the pilot);
- **Load factor:** pooling match rates will allow for an average of 67% of revenue producing seats to be filled by a paying passenger;
- **Gross vehicle weight:** 640 kg;
- **Batteries:** 400 Wh/kg specific energy batteries at the pack level with 2,000 cycle life;
- **Power:** 500 kW short-term takeoff power with 1 minute of full power at takeoff and landing, 88,3 kW power required at 300 km/h;
- **Utilization:** After four years we expect 2080 hours of annual utilization;
- **Electricity cost:** 0,14€ per kWh in electricity cost (PORDATA, 2017).

In addition to the assumptions above, Table 10 shows three cases to explore sensitivities for time-based assumptions across piloting, vehicle price and battery cost.

Table 10: Three cases to explore sensitivities for time-based assumptions across piloting, vehicle price and battery cost (Holden, J., & Goel, N., 2016).



VTOL Assumptions	PILOTING COSTS	VEHICLE PRICE (4 person, without battery)	BATTERY COST (140kWh, 2000 cycles)
INITIAL Existing helicopter production (100 vehicles/yr)	$75K/yr Professional helicopter pilot @ $50k/year with 1.5 pilots per vehicle	$1.2M Lamborghini-like production rate (100/year)	$56K @ $400/kWh Current high-performance battery costs
NEAR-TERM Best current manufacturing near-term case	$75K/yr Professional helicopter pilot @ $50k/year with 1.5 pilots per vehicle	$600K Best recent helicopter production rate (500/year)	$28K @ $200/kWh DOE near-term high-performance battery costs
LONG-TERM Aggressive, long-term case	$60K/vehicle Autonomous avionics kit to replace pilot	$200K Specialty car-like production rate (5000/year with production tooling)	$14K @ $100/kWh DOE longer-term high-performance battery costs

Vehicle operation:

The maintenance of the vehicles is a fundamental assumption in the economic and operational models. Electric vehicles have very low direct operating costs because of their low power consumption, but their recharging plays a significant role in the number of hours that VTOL is available to fly. Assuming that the vehicle is capable of flying 50% of the time between 7 am and 11 pm every day of the week (8 hours a day), and that of the 365 days in a year approximately 100 days will be reserved for maintenance, recharging batteries (i.e. 260 operable days per year) then we assume that for a VTOL, 2080 hours can be operated in a year.

As in the initial launch phase of *Air budJets* services, a VTOL is not expected to be in the air 2080 hours per year; instead, adopting a conservative forecast, we expect:

- In the first year to fly 1040 hours flight midrange and 1400 hours on short-range flights;
- In the second year to fly 1040 hours flight midrange and 1500 hours on short-range flights;
- In the third year to fly 1200 hours on medium-range flights and 1600 hours on short-haul flights;
- In the fourth year to fly 1900 hours on medium-range flights and 2080 hours on short-haul flights;
- In the fifth year to fly 2000 hours on medium-range flights and 2080 hours on short-haul flights; and
- In the sixth year to fly 2080 hours on medium-range flights and 2080 hours on short-haul flights.

As the purchase price of a VTOL is quite high, it is essential to write off most of the cost of capital over the operating hours during the year. Because of these assumptions, we consider that the cost of depreciation of the vehicle is only 10% of the direct operating cost. Thus, the use of the vehicle is closely linked to the purchase price of the vehicle (Holden, J., & Goel, N., 2016).

Vehicle acquisition cost:

The number of units produced is highly dependent on the market and the size of the fleet that is implemented. There are numerous uncertainties about the additional costs that exist in many of the components of VTOL's, in particular with regard to the vertical lift system and electric propulsion.

Since Lilium Aviation has not yet made the purchase price available for Lilium Jet, we assume values that UBER has assessed and assumed: "we had evaluated several different VTOL prices: $ 1.2M for the initial case, $ 600,000 for the near-term case, and $ 200,000 for the long-term case. Conducting this sensitivity analysis allows the impact of uncertain production volumes and component costs to be understood", (Holden, J., & Goel, N., 2016:91).

Vehicle life:

It is assumed that VTOLs are designed for a longer life than cars, which allows their cost to be amortized over a longer period of time. So, we assumed useful life of 25 to 27 thousand hours for the VTOL, which allows a period of 13 years of service with the use of 2080 hours/year. This causes the vehicle to provide 400000 miles of service per year, i.e. about 5 million miles along with its life before the aircraft is recovered with a residual value of 30% (Holden, J., & Goel, N. 2016).

That is, commercial aircraft and personal cars have average lives of 32 and 10 years, respectively. We project that a $200k autonomous VTOL could fly up to 5 million miles considering an annual overhaul between $90-95k per year (Holden, J., & Goel, N. 2016).

Piloting and avionics costs:

The cost of piloting a VTOL is expected to be identical to the cost of piloting a helicopter, which in turn, fully trained, the pilot receives an average salary of 33600€ per year (2400€/month) (Meusalário, 2019); in addition, we assumed that 1.5 pilots are needed for each VTOL. This cost is in line with the current average salary of a helicopter pilot in Portugal. Pilot certification is presumed to be similar to the existing commercial aircraft training requirements in Part 135 with recurrent yearly training. In the long run (a transition to autonomous flight, which will probably last 10 to 20 years), automation can replace the pilot, with a cost of $ 60,000 per vehicle added to account for avionics upgrades and installation of needed sensors.

Infrastructure burden:

To ensure the maximum time-saving benefit, an urban air transport network will require a high level of take-off and landing locations across multiple locations. Although the initial infrastructure that redirects development cost to these strands is large, this cost is amortized over a period of 25 years. This initial cost refers to construction modifications (such as the reform of parking structures to use the top level as a vertiport) along with a combination of high voltage and low voltage chargers (one for each VTOL vertiport parking spot). It is assumed that high voltage chargers have an estimated cost of approximately $ 250,000 each, or 214,410.11€, while low voltage chargers are approximately $ 10,000 each, 8,556.02€.

Vertistops and the use of existing heliports infrastructure are considered part of the infrastructure that does not provide battery recharging services and only accommodates a single VTOL for a temporary drop-off and pick-up.

Vehicle maintenance costs:

Maintenance costs for electric VTOLs are assumed to be much lower compared to maintenance costs for existing light helicopters, therefore we assume a roughly 50% reduction in overall maintenance costs (UBER, 2016). The hypothesis of reduced maintenance cost is based on the elimination of all components of the cyclic rotor as well as on electric motors that can achieve a Time Between Overhauls (TBO) of 10,000 hours due to having only a single moving part (bearings). Maintenance labor rates are assumed to be the same as for existing helicopters, with daily visual inspections and small 100-hour maintenance checks. A major maintenance service would be performed annually to bring the vehicle back to the original service specifications. Maintenance and labor costs represent ~ 22% of VTOL's baseline direct operating costs (Holden, J., & Goel, N.,2016).

Chargers:

Sony is aiming to commercialize 400 Wh/kg Li-S battery packs by 2020. Equally exciting are the high energy chargers which would be capable of recharging in as little as 10 minutes. Additional research into pulse chargers is already showing improved cycle life and maintaining improved maximum charge capacity over time. Achieving rapid charging for large battery packs is as important, if not more important than achieving high specific energy batteries.

Tesla has already shown the efficacy of rapid chargers, achieving an 80% battery charge within 30 minutes. However, high voltage chargers are significantly more expensive than conventional slow chargers, and rapid charging can introduce significant damage to the battery, reducing projected battery life. Providing the right mix of chargers is a market-specific fleet optimization question. However, infrastructure will likely have chargers for every VTOL to enable overnight recharging.

Battery swapping is another alternative to help to maximize vehicle productivity and utilization.

Tesla invested in developing a robotic battery exchange system capable of a battery swap within 90 seconds. While swapping optimizes the vehicle performance, it causes a significant logistics burden, which was one reason for Tesla’s discontinuation of their battery swapping program. Ensuring an appropriate distribution of batteries across all vertiports is required, which may require ground trucking of batteries between vertiports. An additional factor is that batteries are a major expense, and requiring multiple battery sets per vehicle would be a significant additional fleet expense. The certification challenge of reconfirming overall vehicle flight safety after adding a new battery, which the FAA will consider a flight-critical vehicle component, is an important additional consideration (Holden, J., & Goel, N., 2016).

Indirect operating costs:

Indirect operating costs account for non-vehicle specific costs, such as credit card processing fees, registration and permit fees, insurance, and other smaller fees. Indirect costs in commercial aviation can be quite high (an additional 50% over direct operating costs) due to the significant overhead that exists for commercial operations, including overheads for booking agents. Much of commercial aviation cost also resides in indirect taxes linked to fuel use, landing fees, and other airspace operation overhead. In the case of VTOLs, the indirect is assumed to be relatively low due to the use of private infrastructure. A great deal of uncertainty exists as to the indirect overhead, which is an area that will require further study across all the stakeholders. Currently, the indirect costs are modeled as an additional ~12% on top of direct operating costs in the baseline case (Holden, J., & Goel, N., 2016), (Figure 26).

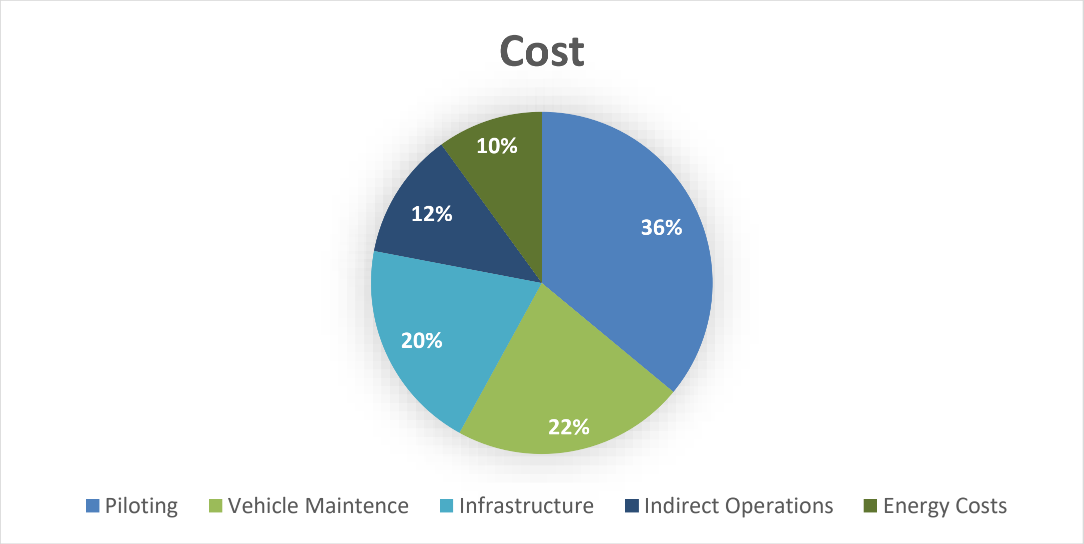


Figure 26: Cost structure chart (adapted from Holden, J., & Goel, N., 2016)

4.4.2 Revenue streams

In order to have a competitive cost and at the same time obtain maximum utilization of each VTOL, the company will present the respective prices for each km of flight separately:

- For short distance flights:
    - **Initial Term:**
        - 0.92 € per kilometer
        - 0.93 € per kilometer
        - 0.94 € per kilometer
        - 0.95 € per kilometer
        - 0.96 € per kilometer
        - 0.97 € per kilometer
    - **Near Term:** 0,65 € per kilometer
    - **Long Term:** 0,53 € per kilometer

- For medium-distance flights:
    - **Initial Term:**
        - 0.78 € per kilometer
        - 0.79 € per kilometer
        - 0.80 € per kilometer
        - 0.81 € per kilometer
        - 0.82 € per kilometer
        - 0.83 € per kilometer
    - **Near Term:** 0,65 € per kilometer
    - **Long Term:** 0,53 € per kilometer

4.4.3 Business plan

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 the thesis but can be consulted if necessary.

As such, in this subchapter, we will present the assumed assumptions, the necessary inputs and finally the outputs and related results. Figure 27 shows the methodology used to prepare this business plan.

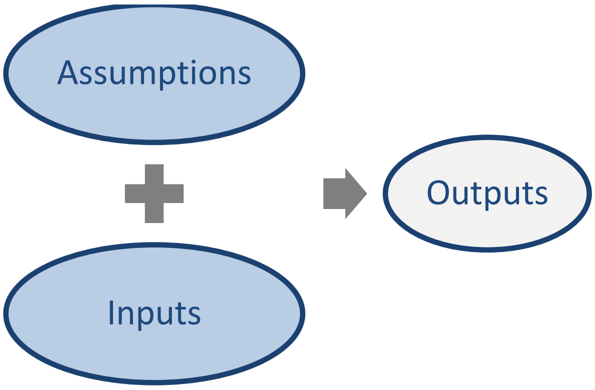


Figure 27: Methodology used to elaborate on the business plan of *Air budJets* (own elaboration).

Assumptions:

In Table 11 we have the general assumptions that we admit for the elaboration of the business plan.

Table 11: General business plan assumptions (own elaboration).

Currency unit	Euros	
1st-year activity	2026	
Number of Months of Activity in Year 1	12	
Average Receipt Term (days)	0	
Average Payment Time (days)	30	
Provisions for Doubtful Collections	0%	
VAT rate - Sales	0%	
VAT rate - Provision Services	23%	
VAT rate - Purchases	23%	
VAT rate - ESF	23%	
VAT rate - Investment	23%	
Average IRS rate	28,90%	
IRC Rate	1st level 21,00%	2nd level 21,00%
Short Term Interest Rate	0,00%	

Interest rate loan ML Deadline	8,85%
Interest rate of risk-free assets - Rf	2,00%
Market risk premium	6,00%
Beta equivalent companies	100,00%
The rate of change of cash flows in perpetuity	0,00%

The evaluation methods considered were:

- **Free Cash Flow to Firm:** In general terms, the discounted cash flow method consists of estimating the future cash flows of the company and bringing them to present value for a given discount rate (WACC). In other words, the value of a company can be expressed as the present value of the Free Cash Flow to Firm (FCFF);
- **Free Cash Flow to Equity:** In the Free Cashflow to Equity (FCFE) method of valuation, the objective is to directly evaluate the net worth of the company.

Inputs:

In Table 12 we have the inputs for the business plan and in Table 13 we have the inputs for the financing. The business plan starts in 2026 because this is the year that Lilium Aviation predicts to start selling the Lilium Jet.

Table 12: Inputs do the business plan (own elaboration).

Inputs / Activity year	2026	2027	2028	2029	2030	2031
Income: 1st Service (interregional)	973 440	1 137 600	1 632 000	1 846 800	1968000	2 071 680
Growth rate		16,86%	43,46%	13,16%	6,56%	5,27%
Income: 2nd Service (regional)	3 091 200	3 348 000	4 060 800	4 742 400	4792320	4842240
Growth rate		8,31%	21,29%	16,78%	1,05%	1,04%
Total services provided on the market	4 064 640	4 485 600	5 692 800	6 589 200	6760320	
Energy (Electricity)	366 796	372 297	377 882	383 550	389 303	395 143
Office Supplies	1800	1827	1882	1911	1939	
Insurance	13 981	14 191	14 404	14 620	14 839	15 062

Representation expenses	6 000	6 090	6 181	6 274	6 368	6 464
Communication	1 800	1 827	1 854	1 882	1 910	1 939
Fees	6 000	6 090	6 181	6 274	6 368	6 464
Advertising and marketing	2 000	2 030	2 060	2 091	2 123	2 155
Cleaning	3 600	3 654	3 709	3 764	3 821	3 878
Maintenance of VTOL's	256 307	260 152	264 054	268 015	272 035	276 116
Wages - Manager	26 000	28 000	28 000	28 000	28 000	28 000
Wages - Engineers	208 000	224 000	224 000	224 000	224 000	224 000
Wages - Administrative	46 800	50 400	50 400	50 400	50 400	50 400
Wages - Designer	561 600	604 800	604 800	604 800	604 800	604 800
Wages - Marketing	23 400	25 200	25 200	25 200	25 200	25 200
Wages - Public Relations	19 500	21 000	21 000	21 000	21 000	21 000
Wages - Pilots	26 000	28 000	28 000	28 000	28 000	28 000
Aerovanes (paid in 12 years)	12 126 413	-	-	-	-	-
Low Voltage Charger (payable in 10 years)	85 760	-	-	-	-	-
High Voltage Charger (payable in 10 years)	3 644 972	-	-	-	-	-
Batteries (payable in 5 years)	563 687	-	-	-	-	-
Infrastructures (paid in 25 years)	3 690 000	-	-	-	-	-
Others	10 000	-	-	-	-	-

In Table 12 we present a possible example of financing; this example acts only to illustrate possible financing, not corresponding to a real situation.

Table 13: Inputs financing (own elaboration).

Financing / Year of activity	2026	2027	2028	2029	2030	2031
Investment = Fixed Capital + FMN	20 755 226	0	0	0	0	0
Safety margin	0%	0%	0%	0%	0%	0%
Financing requirements	20 755 226	0	0	0	0	0
Financing source						
Cash flow	0	2 319 625	2 301 939	3 157 764	3 502 443	3 529 932
Share capital	1 000 000	0	0	0	0	0
Supplementary Capital Payments	5 974 970	0	0	0	0	0
Membership Loans / Supplies	773 025	0	0	0	0	0
Bank financing and other Credit Institutions	13 000 000	0				
TOTAL	20 747 995	2 319 625	2 301 939	3 157 764	3 502 443	3 529 932
No. of years reimbursement of planned bank financing	10	---	---	---	---	---
Associated interest rate	8,85%	---	---	---	---	---

Outputs:

Next three tables compare the income and costs resulting from the company's activity. This is one of the key reports, which allows us to determine the potential for release of project results. It is not necessary to enter any data on this map since the values it presents result from previously introduced assumptions and inputs. By means of the profit and loss account, it is possible to see if the company or project has positive net profitability or if, on the contrary, they give a loss; this constitutes the first approach to the viability of the project. Taking the previous assumptions and inputs we obtain the following outputs/results (Table 14, Table 15 and Table 16).

Table 14: Outputs: Estimated Income Statement (own elaboration).

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
Volume of business	4 064 640	4 485 600	5 692 800	6 589 200	6 760 320	6 913 920
FSE- Fixed Costs	664 284	674 249	684 362	694 628	705 047	715 623
Economic Result	3 400 356	3 811 351	5 008 438	5 803 372	6 055 273	6 198 297
Personnel Expenses	1 142 925	1 228 050	1 228 050	1 228 050	1 228 050	1 228 050
EBITDA (Earnings Before Interests Taxes, Depreciation and Amortization)	2 257 431	2 583 301	3 780 388	4 575 322	4 827 223	4 970 247
Depreciation / Depreciation / Impairment	1 499 178	1 499 178	1 499 178	1 498 845	1 496 345	1 496 345
EBIT (Earnings Before Interests and Taxes)	758 252	1 084 123	2 281 209	3 076 477	3 330 878	3 473 902
Expenses and Losses of Financing	1 195 979	1 195 979	1 076 381	956 783	837 185	717 588
FINANCIAL RESULT	-1 195 979	-1 195 979	-1 076 381	-956 783	-837 185	-717 588
Income before taxes	-437 727	-111 856	1 204 828	2 119 694	2 493 692	2 756 315
Income tax			137 601	445 136	523 675	578 826
NET INCOME FOR THE PERIOD	-437 727	-111 856	1 067 227	1 674 558	1 970 017	2 177 489

The statement of income is the basis for the break-even analysis of the project (point of equilibrium in the business in which there is no loss or gain, neither profit nor loss. For the investor, the break-even is the point from which he ceases to lose money and starts to gain and balance the invested capital), (Iapmei, 2016).

Table 15: Outputs - financial plan (own elaboration).

Financing / Year of activity	2026	2027	2028	2029	2030	2031
ORIGINS OF FUNDS						
Gross Release Capital	2 257 431	2 583 301	3 780 388	4 575 322	4 827 223	4 970 247
Capital Stock (entry of funds)	1 000 000					
Financing Obtained	13 000 000					
Member Financing (PSC / Supplies)	6 747 995					
Total Origins	23 005 426	2 583 301	3 780 388	4 575 322	4 827 223	4 970 247
APPLICATIONS OF FUNDS						
Inv. Fixed Capital	20 121 832					
Inv. Working Fund	633 394					
Income tax				137 601	445 136	523 675
Repayment of Loans		1 300 000	1 300 000	1 300 000	1 300 000	1 300 000
Financial charges	1 195 979	1 195 979	1 076 381	956 783	837 185	717 588
Total Applications	21 951 205	2 495 979	2 376 381	2 394 385	2 582 321	2 541 263
Annual Treasury Balance	1 054 221	87 322	1 404 006	2 180 938	2 244 902	2 428 984
Accumulated Cash Balance	1 054 221	1 141 543	2 545 549	4 726 487	6 971 389	9 400 373
Applications / Short Term Loan	1 054 221	1 141 543	2 545 549	4 726 487	6 971 389	9 400 373

From the analysis so far constructed, it is possible to extract the so-called financing plan, that is, a map that clearly defines the sources and applications of funds of the project and that constitutes usually an important component in its analysis (IAPMEI, 2016).

Like the profit and loss account, this map results from the introduction of the previous assumptions. It expresses the patrimonial situation of the company or project and will also be a fundamental component in the analysis of the project (IAPMEI, 2016). These results can be found in Table 32 of Annex 2.

Table 33 of Annex 2 depicts the main economic indicators. These data represent a set of economic and financial indicators that are widely disseminated and accepted, and which aims to complement the analysis of the project. These indicators are calculated automatically. They represent the most commonly used indicators that analysts will typically analyze. Analysts and financial entities usually have average market values depending on the type of market, business, phase, etc. (IAPMEI 2016).

Table 16: Outputs: Project Evaluation (own elaboration).

	2026	2027	2028	2029	2030	2031
Residual Investment Values						11 766 155
Free Cash Flow to Firm	-18 657 028	2 355 636	3 301 334	3 929 262	4 127 739	16 006 883
WACC	7,33%	7,35%	7,41%	7,50%	7,58%	7,67%
Updated flows	-18 657 028	2 194 413	2 863 169	3 170 123	3 095 511	11 149 099
Cumulative updated flows	-18 657 028	-16 462 615	-13 599 447	-10 429 324	-7 333 813	3 815 286

Net Present Value (NPV)	3 815 286
Internal Rate of Return	12.93%
Payback period	5 Anos

Valuation is a complex subject and depends on models that differ according to the analysts who will perform the work. However, there are basic concepts that are commonly used and are implemented here. Depending on the concrete process, we can/should discuss this point directly with the entity that is evaluating the project. The evaluation of the company or project is presented here in 3 fundamental forms (IAPMEI 2016):

- Internal rate of return;
- Payback period;
- Net present value, that is, in the perspective that its value is the result of the sum of the updated net cash flows at a rate that:
    - In the perspective of the investor: is the result of the sum of the remuneration rate of a risk-free application with a risk premium that the investor understands as its minimum remuneration;

- In the project perspective: is the result of the weighted average cost of capital at Year 0 (the year in which the largest investment volume occurs).

4.5 Conclusion

This case study was developed keeping in mind the sustainability of *Air budJets* and, of course, the client's wallet.

The introduction of these services will create and develop an exchange with other modes of transport, in particular with airlines which, being in tune, will increase urban mobility and accessibility in peripheral regions.

Looking at the business plan, assuming some of the necessary values and determining others, it was possible to introduce all the inputs needed to carry out a business plan. In the next chapter, we will analyze the results obtained and make their discussion.

Chapter 5 – Discussion of the results

5.1 Introduction

As explained in the methodology section the purpose of the 5th chapter is result analysis, that is, to analyze the results obtained in the previous chapter.

We will start by analyzing the developed applications. After that, we will analyze the business plan with an emphasis on costs, revenues, and profits. Then, we will discuss the results of the comparison between the VTOL's transport and other means of transport.

5.2 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 28) where he can choose the type of flight: private or shared flight.

Figure 28 Client’s application: first page - private or shared flight (own elaboration).

Private flight 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, such as:

- Departure:
    - One way or with return;

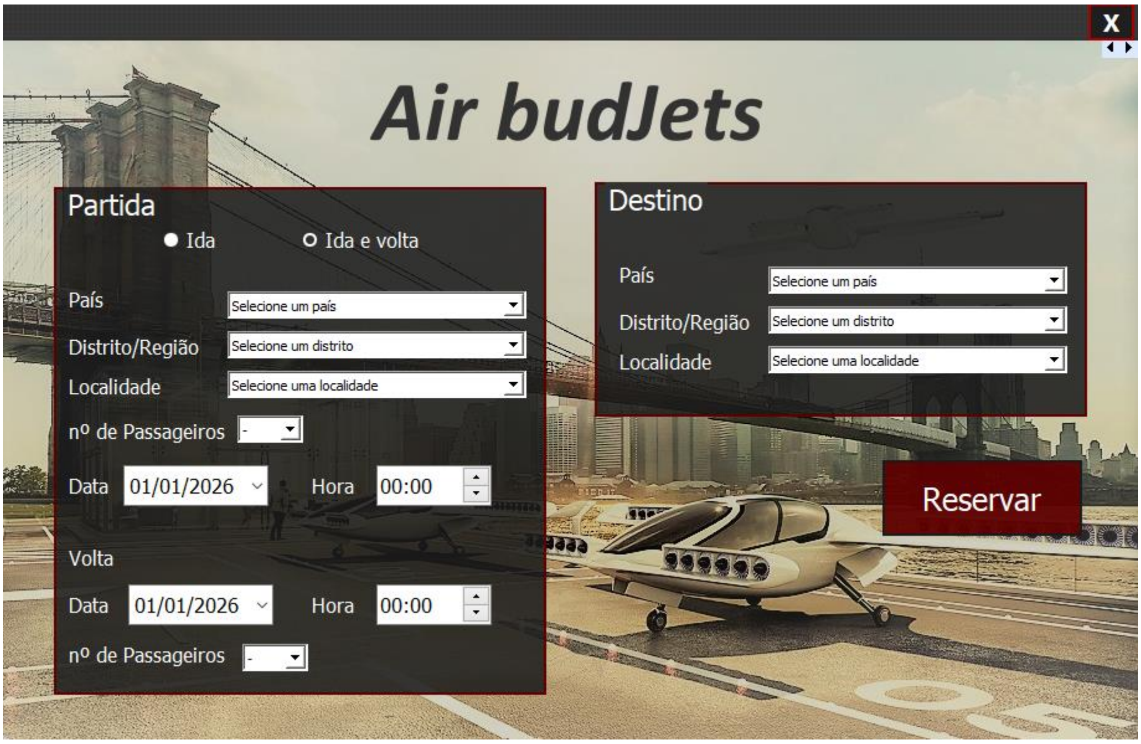
    - Country;
    - District;
    - Town;
    - Number of passengers;
    - Date;
    - Hour.

And if it is the case, on the return:

    - Date;
    - Hour;
    - Number of passengers.

- Arrival:
    - Country;
    - District;
    - Town.

In Figure 29 and Figure 30 we can see an example of completing the form for a private flight request.



Partida

● Ida ○ Ida e volta

País: Selecione um país

Distrito/Região: Selecione um distrito

Localidade: Selecione uma localidade

nº de Passageiros: -

Data: 01/01/2026 Hora: 00:00

Volta

Data: 01/01/2026 Hora: 00:00

nº de Passageiros: -

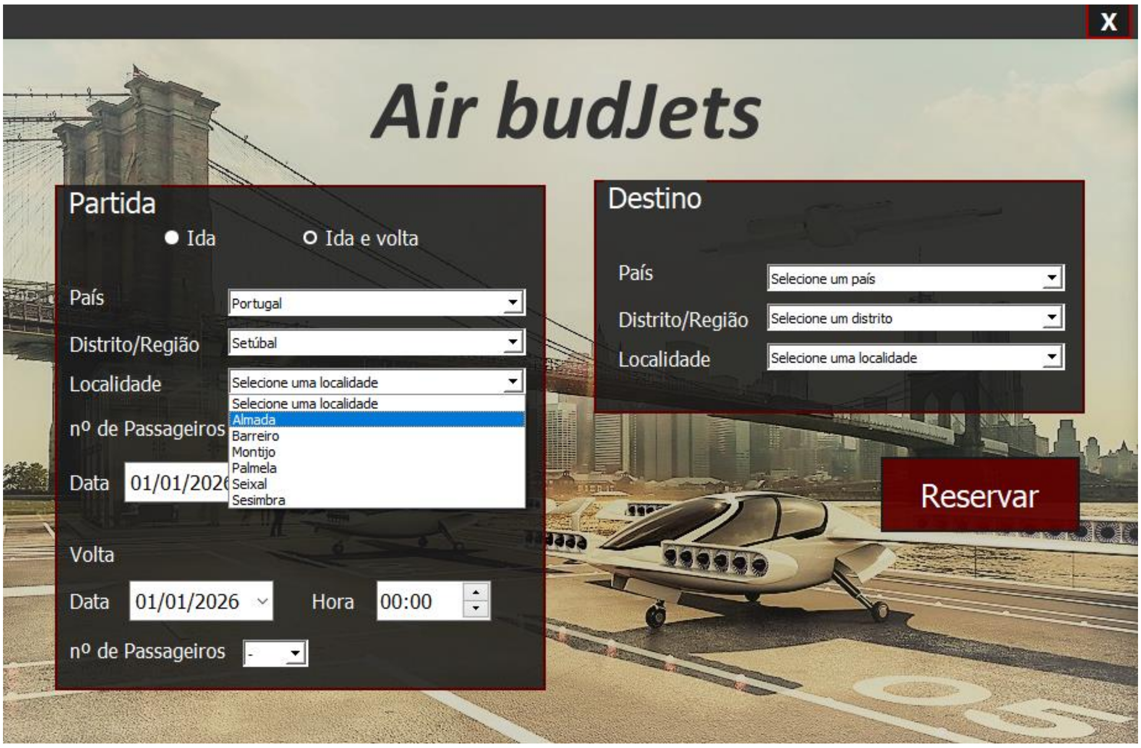
Destino

País: Selecione um país

Distrito/Região: Selecione um distrito

Localidade: Selecione uma localidade

Figure 29: Client’s application: Form - Private Flight (own elaboration).



Partida

● Ida ○ Ida e volta

País: Portugal

Distrito/Região: Setúbal

Localidade: Selecione uma localidade

- Selecione uma localidade
- Almada
- Barreiro
- Montijo
- Palmela
- Seixal
- Sesimbra

nº de Passageiros

Data: 01/01/202

Volta

Data: 01/01/2026 Hora: 00:00

nº de Passageiros: -

Destino

País: Selecione um país

Distrito/Região: Selecione um distrito

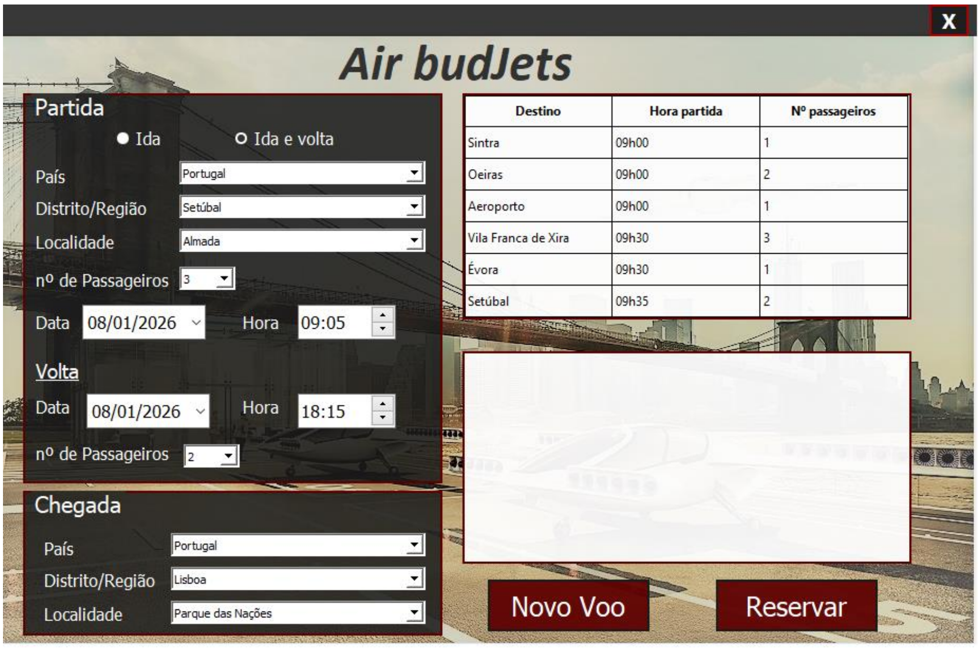
Localidade: Selecione uma localidade

Figure 30: Client’s application - filling the form of a private flight (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, the presentation is different as it can be seen in Figure 31.

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.



Partida

● Ida ○ Ida e volta

País Portugal
Distrito/Região Setúbal
Localidade Almada
nº de Passageiros 3
Data 08/01/2026 Hora 09:05

Volta

Data 08/01/2026 Hora 18:15
nº de Passageiros 2

Chegada

País Portugal
Distrito/Região Lisboa
Localidade Parque das Nações

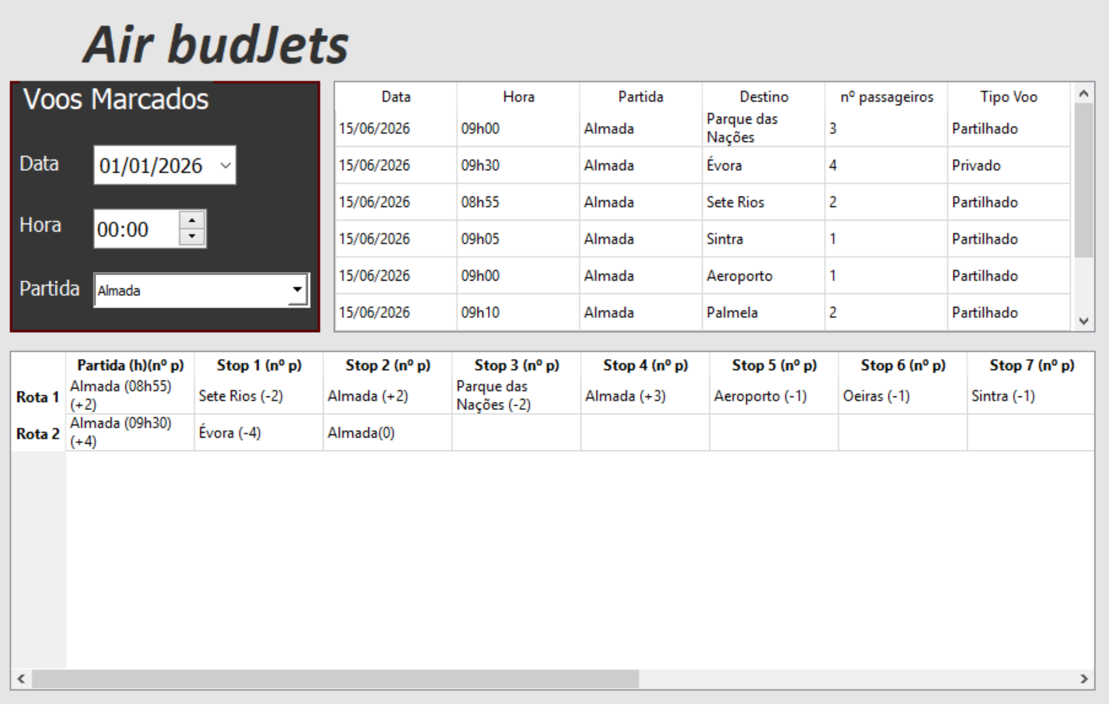
Destino	Hora partida	Nº passageiros
Sintra	09h00	1
Oeiras	09h00	2
Aeroporto	09h00	1
Vila Franca de Xira	09h30	3
Évora	09h30	1
Setúbal	09h35	2

Figure 31: Client’s application - form for a shared flight (own elaboration).

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 routes and optimizes the optimal trajectory.



Voos Marcados

Data 01/01/2026
Hora 00:00
Partida Almada

Data	Hora	Partida	Destino	nº passageiros	Tipo Voo
15/06/2026	09h00	Almada	Parque das Nações	3	Partilhado
15/06/2026	09h30	Almada	Évora	4	Privado
15/06/2026	08h55	Almada	Sete Rios	2	Partilhado
15/06/2026	09h05	Almada	Sintra	1	Partilhado
15/06/2026	09h00	Almada	Aeroporto	1	Partilhado
15/06/2026	09h10	Almada	Palmela	2	Partilhado

	Partida (h)(nº p)	Stop 1 (nº p)	Stop 2 (nº p)	Stop 3 (nº p)	Stop 4 (nº p)	Stop 5 (nº p)	Stop 6 (nº p)	Stop 7 (nº p)
Rota 1	Almada (08h55) (+2)	Sete Rios (-2)	Almada (+2)	Parque das Nações (-2)	Almada (+3)	Aeroporto (-1)	Oeiras (-1)	Sintra (-1)
Rota 2	Almada (09h30) (+4)	Évora (-4)	Almada(0)					

Figure 32: Company application (own elaboration).

On the user side, as shown in Figure 32, 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, one can see the information on the optimized routes. Showing, in the end, the result of the shared flights already optimized, is possible to visualize the optimal trajectory.

5.3 Business plan

In chapter IV, in the subchapter about the business plan we have a set of resulting data that is important to discuss and analyze.

Thus, we divided the discussion of the results of the business plan into two parts: inputs and outputs.

Inputs:

Beginning with the Inputs, and analyzing Table 12 of Chapter IV, we have:

Income: 1st Service (Intercities) - To calculate the performance of the first service we have 4 aircraft to do this service, we estimate that they will fly 4 hours a day in the first year for 260 days, or 1040 hours a year. It was thus possible to calculate the total number of kilometers flown (1 248 000km), and assuming the cost of 0.78 € per km in the first year, we have the total value of 973 440 €.

In Table 17. we have the estimated miles flew and the cost per kilometer.

Table 17: Table of support for the calculation of Inter-Regional service income (own elaboration).

Inter-Regional Flights	2026	2027	2028	2029	2030	2031
Flight time (hours)	1040	1200	1700	1900	2000	2080
Distance (Km)	1 248 000	1 440 000	2 040 000	2 280 000	2 400 000	2 496 000
Price per Km (€)	0,78	0,79	0,8	0,81	0,82	0,83

Income: 2nd Service (regional) - To calculate the performance of the second service we have 8 aircraft to do that, and we estimate that they fly 4 hours a day during 260 days in the first year of operation. The total number of kilometers flown (3 360 000 km) was calculated, and assuming the cost of 0.92 € per km in the first year, we have the total value of 3 091 200 €.

Table 18 shows the estimated kilometers flew and the cost per kilometer.

Table 18: Table of support for the calculation of interregional service income (own elaboration).

Regional Flights	2026	2027	2028	2029	2030	2031
Flight time (hours)	1400	1500	1800	2080	2080	2080
Distance (Km)	3 360 000	3 600 000	4 320 000	4 992 000	4 992 000	4 992 000
Price per Km (€)	0,92	0,93	0,94	0,95	0,96	0,97

Growth Rate – The growth rate between two-year earnings is calculated by making the difference from the previous year's income to the current year, dividing it by the previous year.

Total services provided on the market - Represents the sum of the income of the two services.

Energy / Electricity - In order to calculate the energy value, the cost of 0.14 € per kW / h has been considered, knowing that an aircraft spends 500 kW to land and take off, and cruising speed 300 km / h, where it spends 88.3 kW, and fly 8 hours a day during the 260 annual days; so we calculated a total of 30 556.3 € per month, that is, an annual cost of 366 796 €.

Office Supplies - This value was attributed only by a general estimation.

Insurance - This value was attributed only by a general estimation.

Representation expenses - This value was attributed only by a general estimation.

Communication - This value was attributed only by a general estimation.

Fees - This value was attributed only by a general estimation.

Advertising and marketing - This value was attributed only by a general estimation.

Cleaning - This value was attributed only by a general estimation.

Maintenance of VTOL's - As explained in chapter IV, the cost of maintaining VTOLs is expected to be around 22% of the annual cost, which is around 256 307 €.

Salaries - Manager - calculated value assuming an average gross salary of 2000 € per month for 1 manager.

Wages - Engineers - calculated value assuming an average gross salary of 2000 € per month for 8 engineers.

Salaries - Administrative - calculated value assuming an average gross salary of 1200 € monthly for 3 administrative.

Salaries - Designer - calculated value assuming an average gross salary of 1100 € per month for a designer.

Salaries - Marketing - calculated value assuming an average gross salary of 1500 € per month for one responsible for the marketing and image of the company.

Salaries - Public relations - calculated value assuming an average gross salary of € 1100 per month for a person in charge of public relations/business.

Salários - Pilotos - calculated value assuming an average gross salary of 2400 € per month for 18 pilots; this value is justified because this is the average salary applied to a helicopter pilot in Portugal (Meusalario, 2019).

Aircraft (paid in 12 years) - as referred previously in chapter IV, Lilium Jet has not yet made public the cost of purchasing an aircraft, so it was assumed that the cost of the aircraft is 1 010 534 €, being this value between the values provided by the UBER for the cost of an aircraft of this type. Thus, in 12 years and counting on a total fleet of 12 aircraft, the total cost of 1 010 534 € per year is expected.

Low Voltage Charger (paid in 10 years) - As seen in Chapter IV, the cost of a low voltage charger is 8 576.02 €; considering that we will take 10 and that the equipment will be paid in 10 years, we have a cost of 8 576,2€ per year.

Charger High Voltage (paid in 10 years) - As seen in Chapter IV, the cost of a low voltage charger is 214410.11 €; considering that we will take 17, we have a total of 3 644 972 € that, when paid in 10 years, corresponds to a cost of 364 497,2€ per year.

Batteries (paid in 5 years) - Each battery is expected to cost approximately $ 56,000, or € 46,973.95; assuming that in the purchase price of an aircraft a battery is already included we add another 12 extra batteries to the aircraft. Costing 563 687 €, to be paid in 5 years.

Infrastructures (paid in 25 years) - This value was determined to take into account the total number of vertiports, vertiports parking spots and vertistops, being respectively 15, 7 and 64. The minimum dimensions of an area required to land this VTOL are at least 225m2. We assume that a vertiport will have 400 m2, a vertiport parking spot has 600 m2 and a vertistop has 225 m2. An average random value was assumed for the land price of 150€ per m2. It has been assumed that since the real estate market is volatile, prices change in response to demand and supply and, in addition, land prices change greatly depending on their location and characteristics. In conclusion, summing up, a cost of 3 690 000€ is expected to be paid in 25 years.

Financing:

The costs necessary to finance the company are 20 755 266 €. This amount includes the total investment of fixed capital (intangible and tangible) and investment in working capital. The value of fixed capital is distributed by the purchase value of aircraft, batteries and chargers, administrative equipment and land, and natural resources. This value was distributed in a general way by the various sources of financing.

Outputs:

The success or failure of a business is dictated if it has a profit or a loss.

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. Given that there are several levels of results; and the final results are the result of the difference between all income and all expenses and are designated by net results (profits if the net results are positive, or negative if they are negative).

Looking at the results of the 5-year period, shown in Table 14 of chapter IV 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 (shareholders, bank creditors, etc.) 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 (Portal Gestão, 2019).

Finally, we note that the payback period is 5 years, that is, the period of time that the project takes to generate earnings; or, another word, that equals the expenses incurred to achieve it.

5.4 Comparison between actual transportations and Air budJets transportation

In order to compare the cost between the various modes of transport used, road, rail and air, and between private and public transport, we present in Table 34 of Annex 3, several options of movements between several cities, kilometers made, time spent, price of trip paid (considering the prices of Year 1 of *Air budJets* operation).

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 examples were chosen because they showed a journey from the periphery to the coast within Portugal, a trip within the same central region of Portugal and a trip between Portugal and Spain.

Table 19, Table 20, Table 21 and Table 22 include these examples.

Table 19: Example of a trip from Covilhã to Lisbon airport (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 €

From Table 19 we can see that the travel time between Covilhã and Lisbon airport reduces by approximately 1h30 compared to the road transport, both taxi and car, a reduction of 3h compared to the train and approximately 3h30 compared to the bus. Regarding the price, this service compensates for the taxi, but it is more expensive compared to the car, train, and bus.

Table 20: Example of the trip from Almada to Sintra (own elaboration).

Departure City	Arrival City	Transport type	Km	Time	Price	Price per seat
Lisboa - Almada	Sintra	Train	-	00h56	3,25 €	3,25 €
		Bus	50,7	3h28	9,35 €	10,35 €
		Car (consumption: 5l/100km)	35,2	00h36	7,92 €	1,58 €
		Taxi	35,2	00h36	33,55 €	8,39 €
		VTOL (Year 1)	23,4	00h13	21,76 €	5,44 €

From Table 20 we can observe that the travel time between Almada and Sintra, reduces by approximately 23 min compared to the means of transport by road, both taxi and car, a reduction of 43 min with respect to the train and approximately 3:15 with respect to the bus. Regarding the price per place, this service compensates for the taxi and bus and is a very competitive price for the train.

Table 21: Example of travel from Vila Real de Santo António to Málaga (own elaboration).

Departure City	Arrival City	Transport type	Km	Time	Price	Price per seat
Vila Real Santo António	Málaga	Train	-	-	-	-
		Bus	644	5h14	47,00 €	48,00 €
		Car (consumption: 5l/100km)	357	3h56	48,61 €	9,72 €
		Taxi	357	3h56	336,85 €	84,21 €
		VTOL (Year 1)	266,4	1h10	321,45 €	52,61 €

From Table 21 we can observe that the travel time between Vila Real de Santo António and Málaga, reduces by approximately 4h04 when compared to the bus, both taxi, and car, a reduction of 3h46 min. Regarding the price per place, this service compensates for the taxi and bus, but it is more expensive compared to the car.

Table 22: Example of trip from Évora to Mérida (own elaboration).

Departure City	Arrival City	Transport type	Km	Time	Price	Price per seat
Évora	Mérida	Train	-	-	-	-
		Bus	163	3h40	25,00 €	26,00 €
		Car (consumption: 5l/100km)	163	1h43	27,09 €	5,42 €
		Taxi	163	1h43	154,25 €	38,56 €
		VTOL (Year 1)	141,8	00h39	112,02 €	28,01 €

From Table 22 we can observe that the travel time between Évora and Merida, reduces by approximately 3 hours compared to the bus, both taxi and car shows a reduction of 1h. Regarding the price per place, this service compensates for the taxi and bus, but it is more expensive compared to the car.

5.5 Conclusion

With the development of the design of the application, was possible to create an application 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 pay back the initial investment is 5 years.

In addition, comparing *Air budJets* service with other existing means of transport, it is found that this is advantageous in relation to travel times.

Chapter 6 – Conclusions

6.1 Dissertation synthesis

In this dissertation, we present a possible future solution for the transport needs of Portuguese society. A conjuncture of social, geographic and technological factors **makes** this the ideal moment for the idealization of this type of services. We live in an increasingly fast and instantaneous society, where everything is a click away and, in this way, it is necessary to accelerate our means of transport, ensuring its quality and safety.

It was thus established as the objective of this dissertation to create a virtual company that operates VTOL aircraft, guaranteeing its sustainability. There was also a set of sub-objectives that we wanted to accomplish such as calculating the ideal location of VTOL parking bases, designing two applications for flight booking and optimizing routes, and creating a model and business plan for a sustainable VTOL service.

As was mentioned throughout the dissertation, there are a new means of transport intended to revolutionize the skies, the VTOL aircraft.

Thus, a study was made on the state of the art on these aircraft, the aircraft manufactured by Lilium Aviation was chosen to use as a model for our *Air budJets* service. We also carried out a study on the geographical characteristics of Portugal and we also collect information that was fundamental for the elaboration of the business model and plan for the company that we intended to create virtually.

As I mentioned, we intend to develop two applications, one application for the client and another for *Air budJets* to use in order to manage and optimize the paths to be performed. Through the use and algorithms learned in the Chair of Aeronautical Projects Management: the algorithms of Traveling Salesman and Clarke and Wright, it was possible to make some optimizations of routes. These algorithms allow us to calculate the optimal path to take, i.e. the path with the least cost. With the compensation heuristics, we have calculated the best locations for the various parking bases of *Air budJets* aircraft.

In the case of the study of this dissertation, we present the various information associated to the characterization of this service, among them the characteristics of the aircraft, the trajectories, the operation of the application through flow charts and we present the model and the business plan, financial activity during the first five years of activity, indicating the year of activity start to 2026. From the financial plan, we can extract several financial indicators, but I would like to point out the fact that the project will total VAL, the sum of all inflows and outflows of money over the five years, is 3 815 286 € and that the payback period is 5 years.

Finally, 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.

6.2 Final considerations

The dream of a "flying car" is old, but only now we have technology that will finally make this dream a reality. VTOL aircraft has been developed by new companies (Lilium Aviation) or by aviation giants (Airbus) and are the future of aviation and mobility.

Meeting the needs of companies from the countryside and seeking to increase urban mobility in cities, the creation of an air transport service using VTOL's to transport people is the solution to both problems.

The possibility of optimizing the routes and to share a trip will reduce the cost to the customers, thus optimizing resources and allowing greater efficiency in the management of the fleet.

The elaboration of a business model and plan is fundamental for the definition of how the company will operate and still evaluate the financial strategy of a company.

In the development of the application, some difficulties arose due to the quality of the computers on which we developed the sofware, 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, the simulation was done only in the Lisbon area.

Based on the current work, an oral presentation in ICEUBI 2015-International Conference on Engineering, in Covilhã, an oral presentation in 24th APDR-Intellectual Capital and Regional Development, in Covilhã, an oral presentation in ICEUBI 2017-International Conference on Engineering, in Covilhã, and an oral presentation in VII RIDITA – Air Transportation Sustainability: Technological, Operational, Economic, Social and Environmental Strategies was accomplished.

6.3 Prospects for future work

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 in order to decrease the price per km;
- Finally, make *Air budJets* the pioneer of this business in Portugal!

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Annexes

Annex 1 - Application of Compensation Heuristics

In this calculation, we assume that the cost of travel is equal to the distance between points and we assume that the cost of construction of a new vertiport parking spot is much higher than the cost of travel since the investment of construction of this space is higher. For the calculation, we assume the construction cost of 100€.

1. Lisbon Region

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Aeroporto	0	23	18,1	26,9	21	5,07	3,66	14,1	30,8	37,3	16,3	11,8	15,8
2. Vila Franca de Xira	23	0	40,1	47,2	37,8	28,1	22,7	33,7	43,7	57,7	28,1	34,5	36,3
3. Oeiras	18,1	40,1	0	9,4	13,1	13,6	20,3	20,6	38,4	33,4	29,5	12,3	19,8
4. Cascais	26,9	47,2	9,4	0	12,3	22,8	29,5	30,2	47,1	39,5	38,9	22,6	29,1
5. Sintra	21	37,8	13,1	12,3	0	19,7	24,7	31,2	48,7	46,7	36,8	23,4	30,5
6. Sete Rios	5,07	28,1	13,6	22,8	19,7	0	6,9	11,8	29,7	33,5	17,2	7,2	12,6
7. Parque das Nações	3,66	22,7	20,3	29,5	24,7	6,9	0	12,1	27,6	36,1	12,6	12,1	14,2
8. Barreiro	14,1	33,7	20,6	30,2	31,2	11,8	12,1	0	18,2	24,3	10,2	7,7	2,7
9. Palmela	30,8	43,7	38,4	47,1	48,7	29,7	27,6	18,2	0	22,1	16,3	25,5	18,6
10. Sesimbra	37,3	57,7	33,4	39,5	46,7	33,5	36,1	24,3	22,1	0	30,9	26,2	21,9
11. Montijo	16,3	28,1	29,5	38,9	36,8	17,2	12,6	10,2	16,3	30,9	0	16,8	12,9
12. Almada	11,8	34,5	12,3	22,6	23,4	7,2	12,1	7,7	25,5	26,2	16,8	0	6,9
13. Seixal	15,8	36,3	19,8	29,1	30,5	12,6	14,2	2,7	18,6	21,9	12,9	6,9	0
Location in:	223,83	432,9	268,6	355,5	345,9	208,17	222,46	216,8	366,7	409,6	266,5	207	221,3

Table 23: Distances between each point in the Lisbon region in a straight line in km (own elaboration).

Table 24: Sum of the distances between each point of the Lisbon region (own elaboration).

Location in:	Price
1	223,83
2	432,9
3	268,6
4	355,5
5	345,9
6	208,17
7	222,46
8	216,8
9	366,7

10	409,6
11	266,5
12	207
13	221,3

Table 25: Calculation of the cost of changing the location of the installation of the company base (own elaboration).

Change customers from 12 to 1:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-11,8	88,2
C2	-11,5	88,5
C3	5,8	105,8
C4	4,3	104,3
C5	-2,4	97,6
C6	-2,13	97,87
C7	-8,44	91,56
C8	6,4	106,4
C9	5,3	105,3
C10	11,1	111,1
C11	-0,5	99,5
C12	11,8	111,8
C13	8,9	108,9

Change customers from 12 to 7:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-8,14	91,86
C2	-11,8	88,2
C3	8	108
C4	6,9	106,9
C5	1,3	101,3
C6	-0,3	99,7
C7	-12,1	87,9
C8	4,4	104,4
C9	2,1	102,1
C10	9,9	109,9
C11	-4,2	95,8
C12	12,1	112,1
C13	7,3	107,3

Change customers from 12 to 2:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	11,2	111,2
C2	-34,5	65,5
C3	27,8	127,8
C4	24,6	124,6
C5	14,4	114,4
C6	20,9	120,9
C7	10,6	110,6
C8	26	126
C9	18,2	118,2
C10	31,5	131,5
C11	11,3	111,3
C12	34,5	134,5
C13	29,4	129,4

Change customers from 12 to 8:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	2,3	102,3
C2	-0,8	99,2
C3	8,3	108,3
C4	7,6	107,6
C5	7,8	107,8
C6	4,6	104,6
C7	0	100
C8	-7,7	92,3
C9	-7,3	92,7
C10	-1,9	98,1
C11	-6,6	93,4
C12	7,7	107,7
C13	-4,2	95,8

Change customers from 12 to 3:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	6,3	106,3
C2	5,6	105,6
C3	-12,3	87,7
C4	-13,2	86,8
C5	-10,3	89,7
C6	6,4	106,4
C7	8,2	108,2
C8	12,9	112,9
C9	12,9	112,9
C10	7,2	107,2
C11	12,7	112,7
C12	12,3	112,3
C13	12,9	112,9

Change customers from 12 to 4:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	15,1	115,1
C2	12,7	112,7
C3	-2,9	97,1
C4	-22,6	77,4
C5	-11,1	88,9
C6	15,6	115,6
C7	17,4	117,4
C8	22,5	122,5
C9	21,6	121,6
C10	13,3	113,3
C11	22,1	122,1
C12	22,6	122,6
C13	22,2	122,2

Change customers from 12 to 5:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	9,2	109,2
C2	3,3	103,3

Change customers from 12 to 9:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	19	119
C2	9,2	109,2
C3	26,1	126,1
C4	24,5	124,5
C5	25,3	125,3
C6	22,5	122,5
C7	15,5	115,5
C8	10,5	110,5
C9	-25,5	74,5
C10	-4,1	95,9
C11	-0,5	99,5
C12	25,5	125,5
C13	11,7	111,7

Change customers from 12 to 10:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	25,5	125,5
C2	23,2	123,2
C3	21,1	121,1
C4	16,9	116,9
C5	23,3	123,3
C6	26,3	126,3
C7	24	124
C8	16,6	116,6
C9	-3,4	96,6
C10	-26,2	73,8
C11	14,1	114,1
C12	26,2	126,2
C13	15	115

Change customers from 12 to 11:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	4,5	104,5
C2	-6,4	93,6

C3	0,8	100,8
C4	-10,3	89,7
C5	-23,4	76,6
C6	12,5	112,5
C7	12,6	112,6
C8	23,5	123,5
C9	23,2	123,2
C10	20,5	120,5
C11	20	120
C12	23,4	123,4
C13	23,6	123,6

C3	17,2	117,2
C4	16,3	116,3
C5	13,4	113,4
C6	10	110
C7	0,5	100,5
C8	2,5	102,5
C9	-9,2	90,8
C10	4,7	104,7
C11	-16,8	83,2
C12	16,8	116,8
C13	6	106

Change customers from 12 to 6:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-6,73	93,27
C2	-6,4	93,6
C3	1,3	101,3
C4	0,2	100,2
C5	-3,7	96,3
C6	-7,2	92,8
C7	-5,2	94,8
C8	4,1	104,1
C9	4,2	104,2
C10	7,3	107,3
C11	0,4	100,4
C12	7,2	107,2
C13	5,7	105,7

Change customers from 12 to 13:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	4	104
C2	1,8	101,8
C3	7,5	107,5
C4	6,5	106,5
C5	7,1	107,1
C6	5,4	105,4
C7	2,1	102,1
C8	-5	95
C9	-6,9	93,1
C10	-4,3	95,7
C11	-3,9	96,1
C12	6,9	106,9
C13	-6,9	93,1

2. Oporto Region

Table 26: Distances between each point in the Oporto region in a straight line in km (own elaboration).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Aeroporto	0	50,2	37,8	37,4	47,37	49,4	31,9	12,2	15,7	27,9	38,5	41,7	25,1
2. Viana do Castelo	50,2	0	38,4	52,8	61,6	78,7	71,4	63,1	67,5	81,4	89,6	63,7	59
3. Braga	37,8	38,4	0	16,7	23,6	42	39,7	46,3	49,9	63,3	71,2	26,8	29,3
4. Guimarães	37,4	52,8	16,7	0	9,2	26,3	26,6	42,3	45,6	57,2	62,8	11,6	19,2
5. Fafe	47,37	61,6	23,6	9,2	0	21,8	29,3	50,6	51,3	63,7	65,8	9,7	25,9
6. Amarante	49,4	78,7	42	26,3	21,8	0	19,5	46,7	47,4	55,6	54,2	14,7	24,8
7. Penafiel	31,9	71,4	39,7	26,6	29,3	19,5	0	30,3	29,2	37,2	37,3	19,6	10,7
8. Porto	12,2	63,1	46,3	42,3	50,6	46,7	30,3	0	4,7	17,4	27,1	42,6	25,2
9. Vila Nova de Gaia	15,7	67,5	49,9	45,6	51,3	47,4	29,2	4,7	0	13,9	21,8	43,7	24,2
10. Espinho	27,9	81,4	63,3	57,2	63,7	55,6	37,2	17,4	13,9	0	11,1	55,6	38,9
11. Santa Maria da Feira	38,5	89,6	71,2	62,8	65,8	54,2	37,3	27,1	21,8	11,1	0	57,15	42
12. Felgueiras	41,7	63,7	26,8	11,6	9,7	14,7	19,6	42,6	43,7	55,6	57,15	0	17,7
13. Paços de Ferreira	25,1	59	29,3	19,2	25,9	24,8	10,7	25,2	24,2	38,9	42	17,7	0
Location in:	415,17	777,4	485	407,7	459,87	481,1	382,7	408,5	414,9	523,2	578,55	404,55	342

Table 27: Sum of the distances between each point in the Oporto region (own elaboration).

Location in:	Price
1	415,17
2	777,4
3	485
4	407,7
5	459,87
6	481,1
7	382,7
8	408,5
9	414,9
10	523,2
11	578,55
12	404,55
13	342

Table 28: Calculation of the cost of changing the location of the installation of the company base (own elaboration).

Change customers from 7 to 1:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-31,9	68,1
C2	-21,2	78,8
C3	-1,9	98,1
C4	10,8	110,8
C5	18,07	118,07
C6	29,9	129,9
C7	31,9	131,9
C8	-18,1	81,9
C9	-13,5	86,5
C10	-9,3	90,7
C11	1,2	101,2
C12	22,1	122,1
C13	14,4	114,4

Change customers from 7 to 8:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-19,7	80,3
C2	-8,3	91,7
C3	6,6	106,6
C4	15,7	115,7
C5	21,3	121,3
C6	27,2	127,2
C7	30,3	130,3
C8	-30,3	69,7
C9	-24,5	75,5
C10	-19,8	80,2
C11	-10,2	89,8
C12	23	123
C13	14,5	114,5

Change customers from 7 to 2:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	18,3	118,3
C2	-71,4	28,6
C3	-1,3	98,7
C4	26,2	126,2
C5	32,3	132,3
C6	59,2	159,2
C7	71,4	171,4
C8	32,8	132,8
C9	38,3	138,3
C10	44,2	144,2
C11	52,3	152,3
C12	44,1	144,1
C13	48,3	148,3

Change customers from 7 to 9:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-16,2	83,8
C2	-3,9	96,1
C3	10,2	110,2
C4	19	119
C5	22	122
C6	27,9	127,9
C7	29,2	129,2
C8	-25,6	74,4
C9	-29,2	70,8
C10	-23,3	76,7
C11	-15,5	84,5
C12	24,1	124,1
C13	13,5	113,5

Change customers from 7 to 3:

Change customers from 7 to 10:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	5,9	105,9
C2	-33	67
C3	-39,7	60,3
C4	-9,9	90,1
C5	-5,7	94,3
C6	22,5	122,5
C7	39,7	139,7
C8	16	116
C9	20,7	120,7
C10	26,1	126,1
C11	33,9	133,9
C12	7,2	107,2
C13	18,6	118,6

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-4	96
C2	10	110
C3	23,6	123,6
C4	30,6	130,6
C5	34,4	134,4
C6	36,1	136,1
C7	37,2	137,2
C8	-12,9	87,1
C9	-15,3	84,7
C10	-37,2	62,8
C11	-26,2	73,8
C12	36	136
C13	28,2	128,2

Change customers from 7 to 4:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	5,5	105,5
C2	-18,6	81,4
C3	-23	77
C4	-26,6	73,4
C5	-20,1	79,9
C6	6,8	106,8
C7	26,6	126,6
C8	12	112
C9	16,4	116,4
C10	20	120
C11	25,5	125,5
C12	-8	92
C13	8,5	108,5

Change customers from 7 to 11:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	6,6	106,6
C2	18,2	118,2
C3	31,5	131,5
C4	36,2	136,2
C5	36,5	136,5
C6	34,7	134,7
C7	37,3	137,3
C8	-3,2	96,8
C9	-7,4	92,6
C10	-26,1	73,9
C11	-37,3	62,7
C12	37,55	137,55
C13	31,3	131,3

Change customers from 7 to 5:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	15,47	115,47
C2	-9,8	90,2

Change customers from 7 to 12:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	9,8	109,8
C2	-7,7	92,3

C3	-16,1	83,9
C4	-17,4	82,6
C5	-29,3	70,7
C6	2,3	102,3
C7	29,3	129,3
C8	20,3	120,3
C9	22,1	122,1
C10	26,5	126,5
C11	28,5	128,5
C12	-9,9	90,1
C13	15,2	115,2

C3	-12,9	87,1
C4	-15	85
C5	-19,6	80,4
C6	-4,8	95,2
C7	19,6	119,6
C8	12,3	112,3
C9	14,5	114,5
C10	18,4	118,4
C11	19,85	119,85
C12	-19,6	80,4
C13	7	107

Change customers from 7 to 6:

Constant	**Cost of moving customers (a1)**	**Cost of building new location (100-a1)**
C1	17,5	117,5
C2	7,3	107,3
C3	2,3	102,3
C4	-0,3	99,7
C5	-7,5	92,5
C6	-19,5	80,5
C7	19,5	119,5
C8	16,4	116,4
C9	18,2	118,2
C10	18,4	118,4
C11	16,9	116,9
C12	-4,9	95,1
C13	14,1	114,1

Change customers from 7 to 13:

Constant	**Cost of moving customers (a1)**	**Cost of building a new location (100-a1)**
C1	-6,8	93,2
C2	-12,4	87,6
C3	-10,4	89,6
C4	-7,4	92,6
C5	-3,4	96,6
C6	5,3	105,3
C7	10,7	110,7
C8	-5,1	94,9
C9	-5	95
C10	1,7	101,7
C11	4,7	104,7
C12	-1,9	98,1
C13	-10,7	89,3

3. Region of Coimbra

Table 29: Distances between each point in the Coimbra region in a straight line in km (own elaboration).

	1	2	3	4	5	6	7	8
1. Pombal	0	31,6	32,5	16,4	58,3	39,3	48,2	29,9
2. Figueira da Foz	31,6	0	32,8	20,6	68,6	51,7	30	12,5
3. Coimbra	32,5	32,8	0	21,4	33,6	16,9	23,9	25,4
4. Soure	16,4	20,6	21,4	0	52,9	31,8	32,7	14,1
5. Arganil	58,3	68,6	33,6	52,9	0	20,4	49,9	55,8
6. Lousã	39,3	51,7	16,9	31,8	20,4	0	40,9	40,7
7. Cantanhede	48,2	30	23,9	32,7	49,9	40,9	0	21,5
8. Montemor-o-Velho	29,9	12,5	25,4	14,1	55,8	40,7	21,5	0
Location in:	256,2	247,8	186,5	189,9	339,5	241,7	247,1	199,9

Table 30: Sum of the distances between each point of the region of Coimbra (own elaboration).

Location in:	Price
1	415,17
2	777,4
3	485
4	407,7
5	459,87
6	481,1
7	382,7
8	408,5

Table 31: Calculation of the cost of changing the location of the installation of the company base (own elaboration).

Change customers from 3 to 1:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-32,5	67,5
C2	-1,2	98,8
C3	32,5	132,5
C4	-5	95
C5	24,7	124,7
C6	22,4	122,4
C7	24,3	124,3
C8	4,5	104,5
C9	69,7	169,7

Change customers from 3 to 6:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	6,8	106,8
C2	18,9	118,9
C3	16,9	116,9
C4	10,4	110,4
C5	-13,2	86,8
C6	-16,9	83,1
C7	17	117
C8	15,3	115,3
C9	55,2	155,2

Change customers from 3 to 2:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-0,9	99,1
C2	-32,8	67,2
C3	32,8	132,8
C4	-0,8	99,2
C5	35	135
C6	34,8	134,8
C7	6,1	106,1
C8	-12,9	87,1
C9	61,3	161,3

Change customers from 3 to 7:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	15,7	115,7
C2	-2,8	97,2
C3	23,9	123,9
C4	11,3	111,3
C5	16,3	116,3
C6	24	124
C7	-23,9	76,1
C8	-3,9	96,1
C9	60,6	160,6

Change customers from 3 to 4:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	-16,1	83,9
C2	-12,2	87,8
C3	21,4	121,4
C4	-21,4	78,6
C5	19,3	119,3
C6	14,9	114,9
C7	8,8	108,8
C8	-11,3	88,7
C9	3,4	103,4

Change customers from 3 to 8:

Constant	Cost of moving customers (a1)	Cost of building a new location (100-a1)
C1	-2,6	97,4
C2	-20,3	79,7
C3	25,4	125,4
C4	-7,3	92,7
C5	22,2	122,2
C6	23,8	123,8
C7	-2,4	97,6
C8	-25,4	74,6
C9	13,4	113,4

Change customers from 3 to 5:

Constant	Cost of moving customers (a1)	Cost of building new location (100-a1)
C1	25,8	125,8
C2	35,8	135,8
C3	33,6	133,6
C4	31,5	131,5
C5	-33,6	66,4
C6	3,5	103,5
C7	26	126
C8	30,4	130,4
C9	153	253

As in none of the cases compensated to change the place customers, the cost value is always higher than 0; thus no change of location is made.

Annex 2 - Others results of the Business Plan

Table 32 Outputs: Balance Sheet (own elaboration).

	2026	2027	2028	2029	2030	2031
ACTIVO						
Intangible Assets	667	333	0	0	0	0
Property, Plant, and Equipment	18 621 987	17 123 142	15 624 297	14 125 452	12 629 107	11 132 762
Accumulated depreciation	1 566 821	3 133 642	4 700 463	6 266 950	7 830 938	9 394 926
State and other public entities	701 077					
Cash and Bank Deposits	1 054 221	1 141 543	2 545 549	4 726 487	6 971 389	9 400 373
TOTAL ASSETS	20 377 951	18 265 018	18 169 846	18 851 939	19 600 496	20 533 135
OWN CAPITAL						
Capital Realized	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000
Other Equity Instruments	5 974 970	5 974 970	5 974 970	5 974 970	5 974 970	5 974 970
Reserves and Retained Earnings		-437 727	-549 583	517 644	2 192 202	4 162 219
Net Income for the Period	-437 727	-111 856	1 067 227	1 674 558	1 970 017	2 177 489
TOTAL OF OWN CAPITAL	6 537 243	6 425 387	7 492 614	9 167 172	11 137 189	13 314 677
PASSIVE						
Non-Current Liabilities						
Financing Obtained	11 700 000	10 400 000	9 100 000	7 800 000	6 500 000	5 200 000
Supplies	773 025	773 025	773 025	773 025	773 025	773 025
Current Liabilities						
Financing Obtained	1 300 000	1 300 000	1 300 000	1 300 000	1 300 000	1 300 000
Debts to Suppliers	67 683	68 698	69 729	70 775	71 836	72 914
State and other public entities		270 959	477 411	830 673	923 716	987 110
TOTAL LIABILITIES	13 840 708	12 812 682	11 720 165	10 774 473	9 568 578	8 333 049
TOTAL CAPITAL AND LIABILITIES	20 377 951	19 238 069	19 212 779	19 941 645	20 705 766	21 647 726

Table 33: Outputs: Main indicators (own elaboration).

ECONOMIC INDICATORS

	2027	2028	2029	2030	2031
Business Growth Rate	10%	27%	14%	4%	2%
Operational efficiency	136%	198%	238%	250%	256%
Sales Operational Margin	24%	40%	47%	49%	50%
Net Profitability of Sales	-2%	19%	26%	29%	31%
Weight of Expenses w / Personnel in BV	27%	22%	19%	18%	18%

ECONOMIC - FINANCIAL INDICATORS

	2027	2028	2029	2030	2031
Return On Investment (ROI)	-1%	6%	9%	10%	11%
Asset Yield	6%	13%	16%	17%	17%
Asset Rotation	25%	31%	34%	34%	34%
Rotation of Fixed Assets (Non-Current Assets)	26%	36%	46%	54%	62%
Return on Shareholders' Equity (ROE)	-2%	14%	18%	18%	16%
Rotation of Shareholders' Equity	70%	76%	71%	61%	52%

FINANCIAL INDICATORS

	2027	2028	2029	2030	2031
Financial autonomy	35%	41%	49%	57%	65%
Total Solvency	50%	64%	85%	116%	160%
Total Indebtedness	70%	65%	57%	49%	41%
Long Term Debt	61%	54%	45%	37%	29%

LIQUIDITY INDICATORS

	2027	2028	2029	2030	2031
General Liquidity	70%	138%	215%	304%	398%
Reduced liquidity	70%	138%	215%	304%	398%

BUSINESS RISK INDICATORS

	2027	2028	2029	2030	2031
Gross Margin	4 485 600	5 692 800	6 498 000	6 760 320	6 913 920
Operational Lever Degree	414%	250%	211%	203%	199%
Critical point	3 401 477	3 411 591	3 421 523	3 429 442	3 440 018
Safety margin	32%	67%	90%	97%	101%

Annex 3 - Travel possibilities - features

Table 34: Examples of travel possibilities (own elaboration)

Departure City	Arrival City	Transport type	Km	Time	Price	Price per seat
Covilhã	Lisbon Airport	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 €	42,51 €
Covilhã	Santiago Compostela	Train	-	-	-	-
		Bus + Bus	478	10h50	59,10 €	59,10 €
		Car (consumption: 5l/100km)	478	4h40	88,08 €	17,62 €
		Taxi	478	4h40	438,35 €	109,59 €
		VTOL (Year 1)	368,6	1h35	291,19 €	72,80 €
Covilhã	Évora	Train	-	6h04	26,90 €	26,90 €
		Bus	251,74	3h45	16,60 €	16,60 €
		Car (consumption: 5l/100km)	236	3h00	38,73 €	7,75 €
		Taxi	236	3h00	235,15 €	58,79 €
		VTOL (Year 1)	196,2	0h55	155,00 €	38,75 €
Penafiel	Viseu	Train	-	-	-	
		Bus	162	2h55	16,20 €	16,20 €
		Car (consumption: 5l/100km)	147	1h41	31,14 €	6,23 €

		Taxi	147	1h41	147,65 €	36,91 €
		VTOL (Year 1)	211,77	00h56	167,30 €	41,82 €
Penafiel	Guimarães	Train	-	1h48	4,35 €	4,35 €
		Bus	92	3h3	8,70 €	8,70 €
		Car (consumption: 5l/100km)	38,5	00h40	8,65 €	1,73 €
		Taxi	38,5	00h40	43,65 €	10,91 €
		VTOL (Year 1)	26,6	00h10	24,74 €	6,18 €
Penafiel	Vila Real de Santo António	Train	-	7h50	56,80 €	56,80 €
		Bus	750	10h05	31,40 €	31,40 €
		Car (consumption: 5l/100km)	625	6h15	129,75 €	25,95 €
		Taxi	625	6h15	591,95 €	147,99 €
		VTOL (Year 1)	475,6	2h03	375,72 €	93,93 €
Bragança	Corunha	Bus (to Oporto) + Train	-	9h47	35,70 €	35,70 €
		Bus	510	8h50	55,70 €	55,70 €
		Car (consumption: 5l/100km)	336	3h48	58,64 €	11,73 €
		Taxi	336	3h48	317,25 €	79,31 €
		VTOL (Year 1)	214,3	00h58	169,30 €	42,32 €
Bragança	Ourense	Train	-	-	-	-
		Bus	-	-	-	-
		Car (consumption: 5l/100km)	167	2h05	23,56 €	4,71 €
		Taxi	167	2h05	164,77 €	41,19 €

		VTOL (Year 1)	111,9	00h32	88,40 €	22,10 €
Bragança	Valladoli	Train	-	-	-	-
		Bus	-	-	-	-
		Car (consumption: 5l/100km)	201	2h26	27,02 €	5,40 €
		Taxi	201	2h26	190,15 €	47,54 €
		VTOL (Year 1)	170,2	00h46	134,46 €	33,61 €
Vila Real	Porto	Train	-	-	-	-
		Bus	105	1h30	9,10 €	10,10 €
		Car (consumption: 5l/100km)	93,2	1h08	19,73 €	3,95 €
		Taxi	93,2	1h08	89,45 €	22,36 €
		VTOL (Year 1)	77,37	00h22	71,95 €	17,99 €
Vila Real	Lisbon - Sete Rios	Train	-	-	-	-
		Bus	408	5h30	20,90 €	21,90 €
		Car (consumption: 5l/100km)	378	4h16	72,20 €	14,44 €
		Taxi	378	4h16	362,45 €	90,61 €
		VTOL (Year 1)	403,87	1h45	319,06 €	79,76 €
Viseu	Vigo	Train	-	-	-	-
		Bus	302	5h35	29,20 €	29,20 €
		Car (consumption: 5l/100km)	268	3h00	54,30 €	10,86 €
		Taxi	268	3h00	257,85 €	64,46 €
		VTOL (Year 1)	330,6	1h31	261,17 €	65,29 €

Viseu	Salamanca	Train	-	-	-	-
		Bus	226	4h10	20,00 €	21,00 €
		Car (consumption: 5l/100km)	226	2h31	37,76 €	7,55 €
		Taxi	226	2h31	213,55 €	53,39 €
		VTOL (Year 1)	227,1	1h	179,41 €	44,85 €
Lisbon - Almada	Seixal	Train	-	00h12	1,95 €	1,95 €
		Bus	19,4	1h15	5,35 €	5,35 €
		Car (consumption: 5l/100km)	16,9	0h22	2,92 €	0,58 €
		Taxi	16,9	0h22	16,95 €	4,24 €
		VTOL (Year 1)	6,9	00h06	6,42 €	1,60 €
Lisbon - Almada	Sintra	Train	-	00h56	3,25 €	3,25 €
		Bus	50,7	3h28	9,35 €	10,35 €
		Car (consumption: 5l/100km)	35,2	00h36	7,92 €	1,58 €
		Taxi	35,2	00h36	33,55 €	8,39 €
		VTOL (Year 1)	23,4	00h13	21,76 €	5,44 €
Lisbon - Almada	Badajoz	Train	-	-	-	-
		Train (to Oriente) + Bus	235	6h16	12,99 €	13,99 €
		Car (consumption: 5l/100km)	219	2h16	44,82 €	8,96 €
		Taxi	219	2h16	206,65 €	51,66 €
		VTOL (Year 1)	394,1	1h43	311,34 €	77,83 €
Lisbon - Almada	Málaga	Train	-	11h10	73,40 €	73,40 €

		Train (to Oriente) + Bus	661	9h45	71,00 €	72,00 €
		Car (consumption: 5l/100km)	592	7h22	88,47 €	17,69 €
		Taxi	592	7h22	613,85 €	153,46 €
		VTOL (Year 1)	531,9	2h18	420,20 €	105,05 €
Lisbon - Almada	Lisbon Airport	Train	-	00h35	2,60 €	2,60 €
		Bus	-	-	-	-
		Car (consumption: 5l/100km)	18,7	00h31	5,18 €	1,04 €
		Taxi	18,7	00h31	18,05 €	4,51 €
		VTOL (Year 1)	11,8	00h08	10,97 €	2,74 €
Évora	Sevilha	Train (to Faro) + Bus	-	9h06	47,00 €	47,00 €
		Bus	323	8h	45,00 €	46,00 €
		Car (consumption: 5l/100km)	263	3h50	36,87 €	7,37 €
		Taxi	263	3h50	306,05 €	76,51 €
		VTOL (Year 1)	213,7	00h57	168,82 €	42,21 €
Évora	Mérida	Train	-	-	-	-
		Bus	163	3h40	25,00 €	26,00 €
		Car (consumption: 5l/100km)	163	1h43	27,09 €	5,42 €
		Taxi	163	1h43	154,25 €	38,56 €
		VTOL (Year 1)	141,8	00h39	112,02 €	28,01 €
Évora	Setúbal	Train	-	1h49	10,90 €	10,90 €
		Bus	104	1h45	11,90 €	11,90 €

		Car (consumption: 5l/100km)	99	1h07	20,88 €	4,18 €
		Taxi	99	1h07	94,55 €	23,64 €
		VTOL (Year 1)	138,11	00h38	109,11 €	27,28 €
Beja	Carceres	Train	-	-	-	-
		Train (to Beja) + Bus	261	6h44	32,40 €	32,40 €
		Car (consumption: 5l/100km)	270	3h38	42,13 €	8,43 €
		Taxi	270	3h38	181,05 €	45,26 €
		VTOL (Year 1)	224,5	1h	177,36 €	44,34 €
Vila Real Santo António	Málaga	Train	-	-	-	-
		Bus	644	5h14	47,00 €	48,00 €
		Car (consumption: 5l/100km)	357	3h56	48,61 €	9,72 €
		Taxi	357	3h56	336,85 €	84,21 €
		VTOL (Year 1)	266,4	1h10	210,46 €	52,61 €
Vila Real Santo António	Gibraltar	Train	-	-	-	-
		Bus	489	12h11	47,00 €	48,00 €
		Car (consumption: 5l/100km)	340	3h36	52,37 €	10,47 €
		Taxi	340	3h36	321,45 €	80,36 €
		VTOL (Year 1)	216,2	00h57	170,80 €	42,70 €
Vila Real Santo António	Huelva	Train	-	-	-	-
		Bus	59,8	1h39	21,00 €	22,00 €
		Car (consumption: 5l/100km)	59,8	00h45	8,33 €	1,67 €

		Taxi	59,8	00h46	56,95 €	14,24 €
		VTOL (Year 1)	42,7	00h21	39,71 €	9,93 €
Vila Real Santo António	Bragança	Train	-	11h38	71,65 €	71,65 €
		Bus	710	8h30	32,00 €	33,00 €
		Car (consumption: 5l/100km)	644	8h00	98,41 €	19,68 €
		Taxi	644	8h00	726,75 €	181,69 €
		VTOL (Year 1)	532,3	3h38	420,52 €	105,13 €

Annex 4 - Scientific Articles Accepted for Presentation and/or Publication

1. Scientific Article Accepted for Oral Presentation at International Conference on Engineering ICEUBI 2015

AVIATION BUSINESS MODELS APPROACH TO BUSINESS WORLD MARKET EVOLUTION.

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Abstract

Globalization and the consequent internationalization of companies is a growing trend. Therefore greater speed and flexibility are required from companies. As the Americans say "time is money" and the truth is that with the increase of competition, the time factor has become highly important not only in the business world but also in the whole society. Currently, the fastest, more flexible and more practical mode of transport is undoubtedly Business Aviation. Business Aviation is a market with great potential and a promising future. Unfortunately, Business Aviation is not accessible to all, the high costs of air transport do not allow that many companies and individuals make use of it. In this paper we start to introduce the concept and the history of business aviation, describing what it is, what use has, where and when was born and how it has evolved. It is also analyzed the worldwide distribution of this market, identified the major world markets and projections for its future and the main benefits and values of using this mode of transport. It is made a comparison between the Executive Aviation and its direct competitors: the airline business travel (ABT), ground transportation and the remote communication tools (Internet-based) and also a description of the business models used by business aviation companies that provide this mode of transport. In the conclusion of this paper, it is presented a solution to solve the problem of the high costs for a specific market constituted by a set of countries: Portugal, Spain, and France. This solution consists of creating an air transport network, constituted with small jets that made the connection between airports and airfields in the Iberian Peninsula and France. With this, it would be possible to connect through air various cities of the three countries.

Keywords

Business Aviation, Market distribution, Business models

2. Scientific Article Accepted for 24th APDR Congress: Intellectual Capital and Regional Development: New landscapes and challenges for space planning - 2017

Implementation of a Business Aviation service in Portugal's peripheral regions

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Abstract

Globalization and the consequent internationalization of companies is a growing trend. Therefore greater speed and flexibility are required from companies. The time factor has become highly important not only in the business world but also in the whole society.

There are several companies that, despite being located in peripheral regions, bring a high added value to the regional and national economy. These regions have an accessibility level lower than central regions due to their location far from urban centers and international airports. Therefore, those companies face a huge challenge: the traveling time to the closest airport is longer than the traveling time from that airport to the international destination.

Currently, the fastest and more practical mode of transport is undoubtedly Business Aviation. Thus, we introduce the concept and a brief history of business aviation and it is analyzed the worldwide distribution of this market, identified the major world markets and projections for its future and the main benefits and values of using this mode of transport. It is also made a comparison between Business Aviation and its direct competitors. In this paper, we also present a general concept of business model and business models that already exist in business aviation.

Despite the speed and flexibility, business aviation is not accessible to all companies or identities once this type of transportation depicts high costs. In order to understand the needs of companies located in Portugal's peripheral districts, we present and analyze a survey submitted to a sample of these companies, with the main objective being to create a business model which allows a sustainable business aviation services.

Keywords

Business Aviation, Business Models, Peripheral Regions.

3. Scientific Article Accepted for Oral Presentation at International Conference on Engineering ICEUBI 2017

Business Aviation Service: The Case of Portugal's Peripheral Regions.

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Abstract

There are several companies that, despite being in peripheral regions, bring a high added value to the regional and national economy. These regions have an accessibility level lower than that of central regions due to their location far from urban centers and international airports. Therefore, those companies face a huge challenge: the traveling time to the closest airport is longer than the traveling time from that airport to the international destination. Currently, the fastest and more practical mode of transport is undoubtedly Business Aviation. Thus, we introduce the concept and a brief history of business aviation, and it is analyzed the worldwide distribution of this market, identified the major world markets and projections for its future, and the main benefits and values of using this mode of transport. It is also made a comparison between business Aviation and its direct competitors. In this paper, we also present a general concept of business model and business models that already exist in business aviation. Despite the speed and flexibility, business aviation is not accessible to all companies once this type of transportation depicts high costs. To understand what is the perception of the peripheral districts core business to executive aviation and what is a demand for services offered by *Air budJets*, a fictional Business Aviation company, thus to adapt the business model of the company to the market studied, a survey was conducted.

Keywords

Business Aviation; Business Models; Peripheral Regions;

4. Scientific Article Accepted for Oral Presentation at VII RIDITA – International Congress of the Iberoamerican Air Transportation Research Society

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 routes.

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 routes of the aircraft.

Keywords

VTOL Aircraft; Business Models and Plan; Peripheral Regions, Network Optimization, Operational Performance;