School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

Shift to train for leisure trips within the EU: environmental effect and influencing factors for travellers

Iryna Ozeranska

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences

SUPERVISOR :
Prof. dr. Elke HERMANS

CO-SUPERVISOR :
Prof. dr. Muhammad ADNAN

2021
2022

www.uhasselt.be
Universiteit Hasselt
Campus Hasselt:
Martelarenlaan 42 | 3500 Hasselt
Campus Diepenbeek:
Agoralaan Gebouw D | 3590 Diepenbeek

School of Transportation Sciences

Master of Transportation Sciences

Master's thesis

Shift to train for leisure trips within the EU: environmental effect and influencing factors for travellers

Iryna Ozeranska

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences

SUPERVISOR :

Prof. dr. Elke HERMANS

CO-SUPERVISOR :

Prof. dr. Muhammad ADNAN

PREFACE

I have always been passionate about aviation, which led me to Bachelor degree in Air Navigation in Kyiv - Ukraine. After that, I decided that it was time to extend and to deepen my knowledge in transportation by obtaining Master degree in Transportation Sciences at Hasselt University.

Aviation plays a crucial role for economic development and social welfare, but at the same time, it also significantly contributes to climate change. One of the proposed measures to mitigate the environmental impacts of aviation in the EU is to facilitate a shift to rail. This thesis gave me an opportunity to investigate a modal shift by exploring on one hand air and rail transport from environmental impact perspective and on the other hand travellers perceptions, attitudes and motivation towards a modal shift. In order to do that, I applied research methods and knowledge that I have gained during my distance-learning programme at Hasselt University.

This thesis is intended for transport companies and research centres that are investigating possibilities of modal shift from environmental and travellers' point of view.

I would like to thank my supervisor Prof. dr. Elke Hermans and co-supervisor Prof. dr. Muhammad Adnan for their guidance and valuable feedbacks during the preparation of the thesis. I would also like to thank my husband for enormous support all these years, my little daughter, who joined our family during the thesis preparation and my parents, who always believed in me.

Iryna Ozeranska, Huldenberg (Belgium)

16 August 2022

SUMMARY

This master thesis elaborates on a need of a shift to train from the environmental prospective and determines important factors for travellers for a modal shift by considering their opinions and choices regarding leisure trips within the EU due to the rapid growth of air travel and transport emissions despite a huge technological progress in the world. The focus of this thesis lies on plane and train travel modes but car is included in the survey for a comparison of three alternatives used for leisure trips within the EU.

The main research question of the thesis is "*How can a train be a sustainable alternative for leisure trips with a flight duration of up to 2 hrs or a distance of up to 800 km within the EU?"* and it is investigated by two methods: desk and literature review (secondary data) and survey (primary data).

Literature review shows that evaluation of the environmental impact of air and rail transport is much more complex than it may seem due to a large number of factors that should be taken into account besides CO2 emissions. Many studies conclude that air transport has higher CO2 emissions than rail and they will only increase as air travel is forecasted to grow at a higher rate in the future, therefore a modal shift from short-haul flights to high-speed rail has been considered as an effective measure to reduce the emissions due to its higher energy efficiency.

The results of the survey show that total travel time and ticket price appeared to be the very important for train mode. Safety level has been rated as a very important factor almost equally for all travel modes (with the highest value for train mode). Comfort level was very important for car travel. Respondents found direct connection to be more important for plane mode than for train mode. At the same time, respondents claimed that waiting time between stopovers was very important for train mode. Location of a train station happened to be less important than location of an airport. It could be because airports are usually located further from the city centre while train stations are usually located within the city centre. Frequency of a service was found to be more important for train mode than for plane mode.

The main conclusion of this master thesis is that a modal shift to train is feasible from a traveller's perspective and needed from the environmental point of view. The estimated model shows that car mode is the preferred mode to use when going on a leisure trip within the EU, plane mode ranks second and the least preferred alternative appears to be train. The following factors contribute to the modal shift: lower travel cost and time, excellent Wi-Fi on a train, high comfort level, direct train connection, high frequency of trains and reliable schedule. Both travel cost and travel time appear to be important for the travellers but lower travel cost increases the attractiveness of a train than lower travel time.

Based on the literature review and the survey results, recommendations for the future considerations and implementations of a shift to a train mode are suggested.

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS

GLOSSARY

High-speed rail: rail services operating on specifically designed lines with a maximum operating speed of at least 250 km/h and services operating on conventional lines with a maximum operating speed of at least 200 km/h.

Nomenclature of territorial units for statistics: a geographical nomenclature subdividing the economic territory of the European Union (EU) into regions at three different levels (NUTS 1, 2 and 3 respectively, moving from larger to smaller territorial units). Above NUTS 1, there is the 'national' level of the Member States.

LIST OF ABBREVIATIONS

CO: Carbon monoxide

GHG: Greenhouse gas

HSR: High-speed rail

HST: High-speed train

NOX: Nitrogen oxides

NUTS: Nomenclature of territorial units for statistics, abbreviated from the French version Nomenclature des Unités territoriales statistiques

SAF: Sustainable aviation fuels

SOX: Sulfur dioxides

TTW: Tank-to-wheel

UIC: International Union of Railways

WTT: Well-to-tank

WWT: well-to-wheel

INTRODUCTION

Thanks to the transport systems, accessibility and mobility have vastly improved enabling the development of modern societies and economic growth. However, these transport activities come with negative impacts related to CO2 emissions, accidents, land take, landscape fragmentation, land use changes and others (Carvalho, Partidario & Sheate, 2017). Within a resource constrained world it is important to make the most efficient use of energy and to move towards low carbon mobility (Banister & Givoni, 2013).

The transportation sector has so far not markedly contributed to international efforts to mitigate climate change (Dütschke et al., 2022). On a worldwide basis, the transport sector today is responsible for almost one-third of final energy demand and nearly two-thirds oil demand. It is also responsible for nearly one-quarter of global carbon dioxide (CO2) emissions from fuel combustion and is a major contributor to air pollution, particularly in urban areas (IEA, 2019). Growth in greenhouse gas (GHG) emissions has continued due to growing demand despite the trends towards more efficient vehicles and adoption of climate mitigation policies (O'Riordan et al., 2022). Changes in transportation fuel use are, therefore, fundamental to achieving a global energy transition, which will guarantee energy security, alleviate air pollution and mitigate climate change (IEA, 2019).

In the context of global targets to decarbonise, and in line with its commitment to global climate action under the Paris agreement, the EU has set an objective to be climate neutral by 2050. Protecting the environment and preventing climate change is a strategic priority for the EU (EEA, 2021). As an intermediate step, it is aiming for a 55% net reduction in greenhouse gas emissions relative to 1990 levels by 2030. The decarbonisation of the transport sector, which accounted for 29% of the EU's overall greenhouse gas emissions in 2018, will play an important role. Indeed, the European Environment Agency (EEA) predicts that, without further measures, GHG emissions from transport will continue to grow until 2025, and in 2030 will still be 10% above 1990 levels. Road traffic currently accounts for 72% of total GHG emissions from transport (for 73% of passenger-kilometres), aviation accounts for 14% (for 8% of passenger kilometres), and rail accounts for less than 1% (for 6% of passenger kilometres) (Oxera, 2022).

While our collective use of automobiles, our production of electricity, and the industrial and agricultural sectors each exceed the climate change impact of commercial aviation, passenger air travel is producing the highest and fastest growth of individual emissions, despite a significant improvement in efficiency of aircraft and flight operations over the last 60 years (Overton, 2021).

Railways today consume close to 2% of transport final energy use, a modest share relative to road, maritime and air transport, especially since rail constitutes a much higher share of transport activity (8% of total passenger-kilometres and 7% of total tonne-kilometres) (IEA, 2019). From 2005 to 2015 CO2 emissions from rail transport per passenger kilometre decreased by 21.7% and emissions per tonne kilometre for freight by 19% as a result of increased electrification and decreasing carbon intensity of electricity production (IEA, 2019; IEA & UIC, 2017).

The sustainable growth of aviation is important for future economic growth and development, trade and commerce, cultural exchange and understanding among peoples and nations, and by 2045, international air traffic (expressed in revenue tonne kilometres) is expected to increase by 3.3 times (ICAO, 2019). The 37th ICAO assembly reports a projected 4.7% growth in world revenue passenger kilometers flown between 2010 and 2030 (D'Alfonso et al., 2016).

The European aviation environmental report 2019 indicates that the aviation sector causes substantial environmental problems in terms of climate impacts and local environmental problems (European Union Aviation Safety Agency [EASA], 2019). Although actions can be undertaken by the aviation sector itself to reduce its environmental impacts, a shift to less polluting modes is central to reducing the environmental footprint of travel. Scenarios calculated by the International Energy Agency indicate that limiting the global average temperature increase to below 2 °C also requires the substitution of intra-continental flights on medium distances of up to 1 000 km with high-speed rail (EEA, 2021).

1. PROBLEM DEFINITION, OBJECTIVES, RESEARCH QUESTIONS AND METHODOLOGY

1.1. Problem Statement

Global transport emissions increased by less than 0.5% in 2019 (compared with 1.9% annually since 2000) owing to efficiency improvements, electrification and greater use of biofuels. Nevertheless, transportation is still responsible for 23% of direct CO2 emissions from fuel combustion (IEA, 2021a).

Air travel increased rapidly in the last decade (Graver et al., 2019) and is now considered to be as important as car driving in aggravating climate change. Emissions from aviation and international shipping activities are still an important issue in Europe; they have recently been increasing at a faster rate than for any other transport mode (EEA, 2019; IEA, 2021a).

One-third of total aviation emissions results from short-haul flights (with a travel time range between 50 min and 3 h and 30 min), according to Bourgeois-Bougrine et al. (2003). These flights travel less than 1,500 km, whose average carbon intensity per passenger kilometer is about 35% higher compared to medium-haul flights (Graver et al., 2019). Moreover, the average CO2 emission per passenger kilometer is reported to be 122 g for aviation and only 23 g for high speed rail HSR (Prussi & Lonza, 2018).

Aviation activities emit air pollutants not only during taxiing, take-off and landing, and cruising at altitude but also from the numerous ground support services, such as airport heating, and transport to and from airports (EEA, 2019). CO2 is often considered to be the most important GHG owing to its role in radiative forcing, but is not the only climate-impacting pollution species emitted by aircraft. Other emissions include NOX, SOX, H2O, soot, triggered contrails and contrail cirrus (Anger-Kraavi & Köhler, 2013; Sausen et al., 2005). If GHG emissions from aviation continue to increase, the climate impacts are going to become more severe and extensive. It is therefore desirable to limit or mitigate the quantity of CO2 and other GHG emissions that airlines can emit (Anger-Kraavi & Köhler, 2013).

Flights departing from Europe are currently responsible for 184 million tonnes of CO2 emissions and as a result 4.2% of total EU emissions. Within that, intra-EU (within Europe) emissions account for 62 Million tonnes CO2 (32% of the total). A frequently proposed solution for the emissions growth of aviation is to substitute these intra-EU journeys by rail (Transport & Environment, 2020).

Rail is the most emissions-efficient major mode of transport, compared with road transport and aviation (Figure 1). Electric trains powered by renewable energy can offer practically carbon-free journeys and transport. Rail contributes less than 1.5% of the EU transport sector's total CO2 emissions even though it has over 8.5% of total market share (UIC and CER, 2015). When expressed as final energy use per passenger-kilometre or tonne-kilometre, the energy intensity of rail generally significantly outperforms other transport modes given its unique characteristics (IEA, 2019).

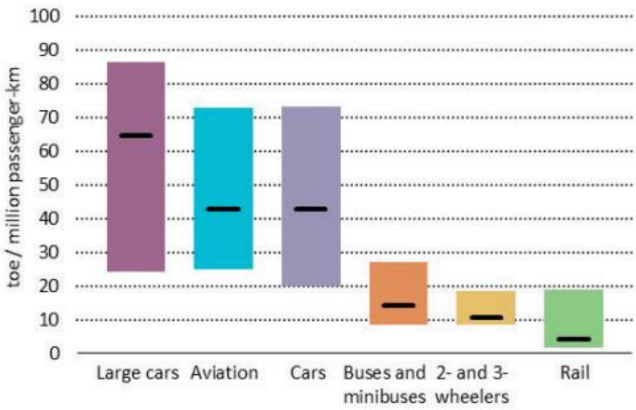


FIGURE 1 Energy intensity of different transport modes (IEA, 2019).

Although rail is an energy consumer, it also makes an important contribution to containing energy demand. If all passenger and freight services currently carried by rail switched to road vehicles, such as cars and trucks, global oil demand from transport today would be 16% higher (8 mb/d). The contribution rail makes to containing GHG emissions is as significant as its energy savings. If all current passenger and freight traffic by rail shifted to road vehicles, global GHG emissions would increase by 1.2 Gt of CO2-eq, or 12% more than total emissions from transport today (IEA, 2019).

The European Green Deal aims to set European transport on a path to full decarbonisation by 2050 and specifically mentions as part of the deal to support modal shift to rail, implement effective tools to implement 'user pays' and 'polluter pays' principles, proper funding for clean mobility and other supporting measures. Additionally the European commission declared 2021 the Year of European Rail to support the delivery of these European Green Deal objectives. In this context it's a priority to understand what proportion of travel can be shifted and where the priorities for modal shift are (EEA, 2021).

Although several authors set different thresholds on the distance for which the HST loses its advantage over aircraft (Socorro & Viecens, 2013), most authors agree that the HST is no longer competitive for distances above 800 km in length (Steer Davies Gleave, 2004; Givoni & Banister, 2007). Therefore, in this thesis the distance between origin and destination of up to 800 km is considered for the modal shift. Bleijenberg (2020) investigated flight time between 72 city pairs and the highest flight time was found to be 105 min (1 hr 45 min) for the distances up to 800 km. For the convenience reason, I decided to use a time value of maximum 2 hrs for flight duration as it can be perceived easier than distance in kilometres.

1.2. The Objectives

The main objective of the thesis is to investigate the need for a modal shift by looking into the environmental impacts of air and rail and determining important factors for travellers for the shift by considering their opinions and choices regarding leisure trips within the EU with a flight duration of up to 2 hours.

The focus of this thesis lies on plane and train travel modes. Car is the dominant mode of passenger transport in Europe and is still often seen as the default choice for intercity travel, even for long distances (EEA, 2021). Therefore, it is included in the survey (see Chapter 3) to examine people's decisions and preferences towards three alternatives used for leisure trips within the EU.

Moreover, the potential of an increase in rail share in the EU and its environmental impact will be examined.

1.3. The Key Research Question And Sub Questions

The main question of the thesis is:

How can a train be a sustainable alternative for leisure trips with a flight duration of up to 2 hrs or a distance of up to 800 km within the EU?

In order to answer this question, the following sub questions should be considered:

- *What is the environmental impact of aviation?*
- *What is the environmental impact of railway?*
- *What is the potential of an increase in rail share in Europe?*
- *What is the environmental impact of a modal shift towards rail in Europe?*
- *Can EU sustainability policies drive a modal shift?*
- *What are the factors influencing a travel mode choice for leisure trips (with a flight duration of up to 2 hours or a distance of up to 800 km) within the EU?*
- *What are the minimum conditions to facilitate the modal shift?*

1.4. Methodology

The main research question will be answered with the help of proposed sub questions. Sub research questions will be investigated by two methods: desk and literature review (secondary data) and survey (primary data).

The desk and literature review method is applied to the following sub questions:

- *What is the environmental impact of aviation?(SQ1)*
- *What is the environmental impact of railway?(SQ2)*
- *What is the potential of an increase in rail share in Europe?(SQ3)*
- *What is the environmental impact of a modal shift towards rail in Europe?(SQ4)*
- *Can EU sustainability policies drive a modal shift?(SQ5)*

The literature review was done via the Internet. The following sources were used: UHasselt library, Google Scholar, ProQuest, ResearchGate, Elsevier's ScienceDirect, websites of European/international organisations and institutions, etc.

The survey method is applied to answer the following sub questions:

- *What are the factors influencing a travel mode choice for leisure trips (with a flight duration of up to 2 hours or a distance of up to 800 km) within the EU?(SQ6)*
- *What are the minimum conditions to facilitate the modal shift?(SQ7)*

The survey was created in Qualtrics XM software, access to which is provided via Hasselt University. This software allows to collect and analyse data and also offers analysis of basic statistics and relative percentages.

The survey consists of open-ended and closed questions. Open-ended questions were used for few demographic questions (age, country and province questions) and to ask if the respondent had any additions to the survey. Closed questions included stated preference questions in order to investigate what factors are important for a modal shift. The stated preference questions are described more in detail in Section 3.2.3.

Although the focus of this thesis lies on plane and train travel modes, car travel mode has also been included in the survey as the dominant mode of passenger transport in Europe to examine people's decisions and preferences towards three alternatives used for leisure trips within the EU.

There are two types of the analysis applied to the survey:

- descriptive statistics (for all questions except the stated preference scenarios questions); and
- development of multinomial logit model (for the stated preference scenarios questions).

The survey respondents were reached via email within Hasselt University, the Unit where I work, Vias institute within the KCC Unit (where I have conducted my internship) and the survey was published online on Facebook, Twitter & Linkedin.

Non-random convenience sampling was used.

Chapter 2 focuses on a literature review of the environmental impacts of aviation and railway, potential and environmental impact of a modal shift and sustainability policies in the EU. Chapter 3 describes the content of the questionnaire. Chapter 4 reviews the results of the questionnaire and its limitations. Chapter 5 summarises the thesis, discusses the conclusions and presents practical recommendations for the future.

2. LITERATURE REVIEW

In this Chapter we discuss environmental impact of aviation and railway sectors by looking into CO2 and non-CO2 emissions including the factors that affect the environmental impact such as journey duration, load factors, emissions of end-to-end journey and full life cycle emissions of air and rail. Moreover, we review potential of air-to-rail shift, its impact on environment and sustainability policies in the EU that are implemented to facilitate a modal shift. Besides, we explore advantages of aviation and railway sectors, railway density and HSR development in the EU, comparison of airline and railway characteristics and difference in passenger-kilometres of both travel modes.

2.1. Introduction

From the environmental point of view, the overall number of trips, the choice of destinations and distances travelled, as well as transport mode choice are all crucial (Böhler et al., 2006). People who want to make medium to longer distance trips in mainland Europe usually have many options: rail (including HSR), air, car and coach. To varying degrees these modes of transport can replace, or substitute for, each other in this market segment.

In a year during which millions in Europe have been confined to their homes and travel activity has dropped dramatically, the question of whether one should take the train or the plane might not seem pertinent. However, before passenger numbers started dwindling in the wake of the pandemic, demand for passenger transport was on a steady upwards trajectory with by far the strongest growth seen in air travel. Over time there has been an expansion in the aviation network, and a liberalisation of the aviation sector, which has brought about a rapid expansion in low-cost carriers, lower prices and increased offers of connections and destinations to travellers. This long-standing trend is set against the backdrop of the climate crisis and persistent problems with air pollution and environmental noise in Europe (EEA, 2021).

Moreover, although environmental efficiency is expected to improve further in the future, air travel is also forecast to grow — although the timeline and the rate of growth have become more uncertain on account of the COVID-19 outbreak — leading to an expected increase in the local and global environmental impacts of air travel. Although actions can be undertaken by the aviation sector itself to reduce its environmental impacts, a shift to less polluting modes is central to reducing the environmental footprint of travel. Scenarios calculated by the International Energy Agency indicate that limiting the global average temperature increase to below 2 °C also requires the substitution of intra-continental flights on medium distances of up to 1 000 km with high-speed rail (EEA, 2021). However, most transport studies focus on the evolution of demand rather than supply, although it is basically the latter that determines environmental damage (Dobruszkes, 2011).

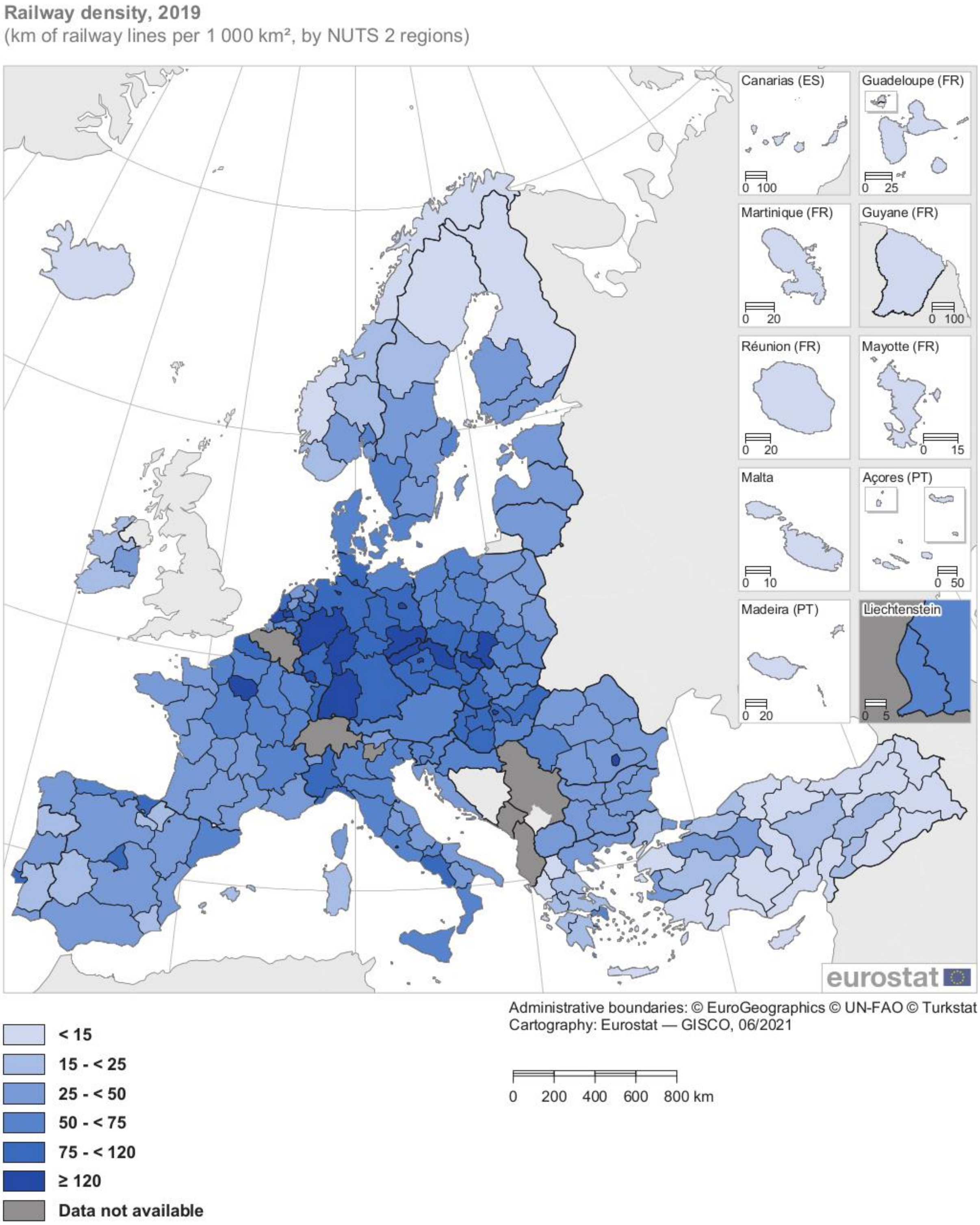
Besides the adverse environmental and economic impacts, the airline industry is accompanied by several advantages, all of which relate to the speed and connectivity of this mode of transport. People and freight are transported quickly and safely by airlines to often remote areas across the world. The number of entities potentially benefitting from this service is considerable. Passengers benefit from fast and reliable transport to almost any possible destination. Workers benefit from jobs created directly or indirectly by air transport. Companies profit from the improved flow of people and goods across borders facilitating global trade, face-to-face meetings of different business partners, opening of new markets as well as the rapid provision of required goods. People in need of healthcare support benefit from timely assistance in the event of emergencies such as natural disasters, conflicts, or disease. Finally, from a macroeconomic perspective, several nations, especially developing and very remote countries, benefit from an economic uplift driven by tourism, which would not be possible without air connections (ATAG, 2018).

Emissions from aviation sector currently account for around 2.0% to 2.5% of total man-made and 10.9% of transport-related CO2 emissions (IEA and UIC, 2017). Compared to aviation services, the railway is characterized on the one hand by its high energy efficiency and low CO2 emissions. Rail transport accounts for only 0.3% of total global emissions and 4.2% of transport-related emissions (IEA and UIC, 2017, Teter et al., 2019). Overall, the fuel consumption of the rail sector constitutes less than one-quarter of that of the aviation sector (United States Department of Energy, 2019). For electric-powered trains, the primary energy source used for electricity generation plays a major role in terms of CO2 emissions. Generally, emissions can be significantly reduced compared to diesel-powered trains (Oliveira et al., 2019). However, a prerequisite for this is that electricity generation is not dependent on fuels rich in carbon, like coal (Timperley, 2019).

In addition to its energy efficiency and low CO2 emissions, the usage of railways is accompanied by many further advantages (Dalla Chiara et al., 2017). Particularly in urban areas, the railway is characterized by its high passenger throughput capacity that cannot be achieved by any other means of transport (Oliveira et al., 2019). Thus, the use of railway systems in urban environments can reduce congestion and save space, especially in comparison to road transport (Teter et al., 2019, Rajendran & Harper, 2021). Moreover, rail transport also offers its passengers higher levels of safety and reliability in comparison to aviation services. In addition, these services operate on a fixed schedule and are less dependent on weather conditions. Furthermore, from a passenger standpoint, it is possible to use the service spontaneously and without long check-in service times (UIC, 2015). To a certain extent, rail operators are also able to adjust the capacity of the rail system according to daily or seasonal peak and off-peak times by simply removing or adding a wagon from the train and/or changing the service frequency (BayRail Alliance, 2020).

The regional distribution of railway infrastructure is shaped by specific historical developments, economic developments and the geographical characteristics of regions. For example, several eastern EU Member States have longer rail networks than their western neighbours, reflecting a legacy from the communist or Soviet era when there was often a greater reliance on rail (compared with road) for transporting passengers and goods (Eurostat, 2021).

Figure 2 presents information on railway density — as measured by the length of railway lines per 1 000 km² of territory. Note that the statistics presented for Denmark, Germany, Lithuania and Makroregion Województwo Mazowieckie (Poland) relate to NUTS level 1 regions, while only national data are available for Austria. In general, the lowest levels of railway density were recorded in peripheral regions of the EU, whereas the highest ratios tended to be in the centre of the EU (where there are more opportunities for establishing a network of connections to surrounding regions). Railway density peaked in a band of regions that ran from the Netherlands and Germany into Czech Republic (Eurostat, 2021).



Note: Denmark, Germany, Lithuania and Makroregion Województwo Mazowieckie (PL9), NUTS level 1. Austria: national data. Spain and Turkey: 2018.

FIGURE 2 Railway density (Eurostat, 2021).

Looking in more detail, the densest rail networks in the EU in 2019 were recorded in the capital regions of Germany and Czech Republic: Berlin (698 km/1 000 km²) and Praha (491 km/1 000 km²). Other capital regions that had relatively high ratios of railway density included Budapest (Hungary), Bucureşti-Ilfov (Romania) and Île-de-France (France). These high ratios in capital regions may reflect, among other factors, the relatively small area covered by most capital regions, as well as the presence of (several) mainline terminals/stations from which railway lines tend to radiate outwards. Other than capital regions, railway density was also relatively high — at least 120 km/1 000 km² (as shown by the darkest shade of blue) — in several largely industrial and/or densely-populated regions; these non-capital regions with a high density of railway lines were located exclusively across Czech Republic, Germany, the Netherlands and Poland (Eurostat, 2021).

At the other end of the range, there was no railway in 18 regions of the EU in 2019. These were predominantly island and/or peripheral regions located in Greece, Spain, France, Cyprus, Malta, Portugal and Finland; they are shown by the lightest shade of blue in Figure 2. The Greek region of Dytiki Makedonia, the Swedish region of Övre Norrland and the Finnish region of Pohjois- ja Itä-Suomi had the three lowest railway densities (among those regions with a railway), at less than 15 km/1 000 km² (Eurostat, 2021).

The development of new rail lines in the EU is today driven by high speed rail projects; high speed lines are part of the rail network of Belgium, Germany, Spain, France, Italy, the United Kingdom, the Netherlands, Austria, and Poland (Prussi and Lonza, 2018). Despite the rapid growth of HSR in the last few decades, passenger rail transport is currently mainly seen as a viable choice for domestic travel (EEA, 2021). The growth in travel by HSR is linked to the expansion of the network. In 2010, Europe had 6,214 km of high speed lines; from 2010 and 2016 the high speed network expanded by 1,400 km (31%) and by 2030 the planned high speed Trans-European Transport Network (TEN-T: Figure 3) should extend HSR to over 30,000 km (Prussi & Lonza, 2018).

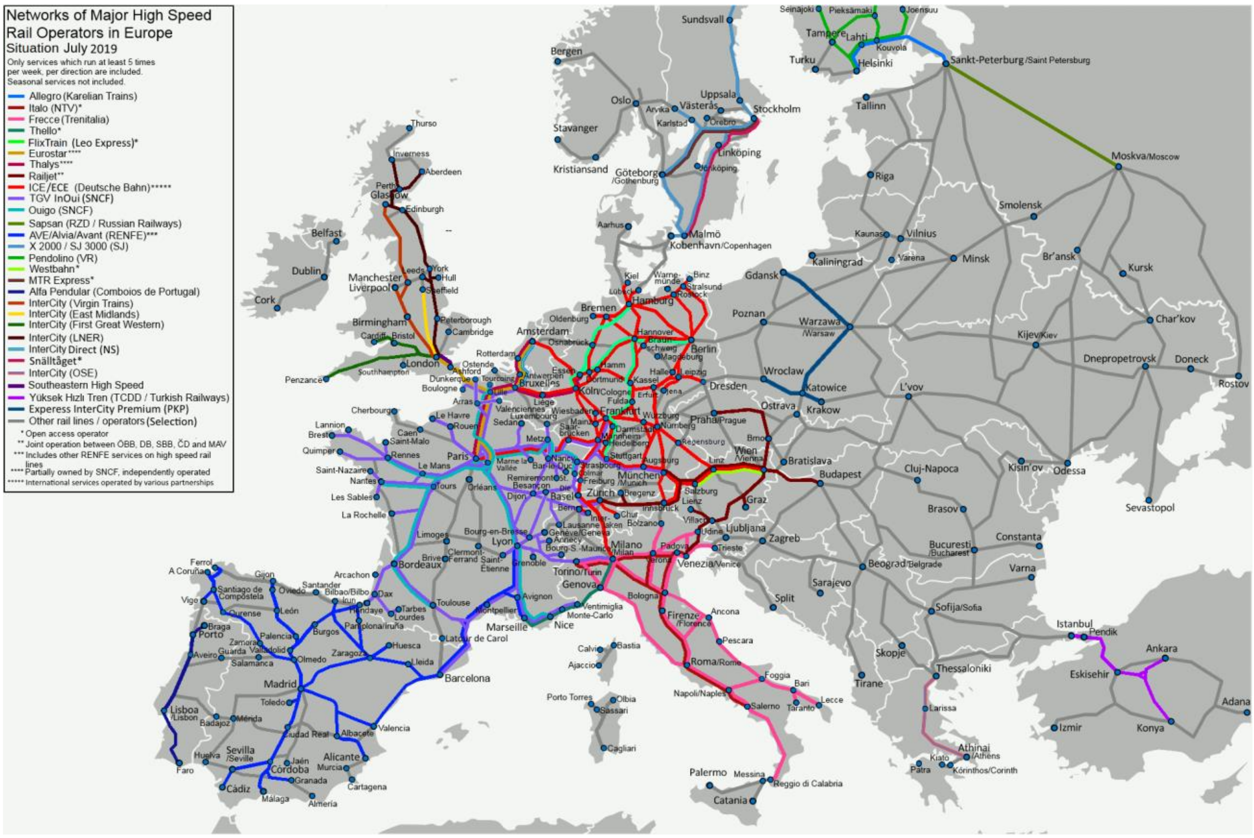


FIGURE 3 Networks of Major High Speed Rail Operators in Europe (Prussi & Lonza, 2018).

Table 1 compares the main characteristics of the two alternative modes of transportation (Rajendran & Popfinger, 2022).

TABLE 1 Comparison of airlines and railways globally according to several selected features (Rajendran & Popfinger, 2022)

Characteristic	**Airlines**	**Railways**
Annual passenger kilometers (trillion)	8.2	3.9
CO_2 emissions	10.9% of transport-related emissions	4.2% of transport-related emissions
Fuel consumption	About 2 tons for a distance of around 400 km	Railways mostly run on electricity (particularly high-speed and urban railways)
Usage of renewable energies	Not foreseeable in the near future	Yes; Renewable energy accounts for 25% of the total energy usage in 2017
Operating cost	$16.60 per seat per hour	$3.56 per seat per hour
Infrastructure cost	Comparatively lower	Relatively higher
Travel time	Considerably lower for medium- and long-haul connections; Moderate advantage for short-haul connections	Relatively higher for medium- and long-haul connections; moderate disadvantage for short-haul connections
Travel cost	Higher than railways in 82% of booking cases	Lower than airlines in 82% of booking cases with an average savings of 37%
Accessibility to rural areas	Limited; airports are usually located in the metropolitan suburbs; relatively low number of airports	Relatively higher; regional/commuter rail enable suburb-city connections; inter-city rails for city-city connections with several stops in between
Accessibility to urban areas	Satisfied; airports are located at a certain distance from the city center; necessity to take another means of transport before take-off and after landing	Superior; urban transport system for connections in the core of a city; regional/commuter rail for connections between the city and its suburbs
Number of stops made between customer pickup and drop-off point	Non-stop or very few, if travel involves more than one leg	Relatively more and depends on the type of rail and distance
Passenger throughput capacity	High	Very high (particularly in urban areas) and superior to airlines

Characteristic	Airlines	Railways
Level of comfort	Slightly lower space per passenger	Relatively more space
Passenger activities before departure and after arrival	Check-in; baggage handling; security control; boarding; passport control	Ticket purchase and inspection

Both rail and air transport have undergone significant changes in the past few decades. Figure 4 presents the evolution of rail and air transport in the EU-27 between 1995 and 2018. For rail transport, a distinction is made between HSR and 'conventional rail transport'. When considering Figure 4, it should be noted that the market segments covered are not completely comparable between rail and air: the data for rail transport also cover shorter distance daily travel, for which air travel is not an alternative, and the data for air transport cover also long-haul flights, for which rail travel is not an alternative (EEA, 2021).

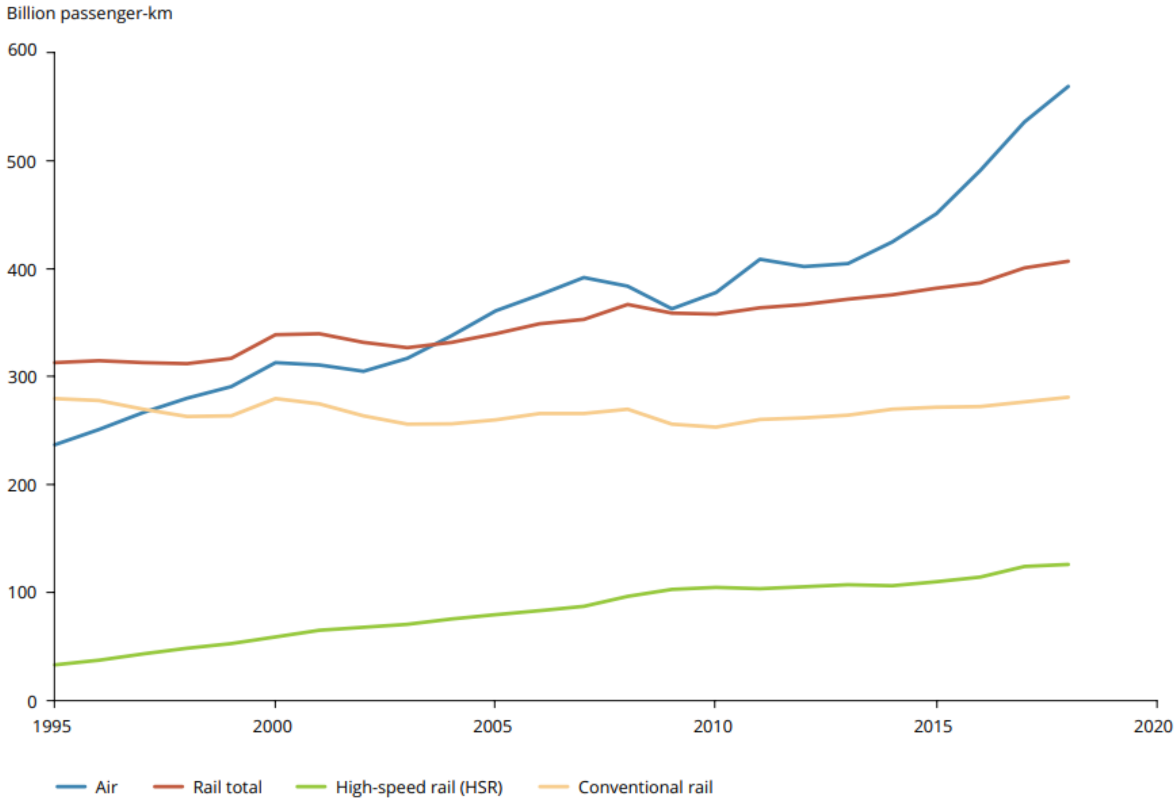


FIGURE 4 Passenger-km travelled by rail and air (EEA, 2021).

In 2018, air passenger-km in the EU-27 were 140 % higher than in 1995 and 82 % higher compared with 2000 (EEA, 2021). According to the European Commission (EC, 2019c), the number of flights operated by low cost carriers within the European Economic Area increased by 88 % between 2006 and 2017. Before the outbreak, the number of flights using EU-28 + European Free Trade Association (EFTA) airports had been projected to grow at an average annual rate of 1.5 % between 2017 and 2040, or 42 % in total (EASA, 2019).

Passenger-km by HSR (the total of domestic and international travel) in the EU-27 has grown by 283 % since 1995 and by 114 % since 2000, with the highest growth rates in the period up to 2001. Rail passenger-km travelled via HSR rose from about 33 billion passenger-km in 1995 to 126 billion passenger-km in 2018 (Figure 4). Rail travel in total grew at a slower pace (by 30 % between 1995 and 2018). This entails an increasing share of HSR in rail travel: from 17.3 % in 2000 to 31 % in 2018 (EC, 2020a).

The demand for air and rail travel was strongly reduced as a result of the COVID-19 pandemic. The longer term effects are still unclear (EEA, 2021).

2.2. Environmental Impact Of Air And Rail Transport

In general, the literature reviewed finds that air transport has higher CO2 emissions than rail per passenger-kilometre in most circumstances. Estimates vary as to the scale of this difference. One study commissioned by the European Federation for Transport and Environment finds that, on average, air travel within Europe emits five to six times more CO2 per passenger-kilometre than travel by train (Bleijenberg, 2020). Another study finds that if flights were replaced by intercity rail travel, the resulting emissions would be 20% lower (Chapman, 2007). The EEA (2021) has estimated the total cost of pollution from different modes of transport in the EU. It finds that total environmental costs, which account for air pollution, climate change impacts, lifecycle CO2 emissions and noise, are substantially higher for air (€32.7bn) than for rail passenger transport (€7.8bn). It estimates that while rail contributes €2.5 of environmental damage per passenger on a 500km trip, the most common aircraft in Europe contribute between €13 and €15 per passenger for the same journey.

However, the above comparisons do not take account of all of the factors that require consideration when comparing the environmental impact of air and rail. For instance, aviation and rail affect the environment in different ways. While the emissions from aviation come largely from tank-to-wheel (TTW) emissions and non-CO2 impacts, emissions from rail come largely from well-to-tank (WTT) emissions. 'Well-to-tank emissions' refers to the upstream production of a fuel—from production of the energy source (e.g. petrol, diesel, electricity) to emissions involved in fuel supply (e.g. transport to the charging point or fuel pump)—while 'well-to-wheel emissions' includes the former emissions as well as those emissions when the fuel is eventually burned (Oxera, 2022).

In undertaking a comprehensive analysis of the current environmental impact of air and rail travel, it is important to take account of the following factors:

• journey duration;

• load factors;

• emissions from the end-to-end journey, including transport to and from the airport and railway station;

• full life cycle emissions of air and rail, taking into account building and maintenance of air and rail infrastructure, and end-of-life processes for aircraft and train carriages;

• non-CO2 environmental impacts of air and rail, including effects of other pollutants such as carbon monoxide (CO), nitrogen oxides (NOx) and particulate matter (PM), noise and biodiversity impacts (Oxera, 2022).

2.2.1. Journey Duration

The comparison of CO_2 emissions between air and rail travel varies by distance. Emissions per passenger-kilometre tend to be higher on short-haul flights than on long-haul flights as a greater proportion of the flight is made up of take-off and landing, which have higher emissions than the rest of the flight. Shorter distances are also the routes for which passengers are more likely to substitute to rail transport, and where rail is more likely to already be available (Oxera, 2022). According to the EEA (2021), assessing the environmental impact of a switch from air to rail on distances of over 500km is 'not straightforward'. This is partially due to the environmental impacts of building the infrastructure necessary to accommodate such journeys, as well as the fact that consumers are less likely to switch to rail on longer journeys, leading to lower load factors on these routes.

2.2.2. Load Factors

Another factor affecting the relative emissions of air and rail is capacity utilisation. According to the EEA (2021), occupancy level is the single most important factor across all modes of transport in determining their environmental impact per passenger, and this factor alone can make a mode of transport the best or the worst choice for the environment. While air and high-speed rail (HSR) both tend to have high capacity utilisation, conventional rail and car often have much lower capacity utilisation, which reduces the emissions gap between these types of transport.

The EEA (2021) has estimated the monetary cost of pollution per passenger for a 500km journey for the five most popular types of aircraft in the EU, HSR, electric intercity train, and petrol, diesel and electric cars with one person and four person occupancy. It assumes a capacity utilisation of 80% for air, 66% for HSR and 36% for intercity train, reflecting their average capacity utilisation in the EU. The results of this analysis for petrol and diesel cars and two of the five types of aircraft, with the highest and lowest emissions respectively, is shown in Figure 5 below. While rail has lower CO_2 emissions than air at these load factors, when petrol and diesel cars have a one-person occupancy, aviation can have a lower cost of emissions than road transport. However, it is important to note that electric cars represent a growing share of road transport.

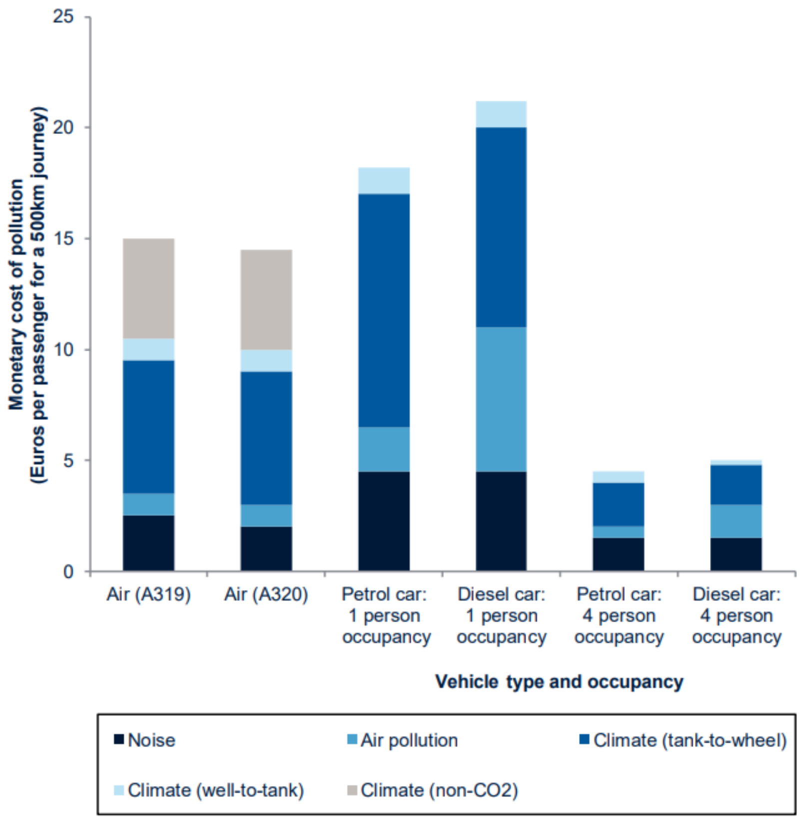


FIGURE 5 Monetary cost of pollution for air relative to car at different occupancy levels (EEA, 2021).

While some of the literature, such as the EEA report referenced above, suggests that rail tends to have lower CO2 emissions per passenger-kilometre than air travel even when occupancy is low on rail, other estimates differ. One study shows that emissions of all major pollutants change with occupancy (EEA, 2021).

Given that both air and rail can be preferable over car transport with one person occupancy, another important factor to consider is the substitutability of air and rail with road transport both now and going forward as transport decarbonises. For example, in the absence of short-haul air travel options, some passengers, particularly connecting passengers, may choose to use cars instead of rail (Oxera, 2022).

2.2.3. End-to-end Journey

Emissions should also be considered in the context of end-to-end transport, which includes the environmental costs of travelling to and from the railway station or airport. This depends on the location of the railway stations and airports, and their accessibility via public transport (Oxera, 2022; Prussi & Lonza, 2018).

Study by the EEA (2021) examines the environmental impact of the first and last leg of the journey for a range of transport modes in several European cities. It finds that these costs are negligible for rail transport, but can be significant for air transport, as airports are often located further away from the city centre. However, many airports are actively encouraging the use of public transport for journeys to/from the airport, and are well connected to rail, coach and sometimes metro networks to the city centre. The proportion of people travelling to and from airports using public transport ranges from between 60% at Copenhagen and Zurich airports to 40% at Frankfurt and Heathrow airports, though it is typically lower at regional airports. Some airports, such as Heathrow, are also actively discouraging access to the airport by car through the introduction of a £5 forecourt access charge. These types of measures are likely to lower the end-to-end journey emissions from aviation, and to reduce the gap in first- and last-mile emissions between rail and air transport (Oxera, 2022).

2.2.4. Full Life Cycle Impacts

Comparisons of emissions between air and rail should also take account of their full life cycle impacts, which includes the direct and indirect processes needed to operate aircraft and rail carriages—for example, raw materials extraction and manufacturing, construction, operation, maintenance, and the end of life of vehicles, infrastructure and fuels (Oxera, 2022).

While aviation has significantly greater tailpipe emissions than rail, the emissions gap shrinks when indirect emissions are taken into account. Indirect emissions account for 21% of overall emissions from aviation, 36% from road, and 39% and 100% from diesel and electric trains respectively. In aviation, indirect emissions come from the production of fuel, while in rail transport, a large proportion stem from infrastructure construction, as well as the operation and maintenance of tracks (Avinor, 2020).

Both air and rail transport also require the use of auxiliary equipment and vehicles. Aviation requires ground support activities, for which various types of equipment are used, such as fuel trucks, aircraft tugs and belt loaders. Rail transport requires machines for shunting, track treatment and infrastructure monitoring (Chester & Horvath, 2010; EEA, 2021).

However it is worth noting that while there is a great deal of literature focusing on the embedded emissions of aviation, there is less literature on the embedded emissions associated with rail—in particular the emissions from vehicle manufacturing and operational procedures and their impacts (EEA, 2021). As a result it is difficult to make an accurate comparison between the total life cycle emissions of air and rail, as emissions figures for rail may be an underestimate (Oxera, 2022).

Recent research has shown that the environmental damage of the HST is particularly acute in the construction phase (Kageson, 2009). However, once the infrastructure has been constructed, the HST seems to have an environmental advantage over air transport. In general, the plane is considered a mode of transport more harmful to the environment than HST, especially in regard to its impact on climate change.

2.2.5. Other Environmental Impacts

In addition to CO2, both air and rail have a variety of other environmental impacts. This includes soil pollution, noise pollution, waste production, biodiversity impacts, and emission of other greenhouse gases, as well as air pollutants such as nitrogen oxides, carbon monoxide and particulate matter.

Aviation emits short-lived climate forcers, including SO2, NOx and black carbon into the upper atmosphere, which leads to warming of the atmosphere through the formation of contrails and cirrus. Resulting from this, the European Commission (2019a) estimated the total climate change costs of aviation to be twice the costs of the CO2 emissions alone. To reduce the climate impact of aviation, it is therefore important to consider not just an aircraft's carbon emissions, but its 'climate-optimised trajectory'. This refers to the optimal routes and altitudes that allow aircraft to avoid climate-sensitive regions and minimise contrail formation (Institute of atmospheric physics, n.d.).

In the next sections, the following impacts are consecutively discussed: climate change, air and soil pollution, noise pollution and impact on biodiversity.

2.2.5.1. Climate impact

Commercial aviation's climate change impact is complex, reflecting the variety of emissions from operations at the surface up to cruise altitudes as high as 43,000 feet, across continents and oceans, and over varied time spans. The climate impacts of jet aircraft emissions are summarized in the Figure 6 below. Within the cloud trailing the aircraft are the various gases and particulates emitted by burning jet fuel (kerosene). The warming or cooling influence of these gases is described below the cloud (in the line labeled "Climate Impact"), and a comparison of each exhaust product to the warming effect of CO2 is included in the color-coded bar with red for a warming impact and blue representing a cooling effect. (Overton, 2021)

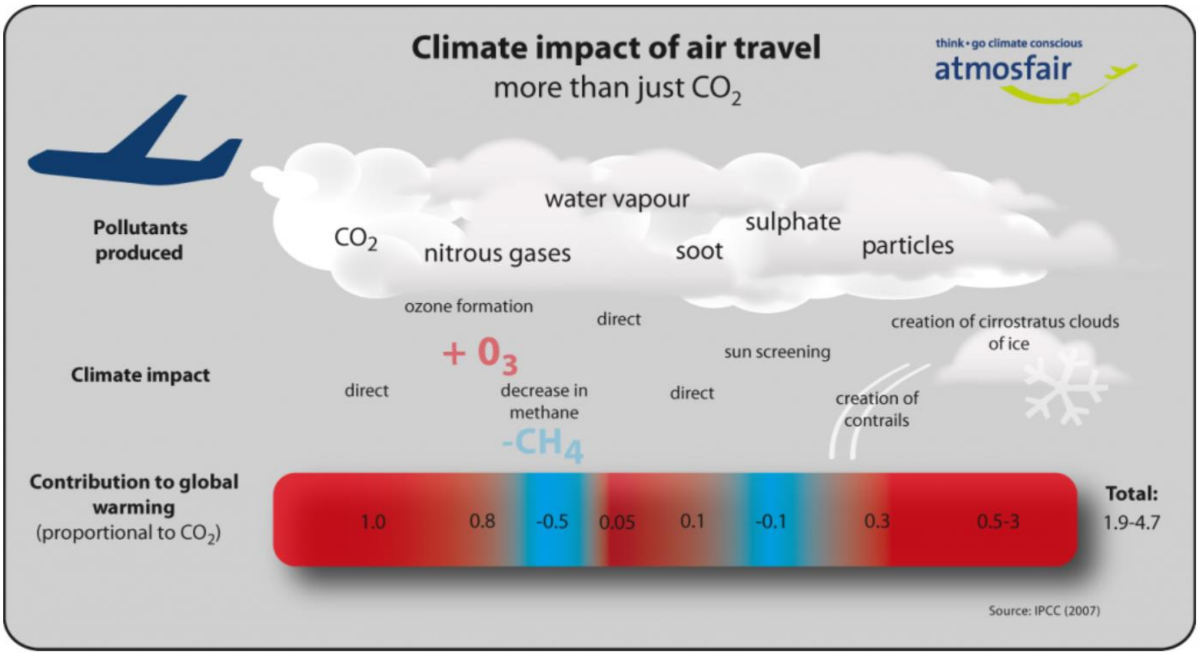
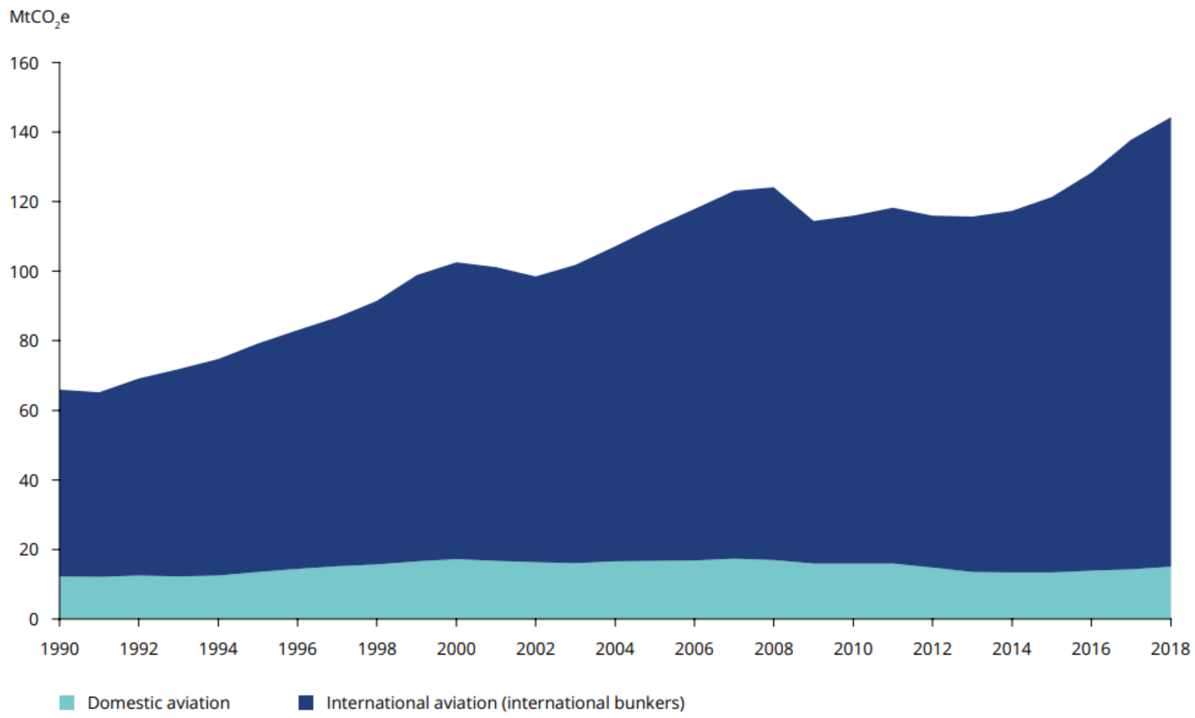


FIGURE 6 Climate impact of air travel (Overton, 2021).

Unlike CO2 emissions, the non-CO2 effects differ as a function of the flight altitude, time of day, weather, location, etc. (Overton, 2021). In the recent update of the handbook on the external costs of transport, the European Commission (2019d) estimated that the non-CO2 effects of aviation contribute about half of the climate warming impact of aviation. The uncertainty about the non-CO2 impacts is larger than for CO2, especially for cloud-induced impacts. A recent report by EASA fully confirmed the importance of non-CO2 climate impacts from aviation (Overton, 2021).

According to EEA (2020a), between 1990 and 2018, the TTW EU GHG emissions from domestic aviation in the EU-27 increased by 22% and those of international civil aviation more than doubled (increase of 141%) (Figure 7).



Note: International bunkers refers to emissions from fuel used for international aviation.

Source: EEA (2020a).

FIGURE 7 CO2 emissions from aviation (EEA, 2021).

The figures do not allow a distinction to be made between passenger and cargo transport. In 2018, the TTW GHG emissions from domestic civil aviation in the EU-27 were 15 MtCO2e and those for international aviation totalled 129.2 MtCO2e (EEA, 2021).

The GHG emissions of aviation are determined by the evolution of air transport demand in combination with additional factors, including:

• the energy efficiency of the aircraft;

• the occupancy rate of the aircraft;

• air traffic management and operations;

• the share of sustainable aviation fuels.

The central outlook for 2040 presented by EASA (2019) for flights departing from the EU-27 and the United Kingdom (UK) and the European Free Trade Association (EFTA) countries projects a growth in CO2 emissions from 21 % to 37 %, compared with 2017, depending on the technological developments. Although the outlook was produced before the COVID-19 outbreak, it still gives an indication of the potential GHG reduction challenges ahead under various scenarios. Even in the low-traffic case, where the number of flights in 2040 is assumed to be only 6 % higher than in 2017, there is still a need for further GHG abatement, although emissions are then projected to be 8-18 % lower than in 2017 (depending on the technological developments). In the high-demand forecast, the emissions are 61-85 % higher in 2040 than they were in 2017.

According to EEA (2021), for rail transport the TTW GHG emissions are determined by rail travel demand in combination with other factors, including the following:

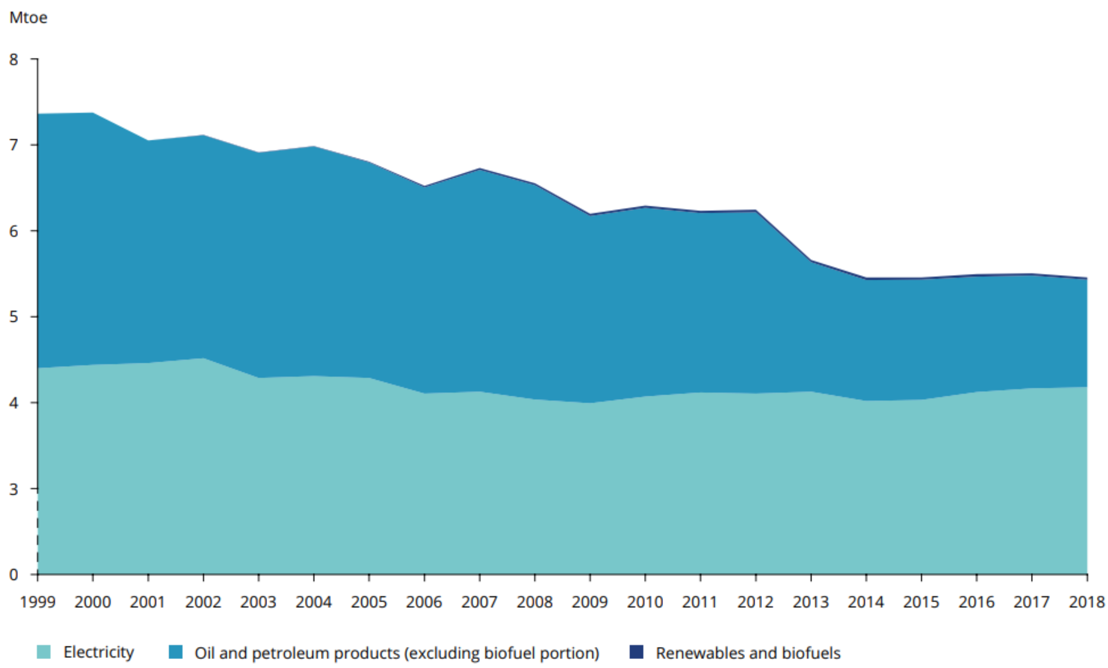
• the specific energy consumption of the passenger trains (energy per vehicle-km);

• the number of passengers on the trains;

• rail traffic management procedures;

• the GHG emission intensity of energy consumed by rail.

The specific energy consumption of the passenger trains increases with the train size and weight and depends on the speed and powertrain type. Other things being equal, electric trains are more energy efficient than diesel trains. For the market segments considered in this report, electric trains are the most relevant. The energy statistics do not allow distinctions to be made between passenger and freight transport or between different distance bands. According to Eurostat, between 2000 and 2018 the consumption of oil and petroleum products by rail in the EU-27 (for the total of passenger and freight rail) more than halved. In 2018 the associated GHG emissions equalled approximately 4.3 million tonnes (Mt). The electricity consumption decreased between 2000 and 2009 and fluctuated thereafter. In 2018 it was 4.7 % higher than in 2009 but 6 % lower than in 2000 (Figure 8).



Note: Mtoe, million tonnes of oil equivalent.

Source: EEA compilation, based on Eurostat (nrg_bal_s).

FIGURE 8 Final energy consumption by rail transport (EEA, 2021).

In the same period, electricity production became less CO2 intensive on average in the EU. Between 2000 and 2017 the average CO2 intensity of electricity production in the EU-27 evolved from 393.3 to 295.7 g/CO2 per kWh (EEA, 2020c), which corresponds to a decrease of almost 25 %. Applying this average emission intensity to the electricity consumption by rail transport, the GHG emissions related to electric rail transport can be approximated to have been 14.4 Mt in 2018.

2.2.5.2. Air and soil pollution

Other environmental impacts of rail include air and soil pollution and the emission of hydrocarbons and particulate matter (PM).

Air transport emits several air pollutants during taxiing, take-off and landing, and cruising at altitude. The TTW emissions of air pollutants by aviation are determined by the evolution of air transport demand in combination with additional factors, including:

• the energy efficiency and the abatement technologies of the aircraft;

• the occupancy rate of the aircraft;

• air traffic management and operational measures.

The share of aviation in the total emissions of air pollutants in the EEA-32 is relatively small. For 2018, the largest share was found for NOx emissions, to which air transport contributes 5.5 %. The share of domestic aviation in the emissions from air transport ranges between 12 % and 30 % depending on the pollutant that is considered (Table 2). The share of landing and take-off in the aviation emissions is the largest for non-methane volatile organic compounds (NMVOC) (39 %), followed by PM (26 %) and NOx and SOx (15 %) (EEA, 2021).

TABLE 2 Share of domestic aviation and landing and take-off in emissions of air pollutants by aviation (EEA, 2021)

Pollutant	Share of domestic aviation in aviation emissions (%)	Share of landing and take-off emissions in total aviation emissions (%)
CO	16	24
NMVOC	30	39
NO_x	12	15
$PM_{2.5}$	14	26
PM_{10}	14	26
SO_x	13	15

Note: $PM_{2.5}$, particulate matter with a diameter of 2.5 µm or less; PM_{10}, particulate matter with a diameter of 10 µm or less.

Source: EEA (LRTAP).

The WTT emissions from air transport also contribute to air pollution. These are the emissions related to the production and transport of jet fuel. These emissions occur at locations other than where the transport activities take place and hence have a different impact on health and the environment.

Rail transport generates TTW emissions of air pollutants via the operation of diesel trains. Both diesel and electric trains also cause non-exhaust particulate matter (PM) emissions via the abrasion of powerlines, wheels on tracks and brakes (EEA, 2021; Fridell et al., 2010).The share of diesel trains in total emissions in the EEA-32 is limited (EEA, 2021).

Rail can lead to soil pollution from abrasion of brakes, wheels, tracks and overhead lines as well as fuel combustion and other sources (EEA, 2021; Oxera, 2022). In an analysis of the operation of the 7 200 km of tracks in the Swiss Federal Railways Network, Burkhardt et al. (2008) found an annual release of approximately 2,270t of metals and 1,357t of hydrocarbons. Friction processes were the main source of the release of metals. The most important sources of hydrocarbons were wooden sleepers treated with oil. Lubricants from track switches and wheel flanges were the next biggest sources.

Aviation similarly leads to soil pollution, as burning jet fuel is one of the sources of atmospheric polycyclic aromatic hydrocarbons, which are deposited on the soil. Soil pollution is also caused by the spreading of aircraft de-icing and/or anti-icing fluids during take-offs in winter time. The pollution may extend for several hundred metres away from the runways (Nunes et al., 2011).

Soil pollution from air travel is likely to be concentrated around airports, while soil pollution from rail transport can extend along the entire route (Oxera, 2022).

2.2.5.3. Noise pollution

Similarly, both air and rail create noise pollution; however, rail creates noise pollution over the entire route, while the impacts of noise from air traffic are concentrated on landing and take-off, and limited to locations near the airport. Therefore there is a trade-off; noise from aviation is expected to impact a smaller proportion of people more heavily, while noise from rail is expected to impact a greater number of people to a lesser extent (Oxera, 2022).

It can cause community annoyance, disrupt sleep, adversely affect academic performance of children, and could increase the risk for cardiovascular disease of people living in the vicinity of airports. In some airports, noise constrains air traffic growth (ICAO, 2016).

According to the data collected for major airports under the Environmental Noise Directive (END), it is estimated for the EEA-32 that approximately 2 million people in urban areas are exposed to air traffic noise levels of at least 55 dB during the day-evening-night period and 0.8 million people during the night period. Outside urban areas, the figures are 0.9 and 0.3 million, respectively (EEA, 2020b), excluding UK data. Moreover, new evidence from the World Health Organization (WHO) shows that the annoyance response to air traffic noise has increased over time and is higher than indicated by exposure-response functions based on older data (EEA, 2020b).

About 20 million people in the EEA-32 (excluding Turkey) are estimated to be exposed to rail traffic noise of at least 55 decibels (dB) during the day-evening-night period. Half of these people are exposed within urban areas and the other half outside urban areas. Nearly 16 million people are affected by night-time rail noise of 50 dB and higher, of which 8.6 million people outside urban areas. This means that about 4.3 % of the population is affected by rail traffic noise levels that exceed the thresholds of the END during the day-evening-night period and 3.4 % during the night-time period (EEA, 2020b). These figures cover both passenger and freight rail; for rail passenger transport they do not make a distinction between short- and long-distance transport.

2.2.5.4. *Biodiversity*

In terms of biodiversity, several studies have found that railways can have adverse effects on wildlife, including through the degradation of the natural habitat of species (Lucas et al., 2017; Forman & Alexander, 1998), and indirect impacts such as noise that can cause disruption to wildlife populations (Clauzel et al., 2013; Penone et al., 2013). One study has found that railways can have a similar effect to roads, including reducing the provision of foraging opportunities, disrupting wildlife corridors, and collision of animals with vehicles (Borda-de-Água et al., 2017). The EU taxonomy technical report (EU Technical Expert Group on Sustainable Finance, 2019) finds that 'the main potential significant harm […] are attributed to air pollution, noise and vibration pollution, and some potential for water contamination' when new railways are built. Land use change from building new railways is another consideration. Railways require large corridors of land, reducing the amount of land available for carbon sequestration and natural habitats (Oxera, 2022).

Aviation also impacts biodiversity and wildlife—e.g. through bird strikes and local soil and water pollution. Several studies have sought to quantify the impact of air and rail on biodiversity in monetary terms. One study found a total yearly cost of €2.7bn for habitat damage in the EU from rail (€0.006/passenger-km) and a smaller cost (of €0.00007/passenger-km) for air transport (EEA, 2021). Aviation additionally impacts land use, requiring land for the airport and in the surrounding areas.

2.2.6. Conclusion

In general, most studies focus on the amount of CO2 emissions produced by transport sector and they find that air transport has higher CO2 emissions than rail. CO2 emissions are an important indicator for environmental impact evaluation as it the primary driver of global climate change, but it is not the only one. As aviation and rail affect environment in different ways, different factors, such as journey duration, load factors, emissions from the end-to-end journey, full life cycle emissions of air and rail and non-CO2 environmental impacts, should be taken into account when estimating the environmental impact of air and rail travel modes.

The non-CO2 environmental impacts of air and rail are air and soil pollution, noise pollution, waste production, biodiversity impacts, land use impact, and emission of other greenhouse gases, as well as air pollutants such as nitrogen oxides, carbon monoxide and particulate matter. Aviation emits short-lived climate forcers, including SO2, NOx and black carbon into the upper atmosphere, which leads to warming of the atmosphere. Total climate change costs of aviation of non-CO2 emissions are estimated to be equal or even twice the costs of the CO2 emissions alone according to different sources but uncertainty about the non-CO2 impacts still exists.

Both railway and aviation have a negative environmental effect. However, total negative environmental impact is higher for air than for rail passenger transport. The modal shift from air to rail is preferred but different factors should be taken into account when facilitating the shift.

2.3. Potential Of An Increase In Rail Share?

Rail has an important role to play in meeting future mobility needs, and a key role in providing long-distance, inter-city surface transport replacing road and air transport and contributing to low carbon mobility (Banister & Givoni, 2013). A modal shift from road and air towards rail is one obvious way to reduce CO2 emissions. In particular, efficient, 100% electric HSR can play a leading role in reducing transport related emissions and contribute to climate protection. HSR offers the best performance in terms of energy consumption and materials use (Jehanno et al., 2011).

Rail is an efficient user of energy provided that there are sufficient densities in terms of passenger and freight demand, and this is now evident in the dominance that rail has established in certain transport corridors, for example in the UK between London and Manchester and in France between Paris and Lyon (Banister & Givoni, 2013). A shift from air travel to high-speed rail could displace 10% of domestic and 8% of international flights in Europe (SLOGAT, 2021).

High-speed train is flourishing. Being at the top end spectrum of surface public transportation, its contribution to changing the image of railways and to revitalizing the railways cannot be underestimated. But by its nature it is only suitable for very specific transport corridors, where demand is very high. Only then the high cost of investments can be justified. But the “glory” of HSR makes it looks an attractive option also when it is clear that it is not suitable (Givoni, 2020).

Behrens and Pels (2012) studied inter- and intramodal competition in the London–Paris passenger market during the period 2003–2009. They find frequency, total travel time, and distance to the UK port as the main determinants of travellers’ behaviour. Business and leisure passengers behave differently regarding these main determinants. They conclude that leisure passengers are more heterogeneous regarding average fares compared with business passengers.

Intermodal agreements between airlines and rail operators are an increasingly prominent feature of the transportation landscape. These agreements offer a number of potential advantages for airlines, rail operators, intermodal airports and consumers of transportation services. They enjoy strong political support, particularly in Europe, in part because of the perceived contribution they can make to the achievement of environmental policy targets. However, air–rail intermodal agreements involve a form of cooperation between airlines and rail operators that could, in principle, raise competition concerns. This is especially the case where agreements involve air and rail services that operate in parallel on a given route, and where the two services are potential substitute forms of transportation (Chiambaretto & Decker, 2012).

HSR offers attractive alternatives to short- and medium-haul intra-EU flights and long distance car journeys (Jehanno et al., 2011; Prussi & Lonza, 2018). Studies indicate that the area of competition between the plane and the long-distance-train is within a range of 200 and 500 km (Böhler et al., 2006). Böhler et al. (2006) found out that persons who travel to more distant destinations (distances as from 3000 km) also travel more often and use air travel for more than 60% of their trips. For the other groups, car travel is more important, local travellers (distance up to 600 km) conduct about 80% of their trips by car, the mid-distant travellers (distance between 600 km and 3000 km) - almost 60%.

Replacing short-haul flights with HSR would release capacity constraints at airports, reduce the need for additional expansion whilst helping to tackle the challenges of climate change (Jehanno et al., 2011). However, the development of HSR remains limited compared to the increase of air services and the potential of HSR is still not fully exploited (Dobruszkes, 2011; Prussi & Lonza, 2018).

Compared with other modes, the HST market share falls as travel time increases. This is the major variable that explains the attractiveness of HSTs (Dobruszkes, 2011). Some studies qualify their results according to the fares being charged. For example, Commission of the European Communities (2006) shows that competition between HSR and air transport is less straightforward where low-cost airlines are present.

According to Barron et al. (2009), the HSR link between Madrid and Seville shifted the air/rail passengers split from 67:33% to 16:84%. Even on an international trip, like the London-Paris route, HSR proves to be highly competitive with air (Behrens & Pels, 2012).

Provided that travel time savings continue to dominate the appraisal of HSR projects, there is a risk that HSR will only contribute to increased mobility. This approach will contribute more rather than less greenhouse gas emissions and it will increase in other adverse environmental effects from transport, as well as having social impacts that might restrict access to the HSR services as these 'super high-speed services' will be directed only at high income and business travellers. This might turn rail transport into a relatively unique and exclusive mode of transport provided in only particular parts (corridors) of a country and serving a particular (and relatively small) part of society (Banister & Givoni, 2013).

In addition to being substitutes, rail and air also offer the potential for multimodal trips. In that case a trip combines air transport on one leg and a railway trip on another leg, rather than travelling the whole way by air. In this respect, the 2011 Transport White Paper states that all major airports should be linked to the railway network. Furthermore, the Trans-European Transport Network (TEN-T) Regulation — Regulation (EU) No 1315/2013 — stipulates that until 2030 the most important core network components, including urban nodes and airports, are expected to have multimodal links, as long as they are economically viable, environmentally sustainable and feasible (EEA, 2021).

The Shift2Rail joint undertaking (S2R JU) is a form of public-private partnership in the rail sector. It supports research and innovation activities that can contribute to achieving the Single European Railway Area and to increasing the attractiveness and competitiveness and improving the safety of rail in Europe. Shift2Rail aims to introduce better trains to the market (quieter, more comfortable, more dependable, etc.) that operate on an innovative rail network infrastructure, at a lower life cycle cost and with the capacity to cope with rising demand for rail transport for passengers and freight. By improving the competitiveness and attractiveness of rail services, combined with increased capacity, the share of travel by rail can increase, which contributes to reducing the CO_2 emissions of the transport sector (EEA, 2021).

2.4. Environmental Impacts Of A Mode Shift Towards Rail In Europe?

According to Chiambaretto and Decker (2012), the potential environmental gains associated with a modal shift toward rail may be significant, although limited by the internalization of part of the aviation's CO_2 footprint inherent in bringing airlines into the EU Emissions Trading

System (EU ETS). EU ETS is the world's first international emissions trading system where companies can choose to reduce emissions or trade allowances with one another in order to achieve GHG emission reductions at least cost which is discussed further in Section 2.5.3.

Givoni (2007) examines empirically the level of air pollution and climate change impact of air and HST travel between the cities of Paris and London. He concludes that replacing a seat on a plane by a seat on a HST is always beneficial from the environmental point of view. However, D'Alfonso et al. (2016) modelled the environmental impacts of London-Paris HSR-air transport competition, capturing the effects of induced demand, schedule frequency, and HSR speed: the authors showed that the net environmental effects can be negative since there is a negative trade-off due to the substitution effect.

The construction of a high-speed rail station at the Madrid Barajas Airport in Spain is an example of the integration of different transportation modes, with expected environmental benefits. The results show that with high-speed rail the number of people choosing air travel and the private car is reduced leading to important environmental benefits: a reduction of close to 5 kg of CO2 per passenger, or 10% of all emissions on the corridor (Zanin, Herranz, & Ladousse, 2012).

According to IEA (2021b), rail requires 12 times less energy and emits 7-11 times less GHGs per passenger-km travelled than private vehicles and airplanes, making it the most efficient mode of motorised passenger transport. If 10% of the European traffic was shifted to rail, the corresponding emission would drop by between 8% and 9%. This would make a significant contribution to the EU's target of reducing net greenhouse gas emissions by at least 55% by 2030. And this result would be achieved with the existing technologies (UIC, 2022).

Shifting from air travel to high-speed rail produces 3.4 times less pollution and uses 80-90% less energy. Rail produces fewer emissions of nitrogen oxides and particulate matter than aviation. Rail also has a lower emission impact than aviation due to its smaller infrastructure footprint and its ability to transport passengers directly to city centres, allowing shorter distances and more sustainable travel options (e.g., urban rail, walking) to reach final destinations (SLOCAT, 2021).

Prussi and Lonza (2018) assessed the environmental impact of modal substitution among six intra-EU28 routes and one national route. The results presented confirm a remarkable advantage of high-speed trains compared to aircraft, with regard to direct CO2eq emissions per pkm. Three scenarios have been proposed to define the effects produced by modal shift. Starting from a business as usual (BAU) scenario, where the allocation of the 3.5% annual pace of passenger growth remains unvaried towards 2025, two additional scenarios are calculated assuming the shift of the same annual growth rate to high-speed rail by 5% in the low-rail scenario and 25% in the high-rail scenario. Scenario computation proves that shifting passengers to HST allows GHG savings of 4% and 21.6% in the low-rail and high-rail scenarios respectively. Some of the analysed routes (e.g., Frankfurt Main–Paris CDG) have interesting GHG saving but the duration of the trip by train today limits a real substitution; increasing the average train speed could potentially fill the gap but that would at the same time reduce the environmental benefits.

Carbon savings from shifting air travel to rail between Glasgow and London between 2005 and 2015 was equivalent to taking 145,000 cars off the road for a year (SLOCAT, 2021).

With serious congestion often clogging the highways, 'bullet trains' travelling on dedicated right-of-way corridors in excess of 220 km per hour are seen by their proponents as improving the mobility of citizens and the connectivity and accessibility of the places they pass through. HSR advocates also expect that proliferation of such systems would entail environmental benefits, namely offsetting increases in automobile and air travel and reducing roadway congestion, fuel consumption, and greenhouse gas (GHG) emissions (Loukaitou-Sideris et al., 2012). Opponents of HSR systems, on the other hand, point to the often enormous construction and significant operational costs of HSR projects, their noise and visual intrusion to adjacent communities, and their adverse impacts on agriculture and wildlife (Loukaitou-Sideris et al., 2012).

A user-friendly online tool based on a sound scientific methodology EcoPassenger is available to compare energy consumption, CO2 emissions and other environmental impacts in respect of planes, cars and trains for passenger transport. EcoPassenger was developed through cooperation between UIC, the Sustainable Development Foundation, ifeu (the German Institute for Environment and Energy) and HaCon (software). This online tool is fed with the most accurate and latest available data for all transport modes that allows highlighting the impact of personal choices on energy consumption, carbon emissions and local air pollution. EcoPassenger does not merely calculate the energy or the fuel it takes to run a train, car or plane. Calculations include emissions from cumulative energy consumption, including the energy used to produce the electricity or fuel, using a “well to wheel” approach. The methodology used for rail services is based on the Environmental Strategy Reporting System, including dual reporting of the national mix and railways mix for companies seeking guarantees of origin of renewable energies (UIC, 2021).

In EcoPassenger, train virtually always comes out better than plane, often by a lot (BBC News, 2019). A journey from Brussels Central Station to Lyon (minimal distance by car is 711 km in Google Maps) would emit 27.1kg of CO2 per passenger by train, 111.5kg by car, but 121.6kg by plane (or 169.2kg if the non-CO2 emissions are included), according to EcoPassenger.

However, the margin between train and plane emissions varies, depending on several factors, including the type of train. For electric trains, the way the electricity they use is generated is used to calculate carbon emissions. Diesel trains' carbon emissions can be twice those of electric ones. Figures from the UK Rail Safety and Standards board show some diesel locomotives emit more than 90g of C02 per passenger per kilometre, compared with about 45g for an electric Intercity 225, for example. The source of the electricity can make a big difference if you compare a country such as France, where about 75% of electricity comes from nuclear power, with Poland, where about 80% of grid power is generated from coal. As with plane journeys, another factor is how full the train is - a peak-time commuter train will have much lower emissions per person than a late-night rural one, for example (BBC News, 2019).

2.5. Sustainability Policies In The EU

The environmental impacts of medium- to long-distance passenger travel by rail and air are mitigated by various policies at EU and international levels on the one hand and at the national level on the other. First of all, a number of general EU policy frameworks apply to both transport modes. In addition, mode-specific policies are used or will come into use at EU, national and international levels. The policy instruments include a wide range of measures, including pricing policies (taxes, charges, subsidies), technology standards, other command-and-control measures, infrastructure measures and support for research and development (R&D) as well as more general measures. Table 3 gives a general overview, with a focus on the control of the environmental impacts caused by climate change, air pollution and noise (EEA, 2021).

TABLE 3 Overview of policy frameworks and policies at the EU, national and international levels (EEA, 2021)

Environmental impact	Government level	Policies	
		Rail	Air
Climate change	EU	General framework: EU climate and energy framework Renewable Energy Directive European Green Deal	
		ETS (electric trains)	ETS (intra-EEA aviation)
	International		CORSIA CO_2 standards for new aircraft (ICAO standards)
	National	Fuel taxes Electricity taxes Renewable energy policies	Fuel taxes (domestic flights) or ticket taxes Policies on sustainable aviation fuels
Air pollution	EU	General framework: Air Quality Directive National Emission Ceilings Directive	
		Emission standards for diesel locomotives and railcars (non-road mobile machinery regulation)	Aircraft emission standards (in line with ICAO standards)
	International		Engine emission standards (ICAO standards)
	National	National taxes/charges	Airport charges differentiated by aircraft emission levels
Noise	EU	General framework: Environmental Noise Directive	
		Rail noise emission limits Regulatory framework for noise-differentiated rail track access charges schemes	Noise certification standards (in line with ICAO standards) Regulation (EU) No 598/2014 on the procedures concerning the introduction of noise-related operating restrictions (also taking into account other environmental impacts)

	International		Noise certification standards Procedures concerning the introduction of noise-related operating restrictions
	National	Noise-differentiated rail track access charges Rail noise abatement programmes	Noise-differentiated airport charges Aviation noise abatement schemes Noise-related operating restrictions
General	EU	Sustainable and Smart Mobility Strategy 2020 EU strategy on low-emission mobility 2016 Transport White Paper 2011 TEN-T programme Connecting Europe Facility ERDF and Cohesion Fund/ESIFs Horizon 2020 transport European digital strategy	
		Railway packages Recast of the Interoperability Directive Shift2Rail	Air Service Regulation SES SESAR Clean Sky joint undertaking
	National	Non-environmental rail charges	Non-environmental airport charges and aviation taxes

Note: CORSIA, Carbon Offsetting and Reduction Scheme for International Aviation; ERDF, European Regional Development Fund; ESIF, European Structural and Investment Fund; ETS, Emissions Trading System; ICAO, International Civil Aviation Organization; SES, Single European Sky initiative; SESAR, Single European Sky Air Traffic Management Research; TEN-T, Trans-European Networks for Transport.

The UN 2030 agenda for sustainable development and the Paris Agreement on climate change form the general background for the relevant EU policies. The EU's commitment to reaching its objectives finds expression in the EU 2030 energy and climate framework, the Energy Union, the circular economy action plan and the EU implementation of the 2030 agenda for sustainable development (EEA, 2021).

2.5.1. European Green Deal

The European Green Deal also forms part of the European Commission's strategy to implement the United Nation's 2030 agenda and the Sustainable Development Goals (SDGs). It seeks a 90 % reduction in transport emissions by 2050 compared with 1990 (EC, 2019a). The European Green Deal proposes actions for sustainable, low carbon transport with key priorities including increasing multimodal passenger and freight transport efficiency, fostering automated and smart mobility, ending fossil fuel subsidies, extending emission trading to shipping and ramping up sustainable fuels (EC, 2019b).

2.5.2. Renewable Energy Directive

The Renewable Energy Directive (2009/28/CE) and its revision in 2015 through Directive (EU) 2015/1513 set the regulatory framework for renewable energy in Europe up to 2020. It sets a target of a 10 % share of renewable energy by 2020 in transport. For evaluating whether the target has been achieved, the target is computed as the ratio of the amount of all types of renewable energy consumed in all forms of transport and of the amount of petrol, diesel, biofuels and electricity used in road and rail transport. Renewable fuel in aviation can in principle also contribute to the target share. The directive imposes additional restrictions on the type of fuels that can be used. In the EU transport sector, renewable energy made up around 8.3 % of all energy use in 2018. With renewable electricity playing only a small role in transport, the bulk of renewable energy use in this sector comes from biofuels (Eurostat, 2020b). The use of sustainable aviation fuels (SAFs) in the EU is very small — for 2017 it was estimated to be only about 0.05 % of the total jet fuel consumption (EC, 2020c). The RED II, as the recast of the Renewable Energy Directive (Directive (EU) 2018/2001) is known, applies to the period 2021-2030 and confirms the increased use of renewable energy as an instrumental part of the actions required to meet the EU climate change mitigation objectives. For transport, which in 2018 still relied on fossil fuels for 94 % of its energy supply (Eurostat, 2020c), the share of renewable energy supplied for final energy consumption should be at least 14 % by 2030. The target is set with respect to all types of fuels consumed in road and rail transport. Limits are imposed on biofuels made from crops with a high risk of causing high indirect land use change, i.e. food or feed crops or those crops for which a significant expansion of the production area would be into land with high carbon stocks. Such biofuels should gradually be phased out by the end of 2030. Certain biofuels and types of biogas get an extra incentive, as their energy content is multiplied by two in calculating the share of renewables. This applies to two groups of fuels: (1) fuels produced from used cooking oil and animal fats, for which a maximum share is also imposed; and (2) the so-called advanced biofuels for which a gradually increasing minimum share also applies. Extra incentives are given to the use of renewable electricity in rail transport and to the use of renewable fuels (other than food- and feed-based fuels) supplied to aviation. No specific target is set for aviation. However, the European Commission is currently considering legislative options to boost the production and uptake of SAFs (EC, 2020c).

2.5.3. EU Emissions Trading System

The EU ETS is a key tool for reducing GHG emissions in the EU. The EU Emissions Trading System (ETS) addresses, directly or indirectly, the GHG emissions of rail and aviation. For rail, the EU ETS is relevant for electrified rail transport. It covers CO2 emissions resulting from the production of electricity used by trains (emissions from stationary installations, including electricity and heat generation, energy-intensive industry and some industrial processes). About 72 % of total rail transport (in terms of train-km) takes place on electrified lines. By incentivising the electrification of rail infrastructure for the Trans-European Transport Network (TEN-T) 'core network', the TEN-T policy leads to a shift in GHG emissions from rail transport into the EU ETS. For aviation, the current scope of the EU ETS covers only flights within the European Economic Area, which corresponds to about 36 % of the CO2 emissions from aviation (including international bunkers) of the countries in the European Economic Area in 2018. Flights to and from the outermost regions of the EU (e.g. the Azores and the Canary Islands) are covered only if they occur in the same outermost region. More than one third of EU aviation CO2 emissions are currently covered by the system. It does not address non-CO2 climate effects. Since 2013, the total emissions of airline operators under the EU ETS have increased from 53.5 MtCO2e to 68.2 MtCO2e in 2019 (an increase of more than 27 %) (EEA, 2021).

The EU ETS is a 'cap and trade' system: it sets a cap on emissions from the activities it covers. Then, within the cap, companies receive or buy emission allowances. An emission allowance grants the right to emit 1 t CO2e. The total number of allowances is set by the cap and is lower than the historical emissions. Companies can choose to reduce emissions or trade allowances with one another as needed in order to achieve GHG emission reductions at least cost. The EU ETS cap on emissions decreases each year according to a linear path. For the period

2013-2020, the total number of emission allowances that can be issued each year decreased by 1.74 % per year. From 2021 onwards, the annual rate will be 2.2 %. Since 2013, operators from the power generation sector must buy all of their allowances for EU ETS through auctions, with exceptions for some countries. In other stationary sectors, the proportion of allowances auctioned increases progressively. In the aviation sector, the large majority (82 %) of allowances is distributed for free (or 'grandfathered'), 15 % is auctioned and 3 % is placed in a special reserve to provide allowances for new operators or for operators seeing a rapid growth in their activities. Even with freely allocated allowances, the opportunity cost of an emission allowance is not equal to zero but rather to the ETS price; it is the benefit that one would gain from selling an allowance at the ETS price, rather than by using the allowance to cover a unit of emissions (EEA, 2021).

The EU ETS includes an incentive to use sustainable aviation fuels. The emission factor associated with such fuels for the monitoring of combustion emissions is set to zero in the guidelines for the monitoring and reporting of GHG emissions. To qualify for this zero-emission factor, the fuel needs to match the sustainability requirements of the Renewable Energy Directive (EEA, 2021).

2.5.4. Sustainable Aviation Fuels

Significant uncertainties exist in predicting the contribution of sustainable aviation fuels in the future. However, a number of near-term scenarios evaluated by AFTF indicate that up to 2.6% of fuel consumption could potentially consist of sustainable aviation fuels by 2025. This analysis also considered the long-term availability of sustainable aviation fuels, finding that, by 2050, it would be physically possible to meet 100% of international aviation jet fuel demand with sustainable aviation fuels, corresponding to a 63% reduction in emissions. However, this level of fuel production could only be achieved with extremely large capital investments in sustainable aviation fuel production infrastructure, and substantial policy support. The effort required to reach these production volumes would have to significantly exceed historical precedent for other fuels, such as ethanol and biodiesel for road transportation. The effect of such an expansion in the use of sustainable aviation fuels on net CO2 emissions from international aviation is shown in Figure 9. (ICAO, 2019)

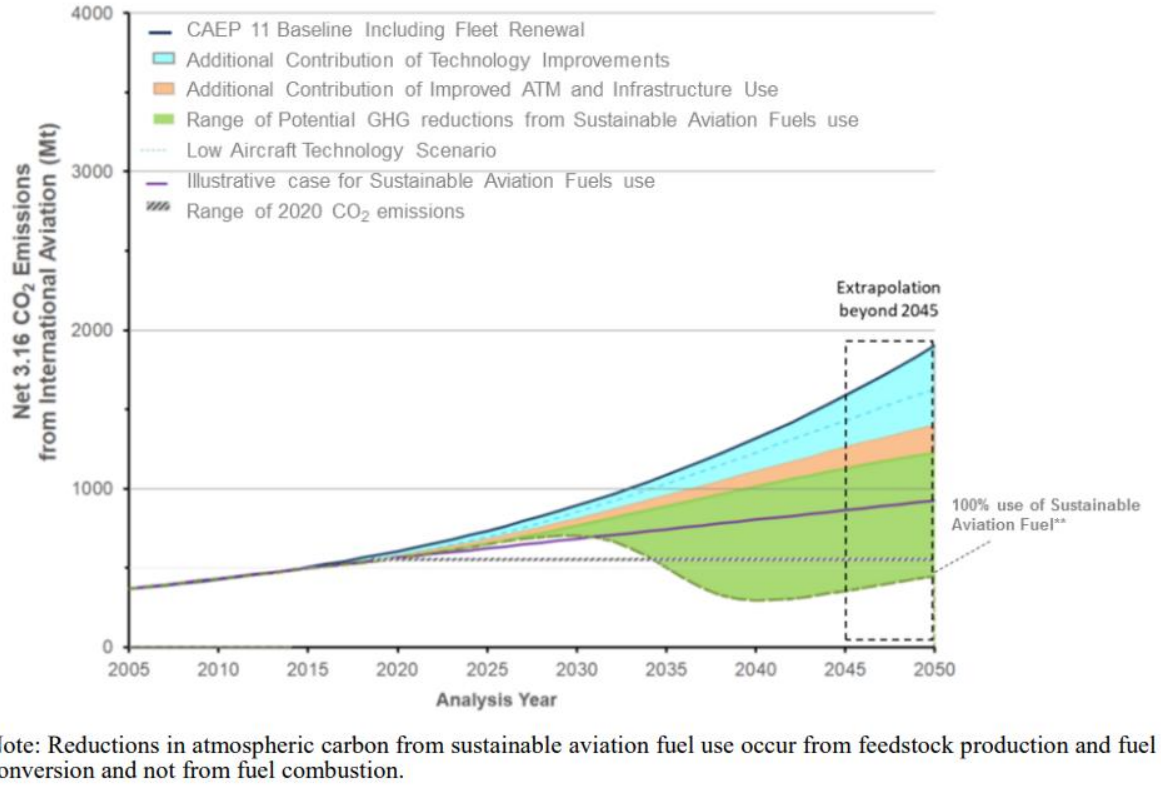


FIGURE 9 CO2 Emissions from International Aviation (ICAO, 2019).

There are initiatives in some European countries to support the uptake of SAF. For example, Norway introduced the world's first national mandate for jet biofuel in 2018, calling for at least 0.5 % SAF from sustainable non-food sources from 2020. The Norwegian government aims to increase this mandate to 30 % by 2030. The Netherlands is studying SAF supply obligations with a 14 % target in 2030. Similar mandates have also been proposed in Finland, France, Germany, Spain and Sweden (EEA, 2021).

2.5.5. Fuel Tax

For air transport, the 1944 Chicago Convention on International Civil Aviation (Article 24) established the principle that fuel on board aircraft flying to, from or across the territory of another contracting state should be exempt from any national or local duties and charges. A series of bilateral agreements have subsequently extended this exemption to 'fuel supplied in the territory of one State party to an airline of the other party' (EEA, 2016). Under the EU Directive on the common system of value added tax (VAT) (2006/112/EC), the supply of goods for the fuelling and provisioning of aircraft for commercial air traffic on international routes should be exempt from VAT (Article 148). The Energy Taxation Directive (2003/96/ EC) states that aircraft fuel, for commercial operations, is exempt from excise duty. Still, Member States may limit the exemption to intra-community and international flights. Currently no aviation fuel taxes are levied in the EU (CE Delft and SEO Amsterdam Economics, 2019). The European Green Deal states that '… in the context of the revision of the Energy Taxation Directive, the

Commission will look closely at the current tax exemptions including for aviation and maritime fuels …' (EC, 2019a).

2.5.6. Modal Shift Support

At the same time, the European Commission is encouraging a modal shift from air to rail. In December 2020, the European Commission published its Sustainable and Smart Mobility Strategy (EC, 2020b). The new strategy acknowledges that reducing emissions and becoming more sustainable is the most important challenge for Europe's transport sector. It also states that achieving the ambition of the European Green Deal requires a 'fundamental transformation' of the mobility system towards sustainability and away from fossil fuels. The strategy calls for a shift towards more sustainable modes of transport and putting in place the right incentives to support the shift.

Rail plays an important role in this context. The strategy includes the objective to increase the number of rail passengers and to create an 'affordable high-speed rail network' across Europe. In concrete terms, the strategy aims to double high-speed rail traffic by 2030 and triple it by 2050. Making high-speed rail services available on short-haul distances and enabling carbon-neutral collective passenger travel for distances below 500 km by 2030 are also among its objectives (EEA, 2021).

Several EU countries have also introduced national measures to encourage this modal shift. Since 2000, the EU has provided €23.7bn in grants to co-finance HSR infrastructure, while the European Investment Bank has provided €29.7bn in loans over the same period (Oxera, 2022). In recent years, many European countries, including Germany, Austria, and Sweden, are encouraging people to use rail services instead of air transport (Tawfik & Limbourg, 2019, Logan et al., 2021). In 2021, France passed a law banning all short-haul domestic flights of less than 2.5 hours where there are rail alternatives, excluding connecting flights, while Italy is considering introducing similar legislation. In January 2022 Belgium announced plans for an air tax of €10 for any flights under 500km. Bans on short-haul flights have also been considered in Germany and Spain, and were introduced in Austria in 2020 for domestic flights with train alternatives under three hours, affecting the route between Vienna and Salzburg (Oxera, 2022). The Sweden-based “flygskam” movement, has emerged as a pan-European environmental movement with the goal of motivating people to avoid air travel (Abend, 2019). Measures to encourage rail transport include the reintroduction of sleeper train services, reduction of rail fares, and the introduction of a carbon tax on flights (Blunt, 2020). Besides the government, passengers have started to understand and advocate for rail transportation (Blunt, 2020).

Moreover, within the context of the COVID-19 pandemic, environmental requirements or reducing competition with HSR, for example by cutting relatively short distance domestic routes or imposing a minimum price for air tickets, are mentioned as a condition for state aid for airlines. Examples can be found in France, Austria and the Netherlands (EEA, 2021).

2.6. Influencing Factors For Travel Choice

In general, people's choice will depend on many factors, which also apply when one considers the choice between rail, car and air travel (EEA, 2021).The main factors determining the choice are price, travel time, travel time reliability, frequency of the connections and other factors such as convenience, comfort and safety (Givoni and Dobruszkes, 2013; Clewlow et al., 2014). For example, HSR is found to be a good substitute for air transport for trips up to 2.5 or 3 hours, but less so for longer travel times (Jiang and Li, 2016). The extent to which each of the factors plays a role depends, however, on the travel purpose (business, leisure) and on the preferences of the person who travels. For example, Behrens and Pels (2012) find for the London-Paris market, business passengers are more sensitive to total travel time and weekly frequency than leisure travellers and are less sensitive to fares. People in both the business and leisure market segments make a trade-off between various trip attributes. In both segments, for example, longer average travel time by rail may be offset by higher frequency and/or lower fares.

2.7. Conclusion

Before the COVID-19 outbreak, demand for passenger transport was on a steady upwards trajectory with by far the strongest growth seen in air travel. The number of flights in the EU had been projected to grow at an average annual rate of 1.5% between 2017 and 2040, or 42% in total, leading to an expected increase in the local and global environmental impacts of air travel. Therefore, a shift to less polluting transport mode as train is seen as an important step in reducing the environmental footprint of travel.

The main factors that can affect people’s choice of a transport mode are: price, travel time, travel time reliability, frequency of the connections, convenience, comfort and safety. The extent to which each of the factors plays a role depends, however, on the travel purpose (business, leisure) and on the preferences of the person who travels.

Compared to aviation, the usage of railways is accompanied by many advantages such as higher energy efficiency, low CO2 emissions, higher levels of safety and reliability, less dependence on weather conditions and absence of long check-in service times.

Regarding railway density, the lowest levels of railway density were recorded in peripheral regions of the EU, whereas the highest ratios tended to be in the centre of the EU (where there are more opportunities for establishing a network of connections to surrounding regions). The growth in travel by HSR is linked to the expansion of the network. Therefore, the level of railway density can slow down or constrain the modal shift.

In general, most studies focus on the amount of CO2 emissions produced by transport sector and they find that air transport has higher CO2 emissions than rail. CO2 emissions are an important indicator for environmental impact evaluation as it the primary driver of global climate change, but it is not the only one. As aviation and rail affect environment in different ways, different factors, such as journey duration, load factors, emissions from the end-to-end journey, full life cycle emissions of air and rail and non-CO2 environmental impacts, should be taken into account when estimating the environmental impact of air and rail travel modes.

Journey duration affects the level of CO_2 emissions: emissions per passenger-kilometre tend to be higher on short-haul flights than on long-haul flights as a greater proportion of the flight is made up of take-off and landing, which have higher emissions than the rest of the flight.

Load factor plays a great role in determining their environmental impact per passenger, and this factor alone can make a mode of transport the best or the worst choice for the environment.

Environmental costs of travelling to and from the railway station or airport should be considered in the context of end-to-end transport. While railway stations are usually located in the city centre, airports are often located further away from it. In this case, environmental costs for air transport can be significant. As many airports are actively encouraging the use of public transport for journeys to/from the airport and are well connected to rail, coach and sometimes metro networks to the city centre, there is a potential to lower the end-to-end journey emissions from aviation, and to reduce the gap in first- and last-mile emissions between rail and air transport.

Direct and indirect processes needed to operate aircraft and rail carriages (e.g. raw materials extraction and manufacturing, construction, operation, maintenance, and the end of life of vehicles, infrastructure and fuels) should be taken into account as well when comparing emissions of air and rail. Indirect emissions decrease the emissions gap between air and rail transport. The fuel production is a source of indirect emissions in aviation, while infrastructure construction and the operation and maintenance of tracks lead to indirect emissions in rail transport. Recent research has shown that the environmental damage of the HST is particularly acute in the construction phase. However, once the infrastructure has been constructed, the HST seems to have an environmental advantage over air transport. It is important to mention that there is less research on the emissions from vehicle manufacturing and operational procedures and their impacts for rail transport than for air transport.

There are also non-CO_2 environmental impacts of air and rail such as air and soil pollution, noise pollution, waste production, biodiversity impacts, and emission of other greenhouse gases, as well as air pollutants such as nitrogen oxides, carbon monoxide and particulate matter. Aviation emits short-lived climate forcers, including SO_2, NO_x and black carbon into the upper atmosphere, which leads to warming of the atmosphere. Total climate change costs are estimated to be equal or even twice the costs of the CO_2 emissions alone according to different sources but uncertainty about the non-CO_2 impacts still exists.

Commercial aviation’s climate change impact is complex, reflecting the variety of emissions from operations at the surface up to cruise altitudes with various gases and particulates emitted by burning jet fuel (kerosene).

Air pollution by rail is mostly caused by the emissions generated via the operation of diesel trains and the abrasion of powerlines, wheels on tracks and brakes. Emissions related to the production and transport of fuel also contribute to air pollution.

Rail can lead to soil pollution from abrasion of brakes, wheels, tracks and overhead lines as well as fuel combustion and other sources while soil pollution from aviation is caused by burning jet fuel as it is one of the sources of atmospheric polycyclic aromatic hydrocarbons, which are deposited on the soil and by the spreading of aircraft de-icing and/or anti-icing fluids during take-offs in winter time. Soil pollution from air travel is likely to be concentrated around airports, while soil pollution from rail transport can extend along the entire route.

Rail creates noise pollution over the entire route while noise pollution of aviation is concentrated on take-off and landing and limited to locations near the airport. Noise from aviation is expected to impact a smaller proportion of people more heavily, while noise from rail is expected to impact a greater number of people to a lesser extent. Noise can cause community annoyance, disrupt sleep, adversely affect academic performance of children, and could increase the risk for cardiovascular disease of people living in the vicinity of airports.

Several studies found that railways and aviation can disrupt wildlife due to air, noise pollution with local water and soil pollution. Land use is impacted as well as rail and air transport require land for operation.

However, air services increase at much higher rate than the development of HSR occurs, as by its nature HSR is only suitable for very specific transport corridors, where demand is very high. Only then the high cost of investments can be justified. Besides, the attractiveness of HSR is explained by travel time and travel cost. By improving the competitiveness and attractiveness of rail services, combined with increased capacity, the share of travel by rail can increase.

In addition to being substitutes, rail and air also offer the potential for multimodal trips. In that case a trip combines air transport on one leg and a railway trip on another leg, rather than travelling the whole way by air. To achieve it, major airports should be linked to the railway network but it has to be economically viable, environmentally sustainable and feasible.

Many studies conclude that a modal shift towards rail, in particular HSR, has many advantages, including reducing CO2 emissions, contributing to climate protection and releasing capacity constrains at the airports, while D'Alfonso et al. (2016) found that the net environmental effects can be negative since there is a negative trade-off due to the substitution effect. HSR advocates expect that proliferation of dedicated right-of-way corridors in excess of 220 km per hour would entail environmental benefits, namely offsetting increases in automobile and air travel and reducing roadway congestion, fuel consumption, and greenhouse gas (GHG) emissions. At the same time, opponents of HSR systems point to the often enormous construction and significant operational costs of HSR projects, their noise and visual intrusion to adjacent communities, and their adverse impacts on agriculture and wildlife.

There are various policies at EU, international and national levels that mitigate the environmental impacts of medium- to long-distance travel by rail and air. There are policies that apply to both modes or are mode-specific. European Green Deal seeks a 90 % reduction in transport emissions by 2050 compared with 1990. Renewable Energy Directive Renewable Energy Directive II focus on an increase of renewable energy use in road and rail transport. EU Emissions Trading System addresses the GHG emissions of both modes: this 'cap and trade' system sets the total amount of certain greenhouse gases that can be emitted by the installations and they are reduced over time. Within the cap, installations buy or receive emissions allowances, which they can trade with one another as needed. Sustainable aviation fuels are supposed to achieve a 63% reduction in emissions if 100% of international aviation jet fuel demand is met with sustainable aviation fuels. However, extremely large capital investments and substantial policy support are required to achieve this level of fuel production. At the same time, the contribution of SAFs in the future is difficult to predict. Currently no aviation fuel taxes are levied in the EU but the situation can change after the revision of the Energy Taxation Directive. Sustainable and Smart Mobility Strategy aims to double high-speed rail traffic by 2030 and triple it by 2050. Making high-speed rail services available on short-haul distances and enabling carbon-neutral collective passenger travel for distances below 500 km by 2030 are also among its objectives. There are also national measures to encourage the modal shift.

3. RESEARCH PLAN: SURVEY SET UP

This Chapter describes all the steps that needed to be undertaken to create and distribute the survey. In this Chapter we discuss why this survey is necessary to be conducted and what its content is, including the types of questions and the proposed answers. The following sections indicate the survey design and how the questions are defined.

3.1. Goal Of The Survey

The main goal of the survey is to investigate people's decisions and preferences towards travel modes for leisure trips within Europe in order to determine which factors are important for a modal shift and how their preferences could be adjusted towards selecting a train as a travel mode over other alternatives.

3.2. Questionnaire

The questionnaire consists of 27 questions divided into 5 blocks. It is crucial that a respondent understands what is meant by “leisure trip within EU” in the context of this thesis before answering the survey. Therefore, the definition of a leisure trip has been provided in the introduction. The first block tries to identify general travel preferences of respondents in relation to leisure trips within EU. The second block investigates relevance of specific factors when planning leisure trips within EU for each presented travel mode and respondents’ attitude to the statements regarding these travel modes. All questions in this block are conditional, meaning that they are adapted to the given reply to the specific question in the first block. If a respondent checks only one travel mode option, then he or she will see only 2 questions from the block related to this travel mode option. If a respondent checks 2 or all travel mode options, he or she will see 4 or 6 questions respectively. The third block contains questions with 32 choice experiments in order to find out which attributes are the most important to the respondents. The forth block aims to find out the measures that would convince respondents to choose train option over car or plane. The last block helps to gain background information of the individuals. The questionnaire can be found in Appendix 1.

3.2.1. Travel Preferences Questions

The first question intends to find out if a respondent has taken, within the last 5 years, at least one leisure trip that suits the definition of a leisure trip provided in the introduction. The next question is conditional and is shown if a respondent chooses “Yes” in the first question. This question asks if a respondent has used, within the last 5 years, one of the transport modes such as car, train or plane.

The second question is about the company a respondent usually travels with if he/she plans a leisure trip. The possible answers are:

- Alone
- With my family
- With my friends

The next question asks a respondent to rank transport modes used within the EU in the order of preference and 4 transport modes are proposed: car, train, low-cost airline and traditional airline.

The last question intends to find out how often transport modes are considered to be used by a respondent for a leisure trip within the EU. The respondent can choose from “Always”, “Sometimes” and “Never”.

3.2.2. Travel Factor Relevance and Attitudes Questions

The questions in this part are conditional and are only displayed if a respondent considers at least one transport mode from the last question of the previous block. There are 2 questions per transport mode. The first question asks how important suggested factors identified from literature are when a respondent plans a leisure trip within the EU by each transport mode. A respondent is able to choose from 5 possible answers:

- Not at all important
- Slightly important
- Moderately important
- Very important
- Extremely important

The second question intends to find out a respondent’s opinion regarding the given statements based on the literature review by proposing the following answers:

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly disagree

3.2.3. Stated Preference Questions

In order to prepare stated preference based scenarios, four attributes have been chosen that are of importance for a respondent when planning a leisure trip within the EU. These attributes are travel time, return trip cost, travel persons and comfort level. Then levels of attributes have been determined and they are presented in Table 4.

TABLE 4 Levels of attributes for transport modes (Own edit, 2022)

	Car	*Plane*	*Train*
Travel time	7 hrs, 8 hrs, 9 hrs, 10 hrs	4 hrs, 5 hrs, 6 hrs, 7 hrs	3 hrs, 4.5 hrs, 6 hrs, 8 hrs
Travel cost	€200, €250, €300, €350	€100, €150, €200, €250	€100, €175, €225, €275
Travel persons	Alone, With travel companions		
Comfort level	High, Low	1st class, Economy (2nd) class	

Levels for *travel time* and *travel cost* were defined by checking the actual times and prices for the trips to the destinations up to 800 km and they were simplified for the convenience. The travel times for a car alternative were defined in Google Maps and the travel cost was defined by taking the average fuel price and multiplying it by the distance/10 (with approximation of using 1 litre per 10 km). The travel times and prices for a plane alternative were checked in Google Flights. The travel times and prices for a train alternative were explored on the website of NMBS International (www.b-europe.com). Levels for *travel persons* are the same for all alternatives. Levels for *comfort level* are the same for all alternatives but the levels for a car alternative have been rephrased to make it more clear to the participants.

There were 32 choice experiments generated per each transport mode according to the determined levels of attributes using SAS statistical software. Consequently, 32 questions were prepared based on the generated scenarios. They were divided into 8 sets (per 4 questions each) and these sets were randomly allocated to the respondents in an equal proportion, while the rest of the survey questions remained the same to each respondent.

A respondent is asked to choose one transport mode with specific levels of attributes that he/she would prefer to get to the destination, when planning a leisure trip of 5 days. The stated preference questions always showed the alternatives in the same order: car, plane and train travel modes.

3.2.4. Convincing Measures Question

It is crucial to know what possibly could convince people to use train instead of car or plane for leisure trips within EU. There is only one question in this block and it consists of 12 measures and 3 possible choices:

- Yes
- Maybe
- No

The measures where proposed based on the literature review, and in particular on the research of Böhler et al. (2006).

3.2.5. Background Questions

In order to be able to better interpret the responses, it is important to obtain information about age, gender, professional occupation, living area, household composition, etc. There are 10 questions in this block.

The first question refers to the age of a respondent and it contains a numerical entry field. This allowed the creation of age groups when the survey circulation was over.

The second question is about the gender of a respondent. There are 3 gender choices:

- Male
- Female
- Non-binary/third gender

The next question aims to find out the current professional occupation of a respondent. There are 5 choices available:

- Student
- Employee
- Self-employed/ independent professional
- Currently no professional occupation
- Retired

The forth question asks the household composition of a respondent. The household composition can have an impact on the travel mode used for leisure trips (Price & Matthews, 2013). The size of the household, for example, determines the frequency of private car use for holiday travels. Younger families with children prefer to use of the private car, whereas singles and younger couples without children are typical users of air travel. Couples and singles above 60 years of age are the major user groups for traveling by train or coach (Böhler et al., 2006). The following choices are given:

- Single without children
- Single with children
- In a relationship without children
- In a relationship with children

The fifth and sixth questions refer to the living area of the respondent. First, a respondent is asked which country he/she lives in and the province is asked in the next question.

There is a difference in the level of development and availability of travel modes between countries. The province of living helps to understand how far international airports are from the respondent.

The next two questions refer to the driver's licence and car ownership status. The answers "Yes" and "No" are provided for the first question. For the second question, there are 4 possible choices and multiple answers can be selected:

- Do not own a car
- Rent a car occasionally
- Lease a car on permanent basis
- Own a car

The ninth question aims to find out if a respondent uses train in his/her everyday live and the frequency of the usage. If a respondent uses a train at least few times per month, then it will be easier for him/her to use it more often for conducting leisure trips within EU. The choices are the following:

- Daily
- A few times per week
- A few times per month
- A few times per year
- Do not use a train

The tenth question contains 10 statements that will help to determine how environmentally friendly a respondent is. A respondent is able to choose as many as are applicable to him/her. They are given below:

- Recycling as much as possible
- Consuming less meat or no meat at all
- Using eco-friendly cleaning products
- Buying second-hand things (clothes, furniture etc.)
- Avoiding car use in daily life
- Buying unpackaged food (e.g. fruit) or food packed in recycled packaging
- Fixing things instead of throwing them away immediately
- Reducing my energy consumption
- Reducing my water consumption
- Using rechargeable batteries

The last question contains a text entry box and is intended to collect any possible additions to the survey from a respondent.

4. SURVEY ANALYSIS AND INTERPRETATION OF RESULTS

In this chapter, the results from the survey are presented. First, there are descriptive statistics such as figures and tables of answers per question. Most of the statistics are available in Qualtrics XM software, where the survey was created. It is necessary to mention that open-ended questions cannot be analysed in the software, therefore the raw data should be exported from Qualtrics XM (see Appendix 2) for the additional analysis. Next, there is a multinomial logit model estimation in order to find the significant factors affecting mode choice.

4.1. Background

In total 128 people participated in the survey. From the 128 respondents, only 98 finished the survey. One response had to be excluded from the analysis due to data inconsistency. The respondent claimed to be an 11 years old student who was single with children, lived in the country “B” within the province “B”, owned a driving licence and rented a car occasionally (Figure 10).

Q16 What i	Q17 What i	Q18 Which	Q19 What i	Q20 Which	Q21 Which	Q22 Do you	Q23 What i
11	Male	Student	Single with children	B	B	Yes	Do not own a car,Rent a car occasionally

FIGURE 10 Data inconsistency in a response (Qualtrics, Own edit, 2022).

Therefore, the analysis of 97 responses will be presented.

From the 97 respondents, 58.76% were male and 41.24% were female participants.

Despite the higher number of male respondents over female ones, the driving licence ownership rate is equally proportionate between both males and females with 80.70% of males and 80.00% of females owning a driving licence.

The question about a respondent’s age was an open question, but there was no possibility in Qualtrics to visualize the answers, therefore raw data from the survey (see Appendix 2) needed to be exported in order to analyse it in Excel. Another sheet in Excel with age responses was created after the export of the survey data (see Appendix 3). It was decided to group the answers into six age categories (Figure 11). It is important to mention that the youngest person was 18 years old and the oldest person was 70 years old. As we can see from the Figure 11, the highest percentage of the respondents belong to the age group 25-34 and an equal percentage of the respondents falls under two age group categories: 18-24 and 35-44. We can also see that with the increasing age as from 34 years old, the percentage of the respondents decreases. It may be perfectly normal as the survey was published online on Facebook, Twitter & Linkedin.

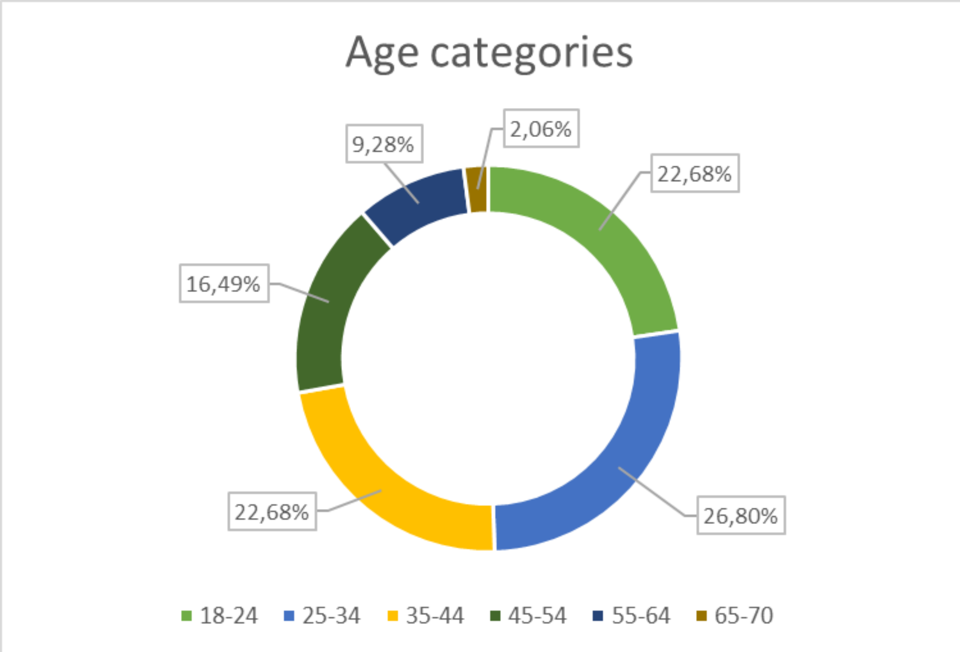


FIGURE 11 Age categories (n=97) (Qualtrics, Own edit, 2022).

Regarding the current professional occupation, 57.73% were employees and 38.14% were students. The remaining respondents were either retired (3.09%) or self-employed/independent professionals (1.03%).

The next question was about the household composition of the participant (Figure 12). More than 60% of the respondents appeared not to have children: 38.14% were single and 25.77% were in a relationship without children. At the same time, 31.96% were in a relationship with children and only 4.12 % were single with children.

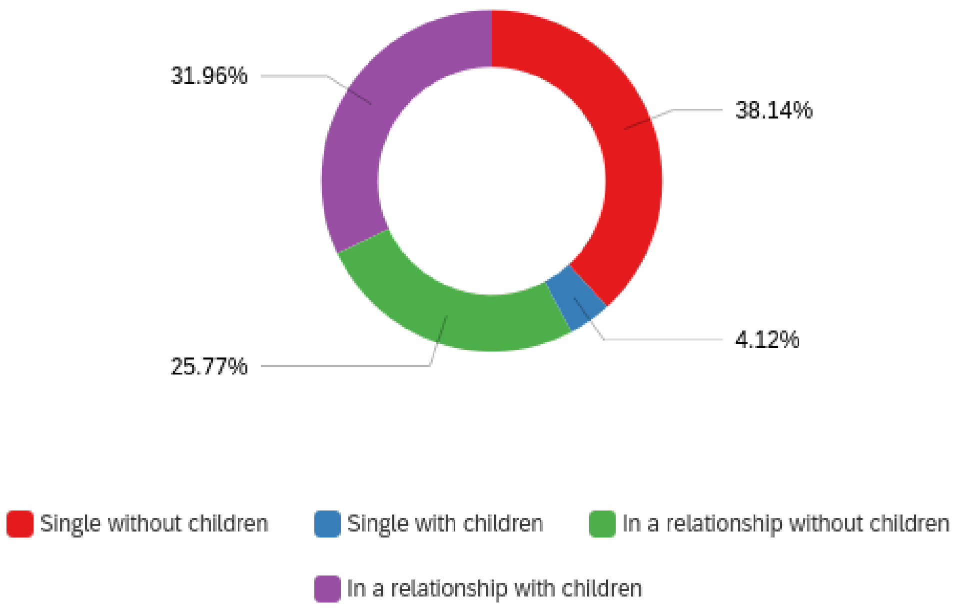


FIGURE 12 Household composition (n=97) (Qualtrics, Own edit, 2022).

The question about a respondent's country of living was an open question. A sheet in Excel with the responses regarding country of living was created. As we can see from Figure 13, there were participants from 8 countries and the majority of them live in Belgium (88.66%).

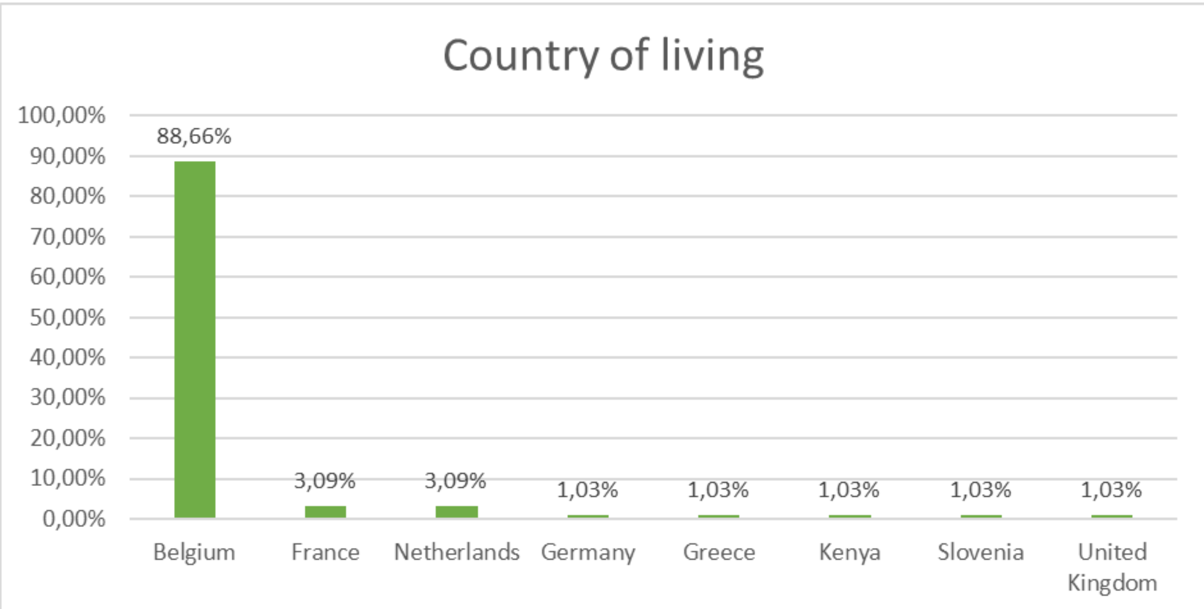


FIGURE 13 Country of living (n=97) (Qualtrics, Own edit, 2022).

The next question is related to the country of living of the respondents. It is an open question about the province where they live. Only one respondent did not answer this question.

As most of the respondents live in Belgium, the percentages of respondents are visualised on the map of Belgium (Figure 14). There are representatives from 7 (out of 10) Belgian provinces and from Brussels-Capital Region. As we can see from Figure 14, there are no respondents from Hainaut, Namur and Luxembourg provinces. A narrow majority of the respondents lives in Limburg province, where Hasselt University is located.

FIGURE 14 Distribution of the respondents on the map of Belgium (n=96) (Qualtrics, Own edit, 2022).

29 students (out of 37 students that participated in the survey) live in Belgium in Limburg province, where Hasselt University is located. 7 students live in the provinces that have a border with Belgian Limburg: Antwerp (2), Flemish Brabant (1), Walloon Brabant (1) and Dutch Limburg (3). One student lives in Germany and the province has a border with Dutch Limburg and Liege provinces. As the survey was distributed within Hasselt University students and staff and was published online, I believe that at least 78% of students (29 out of 37) are day students at Hasselt University.

The following question is related to the car ownership status in the respondent's household. It is a multiple-choice question and the results present the percentages of choices selected by the respondents. The most frequently selected choice (67.65%) was "Own a car". The choice "Do not own a car" was second selected choice with 22.55%. 5.88% of the people leased a car on permanent basis and the least selected choice was "Rent a car occasionally".

The next question asked about the frequency of train use by the respondents (Figure 15). Almost half of the respondents (45.36%) use a train a few times per year. Equal number of the respondents use a train a few times per month or do not use a train at all (19.59%). There are 11.34% of respondents who use a train a few times per week and only 4.12% use it daily. It is essential to understand how many people and how frequently they take a train in everyday life. People who use train at least a few times per year can be convinced easier to change from a plane to train than the ones who do not use it at all.

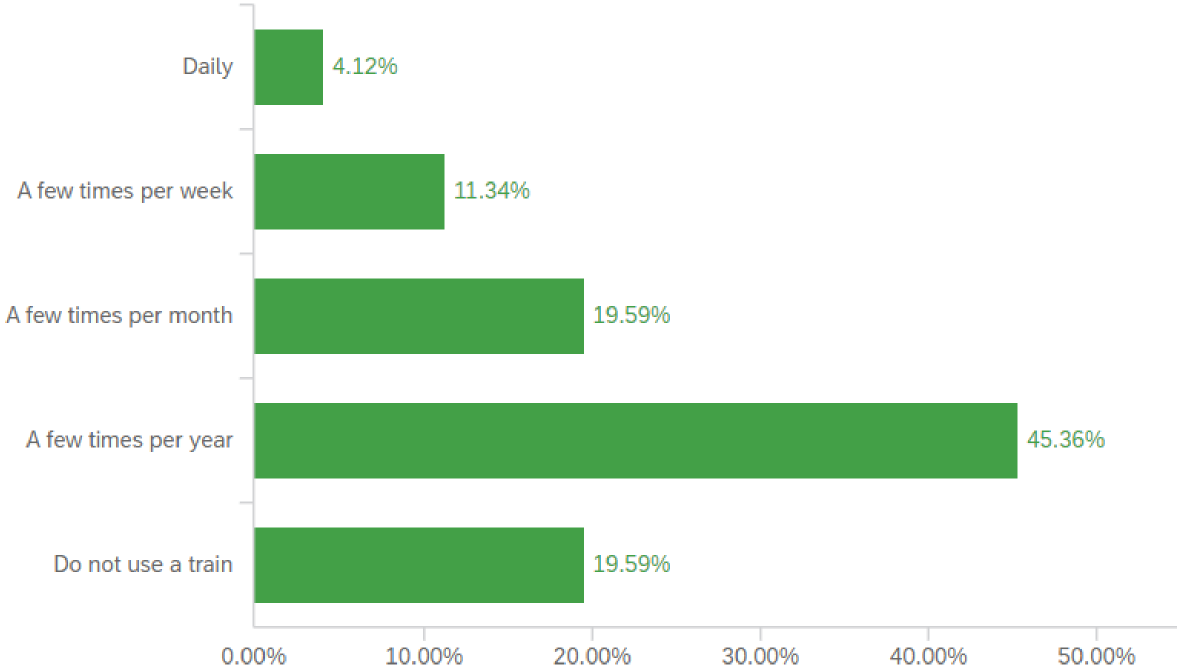


FIGURE 15 Frequency of a train use (n=97) (Qualtrics, Own edit, 2022).

The last question handled about the level of environmental friendliness of the respondents. It is a multiple-choice question and the results present the percentages of responses (Figure 16). As we can see from Figure 16, 1 out of 3 respondents tries to consume less or no meet, to buy used/second-hand things or to buy food packed in recycled material; 2 out of 5 respondents try to use eco-friendly cleaning products; 1 out of 2 respondents tries to avoid car use in daily life, to use rechargeable batteries or to reduce his/her water consumption; 3 out of 4 respondents try to reduce their energy consumption and 4 out of 5 respondents try to recycle as much as possible or to fix things instead of throwing them away immediately. It is clear that the respondents are knowledgeable enough about the concept of being environmentally friendly but there are more opportunities to improve. The more people are conscious about the environment, the bigger chance they will choose more eco-friendly transport modes.

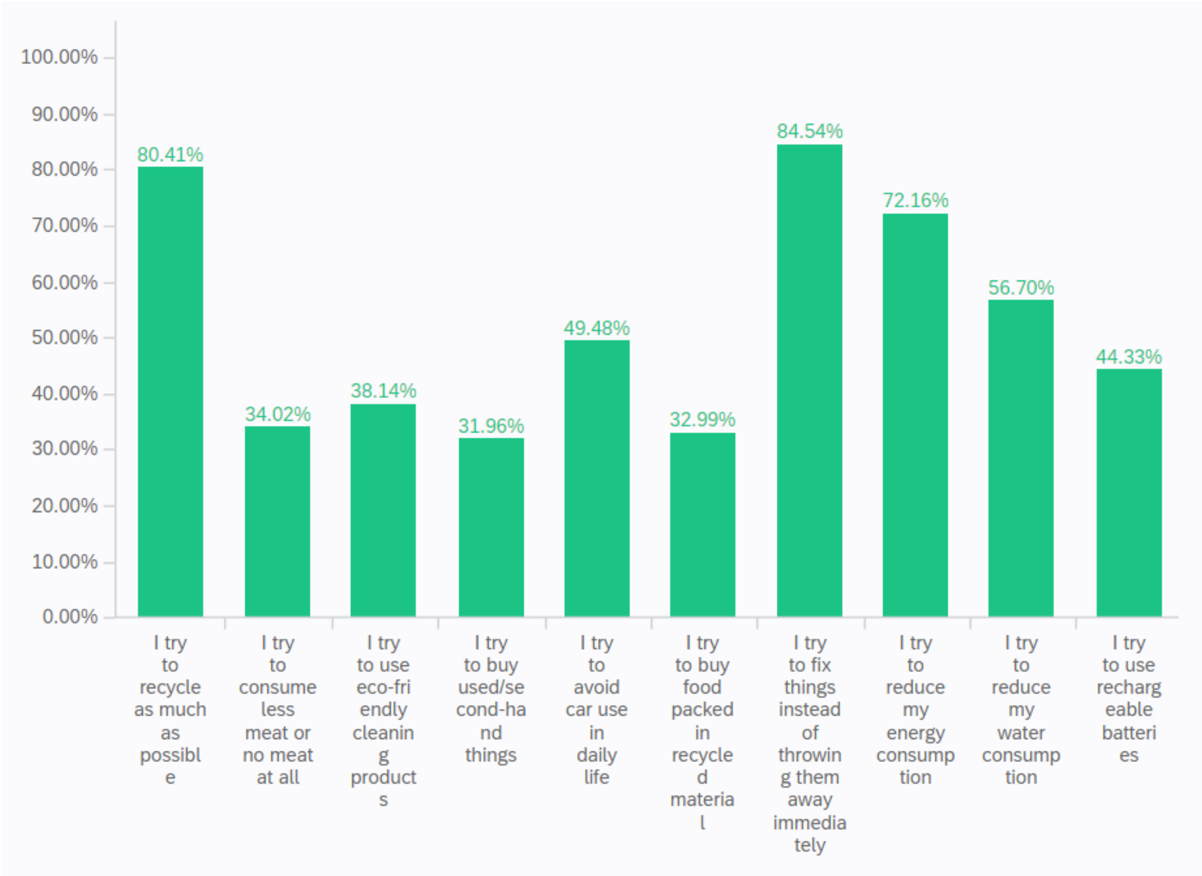


FIGURE 16 Environmental friendliness of the respondents (n=97) (Qualtrics, Own edit, 2022).

4.2. Travel Preferences

These questions are intended to find out more about travel preferences of the respondents. The first question checks if the respondents have taken at least one leisure trip within the EU within the last 5 years. Most of the respondents (92.78%) answered "Yes" to the question and 7.22% of respondents answered "No". If a respondent has taken such leisure trip, then his/her answers further will be based on his previous experiences, if not, then the answers to the next questions will be hypothetical.

The next question is a conditional one and is shown only to the respondents who answered affirmative to the first question (90 out of 97 respondents). This question asks if a respondent has used, within the last 5 years, one of the transport modes such as car, train or plane. 84.44% of the respondents used a car, 74.44% of the respondents used a plane and only 53.33% of the respondents used a train. As we can see, the train was the least used transport mode for the leisure trips within the EU in our dataset.

The following question is related to the people who would accompany the respondent during the leisure trip. 61.86% of respondents would travel with their family, 34.02% would travel with their friends and only 4.12% would travel alone.

The next question tries to capture how the participants rank the transport modes (car, train, low-cost and traditional airlines) in order of their preference. As we can see from Figure 17, car ranked first, low cost airline ranked second, traditional airline ranked third (with low-cost airline falling behind by 1%) and train ranked forth (even if traditional airline prevails by 1%).

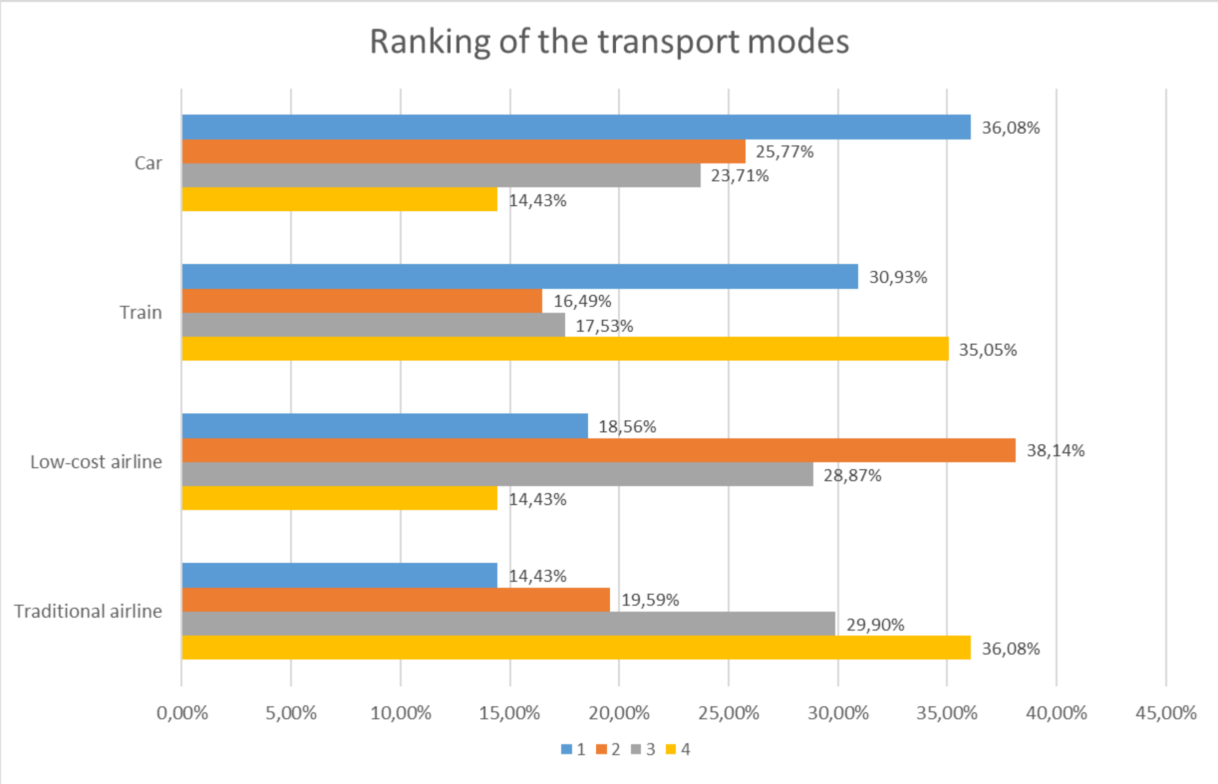


FIGURE 17 Travel Preferences (n=97) (Qualtrics, Own edit, 2022).

The next question is intended to find out how often the respondents check car, train and plane options when planning a leisure trip within the EU. As we can see from Figure 18, half of the respondents always check plane (51.55%) and car (47.42%) options, while train options are always checked only by 37.11% of respondents. At the same time, all three transport mode options are sometimes checked by almost equal number of participants (42.27% and 43.30%). The highest number of the respondents (19.59%) never check train options while 10.31% of the respondents never check car options and 6.19% of the respondents never check plane options for the leisure trips within the EU.

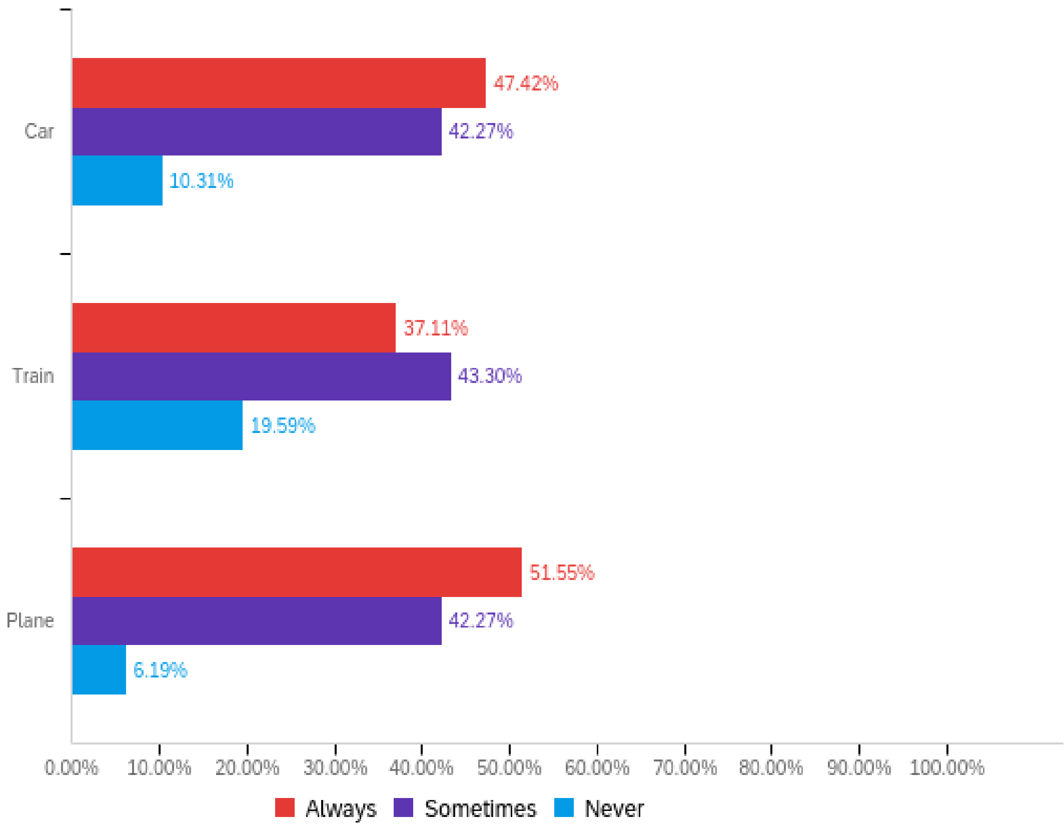


FIGURE 18 Travel Preferences (n=97) (Qualtrics, Own edit, 2022).

4.3. Travel Factor Relevance and Attitudes

4.3.1. Car Related Results

In the first question, 87 participants were asked to express the importance of the given factors when planning a leisure trip by car within the EU (Figure 19). Total travel time was found to be very important by 54.02% of the respondents. 37.93% of the respondents considered total price very important while 29.89% of the respondents found it to be moderately important. 32.18% and 31.03% of the respondents believed that safety level was moderately and very important while 9.20% found it to be not at all important. 54.02% of the respondents considered comfort level very important. Weather conditions were found to be moderately important (31.03%) and slightly important (19.54%), while it scored the highest percentage of the responses (16.09%) as a not at all important factor when travelling by car within the EU. 33.33% of the respondents believed that parking options are moderately and very important.

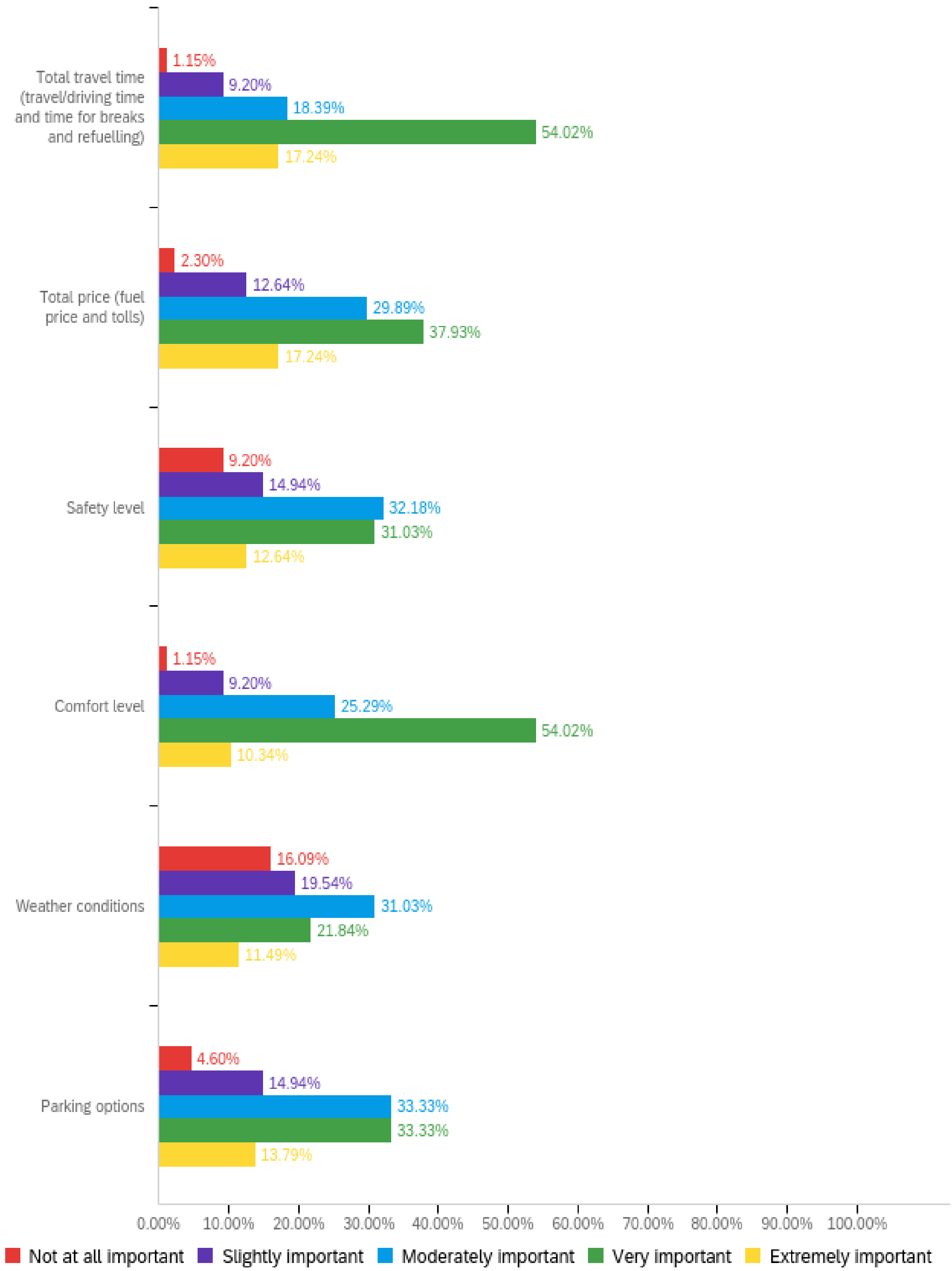


FIGURE 19 Travel Preferences (n=87) (Qualtrics, Own edit, 2022).

The next question refers to the perception about the travelling by car. Respondents were given 11 statements to answer with 5 possible answers: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree and Strongly agree. The data was extracted from Qualtrics and can be found in Appendix 6. The raw data has been modified to give a better overview of the results (Table 5). As we can see from Table 5, 63.22% of the respondents somewhat or strongly agreed that travelling by car gives them a vacation feeling. 75.86% of the respondents somewhat or strongly agreed that travelling by car is convenient. When travelling by car, 72.41% of the participants somewhat or strongly agreed that they feel safe. At the same time, 56.32% of the respondents somewhat or strongly agreed that a car travel is exhausting. 48.28% of the respondents somewhat or strongly disagreed with the statement "*I feel like I am wasting a lot of time when travelling by car".* 86.21% of the respondents somewhat or strongly agreed that travelling by car gives them the freedom to stop where and when they like. 47.13% of the respondents somewhat or strongly agreed that they like to take scenic routes to their destination. 47.13% of the respondents somewhat or strongly agreed that travelling by car is expensive. 65.51% of the respondents somewhat or strongly agreed that they are aware of the impact of travelling by car on environment. 45.97% of the participants do not try to compensate the impact of travelling by car on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products). 81.61% of the respondents somewhat or strongly agreed with the statement "I can take as much luggage as I need in the car".

TABLE 5 Perceptions about car travel (n=87) (Qualtrics, Own edit, 2022)

	Strongly disagree	*Somewhat disagree*	*Neither agree nor disagree*	*Somewhat agree*	*Strongly agree*
Travelling by car gives me a vacation feeling	6,90%	10,34%	19,54%	**37,93%**	**25,29%**
Travelling by car is convenient	4,60%	2,30%	17,24%	**33,33%**	**42,53%**
I feel safe when travelling by car	5,75%	6,90%	14,94%	**37,93%**	**34,48%**
Travelling by car is exhausting	10,34%	11,49%	21,84%	**32,18%**	**24,14%**
I feel like I am wasting a lot of time when travelling by car	**20,69%**	**27,59%**	27,59%	13,79%	10,34%
Travelling by car gives me the freedom to stop where and when I like	1,15%	1,15%	11,49%	**20,69%**	**65,52%**
I like to take scenic routes to my destination	11,49%	13,79%	27,59%	**21,84%**	**25,29%**
Travelling by car is expensive	12,64%	16,09%	24,14%	**29,89%**	**17,24%**
I am aware of the impact of travelling by car on environment	9,20%	5,75%	19,54%	**34,48%**	**31,03%**
I try to compensate the impact of travelling by car on the environment by being more eco-friendly in daily life (e.g.	**33,33%**	**12,64%**	17,24%	16,09%	20,69%

plant trees, recycle, buy eco-products)					
I can take as much luggage as I need in the car	1,15%	8,05%	9,20%	**29,89%**	**51,72%**

4.3.2. Plane Related Results

91 respondents had to express the importance of the given factors when planning a leisure trip by plane within the EU (Figure 20). 45.05% found total travel time to be very important. Ticket price has been evaluated by the respondents as very (46.15%) and extremely (40.66%) important. Only 32.97% of the respondents considered safety level very important. It can be due to the fact that airplane is considered to be the safest means of transport. Besides, safety of a plane is usually improved after the occurrence of a crash and it cannot be controlled by the respondent. Comfort level has been selected as moderately and very important by 31.87% and 35.16% of the respondents. comfort level is less important for the respondents as the trips by plane within the EU usually take up to 3 hrs if there is a direct connection; when there is a stopover, the time spend in a plane is even shorter. Direct connection, waiting time between stopovers (if any) and location of an airport have been found as very important factors by 48.35% of the participants. Frequency of the service has been claimed as a moderately important factor when planning a leisure trip by plane within the EU.

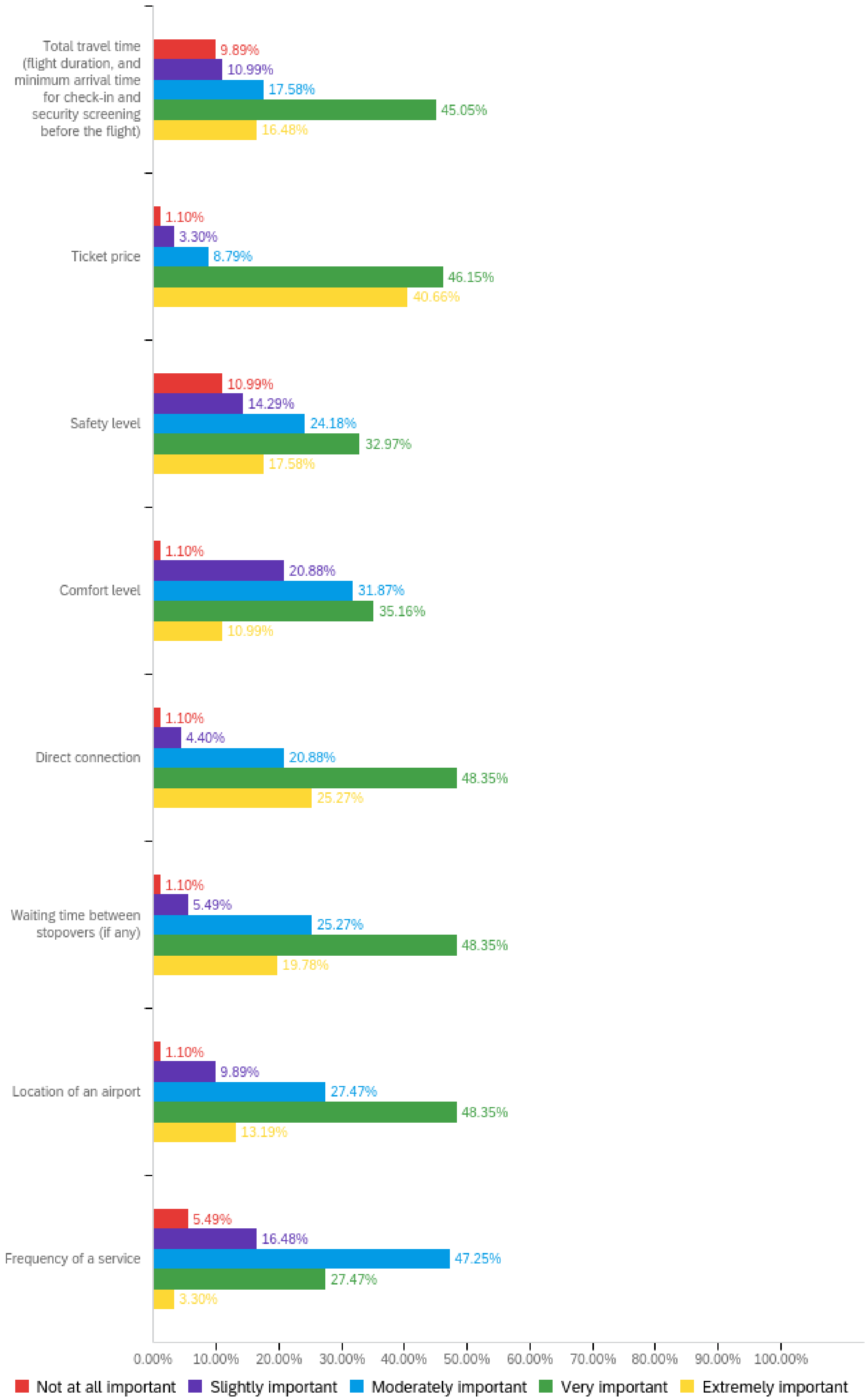


FIGURE 20 Travel Preferences (n=91) (Qualtrics, Own edit, 2022).

The next question refers to the perception about a plane travel. Respondents were given 10 statements to answer with 5 possible answers: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree and Strongly agree. The data was extracted from Qualtrics and can be found in Appendix 7. The raw data has been modified to give a better overview of the results (Table 6). As we can see from Table 6, 82.42% of the respondents somewhat or strongly agreed that travelling by plane gives them a vacation feeling. 53.84% of the participants somewhat or strongly agreed with the statement *"I consider a plane as a more luxurious mode of transport than a train"*. 83.52% of the participants somewhat or strongly agreed that flying shortens the travel time to their destination. 74.72% of the respondents somewhat or strongly agreed that they feel safe while flying. 67.03% of the respondents somewhat or strongly agreed that travelling by plane is convenient. 49.45% of the participants somewhat or strongly agreed that the price of a plane ticket is often reasonable. 52.74% of the respondents somewhat or strongly agreed with the statement *"I feel like I am wasting a lot of time going through security or just waiting at the airport".* 38.46% of the participants somewhat or strongly disagreed they like the services they get at an airport and on board. 73.63% of the participants somewhat or strongly agreed that they are aware of the negative impact of flying on the environment. 43.96% of the participants do not try to compensate the impact of travelling by car on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products).

TABLE 6 Perceptions about a plane travel (n=91) (Qualtrics, Own edit, 2022)

	Strongly disagree	*Somewhat disagree*	*Neither agree nor disagree*	*Somewhat agree*	*Strongly agree*
Travelling by plane gives me a vacation feeling	2,20%	1,10%	14,29%	**27,47%**	**54,95%**
I consider a plane as a more luxurious mode of transport than a train	16,48%	13,19%	16,48%	**17,58%**	**36,26%**
Flying shortens the travel time to my destination	0,00%	4,40%	12,09%	**24,18%**	**59,34%**
I feel safe while flying	3,30%	2,20%	19,78%	**29,67%**	**45,05%**
Travelling by plane is convenient	6,59%	5,49%	20,88%	**37,36%**	**29,67%**
The price of a plane ticket is often reasonable	8,79%	12,09%	29,67%	**38,46%**	**10,99%**
I feel like I am wasting a lot of time going through security or just waiting at the airport	10,99%	15,38%	20,88%	**27,47%**	**25,27%**
I like the services I get at an airport and on board	**20,88%**	**17,58%**	28,57%	27,47%	5,49%

I am aware of the negative impact of flying on the environment	9,89%	4,40%	12,09%	**23,08%**	**50,55%**
I try to compensate the impact of flying on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products)	**32,97%**	**10,99%**	18,68%	15,38%	21,98%

4.3.3. Train Related Results

78 respondents were asked to determine the importance of the given factors when planning a leisure trip by train within the EU (Figure 21). Total travel time and train ticket price appeared to be equally very important to 56.41% of the respondents. Safety level has been rated as a very important factor by 33.33% of the participants. 46.15% of the respondents determined comfort level as a very important factor. Direct connection was very important for 35.90% of the respondents. 53.85% of the participants found waiting time between stopovers (if any) to be very important. People do not mind to have stopovers during a leisure trip by train as long as waiting time between stopovers is proper. Location of a station was a very important factor for 43.59% of the respondents. 33.33% and 38.46% of the participants concluded that frequency of a service was a moderately and very important factor when planning a leisure trip by train within the EU.

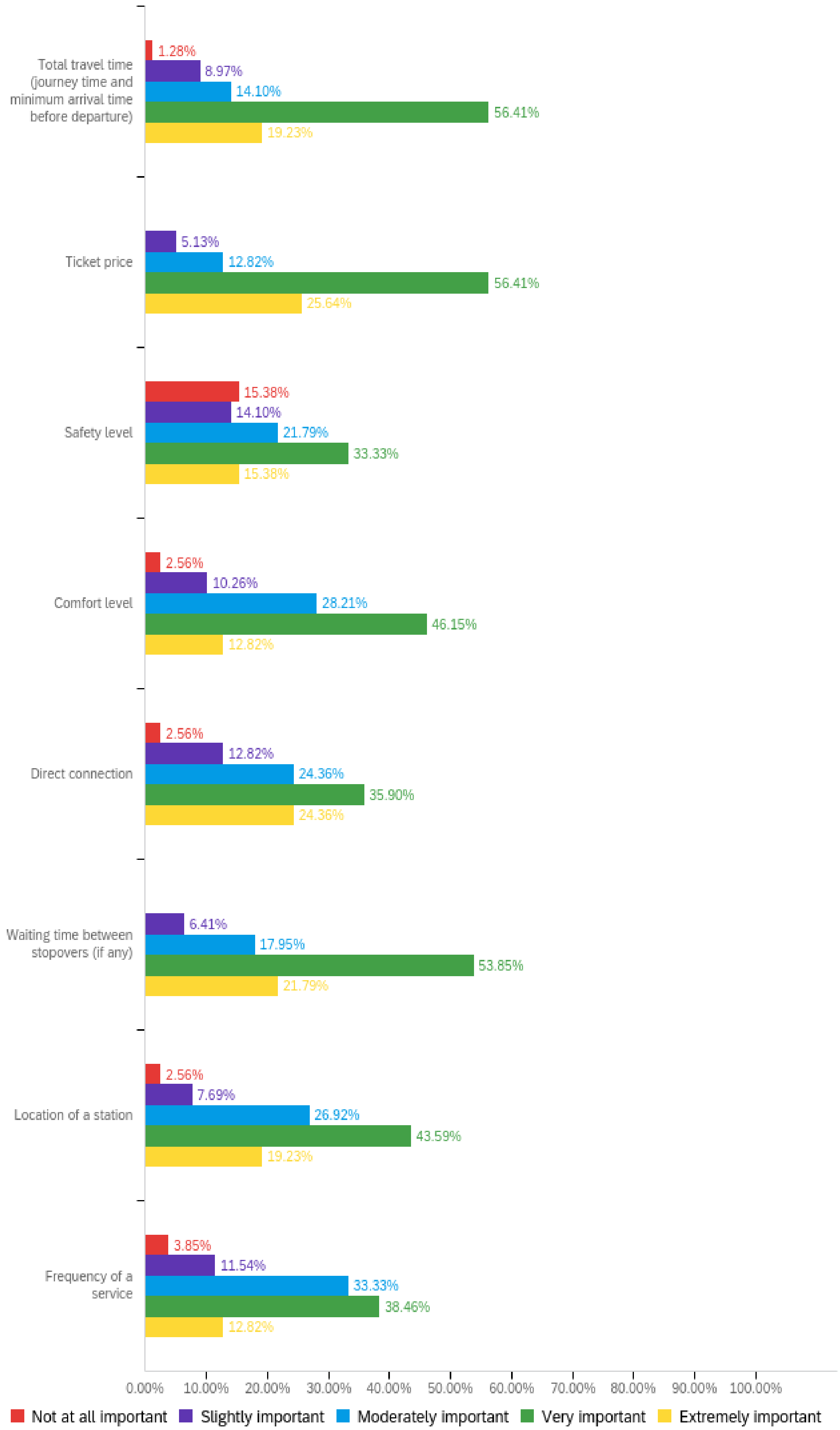


FIGURE 21 Travel Preferences (n=78) (Qualtrics, Own edit, 2022).

The next question refers to the perception about a train travel. Respondents were given 10 statements to answer with 5 possible answers: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree and Strongly agree. The data was extracted from Qualtrics and can be found in Appendix 8. The raw data has been modified to give a better overview of the results (Table 7). As we can see from Table 7, 53.85% of the respondents somewhat or strongly agreed that travelling by train gives them a vacation feeling. 57.70% of the participants somewhat or strongly agreed with the statement *"I like to travel by train as it is more environmentally friendly"*. 44.87% of the participants somewhat or strongly agreed that they avoid lost baggage when travelling by train. 55.13% of the respondents somewhat or strongly agreed that travelling by train is convenient. Only 39.74% of the participants somewhat or strongly agreed that the price of a train ticket is often reasonable. 87.17% of the respondents somewhat or strongly agreed that they feel safe when they travel by train. 78.20% of the participants somewhat or strongly agreed with the statement *"Travelling by train gives me a chance to enjoy beautiful views out of the window"*. 51.28% of the respondents somewhat or strongly disagreed that they feel like they are losing too much time when travelling by train. 57.70% of the participants somewhat or strongly agreed that trains are comfortable (e.g. seats, space, level of noise, temperature, vibration). 87.18% of the participants somewhat or strongly agreed that it is beneficial that trains usually arrive in the city centre.

TABLE 7 Perceptions about a train travel (n=78) (Qualtrics, Own edit, 2022)

	Strongly disagree	*Somewhat disagree*	*Neither agree nor disagree*	*Somewhat agree*	*Strongly agree*
Travelling by train gives me a vacation feeling	6,41%	14,10%	25,64%	**29,49%**	**24,36%**
I like to travel by train as it is more environmentally friendly	6,41%	6,41%	29,49%	**23,08%**	**34,62%**
I avoid lost baggage when travelling by train	17,95%	11,54%	25,64%	**25,64%**	**19,23%**
Travelling by train is convenient	10,26%	6,41%	28,21%	**32,05%**	**23,08%**
The price of a train ticket is often reasonable	15,38%	20,51%	24,36%	**26,92%**	**12,82%**
I feel safe when I travel by train	0,00%	6,41%	6,41%	**21,79%**	**65,38%**
Travelling by train gives me a chance to enjoy beautiful views out of the window	5,13%	0,00%	16,67%	**26,92%**	**51,28%**
When travelling by train, I feel like I am losing too much time	**19,23%**	**32,05%**	19,23%	20,51%	8,97%
Trains are comfortable (e.g.	5,13%	7,69%	29,49%	**34,62%**	**23,08%**

seats, space, level of noise, temperature, vibration)					
Trains usually arrive in the city centre which is beneficial	2,56%	3,85%	6,41%	**41,03%**	**46,15%**

4.3.4. Results Over Car, Plane And Train Modes

Total travel time and ticket price appeared to be the very important for train mode. Safety level has been rated as a very important factor almost equally for all travel modes (with the highest value for train mode). Comfort level was very important for car travel. Respondents found direct connection to be more important for plane mode than for train mode. At the same time, respondents claimed that waiting time between stopovers was very important for train mode. Location of a train station happened to be less important than location of an airport. It could be because airports are usually located further from the city centre while train stations are usually located within the city centre. Frequency of a service was found to be more important for train mode than for plane mode. Weather conditions appeared to be less important than parking options at the destination for car mode.

Vacation feeling was perceived highest related to the plane. Travel was perceived to be convenient highest related to the car. Feeling of safety during when travelling was perceived highest related to the train. Travelling by car was recognized to be exhausting. The price of a plane ticket was identified to be more reasonable than the price of a train ticket, while very second person perceived the car travel expensive. 2 out of 5 persons argue that they like the services they get at an airport and on board. Awareness of negative impact of flying on environment is higher than awareness of negative impact of travelling by car on environment. Compensating the impact of travelling on the environment by being more eco-friendly in daily life was perceived highest related to flying. At the same time, 3 out of 5 people like to travel by train as it is more environmentally friendly. Wasting a lot of time when travelling to the destination was perceived highest related to car travel. Every second person perceived going through security or just waiting at the airport as wasting a lot of time. The fact that trains usually arrive in the city centre was recognized to be beneficial. 3 out of 5 persons found trains to be comfortable. Travelling by train allowed 4 out of 5 people to enjoy beautiful views out of the window, while only every second person takes scenic routes to the destination when travelling by car. Every second person perceived a plane as a more luxurious mode of transport than a train. 4 out of 5 respondents acknowledged that they can take as much luggage as the need when travelling by the car. Every second person recognised that he/she avoids lost baggage when travelling by train. Freedom to stop where and when a person likes was perceived very high.

4.4. Stated Preference

In order to interpret the results of the stated preference questions, a multinomial logit model was developed and the data was analysed with the help of PandasBiogeme software (open source Python package).

For the development of the MNL model it was necessary to create a data file (that is required as an input for the data analysis later) and to write utility functions for the alternatives from the choice set.

A few steps had to be performed in order to create the data file. The first step was to clean the Qualtrics raw data file in .xlsx format by deleting columns with irrelevant data. The irrelevant data in our case were survey metadata, contact fields, travel preferences, travel factor relevance and attitudes, convincing measures and a few demographic questions (country of living, province of living and eco-friendliness). Then the remaining data (like stated preference and the rest of demographic questions) was transformed from a combination of qualitative and quantitative data to only quantitative data by introducing the set of variables in Table 8.

TABLE 8 Set of variables for the data file (Own edit, 2022)

Variable	Coding
GROUP	8 groups for 8 question blocks
ID	Respondent identifier
AGE	Age class of respondents. The age-class coding scheme is of the type: 1: age<24, 2: 25<age<34, 3: 35<age<44, 4: 45<age<54, 5: 55<age<64, 6: 65 <age
GENDER	Respondents gender: 0: female, 1: male
OCCUPATION	Respondents occupation: 0: No occupation, 1: Student, 2: Employee, 3: Self-employed/independent, 4: Retired
HOUSEHOLD COMPOSITION (HC)	Respondents household composition: 1: single without children, 2: single with children, 3: In a relationship without children, 4: In a relationship with children
DRIVING LICENCE (DL)	Driving licence ownership: 0: No, 1:Yes
HOUSEHOLD CAR OWNERSHIP (HCO)	Household car ownership: 0: Do not own a car, 1: Rent a car occasionally, 2: Lease a car on permanent basis, 3: Own a car
TRAIN USE FREQUENCY (TUF)	Frequency of train use: 0: Do not use, 1: Daily, 2: A few times per week, 3: A few times per month, 4: A few times per year
CAR_TT	Car travel time (in minutes)
CAR_CO	Car cost (in euros)
CAR_TP	Car travelling persons: 0: Alone, 1: With travel companions
CAR_CL	Car comfort level: 0: Low, 1: High
PLANE_TT	Plane travel time (in minutes)
PLANE_CO	Plane cost (in euros)
PLANE_TP	Plane travelling persons: 0: Alone, 1: With travel companions
PLANE_CL	Plane comfort level: 0: Economy (2nd) class, 1: 1st class
TRAIN_TT	Train travel time (in minutes)
TRAIN_CO	Train cost (in euros)

TRAIN_TP	Train travelling persons: 0: Alone, 1: With travel companions
TRAIN_CL	Train comfort level: 0: Economy (2nd) class, 1: 1st class
CHOICE	Choice indicator: 1: Car, 2: Plane, 3: Train

The dataset was structured in a trip format in Excel (Figure 22).

GROUP	ID	AGE	GENDER	OCCUPAT	HC	DL	HCO	TUF	CAR_TT	CAR_CO	CAR_TP	CAR_CL	PLANE_TT	PLANE_CO	PLANE_TP	PLANE_CL	TRAIN_TT	TRAIN_CO	TRAIN_TP	TRAIN_CL	CHOICE
2	1	3	1	2	4	1	3	4	420	250	1	1	240	200	1	0	180	175	0	0	2
2	1	3	1	2	4	1	3	4	480	200	0	0	300	150	0	1	270	225	1	1	3
2	1	3	1	2	4	1	3	4	540	350	0	0	360	100	0	1	360	275	1	1	2
2	1	3	1	2	4	1	3	4	600	300	1	1	420	250	1	0	480	100	0	0	1
3	2	3	0	2	4	1	3	4	420	300	1	0	240	150	0	0	180	275	1	1	1
3	2	3	0	2	4	1	3	4	480	250	0	1	300	200	1	1	270	225	0	0	2
3	2	3	0	2	4	1	3	4	540	200	0	1	360	250	1	1	360	100	1	0	3
3	2	3	0	2	4	1	3	4	600	350	1	0	420	100	0	0	480	175	0	1	2
7	3	4	0	2	4	1	2	4	420	200	1	0	240	100	0	1	180	225	0	1	1
7	3	4	0	2	4	1	2	4	480	350	0	1	300	150	1	0	270	275	1	0	2
7	3	4	0	2	4	1	2	4	540	250	1	1	360	200	1	0	360	175	0	0	1
7	3	4	0	2	4	1	2	4	600	300	0	0	420	250	0	1	480	100	1	1	3
5	4	2	1	2	1	1	3	3	420	350	1	1	240	250	0	0	180	100	1	0	3
5	4	2	1	2	1	1	3	3	480	300	0	0	300	100	1	1	270	275	0	1	2
5	4	2	1	2	1	1	3	3	540	200	1	0	360	200	0	1	360	175	1	1	3
5	4	2	1	2	1	1	3	3	600	250	0	1	420	150	1	0	480	225	0	0	2
1	5	6	0	4	1	1	3	3	420	300	0	1	240	150	1	1	180	225	1	0	3
1	5	6	0	4	1	1	3	3	480	350	1	0	300	100	0	0	270	175	0	1	3
1	5	6	0	4	1	1	3	3	540	250	0	0	360	250	0	0	360	100	0	1	3
1	5	6	0	4	1	1	3	3	600	200	1	1	420	200	1	1	480	275	1	0	3
4	6	3	1	2	4	1	3	4	420	250	0	0	240	250	1	1	180	275	0	0	3
4	6	3	1	2	4	1	3	4	480	300	1	1	300	200	0	0	270	100	1	1	3
4	6	3	1	2	4	1	3	4	540	350	1	1	360	100	1	0	360	225	0	1	2

FIGURE 22 Data set in a trip format (Qualtrics, Own edit, 2022).

This .xlsx file has been converted to the .txt file first and then the .txt file has been converted to a .dat file with the aim of using it in PandasBiogeme software for the model estimation.

Then it was needed to write utility functions for the car, plane and train alternatives. The basic utility equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL*

where CAR_TT_SCALED, CAR_CO_SCALED, CAR_TP, CAR_CL, PLANE_TT_SCALED, PLANE_CO_SCALED, PLANE_TP, PLANE_CL, TRAIN_TT_SCALED, TRAIN_CO_SCALED, TRAIN_TP, TRAIN_CL are variables from the dataset and ASC_PLANE, ASC_TRAIN, B_TIME, B_COST, B_PERSONS, B_COMFORT are parameters to be estimated.

The utility equations include scaled travel time and travel cost variables to have a better numerical property of the model. The scales are determined in PandasBiogeme with the help of the special function and equal scales were applied to travel time and travel cost variables.

To estimate a model, model specification has been written in Jupiter notebook and the code can be found in Appendix 9.

The following sections describe the estimation results of the MNL model with different variables.

4.4.1. Basic Model Results

The estimated parameters for the basic utility equations are presented in Table 9.

TABLE 9 Results of the basic model estimation (Appendix 8, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-0.468	0.506	-0.923	0.356	0.513	-0.912	0.362
ASC_TRAIN	-0.226	0.52	-0.435	0.664	0.526	-0.43	0.667
B_COMFORT	0.453	0.135	3.36	0.000767	0.134	3.38	0.000736
B_COST	-7.97	1.1	-7.21	5.55e-13	1.15	-6.94	3.81e-12
B_PERSONS	0.879	0.133	6.6	4.06e-11	0.131	6.73	1.65e-11
B_TIME	-4.38	2.58	-1.7	0.0899	2.66	-1.65	0.0996

The results suggest that comfort level, travel cost and number of people travelling are important variables to explain choice of travel mode at a confidence level higher than 99.9%, while travel time is an important variable at a confidence level higher than 90%. The negative signs of the values of travel cost and travel time indicate that higher travel cost and travel time reduce the probability of choosing the alternatives, which is intuitionally correct. At the same time, the positive signs of comfort level and number of people travelling indicate that higher comfort level and number of travel companions increase the probability of choosing the alternatives. The estimated values for the alternative specific constants for plane and train are negative and not significant and show that, all the rest remaining constant, there is a preference in the choice of a car over a train and a plane. Moreover, the higher value of alternative specific constant for train shows a greater preference for train compared to plane.

Value of time or willingness to pay is (-4.38)/(-7.97) or 0.55 euros per minute, which is equivalent to 33 euros per hour. It is likely that people are willing to pay 33 euros to reduce their travel time by 1 hr.

Final log likelihood value is -333.9652 and rho-square-bar value is -0.202. Akaike Information Criterion is 679.9304 and Bayesian Information Criterion is 703.6964.

4.4.2. Basic Model Including Age

The basic utility equations were modified to include “AGE” variable to investigate whether age has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5)*

The estimated parameters for the basic utility equations with age variable are presented in Table 10.

TABLE 10 Results of the basic model with Age estimation (Appendix 9, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2	0.91	-2.2	0.0276	1.02	-1.97	0.0494
ASC_TRAIN	-1.76	0.916	-1.92	0.0545	1.03	-1.71	0.0875
B_AGE	1.58	0.781	2.03	0.0426	0.866	1.83	0.0672
B_COMFORT	0.463	0.136	3.41	0.00064	0.137	3.39	0.000709
B_COST	-8.03	1.11	-7.25	4.32e-13	1.16	-6.91	4.94e-12
B_PERSONS	0.889	0.134	6.64	3.14e-11	0.131	6.78	1.22e-11
B_TIME	-4.36	2.59	-1.68	0.0926	2.68	-1.63	0.104

The results suggest that comfort level, travel cost and number of people travelling are important variables to explain choice of travel mode at a confidence level higher than 99.9%, while travel time is an important variable at a confidence level higher than 90% as in the basic model. Age appears to be a significant variable in explaining the choice of alternatives, the positive sign of the parameter implies that it positively affects the probability of choosing train and plane for people of all age categories than for older people. The negative signs of the values of travel cost and travel time suggest that higher travel cost and travel time reduce the probability of choosing the alternative, which is intuitionally correct. At the same time, the positive signs of comfort level and number of people travelling indicate that higher comfort level and number of travel companions increase the probability of choosing the alternative. The estimated values for the alternative specific constants for plane and train are negative but significant (at confidence levels higher than 95% and 90% respectively) and show that, all the rest remaining constant, there is a preference in the choice of car over train and plane. Moreover, the higher value of alternative specific constant for train shows a greater preference for train compared to plane.

Value of time or willingness to pay is (-4.39)/(-8.03) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -332.2247 which is slightly higher than the one of the basic model, meaning that this model is better. Rho-square-bar is also higher (0.204) but it can be due to the addition of another variable to the utility equations. Akaike Information Criterion (678.4495) is lower and Bayesian Information Criterion (703.1765) is higher than in the basic model.

4.4.3. Basic Model Including Age And Gender

The basic utility equations were modified to include "GENDER" variable to investigate whether gender has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_GENDER * (GENDER==1)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_GENDER * (GENDER==1)*

The estimated parameters for the basic utility equations with age and gender variables are presented in Table 11.

TABLE 11 Results of the basic model with Age and Gender estimation (Appendix 10, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.01	0.91	-2.2	0.0276	1.02	-1.97	0.0494
ASC_TRAIN	-1.76	0.916	-1.92	0.0544	1.03	-1.71	0.0874
B_AGE	1.61	0.792	2.03	0.0426	0.877	1.83	0.0668
B_COMFORT	0.462	0.135	3.41	0.000641	0.137	3.39	0.000711
B_COST	-8.03	1.11	-7.25	4.27e-13	1.16	-6.91	4.97e-12
B_GENDER	-0.0536	0.311	-0.173	0.863	0.303	-0.177	0.86
B_PERSONS	0.889	0.134	6.64	3.13e-11	0.131	6.77	1.28e-11
B_TIME	-4.36	2.59	-1.68	0.0925	2.68	-1.63	0.104

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time and age) and alternative specific constants is the same as in the previous model. Gender appears to be not significant and has no impact on the choice of a travel mode.

Value of time or willingness to pay is (-4.36)/(-8.03) or €0.54 per minute, which is equivalent to €32.4 per hour and is almost the same as it was in the basic model.

Final log likelihood value is -332.2099 which is slightly higher than the one of the previous model. Rho-square-bar has the same value (0.202) as in the basic model. Akaike Information Criterion (680.4198) and Bayesian Information Criterion (712.1078) are higher than in the basic model with age.

4.4.4. Basic Model Including Age And Household Composition

The basic utility equations were modified to include "HOUSEHOLD COMPOSITION" (HC) variable to investigate whether household composition has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3)*

The estimated parameters for the basic utility equations with age and HC variables are presented in Table 12.

TABLE 12 Results of the basic model with Age and HC estimation (Appendix 11, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.96	0.968	-3.06	0.00223	1.06	-2.8	0.00512
ASC_TRAIN	-2.72	0.973	-2.79	0.00526	1.06	-2.55	0.0107
B_AGE	1.95	0.795	2.46	0.0141	0.877	2.23	0.0259
B_COMFORT	0.467	0.136	3.43	0.00061	0.137	3.4	0.000678
B_COST	-8.08	1.11	-7.26	3.83e-13	1.16	-6.99	2.81e-12
B_HC	0.938	0.314	2.99	0.00278	0.309	3.04	0.0024
B_PERSONS	0.894	0.135	6.65	3e-11	0.132	6.77	1.29e-11
B_TIME	-4.41	2.6	-1.7	0.0896	2.65	-1.66	0.0959

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time and age) and alternative specific constants is the same as in the previous model. The estimated values for the alternative specific constants for plane and train are significant at confidence levels higher than 99.5% and 95% respectively, which are better than the ones that were estimated in the basic model with the age variable. Household composition is positive and important variable (at a confidence level higher than 99.5%) which suggests that household composition has an impact on the choice of a travel mode: a couple with children is more likely to choose a train or a plane over a car.

Value of time or willingness to pay is (-4.41)/(-8.08) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -327.8021 which is a higher value than the final log likelihood value of a basic model with the age variable. Rho-square-bar has higher value (0.212) than the one in the previous models. Akaike Information Criterion (671.6042) is lower and Bayesian Information Criterion (703.2923) is slightly higher than in the basic model with age.

4.4.5. Basic Model Including Age, HC And Household Car Ownership

The basic utility equations were modified to include "HOUSEHOLD CAR OWNERSHIP" (HCO) variable to investigate whether household car ownership has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) +*

*B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_HCO* (HCO==1) + B_HCO * (HCO==2) + B_HCO * (HCO==3)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_HCO* (HCO==1) + B_HCO * (HCO==2) + B_HCO * (HCO==3)*

The estimated parameters for the basic utility equations with age, HC and HCO variables are presented in Table 13.

TABLE 13 Results of the basic model with Age, HC and HCO estimation (Appendix 12, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.42	1.13	-2.14	0.032	1.17	-2.06	0.0391
ASC_TRAIN	-2.18	1.13	-1.92	0.055	1.18	-1.84	0.066
B_AGE	1.84	0.803	2.3	0.0217	0.88	2.09	0.0363
B_COMFORT	0.463	0.136	3.4	0.00067	0.137	3.38	0.000729
B_COST	-8.08	1.11	-7.25	4.2e-13	1.16	-6.97	3.14e-12
B_HC	0.841	0.328	2.56	0.0103	0.315	2.67	0.00756
B_HCO	-0.437	0.488	-0.896	0.37	0.475	-0.92	0.358
B_PERSONS	0.891	0.135	6.62	3.63e-11	0.132	6.74	1.57e-11
B_TIME	-4.41	2.6	-1.7	0.0896	2.65	-1.67	0.0957

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time, age and HC) and alternative specific constants is the same as in the previous model. Household car ownership is not a significant variable, but negative sign of which implies that availability of a car in a household decreases the attractiveness of train and plane over car, which is intuitively correct.

Value of time or willingness to pay is (-4.41)/(-8.08) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -327.3749 which is a higher value than the final log likelihood value of a basic model with the age and HC, nevertheless, HCO is not a significant variable on the model. Rho-square-bar has slightly lower value (0.211) than the one in the basic model with age and HC. Akaike Information Criterion (672.7498) is lower and Bayesian Information Criterion (708.3988) are higher than in the basic model with age.

4.4.6. Basic Model Including Age, HC And Driving Licence Ownership

The basic utility equations were modified to include “DRIVING LICENCE” (DL) variable to investigate whether driving licence ownership has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) +*

*B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_HCO* (HCO==1) + B_HCO * (HCO==2) + B_HCO * (HCO==3) + B_DL * (DL==1)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_HCO* (HCO==1) + B_HCO * (HCO==2) + B_HCO * (HCO==3) + B_DL * (DL==1)*

The estimated parameters for the basic utility equations with age, HC and DL variables are presented in Table 14.

TABLE 14 Results of the basic model with Age, HC and DL estimation (Appendix 13, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.9	1.12	-2.58	0.00977	1.16	-2.49	0.0126
ASC_TRAIN	-2.65	1.13	-2.36	0.0185	1.17	-2.27	0.0232
B_AGE	1.94	0.805	2.41	0.016	0.883	2.2	0.0281
B_COMFORT	0.467	0.136	3.43	0.000614	0.137	3.4	0.000685
B_COST	-8.08	1.11	-7.26	3.87e-13	1.16	-6.99	2.75e-12
B_DL	-0.0492	0.447	-0.11	0.912	0.428	-0.115	0.908
B_HC	0.925	0.333	2.78	0.00539	0.318	2.91	0.00365
B_PERSONS	0.894	0.135	6.65	3.03e-11	0.132	6.77	1.3e-11
B_TIME	-4.41	2.6	-1.7	0.0899	2.65	-1.66	0.096

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time, age and HC) and alternative specific constants is the same as in the previous model. Ownership of a driving licence is not an important variable to explain the choice of a travel mode, but negative sign of which implies that ownership of a driving licence decreases the attractiveness of train and plane over car, which is intuitively correct.

Value of time or willingness to pay is (-4.41)/(-8.08) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -327.796, which is slightly lower value than the final log likelihood value of a basic model with the age and HC variables. Rho-square-bar has a bit lower value (0.21) as well. Akaike Information Criterion (673.592) and Bayesian Information Criterion (709.241) are higher than in the basic model with age, HC.

4.4.7. Basic Model Including Age, HC And Train Use Frequency

The basic utility equations were modified to include “TRAIN USE FREQUENCY” (TUF) variable to investigate whether frequency of train use has an impact on the choice of a travel mode. TUF variable is added only to the train utility equation as it is a train-specific variable. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE **

*(AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_TUF* (TUF==1) + B_TUF* (TUF==2) + B_TUF* (TUF==3) + B_TUF* (TUF==4)*

The estimated parameters for the basic utility equations with age, HC and TUF variables are presented in Table 15.

TABLE 15 Results of the basic model with Age, HC and TUF estimation (Appendix 14, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.7	0.983	-2.74	0.00607	1.01	-2.67	0.00749
ASC_TRAIN	-3.61	1.02	-3.54	0.000406	1.05	-3.44	0.000585
B_AGE	1.74	0.805	2.16	0.0311	0.797	2.18	0.0294
B_COMFORT	0.478	0.139	3.44	0.000576	0.139	3.44	0.000589
B_COST	-8.43	1.14	-7.36	1.84e-13	1.18	-7.14	9.61e-13
B_HC	0.792	0.317	2.5	0.0125	0.305	2.59	0.00952
B_PERSONS	0.925	0.138	6.7	2.02e-11	0.137	6.73	1.66e-11
B_TIME	-4.62	2.66	-1.74	0.0823	2.73	-1.7	0.0898
B_TUF	1.4	0.335	4.18	2.87e-05	0.359	3.91	9.26e-05

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time, age and HC) is the same as in the previous model. Alternative specific constants are with a negative sign but in this model, it appears that there is a greater preference for plane compared to train. Train use frequency is an important variable to explain the choice of a travel mode and it has a positive sign, which means that more frequent use of train increases a possibility to choose a train mode over other alternatives, which is intuitively correct.

Value of time or willingness to pay is (-4.62)/(-8.43) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -317.8228, which is a lower value than the final log likelihood value of a basic model with the age and HC variables. Rho-square-bar has a higher value (0.233) than in the basic model with age and HC. Akaike Information Criterion (653.6456) and Bayesian Information Criterion (689.2946) are lower than in the basic model with age and HC.

4.4.8. Basic Model Including Age, HC, TUF And Occupation

The basic utility equations were modified to include "OCCUPATION" variable to investigate whether a professional occupation of a traveller has an impact on the choice of a travel mode. The equations were written as following:

*V1 = V_CAR = B_TIME * CAR_TT_SCALED + B_COST * CAR_CO_SCALED + B_PERSONS * CAR_TP + B_COMFORT * CAR_CL*

*V2 = V_PLANE = ASC_PLANE + B_TIME * PLANE_TT_SCALED + B_COST * PLANE_CO_SCALED + B_PERSONS * PLANE_TP + B_COMFORT * PLANE_CL + B_AGE **

*(AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_OCCUPATION * (OCCUPATION==1) + B_OCCUPATION * (OCCUPATION==2) + B_OCCUPATION * (OCCUPATION==3) + B_OCCUPATION * (OCCUPATION==4)*

*V3 = V_TRAIN = ASC_TRAIN + B_TIME * TRAIN_TT_SCALED + B_COST * TRAIN_CO_SCALED + B_PERSONS * TRAIN_TP + B_COMFORT * TRAIN_CL + B_AGE * (AGE==1) + B_AGE * (AGE==2) + B_AGE * (AGE==3) + B_AGE * (AGE==4) + B_AGE * (AGE==5) + B_HC * (HC==1) + B_HC * (HC==2) + B_HC * (HC==3) + B_TUF* (TUF==1) + B_TUF* (TUF==2) + B_TUF* (TUF==3) + B_TUF* (TUF==4) + B_OCCUPATION * (OCCUPATION==1) + B_OCCUPATION * (OCCUPATION==2) + B_OCCUPATION * (OCCUPATION==3) + B_OCCUPATION * (OCCUPATION==4)*

The estimated parameters for the basic utility equations with age, HC, TUF and occupation variables are presented in Table 16.

TABLE 16 Results of the basic model with Age, HC, TUF and Occupation estimation (Appendix 15, 2022)

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-0.594	0.347	-1.71	0.087	0.36	-1.65	0.0984
ASC_TRAIN	-1.51	0.382	-3.94	8.01e-05	0.397	-3.79	0.000148
B_AGE	1.73	0.805	2.16	0.0311	0.797	2.18	0.0294
B_COMFORT	0.478	0.139	3.44	0.000576	0.139	3.44	0.00059
B_COST	-8.42	1.14	-7.36	1.86e-13	1.18	-7.14	9.67e-13
B_HC	0.792	0.317	2.5	0.0125	0.305	2.59	0.00952
B_OCCUPATION	-2.1	0.66	-3.19	0.00144	0.677	-3.11	0.0019
B_PERSONS	0.925	0.138	6.7	2.02e-11	0.137	6.73	1.66e-11
B_TIME	-4.62	2.66	-1.74	0.0823	2.73	-1.7	0.0898
B_TUF	1.4	0.335	4.18	2.87e-05	0.359	3.91	9.25e-05

The interpretation of the variables (comfort level, travel cost, number of people travelling, travel time, age, HC and TUF) is the same as in the previous model. Alternative specific constants are with a negative sign but in this model, like in the previous one, it appears that there is a greater preference for plane compared to train. Professional occupation appears to be an important variable to explain the choice of a travel mode and it has a negative sign, which means that people with professional occupation a greater preference for car compared to train and plane, which is intuitively correct.

Value of time or willingness to pay is (-4.62)/(-8.42) or €0.55 per minute, which is equivalent to €33 per hour and is the same as it was in the basic model.

Final log likelihood value is -317.8228, which is equal to the final log likelihood value of a basic model with the age, HC and TUF variables. Rho-square-bar has a lower value (0.231) than in the basic model with age, HC and TUF. Besides, Akaike Information Criterion (655.6456) and Bayesian Information Criterion (695.2556) are higher than in the basic model with age, HC and TUF. Based on these results, the basic model with age, HC and TUF has a better fit.

4.4.9. Conclusions

After estimation of multiple MNL models it became clear that age, household composition and train use frequency are important variables to explain a choice of a travel mode for leisure trips within the EU. The positive sign of the parameter implies that it positively affects the probability of choosing train and plane for people of all age categories than for older people. In addition, the household composition has an impact on the choice of a travel mode: a couple with children is more likely to choose a train or a plane over a car. Train use frequency is also an important variable to explain the choice of a travel mode and it has a positive sign, which means that more frequent use of train increases a possibility to choose a train mode over other alternatives. Nevertheless, the estimated model shows that car mode is the preferred mode to use when going on a leisure trip, plane mode ranks second and the least preferred alternative appears to be train. The values of travel time and travel cost indicate that the respondents are more sensitive to higher cost of the trip than to higher travel time.

4.5. Convincing Measures

This question intends to find out which measures would convince the respondents to choose train for the leisure trips within the EU instead of car or plane. As we can see from Table 17, 61.86% of the respondents replied that a price of train ticket that is lower than the price of a plane ticket would convince them to choose a train over plane. 65.98% of the respondents found that a price of a train ticket that is lower than the price of a car trip (fuel price and tolls) would also encourage them to choose a trip by a train over a trip by a car. Wide range of food and drink options on the train was not as convincing as the previous measures as 43.30% of people chose “Maybe” and 42.27% of people chose “No”. Total travel time by train that is maximum 2 hrs above the total travel time by plane appeared not to be convincing enough: 36.08% of participants answered “Yes” and 37.11% of participants answered “Maybe”. At the same time, total travel time by train that is maximum 1 hr above the total travel time by plane was more convincing as 58.76% of the respondents would be convinced to choose a train over a plane. 40.21 % of the participants would be definitely convinced to use a train instead of a plane or a car if there is excellent Wi-Fi on the train. High comfort level of a train (soft seats, enough legroom, etc.) has been considered a convincing measure by a half of the respondents (56.70%). 67.01% of the participants regarded a direct train connection (no stopovers) as a convincing measure to choose a train over a car or a plan for leisure trips within the EU. Children’s playing space in the train has been viewed as not a convincing measure by 54.64% of the respondents. 57.73% of the participants considered a high frequency of trains a convincing measure. Reliable schedule has been seen as a convincing measure by 58.76% of the respondents. Bonus points for each train travel (that could be used to pay for train tickets or eco-products) have not been perceived as an extremely convincing measure by the respondents: 37.11% of them answered “Yes” and 36.08% of them answered “Maybe”.

TABLE 17 Convincing Measures (n=97) (Qualtrics, Own edit, 2022)

Measure	*Yes*	*Maybe*	*No*
Price of a train ticket that is lower than the price of a plane ticket	**61.86%**	31.96%	6.19%
Price of a train ticket that is lower than the price of a car trip (fuel price and tolls)	**65.98%**	25.77%	8.25%
Wide range of food and drink options on the train	14.43%	**43.30%**	**42.27%**

Total travel time by train is maximum 2 hrs above the total travel time by plane	**36.08%**	**37.11%**	26.80%
Total travel time by train is maximum 1 hr above the total travel time by plane	**58.76%**	24.74%	16.49%
Excellent Wi-Fi on the train	**40.21%**	37.11%	22.68%
High comfort level of a train (soft seats, enough legroom, etc.)	**56.70%**	29.90%	13.40%
Direct train connection (no stopovers)	**67.01%**	22.68%	10.31%
Children's playing space available in the train	15.46%	29.90%	**54.64%**
High frequency of trains	**57.73%**	29.90%	12.37%
Reliable schedule	**58.76%**	34.02%	7.22%
Bonus points for each train travel (that could be used to pay for train tickets or eco-products)	**37.11%**	**36.08%**	26.80%

4.6. Conclusions

The analysis of 97 respondents was conducted. From the 97 respondents, 58.76% were male and 41.24% were female participants. The driving licence ownership rate is 80% for both genders. The age of respondents varied between 18 and 70 years old. Regarding the current professional occupation, 57.73% were employees, 38.14% were students, 3.09% retired and or 1.03% were self-employed/independent professionals. More than 60% of the respondents appeared not to have children: 38.14% were single and 25.77% were in a relationship without children. At the same time, 31.96% were in a relationship with children and only 4.12 % were single with children. The majority of participants live in Belgium and 52.94% of them live in Limburg province. Most of the respondents own a car. Almost half of the respondents (45.36%) use a train a few times per year. Equal number of the respondents use a train a few times per month or do not use a train at all (19.59%). There are 11.34% of respondents who use a train a few times per week and only 4.12% use it daily. It is clear that the respondents are knowledgeable enough about the concept of being environmentally friendly but there are more opportunities to improve their eco-friendliness.

Within the last 5 years, a car was the most and a train was the least used travel mode for the leisure trips within the EU. 61.86% of respondents would travel with their family, 34.02% would travel with their friends and only 4.12% would travel alone. Ranking of the transport modes by the participants was the following: car ranked first, low cost airline ranked second, traditional airline ranked third and train ranked forth. Plane was the most and train was the least checkable option when planning a leisure trip within the EU.

Total travel time and ticket price appeared to be the very important for train mode. Safety level has been rated as a very important factor almost equally for all travel modes (with the highest value for train mode). Comfort level was very important for car travel. Respondents found direct connection to be more important for plane mode than for train mode. At the same time, respondents claimed that waiting time between stopovers was very important for train mode. Location of a train station happened to be less important than location of an airport. It could be because airports are usually located further from the city centre while train stations are usually located within the city centre. Frequency of a service was found to be more important for train mode than for plane mode. Weather conditions appeared to be less important than parking options at the destination for car mode.

Vacation feeling was perceived highest related to the plane. Travel was perceived to be convenient highest related to the car. Feeling of safety during when travelling was perceived highest related to the train. Travelling by car was recognized to be exhausting. The price of a plane ticket was identified to be more reasonable than the price of a train ticket, while very second person perceived the car travel expensive. 2 out of 5 persons argue that they like the services they get at an airport and on board. Awareness of negative impact of flying on environment is higher than awareness of negative impact of travelling by car on environment. Compensating the impact of travelling on the environment by being more eco-friendly in daily life was perceived highest related to flying. At the same time, 3 out of 5 people like to travel by train as it is more environmentally friendly. Wasting a lot of time when travelling to the destination was perceived highest related to car travel. Every second person perceived going through security or just waiting at the airport as wasting a lot of time. The fact that trains usually arrive in the city centre was recognized to be beneficial. 3 out of 5 persons found trains to be comfortable. Travelling by train allowed 4 out of 5 people to enjoy beautiful views out of the window, while only every second person takes scenic routes to the destination when travelling by car. Every second person perceived a plane as a more luxurious mode of transport than a train. 4 out of 5 respondents acknowledged that they can take as much luggage as the need when travelling by the car. Every second person recognised that he/she avoids lost baggage when travelling by train. Freedom to stop where and when a person likes was perceived very high.

After estimation of multiple MNL models it became clear that age, household composition and train use frequency are important variables to explain a choice of a travel mode for leisure trips within the EU. The positive sign of the parameter implies that it positively affects the probability of choosing train and plane for people of all age categories than for older people. In addition, the household composition has an impact on the choice of a travel mode: a couple with children is more likely to choose a train or a plane over a car. Train use frequency is also an important variable to explain the choice of a travel mode and it has a positive sign, which means that more frequent use of train increases a possibility to choose a train mode over other alternatives. Nevertheless, the estimated model shows that car mode is the preferred mode to use when going on a leisure trip, plane mode ranks second and the least preferred alternative appears to be train. The values of travel time and travel cost indicate that the respondents are more sensitive to higher cost of the trip than to higher travel time. Value of time or willingness to pay for a shorter trip was estimated to be €33 per hour.

There were 12 measures proposed to the respondents to find out which measures would convince the respondents to choose train for the leisure trips within the EU instead of car or plane. 8 measures appeared to be convincing, such as a lower train ticket price (than the price of a plane ticket or than the price of a car trip), total travel time by train being maximum 1 hr above the total travel time by plane, excellent Wi-Fi on a train, high comfort level of a train, direct train connection, high frequency of trains and reliable schedule. Two measures were relatively convincing: total travel time by train being maximum 2 hrs above the total travel time by plane and bonus points for each train travel. Wide range of food and drink options on a train appeared to be equally relatively and not convincing. Having dedicated children's playing space in a train was not a convincing measure.

4.7. Limitations

There are two limitations of the thesis. First of all, it is the limited number of respondents (>100). In order to have better estimations of the people's attitudes and factors that influence a travel choice for leisure trips within the EU, a higher participation in the survey is required: the larger the sample size, the more accurate the findings. Second limitation is related to the first one, which is a distribution of the respondents per provinces of Belgium: 53% of respondents live in Limburg province, while 6 out of 10 Belgian provinces are underrepresented (with no respondents or less than 3% of respondents).

5. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Literature review shows that evaluation of the environmental impact of air and rail transport is much more complex than it may seem due to a large number of factors that should be taken into account besides CO2 emissions. They include journey duration, load factors, emissions from the end-to-end journey, full life cycle emissions of air and rail and non-CO2 environmental impacts (air and soil pollution, noise pollution, waste production, biodiversity impacts, and emission of other greenhouse gases, as well as air pollutants such as nitrogen oxides, carbon monoxide and particulate matter). Many studies conclude that air transport has higher CO2 emissions than rail and they will only increase as air travel is forecasted to grow at a higher rate in the future, therefore a modal shift from short-haul flights to high-speed rail has been considered as an effective measure to reduce the emissions due to its higher energy efficiency.

The researches demonstrate that there are issues with a modal shift that need to be addressed. First of all, the growth in travel by HSR is linked to the expansion of the network, which occurs at low rate as by its nature HSR is only suitable for very specific transport corridors, where demand is very high. Then there are often enormous construction and significant operational costs of HSR projects, their noise and visual intrusion to adjacent communities, and their adverse impacts on land use and wildlife. Beside, competitiveness and attractiveness of rail services should be improved to facilitate air-to-rail shift. Therefore, every HSR project should be carefully evaluated in relation to total environmental impact, investment costs and the potential benefits and their significance.

Despite that, many studies conclude that a modal shift towards rail, in particular HSR, has many advantages, including reducing CO2 emissions, contributing to climate protection and releasing capacity constrains at the airports. In addition to being substitutes, rail and air also offer the potential for multimodal trips.

At the EU level, the climate change impacts of rail and aviation are tackled, directly or indirectly, by a 'basket of measures' comprising support for the development of innovative technologies, operational improvements, the promotion of renewable energy through the Renewable Energy Directive and market-based measures, in particular the EU Emissions Trading System. Although the recast of the Renewable Energy Directive does not currently set a specific target for aviation, the European Commission is considering legislative options to boost the production and uptake of sustainable aviation fuels (EEA, 2021).

The survey has been conducted in order to investigate people's decisions and preferences towards travel modes for leisure trips within Europe in order to determine which factors are important for a modal shift and how their preferences could be adjusted towards selecting a train as a travel mode over other alternatives. The results of the survey show that total travel time and ticket price appeared to be the very important for train mode. Safety level has been rated as a very important factor almost equally for all travel modes (with the highest value for train mode). Comfort level was very important for car travel. Respondents found direct connection to be more important for plane mode than for train mode. At the same time, respondents claimed that waiting time between stopovers was very important for train mode. Location of a train station happened to be less important than location of an airport. It could be because airports are usually located further from the city centre while train stations are usually located within the city centre. Frequency of a service was found to be more important for train mode than for plane mode.

Moreover, vacation feeling was perceived highest related to the plane. Travel was perceived convenient related to the car. Feeling of safety during when travelling was perceived highest related to the train. Travelling by car was recognized to be exhausting. The price of a plane ticket was identified to be more reasonable than the price of a train ticket, while very second person perceived the car travel expensive. 2 out of 5 persons argue that they like the services they get at an airport and on board. Awareness of negative impact of flying on environment is higher than awareness of negative impact of travelling by car on environment. Compensating the impact of travelling on the environment by being more eco-friendly in daily life was perceived highest related to flying. At the same time, 3 out of 5 people like to travel by train as it is more environmentally friendly. Wasting a lot of time when travelling to the destination was perceived highest related to car travel. Every second person perceived going through security or just waiting at the airport as wasting a lot of time. The fact that trains usually arrive in the city centre was recognized to be beneficial. 3 out of 5 persons found trains to be comfortable. Travelling by train allowed 4 out of 5 people to enjoy beautiful views out of the window, while only every second person takes scenic routes to the destination when travelling by car. Every second person perceived a plane as a more luxurious mode of transport than a train. 4 out of 5 respondents acknowledged that they can take as much luggage as the need when travelling by the car. Every second person recognised that he/she avoids lost baggage when travelling by train. Freedom to stop where and when a person likes was perceived very high.

According to the survey results, the following measures appeared to facilitate a shift from car or plane to train for the leisure trips within the EU:

- price of train ticket that is lower than the price of a plane ticket;
- price of a train ticket that is lower than the price of a car trip (fuel price and tolls);
- total travel time by train that is maximum 1 hr above the total travel time by plane;
- excellent Wi-Fi on the train;
- high comfort level of a train (soft seats, enough legroom, etc.);
- direct train connection;
- high frequency of trains, and
- reliable schedule.

Estimations of multiple MNL models lead to the conclusion that age, household composition and train use frequency are important variables to explain a choice of a travel mode for leisure trips within the EU. The positive sign of the age parameter implies that it positively affects the probability of choosing train and plane for people of all age categories than for older people. In addition, the household composition has an impact on the choice of a travel mode: a couple with children is more likely to choose a train or a plane over a car. Train use frequency is also an important variable to explain the choice of a travel mode: more frequent use of train increases a possibility to choose a train mode over other alternatives. Nevertheless, the estimated model shows that car mode is the preferred mode to use when going on a leisure trip within the EU, plane mode ranks second and the least preferred alternative appears to be train. The values of travel time and travel cost indicate that the respondents are more sensitive to higher cost of the trip than to higher travel time.

The main conclusion of this master thesis is that a modal shift to train is feasible from a traveller's perspective. Estimations of multiple MNL models lead to the conclusion that age, household composition and train use frequency are important variables to explain a choice of a travel mode for leisure trips within the EU. Age positively affects the probability of choosing train and plane for people of all age categories than for older people. In addition, the household composition has an impact on the choice of a travel mode: a couple with children is more likely to choose a train or a plane over a car. Train use frequency is also an important variable to explain the choice of a travel mode: more frequent use of train increases a possibility to choose a train mode over other alternatives. Nevertheless, the estimated model shows that car mode is the preferred mode to use when going on a leisure trip within the EU, plane mode ranks second and the least preferred alternative appears to be train. The following factors contribute to the modal shift: lower travel cost and time, excellent Wi-Fi on a train, high comfort level, direct train connection, high frequency of trains and reliable schedule. Both travel cost and travel time appear to be important for the travellers but lower travel cost increases the attractiveness of a train than lower travel time. The total environmental impact of a modal shift is challenging to estimate as it depends on many factors but use of high-speed electrical trains is definitely beneficial for the environment.

Based on the literature review and the survey results, the following recommendations are suggested for the future considerations and implementations of a shift to a train mode:

- conducting a thorough analysis of infrastructure, environmental impacts and potential environmental gains when considering a modal shift on specific corridors;
- estimating potential travel cost and travel time for a train as they are important factors for choosing a travel mode;
- providing trains with high comfort level (including excellent Wi-Fi on a train);
- providing direct connections between the cities as much as possible;
- implementing a reliable schedule and high frequency of the trains;
- advertising the benefits of a train travel emphasizing on its environmental contribution, comfort level and convenience of arriving in the city centre.

6. REFERENCES

Abend (2019). “In Europe, the Movement to Give Up Air Travel Is Taking Off. Could the U.S Be Next?” Retrieved from https://time.com/5641390/europe-train-air-travel/

Air Transport Action Group (ATAG) (2018). “Aviation Benefits Beyond Borders”. Retrieved from https://aviationbenefits.org/media/166711/abbb18_full-report_web.pdf

Anger-Kraavi, A. & Köhler, J. (2013). Aviation and the EU Emissions Trading System, *Sustainable Aviation Futures* (*Transport and Sustainability, Vol. 4*), Emerald Group Publishing Limited, Bingley, pp. 109-130. https://doi.org/10.1108/S2044-9941(2013)0000004005

Avinor, the Norwegian Confederation of Trade Unions (LO), the Federation of Norwegian Aviation Industries (NHO Luftfart), Norwegian, SAS and Widerøe (2020). *Aviation in Norway: Sustainability and social benefit.* Retrieved from https://avinor.no/globalassets/_konsern/om-oss/rapporter/en/aviation-in-norway-sustainability-and-social-benefit-2020.pdf

Banister, D., & Givoni, M. (2013). High-speed rail in the EU27: Trends, time, accessibility and principles. *Built Environment (London. 1978), 39*(3), 324-338. doi:10.2148/benv.39.3.324. Retrieved from https://www-jstor-org.bib-proxy.uhasselt.be/stable/43296340?pq-origsite=summon&seq=1#metadata_info_tab_contents

Barron, I., Campos, J., Gagnepain, P., Nash, C., Ulied, A. and Vickerman, R. (2009). Economic Analysis of High-Speed Rail in Europe. Ed., Fundaci´on BBVA, Bilbao, Spain.

BayRail Alliance. (2020). Types of Trains. Retrieved from: http://www.bayrailalliance.org/types_trains/

BBC News. (2019). *Climate change: Should you fly, drive or take the train?* Retrieved from https://www.bbc.com/news/science-environment-49349566

Behrens, C., & Pels, E. (2012). Intermodal competition in the London–Paris passenger market: High-Speed Rail and air transport. *Journal Of Urban Economics*, *71*(3), 278-288. doi: 10.1016/j.jue.2011.12.005. Retrieved from https://www.sciencedirect.com/science/article/pii/S0094119011000921

Bleijenberg, A. (2020). Air2Rail: Reducing CO2 from intra-European aviation by a modal shift from air to rail. https://ariebleijenberg.nl/cms/uploads/Air2Rail-Koios-strategy-rev-1.pdf

Blunt (2020). “How to travel by train - and ditch the plane”. Retrieved from https://www.bbc.com/news/world-europe-51007504

Böhler, S., Grischkat, S., Haustein, S., & Hunecke, M. (2006). Encouraging environmentally sustainable holiday travel. *Transportation Research Part A: Policy And Practice*, *40*(8), 652-670. https://doi.org/10.1016/j.tra.2005.12.006

Borda-de-Água, L., Barrientos, R., Beja, P., & Pereira, H. M. (Eds.). (2017). *Railway ecology*. Springer International Publishing. https://doi.org/10.1007/978-3-319-57496-7

Bourgeois-Bougrine, S., Gabon, P., Mollard, R., Coblentz, A., & Speyer, J. J. (2018). Fatigue in aircrew from shorthaul flights in civil aviation: The effects of work schedules. In *Human factors and aerospace safety* (pp. 177-187). Routledge.

Burkhardt, M. et al. (2008), ‘Diffuse release of environmental hazards by railways’, Desalination, 226:1–3, https://doi.org/10.1016/j.desal.2007.02.102

Carvalho, S., Partidario, M., & Sheate, W. (2017). High speed rail comparative strategic assessments in EU member states. *Environmental Impact Assessment Review*, *66*, 1-13. doi: 10.1016/j.eiar.2017.05.006. Retrieved from https://www-sciencedirect-com.bib-proxy.uhasselt.be/science/article/pii/S0195925516300415#bb0090

Chapman, L. (2007). Transport and climate change: a review. *Journal Of Transport Geography*, *15*(5), 354-367. https://doi.org/10.1016/j.jtrangeo.2006.11.008

Chester, M.V. & Horvath, A. (2010). Life-cycle assessment of high-speed rail: the case of California. *Environmental Research Letters*, 5(1): 014003.

Chiambaretto, P., & Decker, C. (2012). Air–rail intermodal agreements: Balancing the competition and environmental effects. *Journal Of Air Transport Management*, *23*, 36-40. doi: 10.1016/j.jairtraman.2012.01.012. Retrieved from https://www.sciencedirect.com/science/article/pii/S0969699712000130

Clauzel, C., Girardet, X., & Foltête, J.-C. (2013). Impact assessment of a high-speed railway line on species distribution: Application to the European tree frog (Hyla arborea) in Franche-Comté. *Journal of Environmental Management, 127*, 125–134. https://doi.org/10.1016/j.jenvman.2013.04.018

Clewlow, R. R., Sussman, J. M. & Balakrishnan H. (2014). The impact of high-speed rail and low-cost carriers on European air passenger traffic, Transport Policy 33, pp. 136-143 Retrieved from https://doi.org/10.1016/j.tranpol.2014.01.015 .

Commission of the European Communities. (2006). Air and Rail Competition and Complementarity. Final Report by Steer Davies Gleave for DG TREN.

D’Alfonso, T., Jiang, C. & Bracaglia, V. (2016). Air transport and high-speed rail competition: Environmental implications and mitigation strategies. Transportation Research Part A: Policy and Practice, 92, pp.261-276.

Dalla Chiara, B., De Franco, D., Coviello, N., & Pastrone, D. (2017). Comparative specific energy consumption between air transport and high-speed rail transport: A practical assessment. *Transportation Research Part D: Transport And Environment*, *52*, 227-243. doi: 10.1016/j.trd.2017.02.006

Dobruszkes, F. (2011). High-speed rail and air transport competition in Western Europe: A supply-oriented perspective. *Transport Policy*, *18*(6), 870-879. doi: 10.1016/j.tranpol.2011.06.002. Retrieved from https://www.sciencedirect.com/science/article/pii/S0967070X11000837

Dütschke, E., Engel, L., Theis, A., & Hanss, D. (2022). Car driving, air travel or more sustainable transport? Socio-psychological factors in everyday mobility and long-distance leisure travel. *Travel Behaviour And Society*, *28*, 115-127. https://doi.org/10.1016/j.tbs.2022.03.002

EU Technical Expert Group on Sustainable Finance. (2019). Financing a Sustainable European Economy. Taxonomy. Technical Report. European Commission: Brussels. https://www.ecologic.eu/16796 https://www.ecologic.eu/sites/default/files/publication/2021/3567-190618-sustainable-finance-teg-report-taxonomy_en.pdf

European Union Aviation Safety Agency. (2019). European aviation environmental report 2019, European Union Aviation Safety Agency, Cologne, Germany. Retrieved from https://www.easa.europa.eu/eaer/system/files/usr_uploaded/219473_EASA_EAER_2019_WEB_HI-RES_190311.pdf

European Commission. (2019a). Handbook on the external costs of transport.

European Commission. (2019b). The European Green Deal, Brussels. Retrieved from: https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

European Commission. (2019c). Evaluation of the Regulation (EC) No 1008/2008 on common rules for the operation of air services in the Community (SWD(2019) 296 final of 9 July 2019)

European Commission. (2020a). EU transport in figures — statistical pocketbook 2020, European Union, Luxembourg. Retrieved from: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2020_en .

European Commission. (2020b). Sustainable and Smart Mobility Strategy – putting European transport on track for the future, Communication from the Commission (COM(2020) 789 final)

European Environment Agency. (2019). *Air quality in Europe - 2019 report*. Luxembourg. Retrieved from: https://www.eea.europa.eu/publications/air-quality-in-europe-2019

European Environment Agency. (2020a). EEA greenhouse gas — data viewer', European Environment Agency. Retrieved from: https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer

European Environment Agency. (2020b). Environmental noise in Europe — 2020, EEA Report No 22/2019.

European Environment Agency. (2020c). Greenhouse gas emission intensity of electricity generation in Europe (ENER 038). Retrieved from: https://www.eea.europa.eu/ data-and-maps/indicators/overview-of-the-electricityproduction-3/assessment

European Environment Agency. (2021). *Transport and environment report 2020: Train or plane?* Publications Office. Retrieved from: https://data.europa.eu/doi/10.2800/43379

Eurostat. (2021). Transport statistics at regional level. Statistics Explained https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Transport_statistics_at_regional_level#Rail_transport

Forman, R. T. T., & Alexander, L. E. (1998). Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, 29(1), 207–231. https://doi.org/10.1146/annurev.ecolsys.29.1.207

Fridell, E., Ferm, M., & Ekberg, A. (2010). Emissions of particulate matters from railways – Emission factors and condition monitoring. *Transportation Research Part D: Transport And Environment*, *15*(4), 240-245. doi: 10.1016/j.trd.2010.02.006. Retrieved from https://www-sciencedirect-com.bib-proxy.uhasselt.be/science/article/pii/S1361920910000155

Givoni, M. (2007). Environmental benefits from mode substitution: comparison of the environmental impact from aircraft and high-speed train operations. *International Journal of Sustainable Transportation,* 1 (4), pp. 209-230

Givoni, M. (2020). The high-speed bus (HSB) as an alternative to the high-speed rail (HSR): A conceptual approach examined through a case study. *Regional Science Policy & Practice, 12*(3), 507-518. doi:10.1111/rsp3.12192. Retrieved from https://rsaiconnect-onlinelibrary-wiley-com.bib-proxy.uhasselt.be/doi/full/10.1111/rsp3.12192

Givoni, M., & Banister, D. (2007). Role of the Railways in the Future of Air Transport. *Transportation Planning And Technology*, *30*(1), 95-112. https://doi.org/10.1080/03081060701208100

Givoni, M. & Dobruszkes, F., 2013, 'A review of expost evidence for mode substitution and induced demand following the introduction of high-speed rail', Transport Reviews 33(6), pp. 720-742 (DOI: 10.1080/01441647.2013.853707).

Graver, B., Zhang, K. & Rutherford, D. (2019). CO2 emissions from commercial aviation, 2018. The International Council on Clean Transportation.

Institute of atmospheric physics. (n.d.). Climate-compatible air transport system. Retrieved from: https://www.dlr.de/pa/en/desktopdefault.aspx/tabid-4618/7598_read-42498/

International Civil Aviation Organization. (2016). Environmental Report. Aviation and Climate Change. Retrieved from https://www.icao.int/environmental-protection/Documents/ICAO%20Environmental%20Report%202016.pdf

International Civil Aviation Organization. (2019). ICAO global environmental trends – Present and future aircraft noise and emissions (A40-WP/54). Retrieved from https://www.icao.int/Meetings/A40/Documents/WP/wp_054_en.pdf

International Energy Agency. (2019). *The future of rail: Opportunities for energy and the environment.* Retrieved from https://iea.blob.core.windows.net/assets/fb7dc9e4-d5ff-4a22-ac07-ef3ca73ac680/The_Future_of_Rail.pdf

International Energy Agency. (2021a). International Energy Agency: Tracking Transport. Retrieved from: https://www.iea.org/reports/tracking-transport-2020.

International Energy Agency. (2021b). *Rail*. Paris: IEA. Retrieved from https://www.iea.org/reports/rail

International Energy Agency and International Union of Railways. (2017). Railway Handbook. Energy Consumption and CO2 Emissions. Retrieved from: https://uic.org/IMG/pdf/handbook_iea-uic_2017_web3.pdf

International Union of Railways. (2015). High-Speed principles and advantages. Retrieved from: https://uic.org/passenger/highspeed/high-speed-principles-and-advantages

International Union of Railways. (2021). EcoPassenger. UIC - International Union of Railways. https://uic.org/sustainability/energy-efficiency-and-co2-emissions/article/ecopassenger

International Union of Railways. (2022). *Manifesto for the UIC centenary*. Paris. Retrieved from https://uic.org/IMG/pdf/uic-manifesto_rail-solutions-for-a-better-future.pdf

International Union of Railways & Community of European Railway and Infrastructure Companies. (2015). *Rail Transport and Environment: Facts and Figures*. UIC – EFT (Railway Technical Publications), Paris. Retrieved from https://uic.org/IMG/pdf/facts_and_figures_2014_v1.0-2.pdf

Jehanno, A., Palmer, D. & James, C. (2011). High Speed Rail and Sustainability, Paris. Retrieved from https://www.apta.com/wp-content/uploads/High-Speed-Rail-Sustainability-UIC-2011.pdf

Kageson, P. (2009). Environmental Aspects of Inter-City Passenger Transport. Discussion Paper 2009-28. OECD-ITF Transport Research Centre. Retrieved from https://www-proquest-com.bib-proxy.uhasselt.be/docview/189845304?pq-origsite=summon

Logan, K., Nelson, J., McLellan, B., & Hastings, A. (2021). Japan and the UK: Emission predictions of electric and hydrogen trains to 2050. *Transportation Research Interdisciplinary Perspectives*, *10*, 100344. doi: 10.1016/j.trip.2021.100344

Loukaitou-Sideris, A., Cuff, D., Higgins, T., & Linovski, O. (2012). Impact of High Speed Rail Stations on Local Development: A DelFphi Survey. *Built Environment*, *38*(1), 51-70. doi: 10.2148/benv.38.1.51. Retrieved from https://www-jstor-org.bib-proxy.uhasselt.be/stable/23289700?pq-origsite=summon&seq=1#metadata_info_tab_contents

Lucas, P.S., de Carvalho, R.G. & Grilo, C. (2017). Railway Disturbances on Wildlife: Types, Effects, and Mitigation Measures. In: Borda-de-Água, L., Barrientos, R., Beja, P., Pereira, H. (eds) Railway Ecology. Springer, Cham. Retrieved from: https://doi.org/10.1007/978-3-319-57496-7_6

Nunes, L., Zhu, Y., Stigter, T., Monteiro, J., & Teixeira, M. (2011). Environmental impacts on soil and groundwater at airports: origin, contaminants of concern and environmental risks. *Journal Of Environmental Monitoring*, *13*(11), 3026. doi: 10.1039/c1em10458f

Oliveira, L., Bruen, C., Birrell, S., & Cain, R. (2019). What passengers really want: Assessing the value of rail innovation to improve experiences. *Transportation Research Interdisciplinary Perspectives*, *1*, 100014. doi: 10.1016/j.trip.2019.100014

Overton, J. (2021). *The Growth in Greenhouse Gas Emissions from Commercial Aviation* [Fact sheet]. Environmental and Energy Study Institute. Retrieved from https://www.eesi.org/papers/view/fact-sheet-the-growth-in-greenhouse-gas-emissions-from-commercial-aviation

Oxera. (2022). *Short-haul flying and sustainable connectivity*. Retrieved from https://www.aci-europe.org/downloads/content/ERA%20report_240322.pdf

O'Riordan, V., Rogan, F., Ó Gallachóir, B., Mac Uidhir, T., & Daly, H. (2022). How and why we travel – Mobility demand and emissions from passenger transport. *Transportation Research Part D: Transport and Environment*, 104, 103195. https://doi.org/10.1016/j.trd.2022.103195

Penone, C., Kerbiriou, C., Julien, J.-F., Julliard, R., Machon, N., & Le Viol, I. (2013). Urbanisation effect on Orthoptera: Which scale matters? *Insect Conservation and Diversity, 6(3), 319–327.* https://doi.org/10.1111/j.1752-4598.2012.00217.x

Price, L., & Matthews, B. (2013). Travel time as quality time: parental attitudes to long distance travel with young children. *Journal of Transport Geography*, 32, 49–55. https://doi.org/10.1016/j.jtrangeo.2013.08.001

Prussi, M., & Lonza, L. (2018). Passenger Aviation and High Speed Rail: A Comparison of Emissions Profiles on Selected European Routes. *Journal Of Advanced Transportation*, *2018*, 1-10. https://doi.org/10.1155/2018/6205714

Rajendran, S., & Harper, A. (2021). Simulation-based algorithm for determining best package delivery alternatives under three criteria: Time, cost and sustainability. *Transportation Research Interdisciplinary Perspectives*, *12*, 100484. doi: 10.1016/j.trip.2021.100484

Rajendran, S., & Popfinger, M. (2022). Evaluating the substitutability of short-haul air transport by high-speed rail using a simulation-based approach. *Transportation Research Interdisciplinary Perspectives*, *15*(2590-1982), 100632. https://doi.org/10.1016/j.trip.2022.100632

Sausen, R., Isaksen, I., Grewe, V., Hauglustaine, D., Lee, D.S., Myhre, G., Köhler, M.O., Pitari, G., Schumann, U., Stordal, F., Zerefos, V. (2005). Aviation radiative forcing in 2000: an update on IPCC (1999). *Meteorol. Z., 14 , pp. 555-561*

SLOCAT. (2021). *Tracking Trends in a Time of Change: The Need for Radical Action Towards Sustainable Transport Decarbonisation*, Transport and Climate Change Global Status Report – 2nd edition, www.tcc-gsr.com.

Socorro, M., & Viecens, M. (2013). The effects of airline and high speed train integration. *Transportation Research Part A: Policy And Practice*, *49*, 160-177. https://doi.org/10.1016/j.tra.2013.01.014

Steer Davies Gleave. (2004). *High speed rail: International comparisons : final report*. London: The Commission. Retrieved from https://webarchive.nationalarchives.gov.uk/ukgwa/20110304134841mp_/http://cfit.independent.gov.uk/pubs/2004/hsr/research/pdf/hsr.pdf

Tawfik, C., & Limbourg, S. (2019). Scenario-based analysis for intermodal transport in the context of service network design models. *Transportation Research Interdisciplinary Perspectives*, *2*, 100036. doi: 10.1016/j.trip.2019.100036

Teter, J., Le Feuvre, P., Gorner, M. & Scheffer, S. (2019). Tracking Transport. Rail. Retrieved from: https://www.iea.org/reports/tracking-transport-2019/rail#abstract

Timperley, J. (2019). Eight charts show how ‘aggressive’ railway expansion could cut emissions. Retrieved from: https://www.carbonbrief.org/eight-charts-show-how-aggressive-railway-expansion-could-cut-emissions

Transport & Environment. (2020). Maximising air to rail journeys Reducing intra-EU aviation emissions through modal shift to rail: limits and opportunities

United States Department of Energy. (2019). Energy Use by Transportation Mode and Fuel Type. Retrieved from https://afdc.energy.gov/data/10661 2019.

Zanin, M., Herranz, R. and Ladousse, S. (2012). Environmental benefits of air–rail intermodality: The example of Madrid Barajas. Transportation Research Part E: Logistics and Transportation Review, 48(5), pp.1056-1063. Retrieved from https://www-sciencedirect-com.bib-proxy.uhasselt.be/science/article/pii/S1366554512000282.

7. APPENDICES

Appendix 1: Survey

Travel modes for leisure trips within Europe

Start of Block: Default Question Block

Introduction
My name is Iryna Ozeranska and I am studying for a Master's degree in Transportation Sciences at Hasselt University in Belgium. The objective of this research is to investigate people's decisions and preferences towards travel modes for leisure trips within Europe.

The survey will take less than 10 minutes to complete.
Your participation in this survey is greatly appreciated and I would like to ensure you that all your responses will be kept confidential.

Before you start answering the questions in this survey, please read the definition of a leisure trip within the EU that applies throughout the survey.

Definition:

Leisure trip within the EU - a trip to a city abroad for leisure purposes with at least one overnight stay, of which the distance between origin/home and destination does not exceed 800 km, reachable within maximum 2 hrs of flight, 7,5 hrs by train or 8 hrs by car (e.g. Brussels - Lyon, Brussels - Hannover or Brussels - Zurich).

End of Block: Default Question Block

Start of Block: Block 1

Q1 *Have you taken, within the last 5 years, at least one leisure trip within the EU?*

○ Yes (1)

○ No (2)

Display This Question:

If Q1 = 1

Q1.1 *Have you used, within the last 5 years, the following transport modes for leisure trips within the EU?*

	Yes (1)	No (2)
Car (1)	○	○
Train (2)	○	○
Plane (3)	○	○

Q2 *Who would you travel with if you plan leisure trips within the EU?*

○ Alone (1)

○ With my family (2)

○ With my friends (3)

Q3 *Please rank the transport modes used for leisure trips within the EU* in order of preference, where 1 being the most preferred by you.

______ Car (1)
______ Train (2)
______ Low-cost airline (e.g. Ryanair, EasyJet, Eurowings, Wizz Air etc.) (3)
______ Traditional airline (e.g. Brussels Airlines, Lufthansa, Air France/KLM etc.) (4)

Q4 *If you plan a leisure trip within the EU, how often would you check the following options?*

	Always (1)	Sometimes (2)	Never (3)
Car (1)	○	○	○
Train (2)	○	○	○
Plane (3)	○	○	○

End of Block: Block 1

Start of Block: Block 2

Display This Question:

If Q4 = 1 [1]

Or Q4 = 1 [2]

Q5 *How important are the following factors when planning a leisure trip within the EU* ***by car****?*

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Total travel time (travel/driving time and time for breaks and refuelling) (1)	○	○	○	○	○
Total price (fuel price and tolls) (2)	○	○	○	○	○
Safety level (3)	○	○	○	○	○
Comfort level (4)	○	○	○	○	○
Weather conditions (5)	○	○	○	○	○
Parking options (6)	○	○	○	○	○

Display This Question:

If Q4 = 1 [1]

Or Q4 = 1 [2]

Q6 *To what extent do you agree with the following statements?*

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree

Travelling by car gives me a vacation feeling ()	
Travelling by car is convenient ()	
I feel safe when travelling by car ()	
Travelling by car is exhausting ()	
I feel like I am wasting a lot of time when travelling by car ()	
Travelling by car gives me the freedom to stop where and when I like ()	
I like to take scenic routes to my destination ()	
Travelling by car is expensive ()	
I am aware of the impact of travelling by car on environment ()	
I try to compensate the impact of travelling by car on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products) ()	
I can take as much luggage as I need in the car ()	

Page Break

Display This Question:

If Q4 = 3 [1]

Or Q4 = 3 [2]

Q7 *How important are the following factors when planning a leisure trip within the EU* ***by plane****?*

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Total travel time (flight duration, and minimum arrival time for check-in and security screening before the flight) (1)	○	○	○	○	○
Ticket price (2)	○	○	○	○	○
Safety level (3)	○	○	○	○	○
Comfort level (4)	○	○	○	○	○
Direct connection (5)	○	○	○	○	○
Waiting time between stopovers (if any) (6)	○	○	○	○	○
Location of an airport (7)	○	○	○	○	○
Frequency of a service (8)	○	○	○	○	○

Display This Question:

If Q4 = 3 [1]

Or Q4 = 3 [2]

Q8 *To what extent do you agree with the following statements?*

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Travelling by plane gives me a vacation feeling ()					
I consider a plane as a more luxurious mode of transport than a train ()					
Flying shortens the travel time to my destination ()					
I feel safe while flying ()					
Travelling by plane is convenient ()					
The price of a plane ticket is often reasonable ()					
I feel like I am wasting a lot of time going through security or just waiting at the airport ()					
I like the services I get at an airport and on board ()					
I am aware of the negative impact of flying on the environment ()					
I try to compensate the impact of flying on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products) ()					

Page Break

Display This Question:

If Q4 = 2 [1]

Or Q4 = 2 [2]

Q9 *How important are the following factors when planning a leisure trip within the EU* ***by train****?*

	Not at all important (1)	Slightly important (2)	Moderately important (3)	Very important (4)	Extremely important (5)
Total travel time (journey time and minimum arrival time before departure) (1)	○	○	○	○	○
Ticket price (2)	○	○	○	○	○
Safety level (3)	○	○	○	○	○
Comfort level (4)	○	○	○	○	○
Direct connection (5)	○	○	○	○	○
Waiting time between stopovers (if any) (6)	○	○	○	○	○
Location of a station (7)	○	○	○	○	○
Frequency of a service (8)	○	○	○	○	○

Display This Question:

If Q4 = 2 [1]

Or Q4 = 2 [2]

Q10 *To what extent do you agree with the following statements?*

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
Travelling by train gives me a vacation feeling ()					
I like to travel by train as it is more environmentally friendly ()					
I avoid lost baggage when travelling by train ()					
Travelling by train is convenient ()					
The price of a train ticket is often reasonable ()					
I feel safe when I travel by train ()					
Travelling by train gives me a chance to enjoy beautiful views out of the window ()					
When travelling by train, I feel like I am losing too much time ()					
Trains are comfortable (e.g. seats, space, level of noise, temperature, vibration) ()					
Trains usually arrive in the city centre which is beneficial ()					

End of Block: Block 2

Start of Block: Group A

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **7 hrs** Return trip cost : **€ 300 per trip** Travel persons : **Alone** Comfort level : **High** (29)
- ◯ Travel time : **4 hrs** Return trip cost : **€ 150 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)
- ◯ Travel time : **3 hrs** Return trip cost : **€ 225 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **8 hrs** Return trip cost : **€ 350 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)
- ◯ Travel time : **5 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)
- ◯ Travel time : **4.5 hrs** Return trip cost : **€ 175 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **9 hrs** Return trip cost : **€ 250 per trip** Travel persons : **Alone** Comfort level : **Low** (29)
- ◯ Travel time : **6 hrs** Return trip cost : **€ 250 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)
- ◯ Travel time : **6 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **10 hrs** Return trip cost : **€ 200 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **7 hrs** Return trip cost : **€ 200 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)

○ Travel time : **8 hrs** Return trip cost : **€ 275 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

End of Block: Group A

Start of Block: Group B

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **7 hrs** Return trip cost : **€ 250 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **4 hrs** Return trip cost : **€ 200 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **3 hrs** Return trip cost : **€ 175 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **8 hrs** Return trip cost : **€ 200 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

○ Travel time : **5 hrs** Return trip cost : **€ 150 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

○ Travel time : **4.5 hrs** Return trip cost : **€ 225 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **9 hrs** Return trip cost : **€ 350 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

○ Travel time : **6 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

○ Travel time : **6 hrs** Return trip cost : **€ 275 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **10 hrs** Return trip cost : **€ 300 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **7 hrs** Return trip cost : **€ 250 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **8 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

End of Block: Group B

Start of Block: Group C

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **7 hrs** Return trip cost : **€ 300 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)
- ◯ Travel time : **4 hrs** Return trip cost : **€ 150 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)
- ◯ Travel time : **3 hrs** Return trip cost : **€ 275 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **8 hrs** Return trip cost : **€ 250 per trip** Travel persons : **Alone** Comfort level : **High** (29)
- ◯ Travel time : **5 hrs** Return trip cost : **€ 200 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)
- ◯ Travel time : **4.5 hrs** Return trip cost : **€ 225 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ○ Travel time : **9 hrs** Return trip cost : **€ 200 per trip** Travel persons : **Alone** Comfort level : **High** (29)
- ○ Travel time : **6 hrs** Return trip cost : **€ 250 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)
- ○ Travel time : **6 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ○ Travel time : **10 hrs** Return trip cost : **€ 350 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)
- ○ Travel time : **7 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)
- ○ Travel time : **8 hrs** Return trip cost : **€ 175 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

End of Block: Group C

Start of Block: Group D

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **7 hrs** Return trip cost : **€ 250 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

○ Travel time : **4 hrs** Return trip cost : **€ 250 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)

○ Travel time : **3 hrs** Return trip cost : **€ 275 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **8 hrs** Return trip cost : **€ 300 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **5 hrs** Return trip cost : **€ 200 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **4.5 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **9 hrs** Return trip cost : **€ 350 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **6 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **6 hrs** Return trip cost : **€ 225 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **10 hrs** Return trip cost : **€ 200 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

◯ Travel time : **7 hrs** Return trip cost : **€ 150 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

◯ Travel time : **8 hrs** Return trip cost : **€ 175 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

End of Block: Group D

Start of Block: Group E

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **7 hrs** Return trip cost : **€ 350 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

◯ Travel time : **4 hrs** Return trip cost : **€ 250 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)

◯ Travel time : **3 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **8 hrs** Return trip cost : **€ 300 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

◯ Travel time : **5 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)

◯ Travel time : **4.5 hrs** Return trip cost : **€ 275 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **9 hrs** Return trip cost : **€ 200 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)

◯ Travel time : **6 hrs** Return trip cost : **€ 200 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

◯ Travel time : **6 hrs** Return trip cost : **€ 175 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **10 hrs** Return trip cost : **€ 250 per trip** Travel persons : **Alone** Comfort level : **High** (29)

◯ Travel time : **7 hrs** Return trip cost : **€ 150 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

◯ Travel time : **8 hrs** Return trip cost : **€ 225 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

End of Block: Group E

Start of Block: Group F

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **7 hrs** Return trip cost : **€ 350 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

○ Travel time : **4 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **3 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **8 hrs** Return trip cost : **€ 200 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)

○ Travel time : **5 hrs** Return trip cost : **€ 250 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

○ Travel time : **4.5 hrs** Return trip cost : **€ 175 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **9 hrs** Return trip cost : **€ 300 per trip** Travel persons : **Alone** Comfort level : **High** (29)

○ Travel time : **6 hrs** Return trip cost : **€ 150 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)

○ Travel time : **6 hrs** Return trip cost : **€ 225 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **10 hrs** Return trip cost : **€ 250 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)

○ Travel time : **7 hrs** Return trip cost : **€ 200 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **8 hrs** Return trip cost : **€ 275 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

End of Block: Group F

Start of Block: Group G

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **7 hrs** Return trip cost : **€ 200 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)
- ◯ Travel time : **4 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **1st class** (30)
- ◯ Travel time : **3 hrs** Return trip cost : **€ 225 per person** Travel persons : **Alone** Comfort level : **1st class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **8 hrs** Return trip cost : **€ 350 per trip** Travel persons : **Alone** Comfort level : **High** (29)
- ◯ Travel time : **5 hrs** Return trip cost : **€ 150 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)
- ◯ Travel time : **4.5 hrs** Return trip cost : **€ 275 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

- ◯ Travel time : **9 hrs** Return trip cost : **€ 250 per trip** Travel persons : **With travel companions** Comfort level : **High** (29)
- ◯ Travel time : **6 hrs** Return trip cost : **€ 200 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)
- ◯ Travel time : **6 hrs** Return trip cost : **€ 175 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **10 hrs** Return trip cost : **€ 300 per trip** Travel persons : **Alone** Comfort level : **Low** (29)

◯ Travel time : **7 hrs** Return trip cost : **€ 250 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

◯ Travel time : **8 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

End of Block: Group G

Start of Block: Group H

Q11 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

◯ Travel time : **7 hrs** Return trip cost : **€ 200 per trip** Travel persons : **Alone** Comfort level : **High** (29)

◯ Travel time : **4 hrs** Return trip cost : **€ 200 per person** Travel persons : **Alone** Comfort level : **1st class** (30)

◯ Travel time : **3 hrs** Return trip cost : **€ 175 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

Q12 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **8 hrs** Return trip cost : **€ 250 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)

○ Travel time : **5 hrs** Return trip cost : **€ 250 per person** Travel persons : **With travel companions** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **4.5 hrs** Return trip cost : **€ 100 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q13 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **9 hrs** Return trip cost : **€ 300 per trip** Travel persons : **With travel companions** Comfort level : **Low** (29)

○ Travel time : **6 hrs** Return trip cost : **€ 150 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (30)

○ Travel time : **6 hrs** Return trip cost : **€ 275 per person** Travel persons : **Alone** Comfort level : **Economy (2nd) class** (31)

Q14 *Suppose that you plan a leisure trip of 5 days, which option would you choose to get to the destination?*

○ Travel time : **10 hrs** Return trip cost : **€ 350 per trip** Travel persons : **Alone** Comfort level : **High** (29)

○ Travel time : **7 hrs** Return trip cost : **€ 100 per person** Travel persons : **With travel companions** Comfort level : **1st class** (30)

○ Travel time : **8 hrs** Return trip cost : **€ 225 per person** Travel persons : **With travel companions** Comfort level : **1st class** (31)

End of Block: Group H

Start of Block: Block 11

Q15 *To what extent would the following measures convince you to change from car or plane to train for a leisure trip within the EU?*

	Yes (1)	Maybe (2)	No (3)
Price of a train ticket that is lower than the price of a plane ticket (1)	○	○	○
Price of a train ticket that is lower than the price of a car trip (fuel price and tolls) (2)	○	○	○
Wide range of food and drink options on the train (3)	○	○	○
Total travel time by train is maximum 2 hrs above the total travel time by plane (4)	○	○	○
Total travel time by train is maximum 1 hr above the total travel time by plane (5)	○	○	○
Excellent Wi-Fi on the train (6)	○	○	○
High comfort level of a train (soft seats, enough legroom, etc.) (7)	○	○	○
Direct train connection (no stopovers) (8)	○	○	○
Children's playing space available in the train (9)	○	○	○
High frequency of trains (10)	○	○	○
Reliable schedule (11)	○	○	○
Bonus points for each train travel (that could be used to pay for train tickets or eco-products) (12)	○	○	○

End of Block: Block 11

Start of Block: Block 12

Q16 *What is your age?*

____

Q17 *What is your gender?*

- Male (1)
- Female (2)
- Non-binary / third gender (3)

Q18 *Which of the following terms best describes your current professional occupation?*

- Student (1)
- Employee (2)
- Self-employed/independent professional (3)
- Currently no professional occupation (4)
- Retired (5)

Q19 *What is your household composition?*

- ◯ Single without children (1)
- ◯ Single with children (2)
- ◯ In a relationship without children (3)
- ◯ In a relationship with children (4)

Q20 *Which country do you live in?*

____

Q21 *Which province do you live in?*

____

Q22 *Do you have a driving licence?*

- ◯ Yes (1)
- ◯ No (2)

Q23 *What is the car ownership status in your household? Select all that apply.*

- ☐ Do not own a car (1)
- ☐ Rent a car occasionally (2)
- ☐ Lease a car on permanent basis (3)
- ☐ Own a car (4)

Q24 *How often do you use a train in your everyday life?*

- ○ Daily (1)
- ○ A few times per week (2)
- ○ A few times per month (3)
- ○ A few times per year (4)
- ○ Do not use a train (5)

Q25 *Choose statements that are applicable to you:*

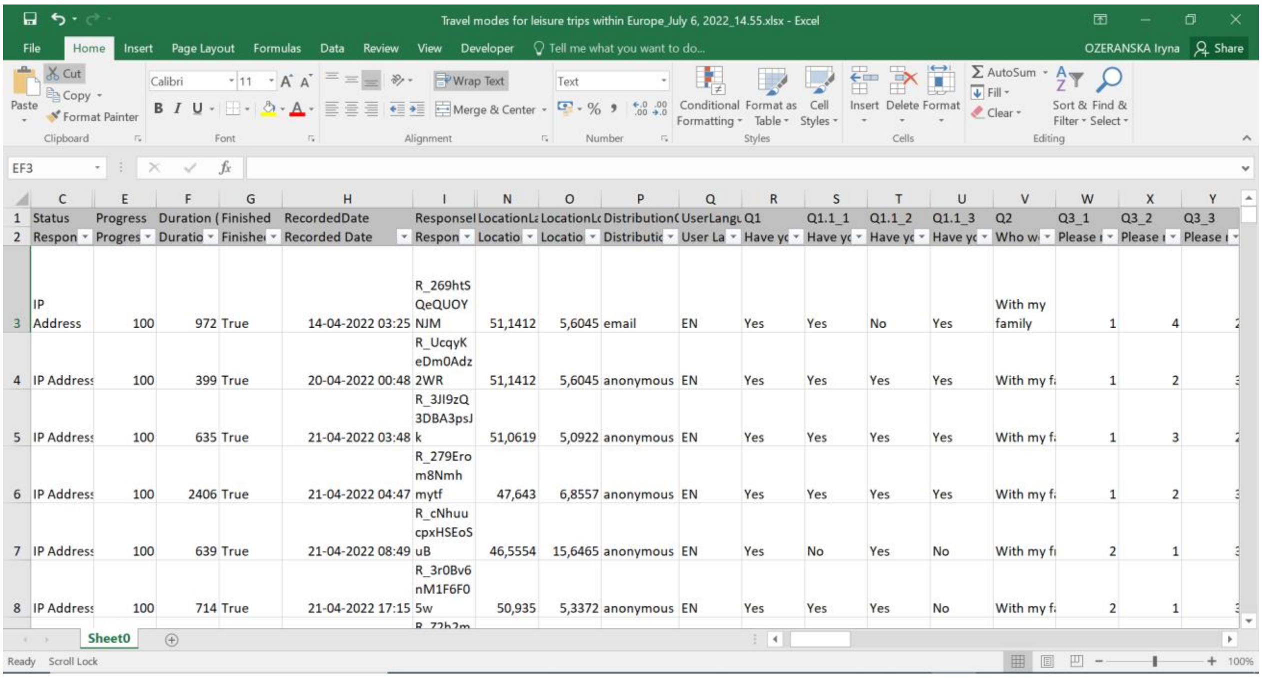
- ▢ I try to recycle as much as possible (1)
- ▢ I try to consume less meat or no meat at all (2)
- ▢ I try to use eco-friendly cleaning products (3)
- ▢ I try to buy used/second-hand things (4)
- ▢ I try to avoid car use in daily life (5)
- ▢ I try to buy food packed in recycled material (6)
- ▢ I try to fix things instead of throwing them away immediately (7)
- ▢ I try to reduce my energy consumption (8)
- ▢ I try to reduce my water consumption (9)
- ▢ I try to use rechargeable batteries (10)

Q26 *Do you have any additions to this survey?*

____

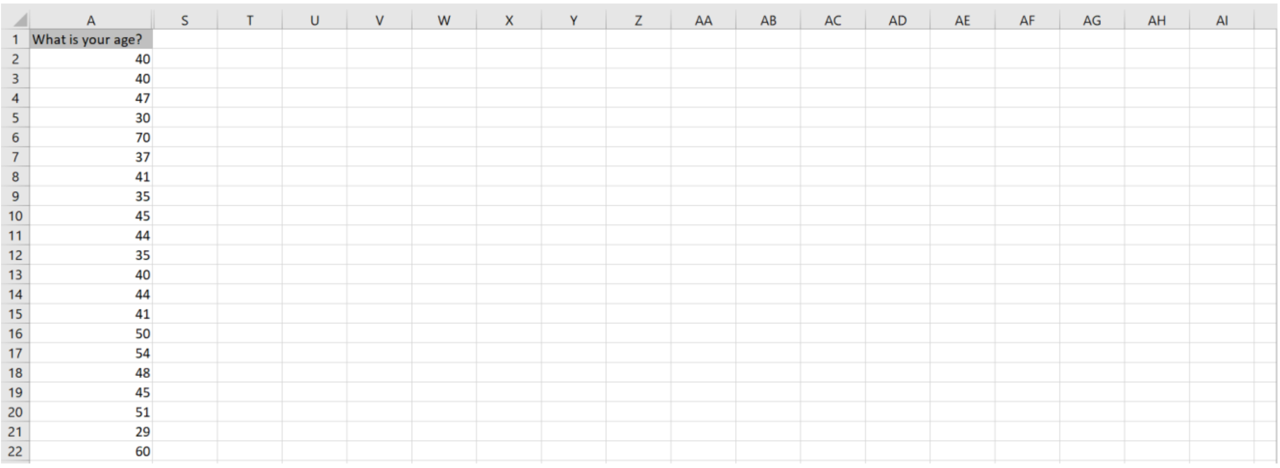
End of Block: Block 12

Appendix 2: Qualtrics Raw Data In Excel



	C	E	F	G	H	I	N	O	P	Q	R	S	T	U	V	W	X	Y
1	Status	Progress	Duration (	Finished	RecordedDate	ResponseI	LocationLa	LocationLo	Distribution(	UserLangu	Q1	Q1.1_1	Q1.1_2	Q1.1_3	Q2	Q3_1	Q3_2	Q3_3
2	Respon	Progres	Duratio	Finishe	Recorded Date	Respon	Locatio	Locatio	Distributic	User La	Have yc	Have yc	Have yc	Have yc	Who w	Please r	Please r	Please r
3	IP Address	100	972	True	14-04-2022 03:25	R_269htSQeQUOYNJM	51,1412	5,6045	email	EN	Yes	Yes	No	Yes	With my family	1	4	2
4	IP Address	100	399	True	20-04-2022 00:48	R_UcqyKeDm0Adz2WR	51,1412	5,6045	anonymous	EN	Yes	Yes	Yes	Yes	With my fa	1	2	3
5	IP Address	100	635	True	21-04-2022 03:48	R_3JI9zQ3DBA3psJk	51,0619	5,0922	anonymous	EN	Yes	Yes	Yes	Yes	With my fa	1	3	2
6	IP Address	100	2406	True	21-04-2022 04:47	R_279Erom8Nmhmytf	47,643	6,8557	anonymous	EN	Yes	Yes	Yes	Yes	With my fa	1	2	3
7	IP Address	100	639	True	21-04-2022 08:49	R_cNhuucpxHSEoSuB	46,5554	15,6465	anonymous	EN	Yes	No	Yes	No	With my fi	2	1	3
8	IP Address	100	714	True	21-04-2022 17:15	R_3r0Bv6nM1F6F05w	50,935	5,3372	anonymous	EN	Yes	Yes	Yes	No	With my fa	2	1	3

Appendix 3: Raw Data – Age



	A
1	What is your age?
2	40
3	40
4	47
5	30
6	70
7	37
8	41
9	35
10	45
11	44
12	35
13	40
14	44
15	41
16	50
17	54
18	48
19	45
20	51
21	29
22	60

Appendix 4: Raw Data – Province Of Living

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Which province do you live in?																
2	Vlaams Brabant																
3	Flemish Brabant																
4	Vlaams-Brabant																
5	Limburg																
6	vl-brabant																
7	Kiambu																
8	Oost-Vlaanderen																
9	Luik																
10	Brussels Capital Region																
11	Antwerp																
12	East Vlanders																
13	Vlaams-Brabant																
14	Antwerp																
15	Brussels																
16	Oost-Vlaanderen																
17	Liege																
18	Brussels																
19	Vlaams-Brabant																
20	Oost-Vlaanderen																
21	Flemish-Brabant																
22	Oost-Vlaanderen																

Appendix 5: Raw Data – Perceptions About A Car Travel

			Total	Total
	Total Count		87,0	
Q6: To what extent do you agree with the following statements?	Travelling by car gives me a vacation feeling	Strongly disagree	6,0	6,90%
		Somewhat disagree	9,0	10,34%
		Neither agree nor disagree	17,0	19,54%
		Somewhat agree	33,0	37,93%
		Strongly agree	22,0	25,29%
	Travelling by car is convenient	Strongly disagree	4,0	4,60%
		Somewhat disagree	2,0	2,30%
		Neither agree nor disagree	15,0	17,24%
		Somewhat agree	29,0	33,33%
		Strongly agree	37,0	42,53%
	I feel safe when travelling by car	Strongly disagree	5,0	5,75%
		Somewhat disagree	6,0	6,90%
		Neither agree nor disagree	13,0	14,94%
		Somewhat agree	33,0	37,93%
		Strongly agree	30,0	34,48%
	Travelling by car is exhausting	Strongly disagree	9,0	10,34%
		Somewhat disagree	10,0	11,49%
		Neither agree nor disagree	19,0	21,84%
		Somewhat agree	28,0	32,18%
		Strongly agree	21,0	24,14%
	I feel like I am wasting a lot of time when travelling by car	Strongly disagree	18,0	20,69%
		Somewhat disagree	24,0	27,59%
		Neither agree nor disagree	24,0	27,59%
		Somewhat agree	12,0	13,79%
		Strongly agree	9,0	10,34%
	Travelling by car gives me the freedom to stop where and when I like	Strongly disagree	1,0	1,15%
		Somewhat disagree	1,0	1,15%
		Neither agree nor disagree	10,0	11,49%
		Somewhat agree	18,0	20,69%
		Strongly agree	57,0	65,52%
	I like to take scenic routes to my destination	Strongly disagree	10,0	11,49%
		Somewhat disagree	12,0	13,79%
		Neither agree nor disagree	24,0	27,59%
		Somewhat agree	19,0	21,84%
		Strongly agree	22,0	25,29%
	Travelling by car is expensive	Strongly disagree	11,0	12,64%
		Somewhat disagree	14,0	16,09%
		Neither agree nor disagree	21,0	24,14%
		Somewhat agree	26,0	29,89%
		Strongly agree	15,0	17,24%
	I am aware of the impact of travelling by car on environment	Strongly disagree	8,0	9,20%
		Somewhat disagree	5,0	5,75%
		Neither agree nor disagree	17,0	19,54%
		Somewhat agree	30,0	34,48%
		Strongly agree	27,0	31,03%
	I try to compensate the impact of travelling by car on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products)	Strongly disagree	29,0	33,33%
		Somewhat disagree	11,0	12,64%
		Neither agree nor disagree	15,0	17,24%
		Somewhat agree	14,0	16,09%
		Strongly agree	18,0	20,69%
	I can take as much luggage as I need in the car	Strongly disagree	1,0	1,15%
		Somewhat disagree	7,0	8,05%
		Neither agree nor disagree	8,0	9,20%
		Somewhat agree	26,0	29,89%
		Strongly agree	45,0	51,72%

Appendix 6: Raw Data – Perceptions About A Plane Travel

			Total	Total
Q8: To what extent do you agree with the following statements?	Total Count		91,0	
	Travelling by plane gives me a vacation feeling	Strongly disagree	2,0	2,20%
		Somewhat disagree	1,0	1,10%
		Neither agree nor disagree	13,0	14,29%
		Somewhat agree	25,0	27,47%
		Strongly agree	50,0	54,95%
	I consider a plane as a more luxurious mode of transport than a train	Strongly disagree	15,0	16,48%
		Somewhat disagree	12,0	13,19%
		Neither agree nor disagree	15,0	16,48%
		Somewhat agree	16,0	17,58%
		Strongly agree	33,0	36,26%
	Flying shortens the travel time to my destination	Strongly disagree	0,0	0,00%
		Somewhat disagree	4,0	4,40%
		Neither agree nor disagree	11,0	12,09%
		Somewhat agree	22,0	24,18%
		Strongly agree	54,0	59,34%
	I feel safe while flying	Strongly disagree	3,0	3,30%
		Somewhat disagree	2,0	2,20%
		Neither agree nor disagree	18,0	19,78%
		Somewhat agree	27,0	29,67%
		Strongly agree	41,0	45,05%
	Travelling by plane is convenient	Strongly disagree	6,0	6,59%
		Somewhat disagree	5,0	5,49%
		Neither agree nor disagree	19,0	20,88%
		Somewhat agree	34,0	37,36%
		Strongly agree	27,0	29,67%
	The price of a plane ticket is often reasonable	Strongly disagree	8,0	8,79%
		Somewhat disagree	11,0	12,09%
		Neither agree nor disagree	27,0	29,67%
		Somewhat agree	35,0	38,46%
		Strongly agree	10,0	10,99%
	I feel like I am wasting a lot of time going through security or just waiting at the airport	Strongly disagree	10,0	10,99%
		Somewhat disagree	14,0	15,38%
		Neither agree nor disagree	19,0	20,88%
		Somewhat agree	25,0	27,47%
		Strongly agree	23,0	25,27%
	I like the services I get at an airport and on board	Strongly disagree	19,0	20,88%
		Somewhat disagree	16,0	17,58%
		Neither agree nor disagree	26,0	28,57%
		Somewhat agree	25,0	27,47%
		Strongly agree	5,0	5,49%
	I am aware of the negative impact of flying on the environment	Strongly disagree	9,0	9,89%
		Somewhat disagree	4,0	4,40%
		Neither agree nor disagree	11,0	12,09%
		Somewhat agree	21,0	23,08%
		Strongly agree	46,0	50,55%
	I try to compensate the impact of flying on the environment by being more eco-friendly in daily life (e.g. plant trees, recycle, buy eco-products)	Strongly disagree	30,0	32,97%
		Somewhat disagree	10,0	10,99%
		Neither agree nor disagree	17,0	18,68%
		Somewhat agree	14,0	15,38%
		Strongly agree	20,0	21,98%

Appendix 7: Raw Data – Perceptions About A Train Travel

			Total	Total
Q10: To what extent do you agree with the following statements?	Total Count		78,0	
	Travelling by train gives me a vacation feeling	Strongly disagree	5,0	6,41%
		Somewhat disagree	11,0	14,10%
		Neither agree nor disagree	20,0	25,64%
		Somewhat agree	23,0	29,49%
		Strongly agree	19,0	24,36%
	I like to travel by train as it is more environmentally friendly	Strongly disagree	5,0	6,41%
		Somewhat disagree	5,0	6,41%
		Neither agree nor disagree	23,0	29,49%
		Somewhat agree	18,0	23,08%
		Strongly agree	27,0	34,62%
	I avoid lost baggage when travelling by train	Strongly disagree	14,0	17,95%
		Somewhat disagree	9,0	11,54%
		Neither agree nor disagree	20,0	25,64%
		Somewhat agree	20,0	25,64%
		Strongly agree	15,0	19,23%
	Travelling by train is convenient	Strongly disagree	8,0	10,26%
		Somewhat disagree	5,0	6,41%
		Neither agree nor disagree	22,0	28,21%
		Somewhat agree	25,0	32,05%
		Strongly agree	18,0	23,08%
	The price of a train ticket is often reasonable	Strongly disagree	12,0	15,38%
		Somewhat disagree	16,0	20,51%
		Neither agree nor disagree	19,0	24,36%
		Somewhat agree	21,0	26,92%
		Strongly agree	10,0	12,82%
	I feel safe when I travel by train	Strongly disagree	0,0	0,00%
		Somewhat disagree	5,0	6,41%
		Neither agree nor disagree	5,0	6,41%
		Somewhat agree	17,0	21,79%
		Strongly agree	51,0	65,38%
	Travelling by train gives me a chance to enjoy beautiful views out of the window	Strongly disagree	4,0	5,13%
		Somewhat disagree	0,0	0,00%
		Neither agree nor disagree	13,0	16,67%
		Somewhat agree	21,0	26,92%
		Strongly agree	40,0	51,28%
	When travelling by train, I feel like I am losing too much time	Strongly disagree	15,0	19,23%
		Somewhat disagree	25,0	32,05%
		Neither agree nor disagree	15,0	19,23%
		Somewhat agree	16,0	20,51%
		Strongly agree	7,0	8,97%
	Trains are comfortable (e.g. seats, space, level of noise, temperature, vibration)	Strongly disagree	4,0	5,13%
		Somewhat disagree	6,0	7,69%
		Neither agree nor disagree	23,0	29,49%
		Somewhat agree	27,0	34,62%
		Strongly agree	18,0	23,08%
	Trains usually arrive in the city centre which is beneficial	Strongly disagree	2,0	2,56%
		Somewhat disagree	3,0	3,85%
		Neither agree nor disagree	5,0	6,41%
		Somewhat agree	32,0	41,03%
		Strongly agree	36,0	46,15%

Appendix 8: Estimation Report For Basic Model

Estimation report

Number of estimated parameters:	6
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-333.9652
Likelihood ratio test for the init. model:	184.5927
Rho-square for the init. model:	0.217
Rho-square-bar for the init. model:	0.202
Akaike Information Criterion:	679.9304
Bayesian Information Criterion:	703.6964
Final gradient norm:	8.8070E-04
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	3.057273e-06
Relative change:	0.027559254901853642
Number of iterations:	5
Number of function evaluations:	16
Number of gradient evaluations:	6
Number of hessian evaluations:	6
Cause of termination:	Relative gradient = 3.1e-06 <= 6.1e-06
Optimization time:	0:00:00.051570

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-0.468	0.506	-0.923	0.356	0.513	-0.912	0.362
ASC_TRAIN	-0.226	0.52	-0.435	0.664	0.526	-0.43	0.667
B_COMFORT	0.453	0.135	3.36	0.000767	0.134	3.38	0.000736
B_COST	-7.97	1.1	-7.21	5.55e-13	1.15	-6.94	3.81e-12
B_PERSONS	0.879	0.133	6.6	4.06e-11	0.131	6.73	1.65e-11
B_TIME	-4.38	2.58	-1.7	0.0899	2.66	-1.65	0.0996

Appendix 9: Estimation Report For Basic Model With Age

Estimation report

Number of estimated parameters:	7
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-332.2247
Likelihood ratio test for the init. model:	188.0737
Rho-square for the init. model:	0.221
Rho-square-bar for the init. model:	0.204
Akaike Information Criterion:	678.4495
Bayesian Information Criterion:	706.1765
Final gradient norm:	1.5748E-03
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	1.278084e-05
Relative change:	8.435634479838575e-06
Number of iterations:	7
Number of function evaluations:	22
Number of gradient evaluations:	8
Number of hessian evaluations:	8
Cause of termination:	Relative change = 8.44e-06 <= 1e-05
Optimization time:	0:00:00.094214

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2	0.91	-2.2	0.0276	1.02	-1.97	0.0494
ASC_TRAIN	-1.76	0.916	-1.92	0.0545	1.03	-1.71	0.0875
B_AGE	1.58	0.781	2.03	0.0426	0.866	1.83	0.0672
B_COMFORT	0.463	0.136	3.41	0.00064	0.137	3.39	0.000709
B_COST	-8.03	1.11	-7.25	4.32e-13	1.16	-6.91	4.94e-12
B_PERSONS	0.889	0.134	6.64	3.14e-11	0.131	6.78	1.22e-11
B_TIME	-4.36	2.59	-1.68	0.0926	2.68	-1.63	0.104

Appendix 10: Estimation Report For Basic Model With Age And Gender

Estimation report

Number of estimated parameters:	8
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-332.2099
Likelihood ratio test for the init. model:	188.1033
Rho-square for the init. model:	0.221
Rho-square-bar for the init. model:	0.202
Akaike Information Criterion:	680.4198
Bayesian Information Criterion:	712.1078
Final gradient norm:	1.5789E-03
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	6.625695e-06
Relative change:	9.955140895089348e-06
Number of iterations:	31
Number of function evaluations:	94
Number of gradient evaluations:	32
Number of hessian evaluations:	32
Cause of termination:	Relative change = 9.96e-06 <= 1e-05
Optimization time:	0:00:00.415457

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.01	0.91	-2.2	0.0276	1.02	-1.97	0.0494
ASC_TRAIN	-1.76	0.916	-1.92	0.0544	1.03	-1.71	0.0874
B_AGE	1.61	0.792	2.03	0.0426	0.877	1.83	0.0668
B_COMFORT	0.462	0.135	3.41	0.000641	0.137	3.39	0.000711
B_COST	-8.03	1.11	-7.25	4.27e-13	1.16	-6.91	4.97e-12
B_GENDER	-0.0536	0.311	-0.173	0.863	0.303	-0.177	0.86
B_PERSONS	0.889	0.134	6.64	3.13e-11	0.131	6.77	1.28e-11
B_TIME	-4.36	2.59	-1.68	0.0925	2.68	-1.63	0.104

Appendix 11: Estimation Report For Basic Model With Age And HC

Estimation report

Number of estimated parameters: 8
Sample size: 388
Excluded observations: 0
Init log likelihood: -426.2616
Final log likelihood: -327.8021
Likelihood ratio test for the init. model: 196.9189
Rho-square for the init. model: 0.231
Rho-square-bar for the init. model: 0.212
Akaike Information Criterion: 671.6042
Bayesian Information Criterion: 703.2923
Final gradient norm: 1.6071E-03
Nbr of threads: 4
Algorithm: Newton with trust region for simple bound constraints
Proportion analytical hessian: 100.0%
Relative projected gradient: 1.306834e-05
Relative change: 7.03615979548542e-06
Number of iterations: 8
Number of function evaluations: 25
Number of gradient evaluations: 9
Number of hessian evaluations: 9
Cause of termination: Relative change = 7.04e-06 <= 1e-05
Optimization time: 0:00:00.124319

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.96	0.968	-3.06	0.00223	1.06	-2.8	0.00512
ASC_TRAIN	-2.72	0.973	-2.79	0.00526	1.06	-2.55	0.0107
B_AGE	1.95	0.795	2.46	0.0141	0.877	2.23	0.0259
B_COMFORT	0.467	0.136	3.43	0.00061	0.137	3.4	0.000678
B_COST	-8.08	1.11	-7.26	3.83e-13	1.16	-6.99	2.81e-12
B_HC	0.938	0.314	2.99	0.00278	0.309	3.04	0.0024
B_PERSONS	0.894	0.135	6.65	3e-11	0.132	6.77	1.29e-11
B_TIME	-4.41	2.6	-1.7	0.0896	2.65	-1.66	0.0959

Appendix 12: Estimation Report For Basic Model With Age, HC And HCO

Estimation report

Number of estimated parameters:	9
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-327.3749
Likelihood ratio test for the init. model:	197.7734
Rho-square for the init. model:	0.232
Rho-square-bar for the init. model:	0.211
Akaike Information Criterion:	672.7498
Bayesian Information Criterion:	708.3988
Final gradient norm:	8.7453E-04
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	7.275001e-06
Relative change:	4.962638167859798e-06
Number of iterations:	7
Number of function evaluations:	22
Number of gradient evaluations:	8
Number of hessian evaluations:	8
Cause of termination:	Relative change = 4.96e-06 <= 1e-05
Optimization time:	0:00:00.133023

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.42	1.13	-2.14	0.032	1.17	-2.06	0.0391
ASC_TRAIN	-2.18	1.13	-1.92	0.055	1.18	-1.84	0.066
B_AGE	1.84	0.803	2.3	0.0217	0.88	2.09	0.0363
B_COMFORT	0.463	0.136	3.4	0.00067	0.137	3.38	0.000729
B_COST	-8.08	1.11	-7.25	4.2e-13	1.16	-6.97	3.14e-12
B_HC	0.841	0.328	2.56	0.0103	0.315	2.67	0.00756
B_HCO	-0.437	0.488	-0.896	0.37	0.475	-0.92	0.358
B_PERSONS	0.891	0.135	6.62	3.63e-11	0.132	6.74	1.57e-11
B_TIME	-4.41	2.6	-1.7	0.0896	2.65	-1.67	0.0957

Appendix 13: Estimation Report For Basic Model With Age, HC And DL

Estimation report

Number of estimated parameters:	9
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-327.796
Likelihood ratio test for the init. model:	196.9312
Rho-square for the init. model:	0.231
Rho-square-bar for the init. model:	0.21
Akaike Information Criterion:	673.592
Bayesian Information Criterion:	709.241
Final gradient norm:	8.8341E-04
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	9.190453e-06
Relative change:	3.7620309573708544e-06
Number of iterations:	10
Number of function evaluations:	31
Number of gradient evaluations:	11
Number of hessian evaluations:	11
Cause of termination:	Relative change = 3.76e-06 <= 1e-05
Optimization time:	0:00:00.180190

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.9	1.12	-2.58	0.00977	1.16	-2.49	0.0126
ASC_TRAIN	-2.65	1.13	-2.36	0.0185	1.17	-2.27	0.0232
B_AGE	1.94	0.805	2.41	0.016	0.883	2.2	0.0281
B_COMFORT	0.467	0.136	3.43	0.000614	0.137	3.4	0.000685
B_COST	-8.08	1.11	-7.26	3.87e-13	1.16	-6.99	2.75e-12
B_DL	-0.0492	0.447	-0.11	0.912	0.428	-0.115	0.908
B_HC	0.925	0.333	2.78	0.00539	0.318	2.91	0.00365
B_PERSONS	0.894	0.135	6.65	3.03e-11	0.132	6.77	1.3e-11
B_TIME	-4.41	2.6	-1.7	0.0899	2.65	-1.66	0.096

Appendix 14: Estimation Report For Basic Model With Age, HC And TUF

Estimation report

Number of estimated parameters:	9
Sample size:	388
Excluded observations:	0
Init log likelihood:	-426.2616
Final log likelihood:	-317.8228
Likelihood ratio test for the init. model:	216.8776
Rho-square for the init. model:	0.254
Rho-square-bar for the init. model:	0.233
Akaike Information Criterion:	653.6456
Bayesian Information Criterion:	689.2946
Final gradient norm:	5.0487E-04
Nbr of threads:	4
Algorithm:	Newton with trust region for simple bound constraints
Proportion analytical hessian:	100.0%
Relative projected gradient:	4.722462e-06
Relative change:	0.0012045039293074095
Number of iterations:	6
Number of function evaluations:	19
Number of gradient evaluations:	7
Number of hessian evaluations:	7
Cause of termination:	Relative gradient = 4.7e-06 <= 6.1e-06
Optimization time:	0:00:00.111855

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-2.7	0.983	-2.74	0.00607	1.01	-2.67	0.00749
ASC_TRAIN	-3.61	1.02	-3.54	0.000406	1.05	-3.44	0.000585
B_AGE	1.74	0.805	2.16	0.0311	0.797	2.18	0.0294
B_COMFORT	0.478	0.139	3.44	0.000576	0.139	3.44	0.000589
B_COST	-8.43	1.14	-7.36	1.84e-13	1.18	-7.14	9.61e-13
B_HC	0.792	0.317	2.5	0.0125	0.305	2.59	0.00952
B_PERSONS	0.925	0.138	6.7	2.02e-11	0.137	6.73	1.66e-11
B_TIME	-4.62	2.66	-1.74	0.0823	2.73	-1.7	0.0898
B_TUF	1.4	0.335	4.18	2.87e-05	0.359	3.91	9.26e-05

Appendix 15: Estimation Report For Basic Model With Age, HC, TUF And Occupation

Estimation report

Number of estimated parameters: 10
Sample size: 388
Excluded observations: 0
Init log likelihood: -426.2616
Final log likelihood: -317.8228
Likelihood ratio test for the init. model: 216.8775
Rho-square for the init. model: 0.254
Rho-square-bar for the init. model: 0.231
Akaike Information Criterion: 655.6456
Bayesian Information Criterion: 695.2556
Final gradient norm: 2.2547E-03
Nbr of threads: 4
Algorithm: Newton with trust region for simple bound constraints
Proportion analytical hessian: 100.0%
Relative projected gradient: 2.657715e-05
Relative change: 6.562734744935743e-06
Number of iterations: 9
Number of function evaluations: 28
Number of gradient evaluations: 10
Number of hessian evaluations: 10
Cause of termination: Relative change = 6.56e-06 <= 1e-05
Optimization time: 0:00:00.234797

Estimated parameters

Name	Value	Std err	t-test	p-value	Rob. Std err	Rob. t-test	Rob. p-value
ASC_PLANE	-0.594	0.347	-1.71	0.087	0.36	-1.65	0.0984
ASC_TRAIN	-1.51	0.382	-3.94	8.01e-05	0.397	-3.79	0.000148
B_AGE	1.73	0.805	2.16	0.0311	0.797	2.18	0.0294
B_COMFORT	0.478	0.139	3.44	0.000576	0.139	3.44	0.00059
B_COST	-8.42	1.14	-7.36	1.86e-13	1.18	-7.14	9.67e-13
B_HC	0.792	0.317	2.5	0.0125	0.305	2.59	0.00952
B_OCCUPATION	-2.1	0.66	-3.19	0.00144	0.677	-3.11	0.0019
B_PERSONS	0.925	0.138	6.7	2.02e-11	0.137	6.73	1.66e-11
B_TIME	-4.62	2.66	-1.74	0.0823	2.73	-1.7	0.0898
B_TUF	1.4	0.335	4.18	2.87e-05	0.359	3.91	9.25e-05