SPACE TOURISM. A FUTURE SUSTAINABLE BUSINESS OR NOT?

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Abstract

Space tourism, which has recently come to the attention of society, has sparked controversy over the environmental consequences of recreational space travel, which has become a lucrative business done by and for the super-rich. This scientific paper investigates, through qualitative and quantitative research, the potential for the success and sustainability of this industry. The interviewed tourism and aviation experts believe that space tourism deserves to be developed in order to colonise other planets and make society responsible for the environmental issues, despite the huge costs, which will be reduced, similar to the aviation trend, by technological advances. Also, the results of the survey in which students participated, as future specialists in business and tourism, indicate an increased share of those aware of the effects of carbon pollution and a percentage of over 30% of those who believe in the development of space tourism, supported by economic benefits of offsetting environmental costs. The overall conclusion of the study highlights technological progress as a mobilising factor in reducing carbon dioxide emissions from spacecraft and in achieving the dream of sustainability of space travel, revealing space tourism as a resource that would benefit society as a whole, scientifically and economically.

Keywords:
Space tourism, sustainable business, carbon emissions, spacecraft, colonisation

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1. Introduction

Space tourism has recently appeared in the headlines of the most popular newspapers worldwide. Seen as an emerging market with huge potential for development, space tourism has proven its ability to attract billionaires to finance business in this industry (Seedhouse, 2021). The prices paid for tickets by the wealthy, who want to travel in space, have decreased slightly over time, but are still at huge levels and turn space tourism into a niche market, accessible only to the super-rich in search of a unique recreational journey (Primal Space, 2020). In addition to the projected profitability of space tourism businesses in the near future, extremely high associated costs, especially environmental costs, must also be taken into account (Ho, 2021).

This paper aims to create an analysis of how the emerging space tourism market is influencing the environment and how space travel can become more "environmentally friendly" or even sustainable. To achieve this goal, the conducted research seeks to provide answers to questions that few people from the general public think when they dream of seeing the curved shape of the Earth. Ideas from the literature review, such as how far in time the general public is from space travel, what are the environmental consequences of a space trip, and what steps can be taken to reduce a space traveller's carbon footprint, help to investigate the future sustainability of space tourism and also to make readers aware of the conservation of the Earth's natural resources.

This study is based, on the one hand, on qualitative research, conducted in the form of one-on-one interviews with tourism and aviation specialists, considered related domains, to determine the environmental impact of aviation and the effectiveness of the measures taken to reduce the carbon emissions from aircraft. Based on this information, the interviewed experts assess the chances of space tourism to become a successful business and achieve the dream of sustainability or at least to offset the environmental costs through

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economic benefits. On the other hand, a quantitative survey of students who specialise in business administration or tourism, as future experts in the field, seeks to identify their concerns about the environmental problems posed by carbon dioxide pollution, and their confidence in the development of space tourism. Moreover, starting from the assumption that those who use air transport for tourism purposes more, contributing more to carbon pollution, are predisposed to invest more in space tourism, the research aims to establish the intensity of the relationship between the two variables and students' perceptions of the sustainability of space tourism in the future.

2. Literature review

In light of recent events, there has been a growing interest in space tourism. Although space travel has been around for about 60 years, its scientific purpose has blended harmoniously with its recreational purpose over time (Seedhouse, 2021). The desire of billionaires to see the curved shape of the Earth, bordered by the darkness of space, does not date back long, and scientific work has tried to keep pace with the speed of evolution of this market.

Articles are still in the process of being written because space tourism is far from its full potential. 2021 has been a fabulous and successful year in achieving the dream of marketing space tourism to the general public, but turning it into reality is also a cause for concern. The thinning of the Earth's ozone layer shapes the mission of those at the helm of space tourism to conserve the environment of the Earth, using technological advances in favour of this approach.

Spiliakos (2018) explains that a sustainable business has positive impacts both on the environment and society and that is what space tourism aspires to become in the future. In the following subchapters, scientific articles, online articles, and videos are used as sources to determine and quantify the environmental consequences of space tourism and to identify solutions in an attempt to protect the Earth from massive greenhouse gas pollution.

2.1 The evolution of space tourism and the costs of a journey to space

Seedhouse (2021) describes space tourism as a form of recreational tourism, through which people travel in space for recreational purposes, facilitated by state-owned or, more recently, private companies. Suborbital and orbital flights, which brought the pioneers of this industry to the front page of newspapers, are just the beginning of what can soon be called exotourism, when travel will pass through classic airspace and reach destinations beyond Earth's orbit (Neacșu, 2021), after the market will develop and reach maturity, and companies will exploit the full potential of new technologies.

Space tourism was built on the pillar of space travel, which made its debut on April 12, 1961, when Yuri Gagarin became the first man to arrive in space. Since then, about 600 people have been fortunate enough to see the Earth from the same angle. Most of them are professional astronauts, who have spent years simulating the conditions of weightlessness and how to react in critical situations. One of the first rich people to pay for a ticket to travel in space was the American entrepreneur Dennis Tito, who gave up about $20 million in 2001 to spend 8 days on the International Space Station (Seedhouse, 2021). Primal Space (2020) mentions that his space adventure caused controversy, as NASA refused to train him for possible obstacles in this experiment, but he chose to travel with the Russians, being a pioneer for commercial rocket launches.

Space travel later became accessible to the private sector, and competing companies in the space tourism market developed spacecraft with reusable capsules, which significantly reduced the cost of a space trip (Primal Space, 2020). The mechanism by which these spacecraft capsules can be reused includes the detachment of the engine from the capsule after reaching an altitude of approximately 100 km. From that moment on, the capsule is in free fall, still maintaining an upward trajectory, and allowing passengers to get up from their seats and experience weightlessness for a few minutes. After this time, the capsule returns to the atmosphere and the passengers leave the state of weightlessness, resuming their seats and preparing for landing on Earth (Primal Space, 2020). The reuse of spaceship capsules has made the cost of space travel more accessible to a wider segment of people, with the average financial cost of an adventure being

$200.000. Still far from being experienced by a middle-income man, space tourism is an emerging industry, and competitors are struggling to offer the lowest price for a ticket to space.

Currently, the costs of reconditioning the capsules are the ones that significantly increase the price of a space trip, but the manufacturers in the space tourism market aim to reduce these costs to be similar to those of the terrestrial tourism industry, charging customers in the future only for fuel and crew's effort. Primal Space (2020) reveals that NASA recently decided to open the International Space Station to the general public, which operates at a cost of $4 billion a year. Visitors can now help reduce this cost by paying $22.500 a day on the ISS, including air and food. For other expenses such as electricity, the final price per day is up to 35 thousand dollars.

Manufacturers of large expandable space station experimental modules have tried to reduce the cost of a stay in space, proposing through their products a large space, obtained through an inflatable mechanism, to serve as a hotel. Taking into account all the progress made with reusable spacecraft and expandable modules (Primal Space, 2020), space tourism is expected to be closer to the general public, thanks to companies' efforts to reduce prices and increase demand. Beyond that, Wendover Productions (2021) points out that the difficulty of increasing demand is due to an economic problem, the fact that there is no concrete reason to travel in space. Experts believe that once people are given a reason to be captivated by space travel, they will become more eager to try such an experience. However, in the rush to achieve the dream of seeing the Earth surrounded by the darkness of the Universe from the outside, few think about the related environmental consequences (Primal Space, 2020).

2.2 The environmental costs of the latest tourist space journeys

Three major events in 2021 showed that it is just the beginning of space rocket commercial launches: Richard Branson's space trip in the Unity rocket, owned by Virgin Galactic, dated July 11, that of Jeff Bezos in the Blue rocket Origin called New Shepard, on July 20, and the first launch into orbit with a crew of tourists led by SpaceX, Elon Musk's company, on September 15.

All of these billionaire extravaganzas have opened the door to a new business opportunity, with the industry's market expected to reach $3 billion annually by 2030, according to estimates by the Swiss-funded UBS investment bank (Gorman, 2021). Beyond the fact that it has endured for days in the headlines, this emerging market raises many concerns about the environment. Ahmed (2021) points out researchers' perspective: although the frequency of these space missions is not quantified in a huge number of carbon dioxide emissions, they endanger the already depleted ozone layer from massive pollution caused by burning fossil fuels on Earth and commercial flights.

Arabesque (2021) explains that what has an impact on the environment in space tourism can be avoided and the same source indicates the main reason why they exist: a competition between billionaires. Virgin Galactic claims that its space adventure from July 2021 produced the same level of pollution as a flight between London and New York, promising to work to reduce the carbon footprint of the supply chain for future commercial space travel. According to an analysis by a French astrophysicist, space travel by Virgin Galactic was much more expensive for the environment, because it includes a much smaller number of passengers than a transatlantic flight (Ahmed, 2021).

Moreover, the Virgin Galactic rocket is powered by a type of synthetic rubber that is burned in a strong greenhouse gas, nitrogen oxide. This combination can cause ozone depletion due to accelerated chemical reactions, leading to increased radiation levels in humans. Also, several trips of this nature will cause the reflection of the sun's rays and will cause a nuclear winter effect. None of this would happen if those in charge of this industry differentiated between space research, which would contribute to the evolution of humanity, and space tourism, which would serve as a source of entertainment for the wealthy.

At the same time, Blue Origin boasts the use of a reusable spacecraft, which affects the ozone layer 100 times less than Virgin Galactic, and the fact that it is moving in an ecological direction 750 times more. compared to the aforementioned benchmark. Heilweil (2021) reveals the reality behind the theory that the

burning of liquid hydrogen and liquid oxygen can give the impression of a company aware of the ecological effects of its activity, as the rocket is powered by water vapours. Researchers have studied in more detail how liquid hydrogen and liquid oxygen are obtained and concluded that this mode of consumption is also expensive, requiring a large amount of electricity (Ahmed, 2021).

Beyond these two adventures of the billionaires who travelled into suborbital space, causing concerns about the environmental consequences, it is worth mentioning the orbital flight of SpaceX, using a more powerful engine, which produced an increased amount of carbon dioxide.

Pollack (2021) specifies that orbital launches (400 km above Earth) generate a more pronounced carbon footprint and higher environmental costs. An analysis made on Virgin Galactic and Blue Origin shows that each of their flights produces on average carbon dioxide emissions of 60, and respectively 90, tons. Dividing these amounts by the number of passengers, it can be concluded that a space flight creates in just a few minutes a carbon footprint equivalent to that of 2-3 people living a year on Earth. Considering the carbon dioxide emissions, much more worrying are the data provided by the orbital launches of SpaceX, which, based on a calculation of carbon emissions, reach the equivalent of 395 transatlantic flights (Ahmed, 2021).

Ho (2021) describes how the dream of rich people to see the Earth from the outside would be catastrophic for the environment. Given the limited passenger capacity and the growing interest in this emerging market, the space tourism industry is not at all sustainable at the moment of speaking. Moreover, this is a threat to the environment, as humanity has already begun to see the effects of climate change, and on human health.

Migraines, shortness of breath, and suffocation are just some of the consequences of exposure to too much carbon dioxide. Each rocket launch belonging to Virgin Galactic and Blue Origin emits 8, and respectively 15, tons of carbon dioxide per passenger (Pollack, 2021), huge quantities compared to the 4.8 tons representing the average annual consumption of a person on Earth.

At the same time, it should be noted that space tourism does not destroy the environment as much as the aviation industry today, but the growth potential of this emerging industry is the issue that worries mankind, regarding the environmental problems generated. A rocket launch emits a considerably higher amount of carbon dioxide than a normal flight, and once the space tourism industry reaches maturity, the numbers will be frightening to protect the Earth from climate change and pollution (Ho, 2021). Concrete action needs to be taken to restrict wealthy entrepreneurs from making a profit while damaging the environment, and if space tourism is never to be sustainable, a minimum effort can be made to reduce the carbon footprint of a space tourist.

2.3 Proposed measures to reduce the carbon footprint of a space tourist

Sheetz (2020) reveals that SpaceX has a deeper purpose in developing and profiting from the space tourism industry. Elon Musk has already made written arrangements with NASA to transport astronauts to and from the International Space Station, offering them orbital flights that last days and affect the environment more than the suborbital ones. Beyond the efforts to train the crew, the resources needed and the costs involved, his ultimate goal is to colonise the planet Mars, planning to use the revenues from space tourism to achieve his dream.

A fully reusable rocket is the spacecraft model SpaceX aspires for future space travel, a measure that would also reduce environmental and economic costs, but which is constrained by several key factors that discourage entrepreneurs from entering this market: the need to make large investments, a lot of time spent on research and development, the need for the latest technologies and equipment and the insecurity of demand elasticity in relation to price changes (Salt, n.d.).

High barriers to entry into the niche market of space tourism have led to the rise of large producers, who have control over prices and enjoy the freedom not to obey complex written laws. Kumar Padhy and Kumar Padhy (2021) point out that the law on suborbital flights does not follow international standards and is interpretable. This allows space tourism producers to interpret the laws favourably and ignore the

consequences of the flights they promote. Billionaires are not afraid of justice and are taking advantage of an insufficient number of space laws, which encourage them to do business with high economic profitability, but also causing huge environmental costs.

Sheetz (2020) notes that the US is currently the only state to enforce national laws on the private space travel sector. The Federal Aviation Administration (FAA) takes care of this and has laws to be followed by pilots and crew, but does not include in the provisions other participants in such a trip. Moreover, the institution is responsible for licensing and monitoring rocket launches, as well as ensuring that aerodromes are located in safe areas (Heilweil, 2021). Since the FAA has no jurisdiction to regulate environmental measures, the government should intervene to regulate and restrict companies from producing devastating effects on Earth.

Forganni (2017) emphasises the need to adapt the existing legal framework to regulate the emerging space tourism market, especially for suborbital flights that are more legally problematic than those upon the orbit. These shorter space travels are done with hybrid vehicles, making it difficult to enforce the law, as the legal wording includes the classic rockets in their text. This lack of functional clarity is compounded by the spatial factor, which implies that this legal context must be applied according to the actions taken in space. Thus, the development of a uniform legal framework is expected to prevent billionaires from monopolising the space tourism market.

Environmental controversies have led companies selling space tourism experiences to argue that their business model is not catastrophic for the environment. Regardless of whether the fuel composition or the level of carbon dioxide emissions are mentioned, manufacturers have the chance to reduce the carbon footprint of a space tourist at the same time as developing their business. Yi-Wei Chang (2020) presents the economic effects of business opportunities in suborbital space tourism, such as reusable rocket launchers. They would also have environmental benefits, as reusing launchers would reduce refurbishment costs, which would help companies benefit from economies of scale and increase the number of passengers on a flight. The carbon footprint of a space tourist would decrease, as the total amount of carbon dioxide emissions will be shared among several passengers.

On the other hand, the increase in the number of tourists in space per flight is not significant for reducing the real level of pollution, but will only lead to its stagnation. The depletion of the ozone layer will become a continuous process, although the carbon footprint of a space traveller will be reduced. Elon Musk's desire to have 100 people on board is worrying for Earth (Sheetz, 2020), considering that it will make regular flights. Heilweil (2021) anticipates that Virgin Galactic's plan to operate 400 flights a year will increase pollution dramatically and aggravate environmental problems. This development can be stopped by slowing down the growing popularity of space tourism. Reducing supply capacity will never be an option for companies in the market, and this is one of the points where governments can intervene to regulate flight conditions.

All these proposals are intended to increase the capacity of passengers onboard spacecraft and regulate the conditions for launching rockets in order to reduce the number of launches. It is hard to believe that space tourism will not follow the same trend of rapid evolution as technological advances in helicopters, private jets, and yachts funded by the super-rich (Ho, 2021). Producers of massive carbon emissions and environmental threats, spacecraft are likely to attract more customers in the future and become an affordable experience for a wider segment of customers. Although they may become completely reusable and use a less threatening fuel for the ozone layer, space tourism is still far from becoming sustainable, and the authorities aim to monitor the evolution of this market. They should find the balance between the needs and desires of those who want to discover the Earth outside of it with the ability of the planet to regenerate and provide renewable resources.

3. Methodology

This research aims to determine the potential of space tourism to become a successful business in the future and the possibility associated with this sector to achieve sustainability, seen both from the perspective of specialists in tourism and aviation and from students who will become specialists in business administration or tourism. To substantiate the research topic, both qualitative research in the form of an interview and quantitative research using the survey were conducted.

The main objectives of the qualitative study are: (1) to identify the perception of the direction of the aviation industry in relation to the environment; (2) to deduce the effectiveness of the measures required to reduce aircraft pollution; (3) to determine the degree of confidence of tourism and aviation specialists in the ability of space tourism to become a sustainable business in the future. This qualitative research was based on an interview, which was given by four specialists in tourism and aviation, considering the two fields as related. The interview was attended by: a director of a travel agency and tourism teacher, a director of a tour-operator and investor in the hotel segment, an aviation consultant and professor, an IATA authorised centre director, tourism and aviation professor.

The first mentioned participant has an experience of over 30 years in tourism, consolidated with a master's degree in Business at the University of Economic Studies in Bucharest, with the teaching of courses, workshops in which he participates, and some that he holds. In 1987 he graduated from the BTT guide school, led groups until 1990, began collaborating with the ITHR, which turned into "Vacanța" (and then closed), after that with student agencies, and eventually set up his own travel agency, which he has been managing ever since. For the administration of the agency, he took numerous courses, including aviation (IATA course on ticket sales).

The second mentioned participant also has a vast experience in tourism, starting the activity of a travel agency 35 years ago and the name of the company still exists and is recognized nationally. He made his first private investment in Vama Veche in 1996 in a tourist complex, consolidating in the 2000s with a jazz & blues festival bearing the same name as the company. He is the director of a tour-operator that promotes holidays in Romania and sells them through 1000 travel agencies in the country, also having an incoming department to bring foreign tourists through international partners. He participated in meetings of the most famous aviators and military aviators in the history of Romanian aviation and knows the only Romanian cosmonaut, Dumitru Prunariu.

The third mentioned participant is an aviation consultant and teaches aviation subjects at the Polytechnic University of Bucharest and the Romanian-American University. He has a passion for aviation, a field that has a direct link with tourism, because aviation supports the development of tourism, expressing interest in space tourism to see how the industry develops and what the benefits may be for society.

The fourth mentioned participant has over 20 years of experience in the tourism and travel industry, focusing her studies on air transport. In 2011 she set up the first IATA authorised centre in a university in Romania, which she continues to coordinate. At the same time, pursuing a teaching career, together with the business environment and with the support of IATA, she created and coordinated a master's program in English, teaching subjects such as Air Transport and International Tourism. The answers of the interviewees were collected from the one-on-one meetings held online, on the Zoom platform, and subsequently interpreted.

The quantitative research has pursued the following objectives: (1) recognizing students' concern about the environmental problems posed by carbon dioxide pollution; (2) identifying students' perceptions of space tourism as a future business opportunity and its sustainability; (3) Determining the intensity of the relationship between the distance travelled by air travel (km) and the potential amount to be invested for the development of space tourism (euro). For this study, the research method used was the survey. The data were collected using an electronic questionnaire, created using Google Forms, which was distributed on WhatsApp and email to students of the University of Economic Studies in Bucharest studying business administration or tourism. Data were collected from 24 March 2022 to 31 March 2022, with 122 responses.

Of these, 16 were deleted, being considered erroneous data. Valid answers were collected from Google Forms and then processed in Microsoft Excel, using a quantitative analysis of the data (percentages, means, medians, correlations, linear regression).

4. Results

Questions about the connection of space tourism with aviation, the environmental consequences of this form of tourism, and the future of space tourism helped investigate the future sustainability of this industry. The interpretation of their answers leads to finding out the direction in which tourism in space is heading and to formulating an answer to the question addressed in the title of the paper. These interpretations, intended to achieve the objectives of the research, highlight the achievement of results for both qualitative and quantitative research, presented in the following subchapters.

4.1. Results of the qualitative research

The first objective of the qualitative research is to identify the perception of tourism and aviation specialists on the direction in which the aviation industry is heading in relation to the environment. None of them believes that aviation, which is the basis of space tourism and a tourism-related industry, is leading humanity to an ecological disaster. The aviation consultant emphasises the need to differentiate between global environmental pollution and the contribution of aviation to the total level of pollution, the latter having a very small share in climate change, "*the contribution of aviation is somewhere between 2-3% of the total emissions*".

The IATA Authorized Center Director supports the aviation consultant's explanation of the contribution of aviation to greenhouse gas emissions, "*aviation has a lower impact than the iron and steel industry, cement production, shipping*", motivating the increased impact of air transport on the environment through the dynamics of modern life, "*the globalisation of trade in recent years, the development of low-cost airlines and the cheapening of passenger flights, the intensification of air traffic are some aspects that have led to increased negative pressure on the environment*".

The tourism professor completes the statement of experts mainly in aviation and remarks that the vision of the ecological disaster caused by aviation pollution is an "*exaggeration*", highlighting the fact that carbon emissions from tourist flights are considerably lower than those of cargo flights, "*if we take into account a cargo plane carrying food for 500 people and a plane carrying 500 tourists, we will find that cargo flights own more of the market"*. However, he explains the development of aviation in the tourism segment by boosting demand, "*we want speed, not to waste our time, to see as many places in our lives*".

The tour-operator director reinforces the views expressed by other interviewees on the potential environmental disaster caused by aviation, "*I do not see things so in black and white*", anticipating that technological advances will cause aircraft to follow the same trend as cars in terms of power supply of electricity, "*we will see a spectacular evolution, even electric planes*". Moreover, it predicts an electric revolution, which would mean that landowners would help increase their electricity supply by installing solar panels, aiming at the sustainability of all industries, "*we will get unlimited electricity, maybe not necessarily cheap, but sustainable and produced in a decentralised way*". Until this dream of sustainability becomes a reality, one of the mechanisms for offsetting environmental costs is facilitated by the economic benefits, which sometimes do not work for low-cost airlines. Thus, the tourism professor reveals that, in these cases, the tourists have a carbon footprint much higher than the price of the paid ticket, some regulations being necessary, "*the costs of the plane ticket should bear part of the environment, for the consumption of kerosene, aircraft noises, landing/take-off noise*". Measures to reduce carbon dioxide emissions from aviation are needed as other industries are already making progress, and sector-wide projects are already being implemented to improve engines and reduce emissions, and their means are mentioned by the aviation consultant, "*by reducing noise pollution, by using hydrogen for ground equipment or electricity for equipment*".

Therefore, tourism and aviation experts point out that although aircraft pollute the air at a considerable height from the ground, the aviation industry is not the main contributor to global warming and climate change, and its impact on the environment is going to be reduced with technological advances and measures taken to limit carbon dioxide emissions.

The second objective of the qualitative research is to deduce the efficiency of the measures imposed to reduce the pollution generated by aircraft, based on the information provided by the interviewees. The aviation consultant considers that the current measures taken independently by economic operators in space tourism are effective, but also notes the need to standardise these measures across the sector, hampered by the huge costs of new technologies, "*not all economic operators have the financial means to introduce new technologies because it is a high cost for them*". Thus, in order to increase the effectiveness of these measures, the authorities should financially support this uniform approach, "*governments need to provide some facilities so that operators have the chance to introduce some technologies that are very expensive for them*".

Beyond the implementation of new technologies to reduce the level of equipment pollution, there is the option of measures to regulate the volume of air traffic, to which the tourism teacher is reluctant, as he considers that the authorities would not engage in such measures, "*No state really wants to reduce consumption, because it gives you a high GDP and enough budget revenue not to be in debt*". He also emphasises the idea of uniformity launched by the aviation consultant, believing that measures to reduce the volume of air traffic must be taken globally to have an effect in limiting pollution and not just economic losses, "*even if Europe would increase the price of flight tickets and reduce the number of flights to combat pollution, it is in vain if India and China intensify flights to gain the market share that Europe has given up*".

The IATA Authorized Centre Director outlines the commitment of economic operators in aviation to reducing carbon emissions and shows already visible results, "*today's aircraft are more efficient due to the use of lighter materials and changes in design*", thinking that the difficulty of this process relates to the high dependency of aircraft on fossil fuels and the increasing demand for air transport.

The aviation consultant points to the existence of global measures already in place to reduce carbon emissions, such as the Airport Carbon Accreditation program, which includes 59 airports worldwide that have reached carbon neutrality (zero carbon emissions). It is a small but solid step in achieving the dream of sustainability, "*until it covers all 2000 airports in the world, there is still some way to go*". He also points to the dependence of carbon emissions on the flow of passengers and aircraft, noting that the need for increased energy cannot be met by solar panels alone, and the use of fossil fuels will continue to exist until the emergence and implementation of new technologies, "*the whole chain must be adapted to the production and distribution of green energy*".

Thus, the aviation consultant highlights the concrete goal of the measures taken by aviation officials, the zero-carbon level in 2050, almost intangible without the technological advances that aviation will benefit from, "*this zero net carbon emissions depends on the technologies that will be developed so that carbon can be drawn from the air*". Moreover, the IATA Authorized Centre Director foresees a shorter time horizon for air traffic to abandon carbon-based fuels and replace them with hydrogen in order to achieve zero carbon emissions, "*For example, Airbus is currently working to create an aircraft that uses hydrogen as its main source of power and by 2035 the world's first zero-emission aircraft will be operational*".

Therefore, the measures imposed to reduce aircraft pollution are relatively effective, but it is necessary to standardise them globally, according to those interviewed, both by participants on the market implementing new technologies, with the support of governments through grants and by limiting the flow, and by increasing the cost of airline tickets. Space tourism will be inspired by the innovative technologies that aviation will use, promoting the hope that the success of this industry will not only be generated by its economic benefits, but also by a plan to protect the environment against carbon dioxide pollution.

The third objective of the qualitative research is to determine the degree of confidence of the interviewed tourism and aviation specialists in the capacity of space tourism to become a sustainable business in the future. In order to achieve this objective, the interviewees were asked, in the first instance, how they foresee the development of the industry. The tourism professor mentions that the success of space tourism and the development of the industry will be linked, first of all, to the duration of space travel, "*space tourism is about seeing things, so it won't be enough to visit the Earth's orbit for just one or two days*". He highlights the dependence of the unpredictable route that space travel for tourism will follow on technological advances, which will inevitably develop the space tourism industry sooner or later, "*you cannot stop progress*".

At the same time, the director of the tour-operator shares a similar point of view and points out that there all signs indicate the development of space tourism, "*if you have good technology and a good vision, any futuristic idea sounds very interesting*", emphasising the dynamics of demand, represented by tourists looking for creativity and novelty, "*there is a clientele that is willing to pay a brief visit to the orbit and I think it has a future*".

The aviation consultant associates the ever-increasing demand for space tourism with the increase in carbon emissions, questioning the success of this industry, which he believes will only be possible with a change of image, promoting benefits that would benefit society as a whole to compensate for wasted resources, "*there should be some higher benefits at the societal level in order to create an image that space tourism is not just for a few and that it benefits everyone*".

The IATA Authorized Centre Director nuances the values promoted by space tourism, "*research, technology, knowledge, development, innovation*," and believes that there are arguments to support the development of space tourism, "*the need for space research and exploration, and the evolution of technology that allows from one year to another the reduction of its impact on the environment*". Despite the higher environmental costs of space tourism than other forms of tourism or intercontinental flights, the tourism and aviation expert draws attention to the key role that society plays in colonizing other planets, with space tourism underpinning this goal, "*this form of tourism can contribute to the empowerment of the population*". However, most people will be mere spectators of space travel, because no matter how fast this industry develops, only a small segment of consumers will have economic access to space tourism, which is accentuated by all those interviewed, "*I believe that space tourism will be for the chosen ones, many years from now*", "*space tourism will probably never be economically accessible to the general public*", "*it is a niche form of tourism, which addresses certain categories of exclusive customers*".

Beyond the fact that technology will advance and that travelling in the Cosmos is a great attraction, tourism and aviation specialists are reluctant to say that space tourism will become sustainable. Moreover, the tourism professor considers this phenomenon almost impossible, as it depends on a major change in technology, which requires a profound research process, comparing the attempt to use alternative energy sources in rockets and spacecraft with the automotive industry, "*electric cars are a great idea, but it remains to be seen what can be done with their used batteries and their energetic costs for destruction*".

At the same time, the tour-operator director points out that sustainability also refers to the consumption of local resources that cannot be defined and nor exploited yet, "*it would be good for people to consume products made by local producers and do not know what local products mean in space tourism*". Also, due to the fact that a space trip produces carbon emissions 100 times higher than a long-haul flight and threatens the destruction of the ozone layer, the IATA Authorized Centre Director believes that it is difficult to associate space tourism with sustainability in the present, but the path to achieving this dream must be paved not only by new technologies but also by the decisions taken by players from this market, "*such activities should be carefully planned and the benefit/risk ratio should be taken into account*".

Thus, the aviation consultant resumes and nuances the idea supported by the IATA authorized centre director, emphasising the responsibility of players in the space tourism market to create the image of sustainability of space tourism. He points out that the level of pollution must also be expressed in emissions

per passenger, the consequences for the environment largely depending on the frequency of space journeys, the number of participating tourists, and the duration of a flight, "*if we talk about a 10 times increase in the number of these flights, the public opinion, which now looks at the phenomenon quite remotely, may suddenly become much more careful and not accept the flights so openly*".

Therefore, the interviewed tourism and aviation experts shared their beliefs about the considerable chances of space tourism becoming a successful business and fighting for sustainability. They describe the space travel industry as a creative and attractive novelty, which will always find a select group of customers to operate. Although sustainability is far from being achieved in space tourism, fundamental change in technology through progress is likely to facilitate a reduced fossil fuel-based energy regime for spacecraft. Designing carefully the image of space tourism is a necessity for players in the space tourism market, as society's contribution to this industry is essential in increasing the quality and profitability of space travel.

4.2. Results of the quantitative research

The first objective of the quantitative research is to recognize the students' concern about the environmental problems generated by carbon dioxide pollution. To achieve this goal, students were asked about the average frequency of personal car travel. Of the 106 respondents, most of them (31 students, accounting for 29.25% of the total) used their personal car as a means of transport less than one day a week or not at all. 50% of students chose the car on less than 1-2 days a week, and 50% of them on more than 1-2 days a week. Thus, there is a slight tendency of respondents in choosing public transport and, implicitly, in limiting excessive pollution. At the same time, the students were asked about their favourite means of transportation in tourist destinations accessible both by land and by air. More than half of the respondents (54 students, meaning 50.94%) opted for the personal car, followed by 34 students (32.08%) who chose the plane. Only 15 respondents (14.15%) prefer the train on the tourist trips, highlighting the trend of increased carbon emissions produced in the tourist journeys of the responding students.

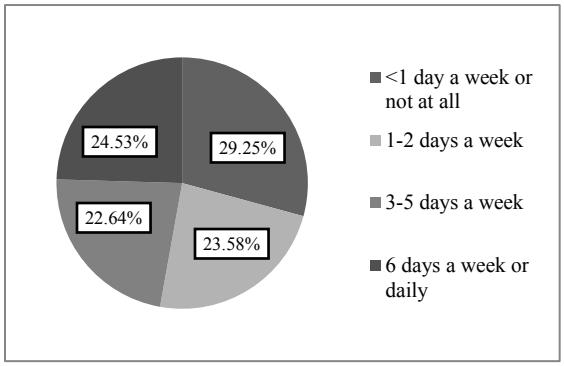

Fig. no. 1. Average weekly travel frequency by car
Source: obtained by processing the research results

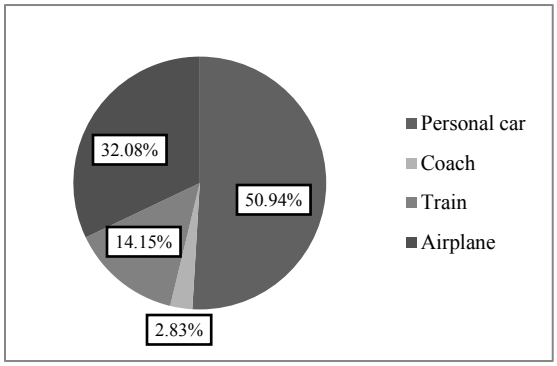

Fig. no. 2. Preference for transportation in tourist travel
Source: obtained by processing the research results

Students studying business administration or tourism were also asked about the intensity of their concern about the environmental problems caused by carbon dioxide pollution. Most of them (61 respondents, meaning 57.55%) stated that they are "somehow" concerned about the effects of carbon dioxide pollution on the environment, while 3.77% (4 students) are "not at all" interested and 15.09% (16 respondents) are "slightly" concerned. Half of the students are at most "somehow" concerned about CO_2 pollution, and half of them are at least "somehow" interested in the subject. However, there is a slight tendency for students to be more concerned about environmental issues, as 18 respondents (16.98%) consider that this aspect interests them "a lot" and 7 respondents (6.6%) even "very much". At the same time, the students' questioning about the degree of attention paid to CO_2 emissions in choosing airline tickets for tourist travel

outlined that most of the respondents (60 students, meaning 56.6%) were "not at all" interested in selecting the airline based on the pollution produced by its aircraft. 50% of them opted for at most "not at all" and 50% for at least "not at all". Therefore, students are aware of the environmental problems caused by CO_2 pollution, taking steps to limit the proportions of this phenomenon (using public transport or choosing the train for their tourist trips), but do not act decisively in combating pollution, most choosing to travel by car or by plane and ignoring carbon emissions from aircraft when choosing flight tickets.

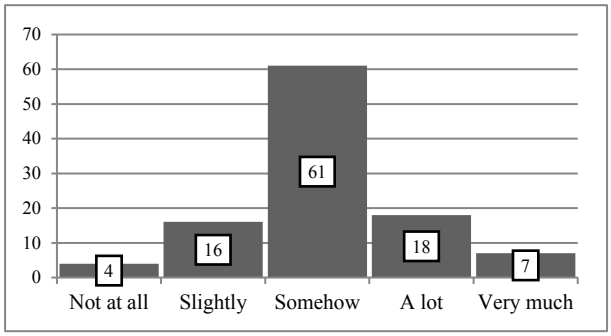

Fig. no. 3. The degree of concern about the effects of CO_2 pollution on the environment
Source: obtained by processing the research results

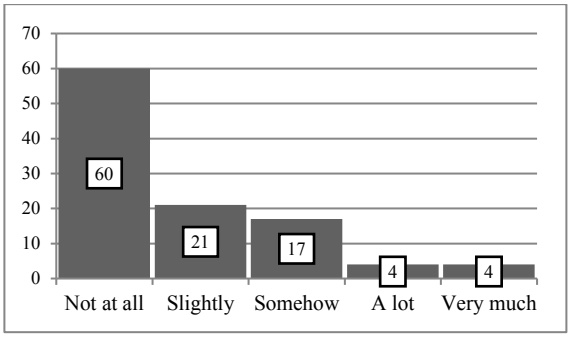

Fig. no. 4. The degree of attention paid to CO_2 emissions when choosing airline tickets
Source: obtained by processing the research results

The second objective of the quantitative research is to identify students' perceptions of space tourism as a future business opportunity, and of its sustainability. To achieve this goal, students were asked in the first instance about identifying the main purpose of space travel. Most of them (42 respondents, meaning 39.62%) believe that visiting space should be educational, to know more about space and Earth. Another 40 students (37.74%) believe that the basic purpose of space travel is scientific, to colonise other planets in the future. Only 20 respondents (18.87%) describe visiting the space as a recreational activity, while 4 respondents (3.77%) find no benefit associated with these trips. At the same time, the respondents were invited to express their agreement on the capacity of space tourism to become a successful business in the future. Thus, there is a pronounced trend of approval of this statement by students, most of them (33 respondents, meaning 31.13%) agreeing with the theory mentioned. 50% of the students surveyed are "at most" confident that space tourism will become a successful business, despite the environmental consequences, and 50% of them are "at least" confident.

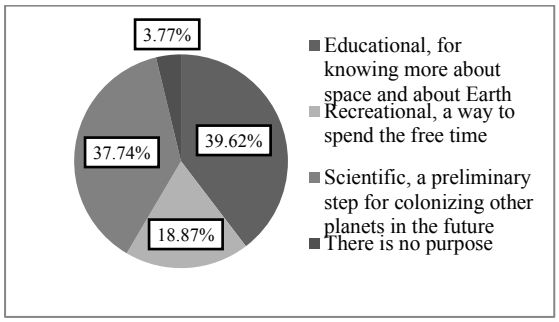

Fig. no. 5. The main purpose of space travel
Source: obtained by processing the research results

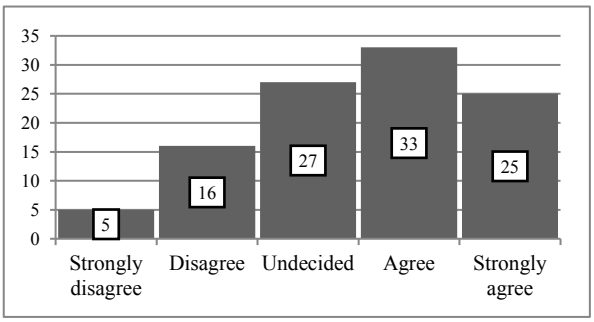

Fig. no. 6. Agreement level on the ability of space tourism to become a successful business, despite environmental consequences
Source: obtained by processing the research results

Beyond the potential profitability of the space tourism that the respondents predict, the students were also questioned about the direction of the sustainability of this industry in the future. Half of them opted for at most "undecided" and half for at least "undecided". However, most students (28, meaning 26.42%) have an "undecided" point of view or agree with the statement that environmental costs can be covered by revenues generated by space tourism. At the same time, having opinions mainly for the approval of the statement, the students also expressed their opinion on the chances of space tourism becoming sustainable. The majority of them (40 respondents, meaning 37.74%) consider it "somehow likely" that this will become a reality. However, there is a significant tendency for respondents to point out that students believe, in particular, that the approach of space tourism to have a minimal impact on the environment will have an "unlikely" result (31 respondents, 29.25% of total) or even "impossible" (7 respondents, 6.6% of the total).

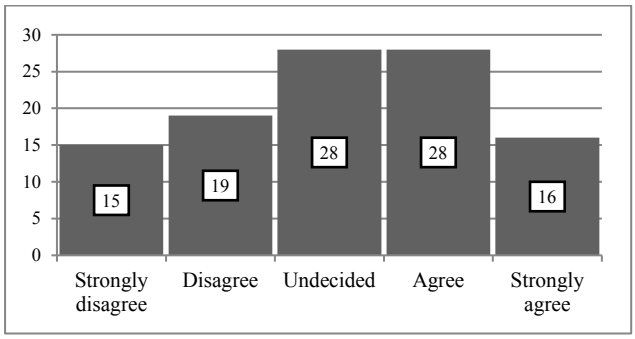

Fig. no. 7. Level of agreement on the capacity of the economic benefits of space tourism to offset the related environmental costs
Source: obtained by processing the research results

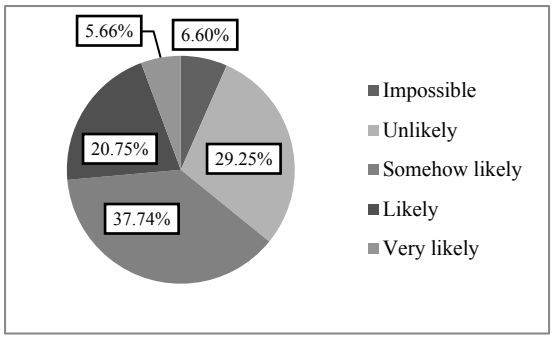

Fig. no. 8. The likelihood of space tourism becoming sustainable in the future
Source: obtained by processing the research results

Moreover, correlating the ability of space tourism to become a successful business with the potential economic benefits of the same industry to offset the related environmental costs, it is observed that among students who believe in the development of space tourism, by "agree" or "strongly agree", 14 respondents (13.2%) believe that the size of environmental costs cannot be covered by economic benefits (by "strongly disagree" or "disagree"), while 33 respondents (31.13%) have a favourable opinion (by "agree" or "strongly agree").

Table no. 1: Correlation between the level of agreement on the ability of space tourism to become a successful business, despite the environmental consequences, and the level of agreement on the capacity of the economic benefits of space tourism to offset the related environmental costs.

The level of agreement on the ability of space tourism to become a successful business, despite the environmental consequences	The level of agreement on the capacity of the economic benefits of space tourism to offset the related environmental costs					
	Strongly disagree	Disagree	Undecided	Agree	Strongly agree	Total
Strongly disagree	3	0	2	0	0	5
Disagree	4	7	1	4	0	16
Undecided	2	4	14	6	1	27
Agree	6	3	7	13	4	33
Strongly agree	0	5	4	5	11	25
Total	15	19	28	28	16	106

Source: obtained by processing the research results

Therefore, although most respondents see space travel as having more important purposes than the recreational one proposed by space tourism, students believe that this industry has a significant chance of becoming a successful business and that there is a considerable possibility that the economic benefits will cover related environmental costs. Despite the confidence of over 30% of those surveyed that space tourism will be successful and that its revenues will offset the environmental costs, there is a growing trend of responses indicating the largely unsustainable regime in which this industry is likely to activate.

The third objective of the quantitative research is to determine the strength of the relationship between the distance travelled by airplane (km) by students in the last two years and the amount they would invest in the development of space tourism (euro). To achieve this goal, the students were asked about the flights for tourist purposes that they went on in the last two years and the destinations of these trips. Based on the destination cities mentioned by the respondents, considering the "Henri Coandă" International Airport in Otopeni as a starting point, the distance travelled by airplane (km) by each student was calculated. Also, by collecting the amount that each student would invest in the development of space tourism, a simple linear regression model was developed. Assuming that those who travel more by plane for tourism purposes (implicitly having a greater contribution to carbon pollution) tend to invest more in space tourism, the potential amount to be invested was selected as a variable dependent on the distance travelled by airplane.

Table no. 2: The simple linear regression model between the amount that students would invest in the development of space tourism (euro) and the distance travelled by airplane (km)

Regression Statistics	
Multiple R	0.0535
R Square	0.0029
Adjusted R Square	-0.0067
Standard Error	36502.4394
Observations	106

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	398389786.5	398389786.5	0.2990	0.5857
Residual	104	1.38573E+11	1332428084		
Total	105	1.38971E+11			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	9620.335	4230.476	2.274	0.025	1231.141	18009.528
Total km flight	0.405	0.741	0.547	0.586	-1.064	1.874

Source: obtained by processing the research results

Thus, it is observed that the relationship between the distance travelled by airplane (km) by students in the last two years and the amount they would invest in the development of space tourism (euro) is extremely weak or even negligible, as the correlation coefficient between the two variables is 0.0535, tending to zero. At the same time, the P-value determined by the distance travelled by airplane (0.586) exceeds the critical threshold of 0.05, emphasising that the amount invested in the development of space tourism cannot be estimated based on the distance travelled by airplane. The simple linear regression model is not valid, because the F-test shows that the calculated value (0.5857) exceeds the critical threshold of 0.05, the influence of the distance travelled by airplane on the potential amount to be invested in space tourism being less than the residual factors. When other factors of influence are kept constant, the variation of the potential amount to be invested in space tourism is explained in the proportion of 0.29% by the variation of the distance travelled by airplane. Therefore, the strength of the relationship between the distance travelled by airplane (km) by students in the last two years and the amount they would invest in the development of

space tourism (euro) tends to be zero, and the dependence of the potential amount to be invested on the distance travelled by airplane is negligible in the sample of students surveyed, being impossible to extend the correlation at the population level and rejecting the hypothesis.

5. Future directions and limitations

Starting with an overview of space tourism and going on to explore how sustainable it would be in the future, the paper briefly describes the environmental issues facing Earth as this market develops rapidly. Using in-depth knowledge of chemistry and interviewing experts to comment on the composition of the fuel used by spacecraft manufacturers would be significant improvements for future research to help readers better understand how the carbon-based fuel currently used can be reduced or replaced with a less polluting one.

Moreover, astronauts or players from the aviation market could be involved in research to determine in which direction space tourism is heading in the future and to predict more accurately the evolution of this industry. Being an innovative niche market that seems attractive, space tourism has not provided enough information from spacecraft-producing businesses, as they are still studying the openness of the general public to the desire to become space tourists. Consequently, few scientific articles have been written on this topic, and even fewer of them analyze the environmental effects of space tourism. Implicitly, the limitations of the study include a small number of respondents and the lack of representation, as well as the focus on a single socio-professional category (students), deficiencies that can be mitigated in future research, showing my desire to take part as an author to continue the scientific work. Extensions of the present study may also include other variables that better describe the amount that respondents would invest in the development of space tourism.

Over time, researchers will be able to gather more information about the consequences of rocket launches as these events become more frequent. Space tourism is becoming more and more commercial and there are already customers who have booked seats for space travel. Future research may interview passengers to share the experience of crossing the Earth's edges and to hold the population aware of the environmental effects of these flights. Making humanity aware of the consequences it will suffer if space tourism follows the same trend of carbon pollution is a solid step in researching the utility of recreational space travel and the means of space tourism to achieve sustainability.

Conclusions

Space tourism is an emerging niche market that has recently become popular due to the travel of billionaires beyond the edges of Earth. Although it seems fascinating to see such a rare image of Earth, space travel is, in fact, very expensive and not only economical but also in terms of the environment. A person who pays 200-250 thousand dollars to pay a few minutes to visit space produces the same level of carbon emissions as 2-3 people who live a year on Earth (Pollack, 2021). Companies from this market are trying to cover the huge environmental costs by developing new technologies that reduce carbon dioxide emissions and make spacecraft completely reusable (Primal Space, 2020), but the usefulness of these efforts for the leisure trips of the rich people is questioned in the literature. The research was aimed at determining the chances of space tourism becoming a successful business in the future and reaching the threshold of sustainability. Tourism and aviation experts, interviewed in the qualitative research, draw the modernity of air transport infrastructure and technologies as a source of inspiration in the development of space tourism. Pointing out that aviation contributes only 2-3% to the global carbon pollution and that effective measures are already in place to target the use of the first hydrogen-based aircraft in 2035 (an alternative source of fossil fuels), they believe in the future potential of space tourism and in its popularity for an exclusive clientele. However, the interviewed specialists express their reluctance to achieve the sustainability of space tourism, noting, however, that technological progress can offset the environmental costs through the advantages that will benefit the whole society.

SpaceX, one of the major players on the market along with Virgin Galactic and Blue Origin, mentions that revenues from space tourism would be invested for the benefit of humanity, capitalizing on resources from

space or colonizing other planets (Sheetz, 2020). The results of the survey, the quantitative research part of the study, in which students pursuing business or tourism disciplines participated, highlights the point of view of future experts in the field on the purpose of space travel. Students see the educational and scientific side of space travel above the recreational side of space tourism, but believe that this industry has a good chance of success. Aware of the environmental problems posed by carbon pollution, respondents have difficulty taking individual action to combat the effects of greenhouse gas emissions, with most choosing the personal car or the plane for travel. Assuming that those who travel more by plane, implicitly contributing more to pollution, would be willing to invest more in the development of space tourism, it turned out that there is a negligible relationship between the two variables at the sample level. However, students tend to expect the success of space tourism as a business in the future, despite the fact that their opinions also indicate a relatively low chance of this industry achieving sustainability. Moreover, more than 30% of the 106 valid answers of the students surveyed emphasize the possibility that the economic benefits of recreational space travel offset the related environmental costs, confirming the statement of tourism and aviation specialists about the progress of society from space tourism.

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