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Virtual airport hub – a new business model to reduce GHG emissions in continental air transport

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Abstract:
The virtual airport hub business model is an innovative solution supported by digital technologies, the implementation of which in continental air transport may lead to a reduction in energy consumption and to a reduction in greenhouse gas emissions. The prerequisites for the implementation of the described solution are: striving to implement the GHG emission reduction strategy laid out in the Paris Agreement (2015) and the European Green Deal (2019) as well as the EU digitalization strategy (2020). The use of predictive analitics to identify the mobility needs of population and operational capabilities of the sector, gives an opportunity to plan travel flows and to create an appropriate set of direct connections among regional airports every day. The results of the analysis of data from 2019 on the amount of energy consumption and GHG emissions indicate that in Europe, it would be possible to achieve reduce GHG emissions by 5% without reducing the number of passengers using air transport. The study was prepared after conducting literature studies, data analysis and using the method of formulating scenarios. The proposed solution has the features of an innovative business model, the implementation of which allows for obtaining more favorable effects using already available resources.

Keywords: mobility, sustainability of air transport, digital technologies, climate policy, new business model

1. Introduction

Across the world, in response to the increasing environmental debt and the deepening of the phenomenon of climate instability, referred to as “climate warming”, a public policy called “Green Deal” was formulated and since its implementation began, more and more attention has been paid to reducing GHG emissions. Many debates of experts and published research results indicate the need to replace secondary energy carriers in the form of fuels of organic origin, mainly from aviation kerosene, with other carriers, the use of which in transport would not cause the emission of GHG [1]. The available materials show that none of the solutions is yet mature for commercialization, but the implementation of innovative solutions has been announced for the fourth decade of the 21sth century. As long as zero-emission is popularized in the aviation sector, the main challenge is to achieve reduction in energy consumption and thus reduce GHG emissions. The development of digital technologies is an important factor which favors the preparation and implementation of new organizational solutions. Access to cloud computing eliminates the barriers to generating very large data sets and their very fast processing. The conditions have already been created for the founding of a virtual platform in air transport, as in other areas of socio-economic activity, the operation of which would lead to so-called uberization of air transport. The moment such a platform is launched, the conditions will come into being to enable the provision of multimodal travel services, which is provided by EU-wide, integrated, multimodal information, ticketing and payment services [2].

The aim of the research is to fill the gap in the theory of management sciences, transport sciences and environmental sciences concerning the use of original, innovative solutions in air transport. Considerations were conducted to answer the following research question: Can the use of digital technologies and the introduction of new business model lead to such an adjustment of operational activities in passenger air transport that would ensure a reduction in energy consumption and GHG emissions without reducing the quantitative scope and lowering the quality of consumer service? The original concept was developed, which presents the steps to achieve the goals defined in the European Green Deal in the continental mobility system, in which air transport plays a major role. While formulating the proposal for a new "virtual airport hub" (VAH) business model, the available solutions which characterize the digital economy were taken into account [3]. Theoretical achievements and analysis of solutions already applied in practice were used, which relate to the creation of huge databases and their processing (Big Data) and the use of probabilistic models in place of deterministic models thanks to the use of artificial intelligence solutions [4]. With the use of these models, it will be possible to permanently – in a 24-hour cycle – adjust the offer of air carriers to the current needs of travelers. On the basis of data obtained from potential travelers about their needs regarding planned mobility in the next day or the following days and the data obtained from air carriers, what resources and where they have at their disposal in the next day, an new offer of a network of direct connections between airports on the continent may be created every day. Therefore, it is proposed to use the new conditions that occurred in the economy at the beginning of the third decade of the 21st century to introduce a new business model. The purpose of such an innovation, which assumes the use of the existing resources of the aviation sector, is to achieve new effects unattainable should the sector continue to operate in accordance with established principles [5].

Using the method of formulating scenarios for the implementation of new technological solutions and new business models as well as the method of analyzing the relationship between the volume of operational work, transport performance and GHG emissions, both the attractiveness of the new solution under consideration and its usefulness for the implementation of climate policy objectives in air transport were assessed. The paper presents tools for the quantitative analysis of secondary statistical data and the results of estimates made with the use of these tools. The obtained results were used in formulating conclusions and proposals for further research. The study presents: the activities of the aviation sector and the conditions for the development of this sector, the applied research methods, a proposal for a new "virtual air hub" business model, estimation of the possible reduction of GHG emissions and final conclusions.

2. Background

2.1 Passenger Air Traffic

Passenger air transport has become more and more popular in the past decades, which is illustrated by the chart in Appendix A. in 2019, 4.397 billion passengers [6] were handled worldwide, including 1.034 billion passengers from the EU-27 states [7]. In 2020, due to the

COVID-19 pandemic, the air services market collapsed (which is shown in a decrease in both the volume of international transport by 75.6% and domestic transport by 48.8%) [8].

In the mid-twentieth century, the market was dominated by the so-called national carriers, each of which wanted to provide the best service to passengers from their own country and strove for expansion on the market of countries to which direct flights were launched. With the opening of new lines to other airports, they strengthened both their position and the position of a selected airport in their own country which became the basic communication hub in the "hub-and-spoke" system [9]. The carriers of this group were focused on servicing various market segments (full service). In the domestic, continental and intercontinental markets, these airports were of fundamental importance as they became large transfer hubs working primarily for the parent airline. In Europe this group of airports included London, Paris, Amsterdam and Frankfurt / M. In 1979, London Heathrow Airport served 27 million passengers, making it the largest hub on the continent [10]. From the late 1970s, new carriers began to enter the American, Asian and European markets and adopted a marketing strategy of offering very low prices, completely different from the strategy of traditionally applied by incumbents, including carriers belonging in many countries to the state sector, the so-called "national carriers". The development of the activity of this new group of carriers referred to as "low cost carriers" (LCC) resulted in the fact that, apart from the segments of business transport and quite exclusive tourist transport in intercontinental and continental routes, a mass segment of cheap tourist transport in continental routes was created, largely replacing the segment of charter transport flights organized by travel agencies [11].

LCC carriers have introduced a new business model to the aviation sector. They departed from two basic assumptions included in traditional marketing strategies: (1) building a network of regular connections in the "hub-and-spoke" system and (2) combining the service of passengers using transport within the continent with the service of passengers using intercontinental transport. LCC carriers have created their own bases for crews and fleets at regional airports. They chose airports in those regions of the continent where the local demand justified the creation of operational capacity allowing the handling of many routes by direct connections. The LCC strategy shows three advantages by adopting the ESG (Environmental, Social and Governance) assessment criteria. Firstly, due to the fact that LCC carriers avoided handling the hubs shaped by incumbents, air traffic was decentralized in the airspace and the availability of air transport services increased on the scale of individual countries and the entire continent. Secondly, the elimination of connecting flights contributed to keeping energy consumption as low as possible and thus reducing GHG (greenhouse gases) emissions. Thirdly, thanks to the revival of regional airports, it was possible to slow down the concentration of traffic at interchange airports and thus to avoid an increase in noise pollution and the emission of pollutants by the population and the environment in the vicinity of hub airports.

Until the beginning of 2020, incumbents consistently extended their networks of radial connections, obtaining up to 30% share of travelers using flights connected at the hub among all passengers served [12]. The subject of cooperation between Lufthansa and Condor in 2019 led to a situation where, on average, 1,500 Condor customers used transfers at airports in Germany during one day [13]. At the Zurich-Knoten hub airport in Switzerland in 2019, a situation was achieved that during the day (from 6 am to 11 pm) passengers changed through this hub in six waves, and the transit became an important factor contributing to the

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deterioration of living conditions for the inhabitants of the country where the hub is located [14].
Contrary to LCC, whose planes accelerated and ascended only once, incumbents accepted the fact that their fleet consumed a significantly larger amount of energy stored in kerosene to perform comparable transport performance (pkm) as a considerable part of their customers during a one-way journey used two or even more planes, and therefore double (or triple) the amount of energy needed to accelerate the means of transport, take off and ascend to cruising altitude.

2.2 Green Deal and Sustainable Finance Action Plan

Since the beginning of the 1970s, research has been carried out, the results of which indicate an increasing burden on the planet: earth, water and air in the atmosphere caused by economic activity and human consumption. It is a continuation of the report of 1972 entitled *The Limits to Growth* [15]. Being more and more aware that people should react to undesirable changes in the environment, the state authorities, influenced by social movements and recommendations presented by the scientific community, decided to prepare a program of adjusting the socio-economic policy, including both the concept of a circular economy and climate policy. In 2015, the Paris Agreement was concluded [16]. The governments of almost all countries around the world declared that they would join the implementation of the climate policy aimed at limiting the increase in the temperature of the Earth's atmosphere by reducing GHG emissions. However, by the end of 2019, no significant effects of the implementation of the obligations specified in this agreement were observed. The results of measuring GHG emissions confirmed that from 1970 to 2019 the emission continued to increase and reached the level of 36.6 $GtCO_2$.
Air transport is often considered to be one of the greenhouse gas emitting sectors that is the least involved in mitigating climate and environmental impacts. According to ATAG the aviation sector has been successful in improving its fuel efficiency by a yearly rate of 2.3%, which was stronger than the industry target of 1.5% per annum from 2009 to 2020. Graver, Zhang, and Rutherford published in 2019 that estimated total CO_2 emissions from all commercial operations, including passenger movement, belly freight and dedicated freight, totaled at 918 million metric tons in 2018 made up of 40% domestic and 60% international trips. This figure equaled 2.4% of the global CO_2 emissions from fossil fuel use. Despite this small share in the CO_2 emissions global contribution, the growth of the sector's CO_2 emissions was fast, i.e., 32% between 2013 and 2018, which was 70% higher than assumed under ICAO projections. UNFCCC in 2014 estimated that emissions from international air traffic grew by over 75% between 1990 and 2012, which was almost double the average emissions growth rate from all other economic sectors [17].
Globally, GHG emissions were unexpectedly reduced by 2.6 $GtCO_2$ due to the partial blockade of global activity in 2020 during the COVID-19 pandemic [18]. Climate policy, referred to in many scientific and journalistic publications as the "Green Deal", in the opinion of many authors, should be implemented in a radical manner. J. Rifkin points out that a drastic reduction in GHG emissions should be achieved by 2028, and if this is not the case, undesirable phenomena of climate instability will occur on an increasing scale [19]. In the European Union, the "European Green Deal" [20] climate strategy was announced in 2019. J. Biden, elected the president of the United States in 2020, introduced the issues of climate change and energy

transformation to his agenda and, after taking office, confirmed his will to implement it in 2021 [21]. The attitude of the People's Republic of China (PRC) raises the greatest concerns of climate activists because at the Chinese Communist Party (CCP) congress held in March 2021, the implementation of such an economic program that would reduce GHG emissions was not mentioned, although the program does mention the promotion of pro-climate solutions [22]. According to scientists and experts, at the beginning of the third decade of the 21st century, there may be doubts as to whether the goals of climate policy will be pursued with sufficient determination in Europe and other continents, and therefore whether this policy will be effective. The factor that may help in the realization of the positive scenario is the involvement revealed by the financial sector which is increasingly involved in projects meeting the ESG assessment criteria. D. Busch points out that by implementing the provisions of the Sustainable Finance Action Plan [23] of 2018, the EU may become a global player that shows other regions of the world the course of action (global standard-setter) [24].
Striving to meet the sustainability requirements is treated as one of the most important factors that encourage enterprises to modify their business models or introduce new models [25].

2.3 Digital Economy and New Business Models

In the literature on the functioning of the modern economy, there is a view that the new business model, which is the new technology platform, was created in July 1980, when B. Gates, concluded an agreement with IBM regarding the development and use of the MS-DOS (Microsoft Disk Operating System). The decisive factor for the birth of the digital economy was the fact that "*Microsoft was thinking platforms. IBM and Apple were thinking products*" [26]. The importance of the development of the digital economy is recognized in Europe. In 2020, a strategy was announced which indicates that the aim is to create a single data space – a genuine single market for data, open to data from across the world – where personal as well as non-personal data, including sensitive business data, are secure and businesses also have easy access to an almost infinite amount of high-quality industrial data, boosting growth and creating value, while minimizing the human carbon and environmental footprint [27].
Over the past three decades, the path of building platforms has been taken by many start-ups in various regions of the world. It is significant that only few of them have gained a strong enough position in their chosen market segments, as did GAFAM on the consumer goods market in the western world, and Alibaba and Tencent in Asia. In many sectors of the economy, including air transport, only first steps of creating virtual platforms have been taken and further changes have been abandoned. In these sectors, the business activity model is maintained which continues to implement the traditional strategy of protecting its position on the market thanks to improving operational efficiency using IT solutions of the generation from the end of 20th century. These are service providers who mainly strive to maintain the attitude of loyalty on the part of their customers, especially the inhabitants of their country. At the same time, these are the entities which have not mastered the ability to use potentially available big data sets concerning customers and build their position by expanding relations with their customers. These enterprises overlooked the changes in information technology and completely failed to see an opportunity to build new business models [28]. They continued to use computer software built according to their individual internal requirements, failing to see the need to transform their business model into being "customer-centric" [29]. They neglected the development of digital

technologies, the use of which allows for an in-depth analysis of the evolving needs of passengers. Aircraft carriers did not notice in time the change in the attitudes of the customers who, in the era of "uberization of the service sector", became increasingly used to the comprehensive service by platform operators suggesting the possibility of using many complementary services. The most spectacular example of the anachronistic behavior of carriers is the maintenance of a constant, duplicated for decades, flight schedule offered by incumbent carriers. The main premise of "freezing" the offer is the attachment to slots at overloaded airports acting as hubs. The lack of flexibility of carriers in shaping fight schedules forces passengers to adjust their travel plans to these schedules, both in terms of the choice of airports and the flight time.

In the third decade of the 21st century, billions of smartphone users use the services of virtual platform operators, taking it for granted that countless services, thanks to "mobility", "connectivity", and "cloud", are available to consumers in almost every situation. Achieving the current digital economy phase required many groundbreaking innovations, including ordering a means of transport that replaces the traditional taxi using a smartphone. In August 2008, the website www.ubercab.com was registered. G. Camp noticed that the smartphone is connected to the cloud computing, it has a user location chip (GPS) and a semiconductor necessary for data transmission, so it is possible to create a service of a platform associating car drivers and people who want to travel, and the time and the route of the driver on the one hand and the preferences of a potential passenger on the other hand can be mutually adjusted [30]. Over the next several years, from the moment such platforms as Uber were created, the development of technology, including artificial intelligence solutions, led to a situation where resource management with the use of digital technologies is considered a condition for improving the ability to compete on the market [31]. The condition is to be able to notice that data can be recorded at anytime and anywhere, and their processing, especially when the data sets are very big, can provide information which was inaccessible in the past, and that nowadays it is possible to use Big Data technology [32]. With regard to mobility, Big Data has been successfully used for years [33]. The Institutional Theory of Information Technology indicates that there are numerous factors today that could lead to change in the attitude of air carriers and airport managers to the use of digital technologies, which would make them susceptible to the implementation of a new business model supported by these technologies [34]. There are announcements that in the coming years there will be a transformation of the currently created digital economy into another form of economy with new features of functioning, called Q economy [35], [36], [37].

3. Methodology

For several decades, traditional methods of defining and calculating external costs have been used to analyze the external effects of transport. A review of these methods and their effects is available in the literature [38]. Despite the popularity of the use of these traditional methods and the growing awareness of many stakeholders of the importance of the level of these costs and the sustained dynamics of their growth, until 2019 no significant corrections in the functioning of transport systems, including air transport serving passengers, had been observed. In order to analyze the application of disruptive innovations that may lead to radical changes in reducing the environmental burden, the method of scenario analysis was used in this study. This is a method by which possible changes in management processes and possible effects of such changes are described [39]. The criterion for assessing the implementation of a new business model constitutes the potential for changes in energy consumption, reduction in pollutant emissions, noise and vibrations as well as GHG emissions, and the decentralization of these burdens for people and the environment. This is a criterion used to evaluate economic processes using the measurement of natural quantities, without using the analysis of economic indicators [40]. Energy consumption analysis has become popular in relation to cargo transportation. The basic tools of analysis are widely discussed in the literature [41].

The study also uses statistical data, both the quantitative analysis of which and the interpretation based on the analysis of cause-and-effect relationships allow for the demonstration of the significance of the range of environmental effects provided for in the case of applying a new business model.

The quantitative analysis was adjusted to the content of the research question and is used to determine the following values.

1) Insofar as the use of direct flights replacing connecting flights with a transfer at the hub contributes to shortening the distance on which the air travel takes place (absolute values in km and relative values in percentage).
2) Insofar as the use of direct flights replacing connecting flights with a transfer at the hub contributes to the reduction of energy consumption necessary for propulsion of the plane, in particular due to the avoidance of the re-acceleration, take-off and re-ascend phases (absolute values in kg of fuel mass per passenger and relative values in percentage).
3) Insofar as the use of direct flights replacing connecting flights with a transfer at the hub contributes to the reduction of GHG emissions (absolute values in kg of CO2 mass per passenger and relative values in percentage).

The presentation of the new scenario, which concerns the application of a new business model using digital technologies in passenger air transport, is limited to the description of the basic elements of this scenario. This is due to the fact that the proposed new business model has so far been described only in the form of a concept, and there is no version prepared using the digital twin technology yet [42].In this study, the new proposal is limited to the ”business model design” and it is a subject of theoretical considerations and the object of strategic decisions made by operators, described quite modestly in the literature [43].

4. New Business Model: Virtual Airport Hub (VAH)

4.1 The Requirement to Reduce Energy Consumption and GHG Emissions

The implementation of climate policy requires the introduction of new technological solutions and business models in all sectors of the economy around the world. It must therefore also be taken into account by the aviation sector which includes both aircraft manufacturers and air carriers. The main goal is to introduce groundbreaking changes in propulsion design, as the experience of the past decades shows that “[s]ince1960, aircraft technology developments have allowed for a reduction in energy intensity measured in megajoules per available seat kilometer of approximately 70%. However, this tendency is becoming asymptotic as achieving marginal improvements in efficiency becomes more and more difficult” [44]. An innovative solution under preparation is the use of a completely new propulsion solution in aircraft. Turboprop and jet engines are to be replaced with electric engines powered by a hydrogen cell, constructed in the form of a three-element module, containing a hydrogen (H_2) tank used as fuel. One of such projects is the ZEROe propulsion module concept of the European aircraft manufacturer Airbus, presented in December 2020 [45]. In the opinion of G. Vittadini, responsible for technology development (CTO) at Airbus, the use of such modules will be possible from 2035 in aircraft with a number of seats from 30 to 70, which until now are equipped with turboprop engines and serving short- and medium-haul flights [46].

Regardless of the time horizon of the implementation of the new aircraft propulsion solutions, economic and administrative pressure will increase in the coming years to reduce the emission of pollutants, noise and vibrations as well as GHG emissions in air transport. It should be foreseen that additional charges will be imposed on tradition aviation fuel, mainly climate or excise duty charges, and additionally air carriers will be charged with GHG emission charges. So as to maintain the competitiveness of the aviation sector services, it will be necessary to search for new solutions to reduce energy consumption indispensible for air transportation.

The implementation of a new concept can only take place if the entire aviation sector apply a new business model to continental flights. This means institutional changes on the part of the air carriers, which are the most important service providers on the supply side of this sector, and on the part of public authorities regulating and controlling air traffic. In the past in Europe (data as of 2008) 38 managers of airspace located above each country separately were educated [47], which requires incurring transactional costs so as to coordinate their activities under the "European Sky". An institutional change which would lead to the creation of a single airspace agency in Europe would significantly reduce air traffic control costs.

4.2 Assumptions of the Operation of the VAH

The new business model called "virtual airport hub" (VAH) assumes the implementation of thorough changes in shaping the air transport offer. The effects of implementing these changes are to be at the same time:

- reducing energy consumption in transport, measured in absolute and relative values, and thus reduction in pollution and GHG emissions in air transport,
- increasing the quality of customer service by reducing the time of their multi-segmental multi-modal journey along the entire "door-to-door" route due to the network's better adjustment of air transport services offered to the needs of passengers and shortening the route by land transport to the airport on the first section of the journey and shortening the route of pick-up from the airport by land transport on the last section of the journey,

increasing the resilience of the aviation sector to the occurrence of unexpected disturbances, e.g., related to the outbreak of a pandemic, thanks to the decentralization of travel flows and the limitation of transit traffic at communication hubs.

VAH would function as a virtual platform operated by the operator managing the hybrid-economy project, i.e., able to monitor, create and implement the provision of services and customer service both in the virtual and real world. The platform operator acts as a mobility service organizer to consumers, which, in cooperation with air carriers and operators of other means of transport, offers a comprehensive "door-to-door" movement service. It acts as a service broker charging a commission for its services.

The basic principles of VAH functioning are:

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- no fixed flight schedule within the continent,
- the use of data on the needs of travelers and the staff and equipment potential of carriers and the potential of airports to determine the network of air connections conducted in the next day,

the avoidance of situations in which the offer for the passenger provides for the use of flights connected at transfer hubs.

The method of operations of VAH is the management of operational and commercial processes using digital technologies: Big Data, Digital Twin and Artificial Intelligence.

Big Data and Artificial Intelligence technologies are used to collect data concerning the needs of customers, including the repeatability of their needs as well as concerning the staff and equipment potential of aviation operators. Digital Twins and Artificial Intelligence allow for the creation of operational and commercial service scenarios for customers in the next day, the selection of the scenario in accordance with the criterion of reducing energy consumption and emissions within the entire aviation sector and the general transport sector (including private motorization) involved in handling journeys from the place of departure by the consumer to the airport to the place where the consumer ends his/her journey. The cycle of activities performed by the VAH within 24 hours is shown in Fig. 1. It is assumed that all consumers who will be served on day T make their needs available to the VAH operator at the latest at 10:59 pm on day T-1.

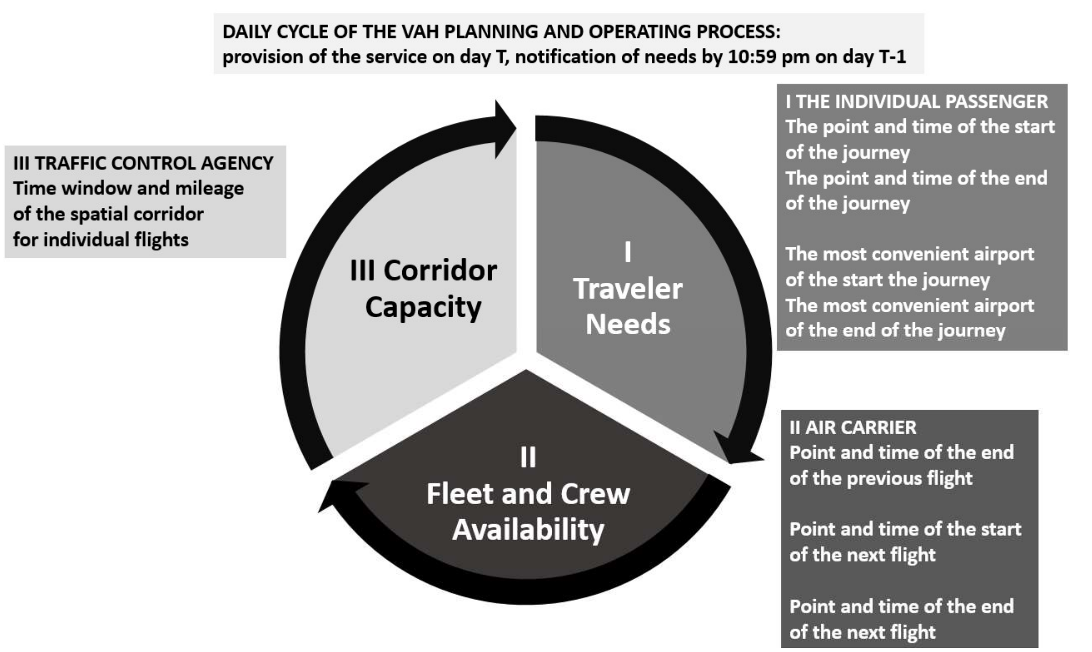

Figure1.The process of the daily creation and implementation of a virtual daily flight schedule for air carriers participating in the VAH project

The new business model may be introduced by a new player that enters the market. A scenario may also be considered that a certain group of carriers already present on the market will make a strategy adjustment agreed upon among themselves and, as part of an alliance, jointly introduce a new offer to the market.

4.3 Spatial Dispersion of the Offer and Organizational Decentralizationin the Aviation Sector – the Market in Europe and the Market in Germany in 2019.

The analysis of data on the functioning of the aviation sector before the COVID-19 pandemic allows for the presentation of a scenario of enriching the offer of this sector upon the implementation of the VAH business model.

On a continental scale, the analysis of the spatial dispersion of the offer in the aviation sector can be carried out using data for the market covering all countries in Europe. The data available for the EU-27 states that three countries play a fundamental role in continental traffic. The data presented in Table 1 shows that in 2019, 68 093 000 passengers traveled by air between Germany and five countries, including Spain and France, between Spain and four countries, including Germany and France – 69 239 000 passengers, and between France and four countries, including Spain and Germany – 43 582 000 passengers. The market including France, Spain and Germany in 2019 accounted for 38.0% of the total EU-27 transport market. The position of these domestic markets is strong compared to the other EU-27 member states, but not dominant.

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Table 1
Air traffic in the three leading countries among EU-27 in 2019

Country	Partner Country	Passengers (1 000)	Share of intra EU-traffic [%]	Subtotal share of intra EU-traffic [%]
Germany	Spain	28 949	8.50	20.10
	Italy	15 206	4.50	
	France	8 504	2.50	
	Greece	8 104	2.40	
	Austria	7 330	2.20	
Spain	Germany	28 949	8.50	20.40
	Italy	16 256	4.80	
	France	15 265	4.50	
	Netherlands	8 769	2.60	
France	Spain	15 265	4.50	12.90
	Italy	12 452	3.70	
	Germany	8 504	2.50	
	Portugal	7 361	2.20	
Three leading countries (DE, FR, ES)	Eight partner countries (DE, FR, ES, IT, GR, NL, PT, AU)	128 196		38.00

Source: Own calculation based on Eurostat data [48].

Germany plays a special role in the European market. In 2019, the largest number of passengers in Europe started their foreign air travel from the territory of this country. Of the total number of 101 338 253 people leaving Germany by plane, the largest group of 79 531 356 people traveled within the European continent [49]. The number of 599 regular connections were serviced daily, including 123 domestic connections. Within the EU-27, the most connections were to airports in Spain (57), Italy (49) and France (43). In addition, 53 connections with the United Kingdom were operated within Europe. The list of 15 airports in Germany with the highest number of direct flights (more than 20) is presented in Table 2.

Table2. List of the airports in Germany offering flights to more than 20 destinations

	Code IATA	Airport	Number of destinations	Number of carriers	Remarks
1	FRA	Frankfurt/M	239	100	Hub of Star Alliance
2	MUC	Munich	191	77	Hub of Star Alliance
3	BER	Berlin Brandenburg	170	97	opened in 2020
4	DUS	Duesseldorf	147	57	
5	CGN	Cologne	92	26	
6	HAM	Hamburg	87	42	
7	STR	Stuttgart	80	30	
8	HAJ	Hannover	50	24	
9	HHN	Hahn	47	2	
10	BRE	Bremen	43	13	
11	NRN	Weeze	38	1	
12	NUC	Nuremberg	32	17	
13	LEJ	Leipzig	28	13	
14	DTN	Dortmund	28	11	
15	FMM	Memmingen	21	8	

Source: Own calculation based on data of Laenderdaten [50].

The analysis of the data presented in Table 2 shows that the largest number of connections, including intercontinental ones, was offered at two airports acting as Lufthansa hubs: in Frankfurt / M (239) and in Munich (191). In addition, there were airports in Germany in two cities with more than 100 connections: Berlin (Airport Berlin Brandenburg – 170, opened in 2020) and Dusseldorf (147). At the remaining 9 airports, the number of connections ranged from 21 to 91. The geographical dispersion of the aviation sector offer was accompanied by a large organizational decentralization. In Frankfurt / M, 239 connections were offered by 100 air carriers, and at the Berlin-Brandenburg airport, 170 connections were offered by 97 air carriers. In addition, in 2019, there were 12 airports with the number of direct connections ranging from 1 to 18.

The geographical dispersion of the offer in the aviation sector is conducive to the sector's evolution towards the implementation of the VAH business model. The more direct connections between airports within the continent, the closer it is to achieving the situation where passengers avoid using connecting flights at the hub. The existing organizational decentralization in the aviation sector has a different meaning. Since the VAH business model is to optimize the use of human and material resources in the sector with the use of the criterion of minimizing energy consumption in the entire sector, organizational decentralization can be treated in two ways. On the one hand, as a barrier to adjusting the offer as individual carriers, following the traditional marketing strategy, are focused on defending their position on the market, i.e., promoting their own network of connections. This attitude blocks the activities of the platform which aims to coordinate operating activities across the entire sector. On the other hand, organizational decentralization can be treated as a favorable situation for the implementation of the VAH business model as it is possible to make shareholders of air carriers aware that they can significantly improve the value of their entities (company value) by participating in activities

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in accordance with the VAH business model as they can contribute to the reduction of energy consumption in the entire aviation sector and thereby improve off-balance ESG indicators in their companies.

4.4 Non-Sustainability of Regional Air Traffic – Interregional Analysis(Case study)

There is a strong variation in the regional concentration of air traffic in Europe. This phenomenon reveals the deviation of the level of air mobility in the region from air mobility in the country. Three regions in Europe, which are fundamentally different from each other, have been selected for the case study. The region of southern Poland includes Kraków, which is a world-famous tourist attraction and at the same time a large business center as well as the Silesian agglomeration, from which many residents set off to rest abroad. Eastern Spain is a holiday region (Costa Blanca) that not only enjoys popularity with foreign tourists but also is a significant economic center. The Netherlands is highly developed economically, and the attractiveness of the Amsterdam-Shiphol air hub is so great that this hub prevails over the regional airports.
Table 3 presents data for the volume of air traffic in four European regions: in southern region of Poland (NUTS PL 2), the Valencia region in the east of Spain (NUTS ES 53), the central region (NUTS NL 3) and the southern Netherlands (NUTS NL 4).

Table 3.Relation between the size of the region's population and the size of the flow of travelers served at airports located in these regions – data as of 2019.

<table>
<tr><th>Airports</th><th>Region</th><th>Population</th><th>Passengers (airports)</th><th>Air mobility in the region</th><th>Air mobility in the country</th><th>Relation of regional and country air mobility</th></tr>
<tr><td>KRK, KTC</td><td>NUTS PL 2</td><td>7 943 467</td><td>13 254 861</td><td>1.6686</td><td>1.2392</td><td>1.3465</td></tr>
<tr><td>VLC, ALC</td><td>NUTS ES 53</td><td>5 094 675</td><td>22 810 400</td><td>4.4773</td><td>4.8591</td><td>0.9214</td></tr>
<tr><td>AMS</td><td>NUTS NL 3</td><td>8 032 438</td><td>71 706 999</td><td>8.9272</td><td rowspan="2">4.7386</td><td>1.8839</td></tr>
<tr><td>EIN</td><td>NUTS NL 4</td><td>3 609 912</td><td>6 700 000</td><td>1.8560</td><td>0.3917</td></tr>
</table>

Source: own calculation using data of local authorities.

An unusually high level of air mobility in the region is noticeable for the NUT NL 3 region of the Netherlands. This region is home to one of the largest European air hubs at Shiphol airport (AMS), the main air operator of which is the AirFrance-KLM alliance. On the other hand, the region of the southern Netherlands, where Eindhoven Airport (EIN) is located, shows an unusually low level of air mobility in the region. This is due to the fact that the attractiveness of the offer of the AMS airport located in the territory of another region of the country for residents and visitors to the southern Netherlands region is drastically higher than the attractiveness of their own regional airport EIN. The diversification of the attractiveness of airports located in neighboring regions is well shown by the relation between the value of the indicators of air mobility in the region and air mobility in the country. For airports in southern Poland and eastern Spain, this ratio is close to 1 while in both Dutch regions it significantly deviates from the value of 1.

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The implementation of the VAH business model should lead to such an adjustment of the operational activity of the entire aviation sector where in individual regions of the continent the value of the deviation of the relation between the regional air mobility and the country air mobility from the value of 1 would be reduced. This would mean that the number of consumers who use connecting flights and thus participate in transfers at hub airports decreases. The effect would be the reduction in energy necessary to meet the mobility needs of these consumers across the aviation sector.

4.5 The Potential Shape of the Connection Network in the VAH Business Model – Estimate for Europe by the Size of the Passenger Flow in 2019

In the aviation sector, trade secret protection is so advanced that there is no access to basic data. Only having the insider's knowledge makes it possible to precisely determine the number of people who use the services of this sector. The published data concern the registration of passengers served at the airports. In such a situation, model estimates can be used. Their level of inaccuracy is not significant enough to considerably affect the content of conclusions concerning the possibility of shaping passenger air traffic in Europe using the VAH business model.

For the purposes of this analysis, the following assumptions were made:

1) In 2019, around 1 billion passengers were served at airports in Europe.
2) Within 2022 and 2025, air traffic in Europe may return to the level of 2019.
3) Since each passenger was registered at least twice at the airports (at the airport where he/she started the flight and at the airport where he/she ended the flight), there are at least 500 million of these passengers annually.
4) If 10% of this group used connecting flights at transfer hubs while traveling within the continent (and other passengers using the hubs transferred to intercontinental flights), then their stay at the airport was registered not twice, but four times (or more if they transferred more than once). The above mentioned number of 500 million travelers should therefore be reduced by 50 million people who would stop using transfers when traveling within the continent.
5) If 450 million people traveled in a year, the average daily passenger flow is around 1 230 000 people.
6) If we assume that there are 609 airports in operation with regular air traffic in Europe – Appendix B presents a list of the number of such airports in individual countries, but the new VAH business model would use the potential of approximately 100 airports, then at one airport the daily flow would amount to 12 300 people on average. This is the number of people who would depart from a given airport on a direct flight (and the same average number would arrive at that airport).
7) With the use of B737 or A320 / 321 aircraft, on average approximately 70 aircraft could depart (and arrive) daily, almost fully utilized with 180 seats on board, which means a take-off and landing operation almost every 8 minutes during 18 hours of the operation of airspace during the day. This means that in the VAH business model it is possible to offer a network of connections ensuring direct travel from any region (where the airport is located) to approximately 70 destinations within the continent. These are average values.

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In the case of gradual replacement of aircraft using emission fuel with a capacity of 180 seats with smaller aircraft with zero emission propulsion (e.g., ZEROe) with a capacity of around 60 seats, the number of connections per day would triple. This means a reserve for increasing the number of direct connections from each airport and / or multiplying the number of flights in the direct connection already served. At the same time, there is no risk that the capacity of airports will be exceeded, as the number of passengers will not increase, and the increased number of take-off and landing operations would lead to a situation in which the take-off and landing operation would take place almost every 3 minutes on average.

5. Reduction in Energy Consumption and Reduction in GHG Emissions After the Implementation of the VAH Business Model in Europe - Estimation

By implementing the VAH business model, the volume of operational work in the aviation sector could be reduced, but it would be done without changing the number of travelers using the services of this sector.

Data illustrating the potential to reduce energy consumption and GHG emissions in absolute values of kg of mass for one flight and kg of mass for one passenger are presented in Table 4. The analysis of indicators is presented for selected routes within Europe, including connecting flights with transfers at 6 hubs.

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Table 4
Case studies in continental air passenger traffic in direct flights and connecting flights
Reduction possible in case of avoiding of connecting flights

	Direct flight					Connecting flight						Reduction avoiding connection flight			
One way travel	distance [km]	Fuel consumption total [kg]	CO2 emissions total [kg]	CO2 emissions per pax [kg]		transit hub	distance [km]	Fuel consumption total [kg]	CO2 emissions total [kg]	CO2 emissions per pax [kg]		distance [%]	fuel consumption total [%]	CO2 emissions total [%]	CO2 emissions per pax [%]
WAW - ALC	2 268	10 931.7	34 544.2	183.4		FRA	2 387	11 161.4	35 270.0	251.9		-5.0%	-2.1%	-2.1%	-27.2%
WAW - FCO	1 324	6 770.7	21 395.4	121.3		FRA	1 849	9 472.3	29 932.5	221.7		-28.4%	-28.5%	-28.5%	-45.3%
WAW - LIS	2 747	10 911.0	34 478.8	245.8		BCN	2 859	13 522.2	42 730.2	275.7		-3.9%	-19.3%	-19.3%	-10.8%
						CDG	2 810	19 924.4	40 841.1	291.7		-2.2%	-15.6%	-15.6%	-15.7%
HEL - LHR	1 846	10 314.0	32 595.1	155.1		CPH	1 867	10 121.6	31 984.3	213.2		-1.1%	1.9%	1.9%	-27.3%
						FRA	2 190	11 222.6	35 463.4	236.4		-15.7%	-8.1%	-8.1%	-34.4%
ATH - BCN	1 902	8 620.8	27 241.7	164.0		MUC	1 902	14 556.1	45 997.3	267.4		0.0%	-40.8%	-40.8%	-38.7%
RIX - MXP	1 635	6 990.6	22 090.3	164.3		VIE	1 755	9 433.1	29 808.6	200.1		-6.8%	-25.9%	-25.9%	-17.9%
STR - BCN	995	5 300.0	16 748.0	109.1		FRA	1 247	7 475.7	23 623.2	162.9		-20.2%	-29.1%	-29.1%	-33.0%
HAM - SOF	1 564	6 930.0	21 898.8	135.3		MUC	1 698	9 397.5	29 696.1	194.1		-7.9%	-26.3%	-26.3%	-30.3%

Source: own calculation using data of ICAO [51].

The data was obtained from the ICAO calculator which used operational data provided by the carriers. The analysis of the results of selected routes of direct flights and connecting flights shows two regularities. Firstly, the savings in energy consumption and the reduction of GHG emissions result from the shortening of the flight route. The higher the savings the more the route of two connecting flights needs extending compared to the route of a direct flight. Secondly, if the transfer hub is located on the axis or a short distance from the axis of the direct flight, the energy savings result primarily from the elimination of the additional acceleration and ascend to the second flight, and these operations require disproportionately (even 50% more) than powering engines in flight at cruising altitude [52].
The main expected effect of the VAH business model is the elimination of travel with a transfer. The description of point 4.5 shows that approximately 50 million fewer passengers would use an additional flight. Assuming that each of them would save around 75 kg of GHG emissions, the total annual savings in continental traffic in Europe could reach approximately 0.0072 $GtCO_2$. This would correspond to around 5% of the GHG emissions from continental flights in Europe annually.

6. Conclusions and Implications

By the end of 2021, most restrictions on the freedom to travel are expected to be lifted in various regions of the world, including Europe. It is expected that there will be changes in the behavior of people who used air transport services for intercontinental and continental travel prior to the COVID-19 pandemic. In the event of a permanent decrease in the demand for air carrier services, the effect will be reduction in GHG emissions in the coming years. Since the goal of public policy on counteracting climate change is to control the recovery process in the aviation sector with the support of active and pro-innovative behavior of stakeholders, the presented VAH business model deserves to be continued in both design and analytical work until it reaches the stage of operational and commercial maturity and implementation. A relatively small reduction in GHG emissions with an unchanged volume of transport activity in air transport, constituting around 5% of total GHG emissions in continental flights, would be of significant importance as an element of the European Green Deal objectives.
Particularly interesting is the inclusion of new technologies in the functioning of the VAH business model: Big Data, Digital Twin and Artificial Intelligence. Thanks to their application, efficient construction of operational plans and commercial activities of air carriers "in the next day" is to be ensured while offering a significant number of direct connections from many airports across the continent. The potential of these airports is very large, much larger than the volume of air traffic as it was in 2019, therefore it is possible to provide services even to a much larger number of passengers thanks to the decentralization of this traffic, without having to invest in the point infrastructure of the aviation sector. Probabilistic analyses should provide access to reliable information on how to manage the human and material potential of carriers so as to achieve a satisfactory level of microeconomic effectiveness of the operation of these carriers in the implementation of transport in the scenario ensuring the maximum reduction of energy consumption and thus GHG emissions.
The conducted analysis showed that the introduction of the new VAH business model leads to such an adjustment to the operational and commercial activity in the aviation sector which

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allows achieving a reduction in energy consumption by aircraft and, consequently, a reduction in GHG emissions.

It should be emphasized that the application of the VAH business model may provide an additional reduction in GHG emissions, obtained regardless of the effects of other undertakings, including those related to the introduction of subsequent generations of aircraft into service, change of propulsion and the introduction of synthetic fuels produced by the use of electricity obtained from renewable energy sources.

However, it can be expected that the GHG reduction potential is much larger, as the VAH business model does not provide for the use of fixed flight timetables at all. This opens a path for eliminating the operation of aircraft in those cases where there is low utilization of their potential. Since the average level of seat occupancy in 2018 for the aviation sector was estimated at approximately 84% [53], it can be assumed that during some flights this indicator was relatively low and it could be improved both by making the flight schedule more flexible and by eliminating flights with a small number of seats taken.

The scenario taking into account the introduction of the new VAH business model will certainly achieve effects that go beyond the reduction of energy consumption and reduction in GHG emissions. The dissemination of the operating model of the virtual digital platform operator in the aviation sector, which constitutes an element of the hybrid economy being created, may contribute to the improvement of the quality of service to consumers who satisfy their mobility needs by using the services of an air carrier. Along with the use of the Digital Twin technology to manage the entire mobility system on a continental scale, there will be opportunities to include the optimization process into the transit both to and from regional airports using various solutions in public rail and road transport as well as using individual means of transport. The prospects of obtaining additional potential effects may become the subject of further research tasks.

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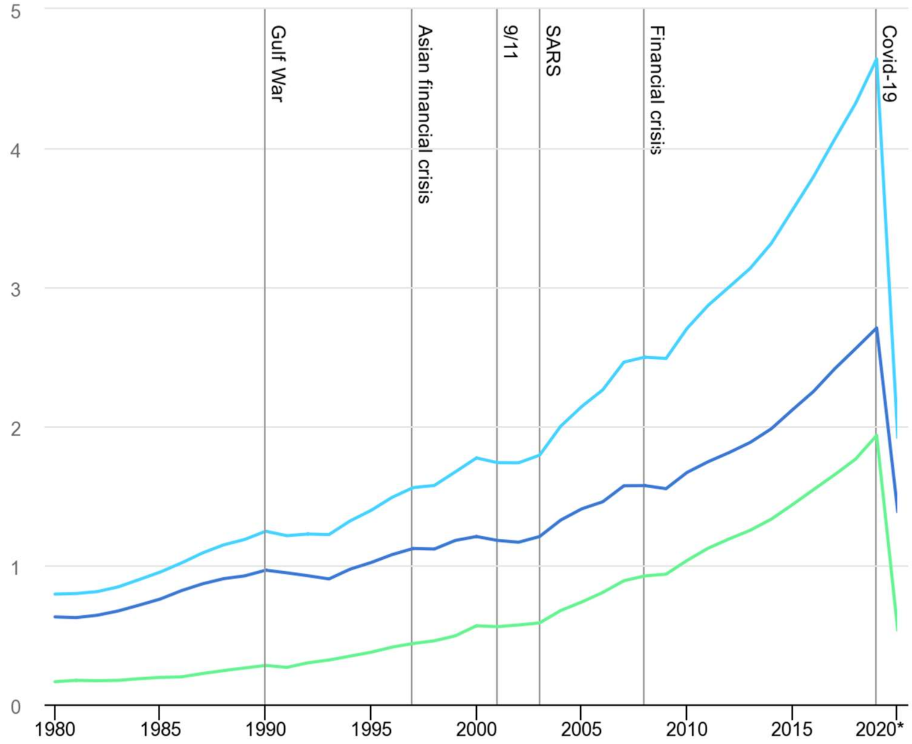
Appendix A
Figure A1
World air passenger traffic evolution, 1980-2020 .

Billions of passengers



*) 2020 – estimation
Source: [54].

Appendix B

Table B1
List of selected airports in European countries (only airports with regular passenger traffic)

Country	EU	non EU	Country	EU	non EU
Albania		1	Luxembourg	1	
Austria	7		Malta	1	
Belarus		6	Moldova		2
Belgium	7		Montenegro		2
Bosnia and Herzegovina		4	Netherlands	6	
Bulgaria	7		North Macedonia		2
Croatia	9		Norway		48
Cyprus	4		Poland	13	
Czech Republic	5		Portugal	13	
Denmark	10		Romania	13	
Estonia	5		Russia (European part only)		94
Finland	19		Serbia		2
France	53		Slovakia	3	
Germany	29		Slovenia	2	
Greece (international only)	17		Spain	36	
Hungary	5		Sweden	36	
Iceland		13	Switzerland		3
Republic of Ireland	6		Turkey (entire country)		36
Italy	46		Ukraine		10
Kosovo		1	United Kingdom		26
Latvia	2				
Lithuania	4		Subtotal	359	250

Source: Ownanalysis.

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