ECOLOGICAL AWARENESS AND MOTIVATION TO USE INTELLIGENT TRANSPORT SYSTEMS

MICHELLE MEDEIROS CRUZ FIDELIS

Dissertação submetida para satisfação parcial dos requisitos do grau de

MESTRE EM ENGENHARIA CIVIL — ESPECIALIZAÇÃO EM PLANEAMENTO DO TERRITÓRIO E TRANSPORTES

Orientador: Professor Doutor António Fidalgo do Couto

Coorientador: Doutor Marco Raul Soares Amorim

OCTOBER 2024

MESTRADO EM ENGENHARIA CIVIL 2023/2024

DEPARTAMENTO DE ENGENHARIA CIVIL

Tel. +351-22-508 1901

✉m.ec@fe.up.pt

Editado por

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Rua Dr. Roberto Frias

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

✉feup@fe.up.pt

http://www.fe.up.pt

A meus pais, irmãos e avós

It always seems impossible, until it's done

Nelson Mandela

ACKNOWLEDGMENTS

Firstly, I would like to thank God for the gift of life and all the other gifts that were given to me. I also thank Him for all the people that He had put in my life.

I also thank my parents, Marcelito and Maria do Carmo, for all the love, support, and encouragement since always; and my brothers, Marcello and Victor for being so present in my life and for expressing their support and friendship, especially in these two years away from home.

My gratitude to Professor António Couto for supervising this work and helping me whenever needed, and to Fraunhofer IAO, namely Dr. Marco Amorim, for providing the data set that was used in the development of this dissertation.

I also acknowledge the importance of other professors from the program of the master's in civil engineering at FEUP, especially those allocated on the transports and planning section, on my academic development during the past couple of years.

And finally, my gratitude to all my friends. To those from home, especially Amanda, David, Rafaela and Tayná, thank you for being present despite the distance. And to those that I met here, Ana Cláudia, Carol, Carolina, Duarte, Lívia, Marina and Vanessa, thank you for all your support and for making the whole process a little lighter.

RESUMO

Os sistemas de transporte têm grande importância no desenvolvimento e evolução do ser humano e suas relações desde o princípio das civilizações. Atrelado a isso, o advento de novas tecnologias tem o poder de provocar mudanças significativas nos comportamentos das pessoas, o que deveria ser explorado de maneira mais sustentável para o planeta. O setor dos transportes é responsável por cerca de 25% das emissões de gases de efeito estufa na Europa, com o transporte rodoviário representando três quartos desse montante, o que indica que mudanças devem ser feitas nesse setor para que os objetivos para uma União Europeia 55% menos poluente até 2030 sejam alcançados. Desse modo, a presente dissertação teve como principal objetivo analisar como a consciência ecológica de um indivíduo influencia as suas escolhas modais, e, ainda mais, em sua inclinação para uma mobilidade inteligente e multimodal. Dentre as novas tecnologias, destaca-se para a produção desse trabalho o conceito de *mobility as a service* (MaaS), que introduz o paradigma de utilizar a mobilidade como um serviço e não como um bem, como a posse de um veículo, por exemplo. A base do estudo foi um inquérito realizado em 2021 em quatro países Europeus, Alemanha, Reino Unido, Chéquia e Polónia, e essa análise foi realizada por meio de métodos de análise estatísticos, nomeadamente, análises de *cluster*, análises da principal componente, e regressão multinomial. A partir dessas análises, é possível traçar relações entre os grupos formados e a escolha modal de cada um, e como os diferentes componentes considerados para esses agrupamentos impactam de forma individual e em conjunto essa decisão. Ao final, pretende-se, para além da análise, discorrer sobre como os grupos que apresentam certo nível de consciência ecológica, mas que não têm esse fator como determinante de suas escolhas podem passar a agir de outra forma.

PALAVRAS-CHAVE: mobilidade inteligente, análise de *cluster*, consciência ecológica, sustentabilidade, intermodalidade.

ABSTRACT

Transport systems have great importance in the development and evolution of human beings and their relationships since the beginning of civilizations. Linked to this, the advent of new technologies has the power to cause significant changes in people's behaviours, which should be explored in a more sustainable way for the planet. The transport sector is responsible for around 25% of greenhouse gas emissions in Europe, with road transport representing three quarters of this amount, indicating that changes must be made in this sector if the objectives for a European Union are to be achieved. % less pollutants by 2030 are achieved. Therefore, the main objective of this dissertation was to analyse how an individual's ecological awareness influences their modal choices, and, even more so, their inclination towards intelligent and multimodal mobility. Among the new technologies, the concept of mobility as a service (MaaS) stands out for the development of this work, which introduces the paradigm of using mobility as a service and not as a good, such as owning a vehicle, for instance. The basis of the study was a survey carried out in 2021 in four European countries, Germany, United Kingdom, Czechia and Poland, and this analysis was carried out using statistical analysis methods, namely, cluster analysis, main component analysis, and regression multinomial. From these analyses, it is possible to draw relationships between the groups formed and the modal choice of each one, and how the different components considered for these groupings impact this decision individually and jointly. In the end, we intend, in addition to the analysis, to discuss how groups that have a certain level of ecological awareness, but that do not have this factor as a determinant of their choices, can start to act differently.

KEYWORDS: intelligent mobility, cluster analysis, environmental awareness, sustainability, intermodality.

GENERAL INDEX

INDEX OF FIGURES

INDEX OF TABLES

SYMBOLS, ACRONYMS AND ABBREVIATIONS

ºC - Celsius degrees

R^2 - Correlation squared

BRT - Bus rapid transit

CZ - Czechia

DE - Germany

EIT - European Institute of Innovation & Technology

GHG - Greenhouse gases

MaaS - Mobility as a Service

PCA - Principal components analysis

PL - Poland

UK - Unitted Kingdom

VBN - Value belief norm

Fig - Figure

1
INTRODUCTION

Transport systems and transport modes exist since the beginning of civilizations around the world. Over time, the need to move people, freight and information around has made society gradually more dependent on their transportation systems, and with that the development of modern forms of transportation. More than a mean of moving people around, transport plays an important role in several sectors, such as: social, when it allows the access to culture, healthcare, employment and education; political, when the government decides to subsidize their population's mobility; economic, since not only the sector is by itself an industry as a whole, but also because it impacts other areas, like land value; and environmental, since it impacts life quality due to the different types of pollution (Rodrigue, *et al.*, 2013).

In the European Union, the transport sector alone takes responsibility for about one quarter of the continent‘s greenhouse gas (GHG) emissions, with road transport alone emitting 76% of the GHG of that amount. These gases are important to regulate Earth's temperature and maintain life on the planet, since they are natural to the terrestrial atmosphere and absorb part of the radiation that is emitted by the Sun and reflected by Earth's surface. However, the increase in GHG concentration in the atmosphere caused by human actions leads to an increase in the global average temperature (European Environment Agency, 2023).

The Intergovernmental Panel on Climate Change, IPCC, states that an increase greater than 1,5ºC in the global average temperature when compared to pre-industrial levels (period between 1850 and 1900) would lead to a global imbalance, with changes in both terrestrial and aquatic ecosystems, the increase in the frequency of extreme events, such as heavy rainfall and intense heat and drought waves, and global mean sea level rise. It is also stated that if the global average temperature increases up to 2ºC these and other effects would be even more severe (Hoegh-Guldberg, et al., 2018).

Aiming at the reduction of net GHG emissions by at least 55%, when compared to 1990 until 2030, the European Union (EU) approved in 2023 a set of actions across all sectors. On what concerns mobility services, it previews that there should be a strong development of public transport, promotion of zero emissions vehicles and increase in the use of sustainable transport modes along with multi-modal solutions. It also states that digital technologies will have an important role achieving climate neutrality (European Comission, 2020).

The European Institute of Innovation & Technology (EIT) founded in 2019 the EIT Urban Mobility, a community for sustainable urban mobility, that aims to speed up the transition to sustainable mobility. (EIT, 2020). In that context, Fraunhofer IAO's MaaS_Together was a project carried out within the EIT that aims the development of a service for standardization and certification of Mobility as a Service (MaaS) components to cities, contributing to the research in this area. (Fraunhofer IAO, 2020).

1.1. Objective

This dissertation aims to discuss the influence of an individual’s ecological awareness in their motivation to use intelligent transport systems.

In order to achieve it, the study will proceed with a cluster analysis of the data set, as well as principal component analysis (PCA) and a multinomial regression, allowing the comparison of the results obtained by both methods.

1.2. Methodology

A quali-quantitative approach was followed to develop this work, with a component of bibliographic review and another component of data analysis, with data obtained from a survey carried out on October 2020 and made available by Fraunhofer IAO.

The literature review addresses issues and solutions related to urban mobility and an ecological mindset.

Regarding the data analysis, it was chosen to follow this sequence:

- Selection of the questions to be used.
- General descriptive analysis.
- Cluster analysis.
- Principal components analysis (PCA).
- Multinomial logistic regression.

After the analysis the final impressions on the matter are presented, along with measures to promote the use of intelligent and sustainable means of transportation.

1.3. Summary of the Contents of the Chapters

This dissertation is divided in 6 chapters, with the first being the present, and the other five following the methodology explained on item 1.2.

The second chapter consists of the literature review, which aims to present the concepts of sustainable mobility, mobility as a service (MaaS), intelligent mobility, in addition to the citation of authors and studies that address how the level of ecological awareness can influence on the individual’s transport modal choice.

Chapter 3 is composed of the data set and the study area characterizations, followed by a more detailed view of the methodology used to get to the results displayed on the fourth chapter, presenting the tools used.

The fourth chapter presents the results of the cluster analysis, three different approaches to the principal components analysis (PCA), and multinomial regressions for different scenarios.

The final two chapters, 5 and 6, are reserved for the discussion of all the results and presenting the main conclusions of this study.

2
LITERATURE REVIEW

This chapter aims to give context to the data analysis that will be carried out on chapter 3, presenting a series of concepts related to transportation, the relation between ecological awareness and transport modal choice, and the methods of data analysis that will be used on the next chapter.

Transport has an important role in city life and should assume a supporting attitude towards improving the population's quality of life, promoting a more sustainable environment along with the other spheres that constitute the urban territory. The traditional urban development model, focused on making accessibility easier to those who own a car, should give place to one that enables the sustainable transport (Banister, Hickman, 2007).

Other than acting on the local sphere and people's daily commuting life, transportation also has a key role in the process of globalization, being responsible for the movement of people, freight and information, through the course of society. With the opening dated to the second century BC and being used for more than a millennium, The Silk Route was the most long-lasting trade route in human history. Since then, with the evolution of technology and economy, the search for efficiency and cohesion of economic systems within this field has overcome a series of both revolutions and evolutions (Rodrigue, *et al.*, 2013).

This transport development comes in waves, where the next one is the result of the new technologies implemented in each of these waves combined with the transport capacity and mobility potential of the technologies that appeared before, as well as the substitution of those when the newer technologies serve a similar market (Rodrigue, *et al.*, 2013).

2.1. SUSTAINABLE URBAN MOBILITY

Sustainable urban mobility is described as the result of transport policies based on people, aiming the promotion of democratic access to the urban environment, by choosing collective and non-motorized modes of transport so that this choice is efficient in the access to goods and services, socially inclusive and ecologically sustainable (Boareto, 2003).

More than that, the concept is considered in two different contexts. The social-economic, that addresses that a sustainable mobility should ensure both the access to goods and services through actions on land use and occupation and transport management, and the maintenance or improvement of the quality of life of the current population, without harming future generations. The other context, the environmental, considers the impacts of the transport sector on the environment, through factors such as noise and air pollution and energy consumption, and how the new technologies can be addressed (Campos, 2006).

As previously mentioned, transportation has a huge impact on the climate change issue, due to its contribution on the GHG emissions. Other than the impact caused by GHG emission, the list of external costs related to the transport sector is quite ample and these factors, such as accident costs, and noise and pollutants emissions, should be considered in one’s commuting decision (European Commission, 2008).

Taken as an example on sustainable transport planning, after experiencing a rise in private transport numbers between the 1950s and the 1970s, the German city of Freiburg decided to introduce the first Integral Traffic Plan in 1969, which was followed by a series of plans and systems not based on private motorized vehicles. Among the policies to get to this position, the city decided to maintain and develop their tram system, promote the use of bicycles and provide infrastructure for that to happen, and reduce the use of cars in zones by establishing zones where they are not needed (Beim, Haag, 2010).

Public transportation is closely linked to walking and cycling, especially the former, since the trips on this modal usually begin and end with a walk to the station. Regarding the bicycles, it helps to increase the distance of the buffer from the bus or train stops and has a cost of infrastructure considerably smaller than park and ride facilities for cars, in addition to this connection establishing a travel alternative for cyclists under adverse conditions or even to increase the distances travelled. That said, it is extremely important to design and project safe and useful stations and paths both for pedestrians and cyclists (Pucher, Buehler, 2010).

2.2. INTELLIGENT TRANSPORT AND MOBILITY AS A SERVICE (MAAS)

Working as a facet of sharing economy, which is based on borrowing or renting goods and services, the concept of shared mobility emerges, enabling efficiency, cost savings, monetization of underutilized resources and both social and environmental improvements. It provides a reduction in the number of private vehicles on the network, since it consists of the shared use of bicycles, motorized vehicles, or other low-speed transportation mode, and has the power to enhance transportation accessibility and to increase multimodal mobility (Shaheen, *et al.*, 2016).

To this date, the intelligent, or smart, transport idea covers different approaches, such as Mobility as a Service (MaaS); services based on real-time data based on both user-centered and user-gerenated information; the development of an infrastructure that connects vehicles and that also uses real-time information to optimize the whole transportation system by influencing human behaviour; the electrification of the fleet and a more well thought energy distribution grid, aiming carbon neutrality for this sector; and the use of automated vehicles, which could lead to trips where all the occupants of the vehicle could carry out other activities while in transit (Docherty, *et al.*, 2018).

It is expected that the digitalization wave that hit several industries and transformed services of different sectors in the past years might get to the way people commute into and from the cities more intensively in a near future. These new technologies, along with the growing mobility problems, allow the user to take a more active role in the transport system (Hietanen, 2014).

The term Mobility as a Service (MaaS) refers to the possibility of users of mobility services to improve accessibility and reduce congestion and transport emissions, by enabling users to access different types of mobility services, like planning, booking and paying, through a singular digital platform also based on real time information. The innovative content of this concept may lead to sustainability gains due to its multimodal and shared-use nature (Sarasini, *et al.*, 2017).

MaaS induces a change in the mobility paradigm, introducing the "using instead of owning", where the traveller's needs and travel demands are met by the available mobility solutions, making the necessity to own a mean of transport no longer exist, since it is derived from the need to get to several places. This is achieved by providing to the user a platform that shows the options available by both public and private transportation providers (Schikofsky, *et al.*, 2020).

2.3. ECOLOGICAL AWARENESS AND TRANSPORT MODAL CHOICES

At the beginning of the century, a study from London's Department for Transport showed that, at the time, road users did not have much consciousness of transportation impact on the environment. This issue was only addressed when prompted, with users electing cars as the main contributor to negative environmental impact, due to air pollution, fuel emissions and congestion (Anable, *et al.*, 2006).

Around the same time, another study also conducted in London indicated that, even though people were aware of the climate changes and other environmental issues, this knowledge did not have much influence on the process of acquiring a private vehicle. For that public, despite the concerns about fuel economy before the acquisition of the car, the closer they got to the actual purchase, the less importance this factor would have on the final decision (Anable, *et al.*, 2006).

Later, another study gathered information on what could motivate an individual to change their behaviour. One of the theories infers that one's personal norms, as in their moral obligations, influence on how they act when facing the negative consequences of car-use, for instance, and the feeling of responsibility to reduce these impacts. This value-belief-norm (VBN) theory assumes that the change in one's behaviour is induced by how aware they are of the consequences of their actions (Gärling, Schuitema, 2007).

More recently, a study from 2018 attempted to relate the ecological mindset of Luxembourg's commuters and the choice between car and train when making their journeys. Using different methods than the ones intended in this dissertation, the results indicated a poor relation between an individual's environmental beliefs and having a pro-environmental attitude towards choosing their transport modes. At a second stage, it was concluded that, even though people are aware of the benefits of commuting by train, it was not enough to make them change from traveling in their own vehicle (Gerber, *et al.*, 2018).

3
DATA AND METHODOLOGICAL APPROACH

3.1. DATA CHARACTERIZATION

The survey was carried out online by Fraunhofer IAO within the EIT Urban Mobility Business plan 2020 project *MaaS_together* with citizens of four European countries. Two of them, the United Kingdom and Germany, considered well established in the field of multimodal and seamless mobility, and the other two, Czech and Poland, identified by the project as growing markets (MATOWICKI *et al.*, 2022). The data collected was made available for the development of the present study and consists of around 7700 respondents spread across these countries, and a simple process to make the data set more suitable to the analysis intended, with the selection of the questions, was applied.

The survey had some differences depending on which country it was being conducted, particularly with what regards educational level, salary level and currency and prices. These differences were not in terms of questions, but regarding the possible answers. The questionnaire consisted initially of five blocks of questions, plus introduction and conclusion, totalizing 99 questions. For this study, the data received had already been treated (not all the questions were presented) but still had some more treating left to be done.

The questions used in the development of this study came from this pre-treated dataset and were chosen either because had some relation with the environmental concern of an individual or was valid to characterize the person.

From the questions regarding the demographic characteristics, only four were included as variables on the analysis, while the others were used after the cluster analysis to characterize the individuals in each cluster. Those chosen as variables were about the age of the respondent, as an integer; the household size, ranked from 1 to more than 5 people; and education level and professional situation.

To standardize the answers for the question regarding education level and enable the analysis with all the data at once, the items were grouped resulting in only four possible values, not mattering the country of the respondent. Namely: 0 – not applied or not schooled; 1 – until secondary level; 2 – professional/technical courses; 3 – licentiate, bachelor’s and master’s degree; and 4 – doctorate or higher degree.

The other question that had the answers grouped, but this time to simplify the analysis once it was understood that there would be no negative impact on doing so was the one about the respondent’s employment status. At first there were eight options, but they were also reduced to four: 1 – unemployed; 2 – student; 3 – employed; and 4 – senior executive.

Concerning the commute related, the questions chosen were about the average travel time per route (AvgCommutingTime), the average travel distance per route (AvgCommutingDistance), and one about the frequency of use of different modes of transport, in which each mode was used as a variable. The variables used and values assumed by each one of them were as following:

- AvgCommutingTime: 1 – less than 5 minutes, 2 – 5 to 9 minutes, 3 – 10 to 19 minutes, 4 – 20 to 29 minutes, 5 – 30 to 44 minutes, 6 – 45 to 60 minutes, and 7 – More than 60 minutes.
- AvgCommutingDistance: 1 – less than 3 miles (~5 km), 2 – 3 to 6 miles (~5 to 10 km), 3 – 6 to 15 miles (~10 to 24 km), and 4 – More than 15 miles (~48 km).
- Use_Private_Car, Use_Car_Sharing (carsharing or rental car), Use_Taxis (taxicab or other mobility service provider), Use_Bus (bus and streetcar), Use_Subway (subway or city train), Use_Train (local train or long distance train), Use_EScooter (electric scooter or e-kick-scooter), Use_Shared (shared on-demand-shuttles, such as ride-pooling or ride-hailing systems), Use_Foot_Bike (on foot, bike or other means of transport): 45 – several times per day, 22 – at least once a day, 11 several times per week, 4 – at least once a week, 3 - several times per month, 1 – once a month, and 0 – rather than that.

And for the last set of questions, related to how users perceive ecological issues and its link with daily life mobility. On these questions the respondents had to state how much they agreed or disagreed with some statements, and, assuming values from 1 (strongly disagree) to 5 (strongly agree), the following were chosen to be used as variables:

- Collaborative_consumption_save_natural_resources: Collaborative consumption helps save natural resources.
- Collaborative_consumption_environmentally_friendly: Collaborative consumption is environmentally friendly.
- New_technologies_solve_fossil_energies_shortage: New technologies will solve fossil energies shortage
- Collaborative_consumption_sustainability: Collaborative consumption is a sustainable mode of consumption.
- Reduce_GHG: When travelling, I try to reduce my GHG (greenhouse gas emissions).
- Safeguard_more_important_environment_and_energy_consumption: Safeguard my lifestyle is more important than environment and energy consumption.
- MaaS_helps_save_natural_resources: Using Mobility-as-a-Service helps save natural resources.
- MaaS_ecological: Using Mobility-as-a-Service is ecological.
- MaaS_environmentally_friendly: Using Mobility-as-a-Service is environmentally friendly.
- Collaborative_consumption_ecological: Collaborative consumption is ecological.
- Collaborative_consumption_efficient_energy: Collaborative consumption is efficient in terms of using energy.
- Increase_energy_consumption_overstated_issue: Increase of energy consumption is an overstated issue.

In addition to the questions used as variables, others contained in the questionnaire served for the subsequent characterization of each cluster, to understand the profile of the individuals in each one of these groups, and to the proposition of the multinomial logistic regressions. An extract of the questions used from the English version of the questionnaire can be found on the Annex at the end of this document.

It is also important to mention that the survey was carried out during ten days in October 2020, in which the world was still facing the consequences of the pandemic situation caused by Covid-19, what may have had impact on the respondents' choices.

3.2. STUDY AREA CHARACTERIZATION

As mentioned before, the survey was conducted in four different countries. In this section it is intended to give an overview of each country in terms of population sizes and mobility services, giving examples of typical places that represent said category within each country.

For describing the territory sizes, the same categories used on the questionnaire will be followed here. Which are, by population: A3 – town with 80 000 to 99 999 inhabitants; A4 – city with 100 000 to 299 999 inhabitants; A5 – large city with 300 000 to 999 999 inhabitants; A6 – megacity with 1 000 000 to 3 000 000 inhabitants; and A7 – Metropolis with more than 3 000 000 inhabitants. The categories A1 (village with less than 10 000 inhabitants) and A2 (small town with 10 000 to 79 999 inhabitants) had no respondents and, therefore, will also not be covered in this section.

3.2.1. United Kingdom (UK)

According to data collected from the 2021 Census, the most recent one in the United Kingdom, the Table 1 shows cities that fit in each of the categories for territory size exposed on item 3.2 (Brinkhoff, 2024c).

Table 1 - Cities by population size in the UK. Source: elaborated by author.

Category	Examples
A3 (80 000 – 99 999 inhabitants)	Bath, Chester, Preston
A4 (100 000 – 299 999 inhabitants)	Cambridge, Nottingham, Oxford
A5 (300 000 – 999 999 inhabitants)	Belfast, Glasgow, Manchester
A6 (1 000 000 – 3 000 000 inhabitants)	Birmingham
A7 (+ 3 000 000 inhabitants)	London

In the United Kingdom, of the 1920 answers, 32,76% said they reside in a town of type A3; 27,19% in a city on the category A4; 21,67% in a larger city A5; 5,21% in a megacity A6; and the other 13,18% in a metropolis A7.

A report published in 2023 by the British Department for Transport (DfT) shows that, on a typical weekday, more than 1,5 million passengers arrive at England and Wales major cities using the rail system. From that total, 997 thousand passengers had London as their destination, while Birmingham, that occupies the second place in terms of arrivals, had about 1/9 of that value, with 108 thousand. For Manchester, the number of arrivals on a day was around 77 thousand, or almost 1/13 of the one registered in London (Department for Transport, 2023).

The same report points out that it is estimated that, as of 2019 to 2020, annual passenger rail journeys almost doubled when compared to the previous 20 years. After that, due to the impacts of the coronavirus pandemic the number fell 77% in 2020 to 2021 but faced a recovery in the year 2022 to 2023, getting close to the number of rail journeys experienced before the pandemic.

Other than the commuter trains that are present in cities from all the categories presented before, the UK also has several examples of urban rail transit systems, such as London Underground and Glasgow Subway, and tramways and light rail systems, such as Nottingham Express Transit and Manchester's Metrolink.

Concerning public transport, the other main mean of transportation is the bus. They are in all the cities mentioned before, as well as the smaller ones that fall into category A3, and the UK has examples of different ways it can be presented, such as guided bus systems, bus rapid transit (BRT), other segregated busways, bus lanes, and bus priority schemes.

3.2.2. Germany (DE)

In Germany, the data was collected from the most recent Census of 2022, the Table 2 shows cities that fit in each of the categories for population size exposed on item 3.2 (Brinkhoff, 2024b).

Table 2 - Cities by population size in Germany. Source: elaborated by author.

Category	Examples
A3 (80 000 – 99 999 inhabitants)	Gießen, Ludwigsburg, Witten
A4 (100 000 – 299 999 inhabitants)	Freiburg, Rostock, Würzburg
A5 (300 000 – 999 999 inhabitants)	Dortmund, Dusseldorf, Frankfurt
A6 (1 000 000 – 3 000 000 inhabitants)	Cologne, Hamburg, Munich
A7 (+ 3 000 000 inhabitants)	Berlin

Amongst the German responses, out of the 1923 answers, 16,17% said they reside in a town of type A3; 27,98% in a city on the category A4; 28,24% in a larger city A5; 13,99% in a megacity A6; and the other 13,62% in a metropolis A7. A bit more balanced, when compared to the British portion.

As it happens in the UK, the most populated city in Germany, Berlin, is also served by an underground system (U-Bahn). The metropolis also counts with services of the German commuter rail system, the S-Bahn, buses and tram and metrotram systems, as well as electric scooters, bicycles and car sharing stations (State of Berlin, 2024).

Germany's U-Bahn is also present in Hamburg, Munich and Nuremberg, while the S-Bahn reaches other 10 zones, totalizing 14 covered areas that include cities from all the categories shown on Table 2. To conclude with the rail systems, some of the cities with over 300 000 inhabitants are also served by light rail or tram systems.

On what comes to bus systems, they are the most important mode of transportation in many German cities and towns, due to its range, both regarding territory and times of service (IamExpat Media B.V., 2024).

3.2.3. Czechia (CZ)

In what concerns Czechia, the data was collected from the 2021 Census, the Table 3 shows cities that fit in each of the categories for population size exposed on item 3.2 (Brinkhoff, 2024a).

For the Czech respondents, of the 1876 answers, 18,92% said they reside in a town of type A3; 20,95% in a city on the category A4; 20,47% in a larger city A5; 32,14% in a megacity A6; and the other 7,52% in a metropolis A7. Interestingly, according to the 2021 Census, the largest city in Czechia is Prague, with 1,3 million inhabitants, which means that it is likely that the last group of people considered not the city itself but the region consisting of the city of Prague and the Central Bohemian Region, resulting in around 3 million inhabitants.

Table 3 - Cities by population size in Czechia. Source: elaborated by author.

Category	Examples
A3 (80 000 – 99 999 inhabitants)	Budweis, Hradec Králové
A4 (100 000 – 299 999 inhabitants)	Liberec, Olomouc, Ostrava, Pilsen
A5 (300 000 – 999 999 inhabitants)	Brno
A6 (1 000 000 – 3 000 000 inhabitants)	Prague
A7 (+ 3 000 000 inhabitants)	-

Among Czech cities, Prague is the only one that counts with a subway system, with three lines serving the city. Other than that, public transportation in the capital also includes several bus services, tramways and trolleybuses (Prague Public Transit Company, 2024).

The second half of the 20th century had a high impact on how the transport systems developed in Czechia (at the time, Czechoslovakia), with the establishment of trolleybus networks in many cities. That said, basically all the cities with more than 100 thousand inhabitants have a combined tramway-trolleybus system, with integration with the other modes, such as bus transport services and in some cases the national rail service (Fitzová, Markéta, 2020).

Moreover, Czechia had one of the highest densities of railway lines among the European Union Member States, along with Germany and Luxembourg according to data from 2020 (Eurostat, 2022).

3.2.4. Poland (PL)

The most recent Census in Poland is also from 2021, and the Table 4 is based on data from this source to show cities that fit in each of the categories for population size exposed on item 3.2 (Brinkhoff, 2024d).

Table 4 - Cities by population size in Poland. Source: elaborated by author.

Category	Examples
A3 (80 000 – 99 999 inhabitants)	Kalisz, Legnica, Słupsk
A4 (100 000 – 299 999 inhabitants)	Białystok, Koszalin, Płock
A5 (300 000 – 999 999 inhabitants)	Krakow, Lodz, Wroclaw
A6 (1 000 000 – 3 000 000 inhabitants)	Warsaw
A7 (+ 3 000 000 inhabitants)	-

In Poland, from the 1998 answers, 11,06% said they reside in a town of type A3; 31,93% in a city on the category A4; 39,24% in a larger city A5; 11,81% in a megacity A6; and the other 5,96% in a metropolis A7. Just like in Czechia, according to the 2021 Census, the largest city in Poland is Warsaw, with almost 1,9 million inhabitants, which means that it is likely that the last group of people considered the Warsaw Metropolitan Area (WMA), that in 2022 was inhabited by more than 3,3 million people (Dudek-Mańkowska , *et al.*, 2024).

Polish transport systems follow the pattern existent in Czechia, especially in Warsaw's Metropolitan Area. The municipalities that compose the WMA act together to provide, among other things, good public transport services, with metro lines, tramways, railways, and buses (Zarząd Transportu Miejskiego, 2024).

3.2.5. Overview

That said, the next step was to try to understand how the residence type and, consequently, their options available in terms of transportation means, impact the modal choice. Fig. 1 displays the results of this analysis.

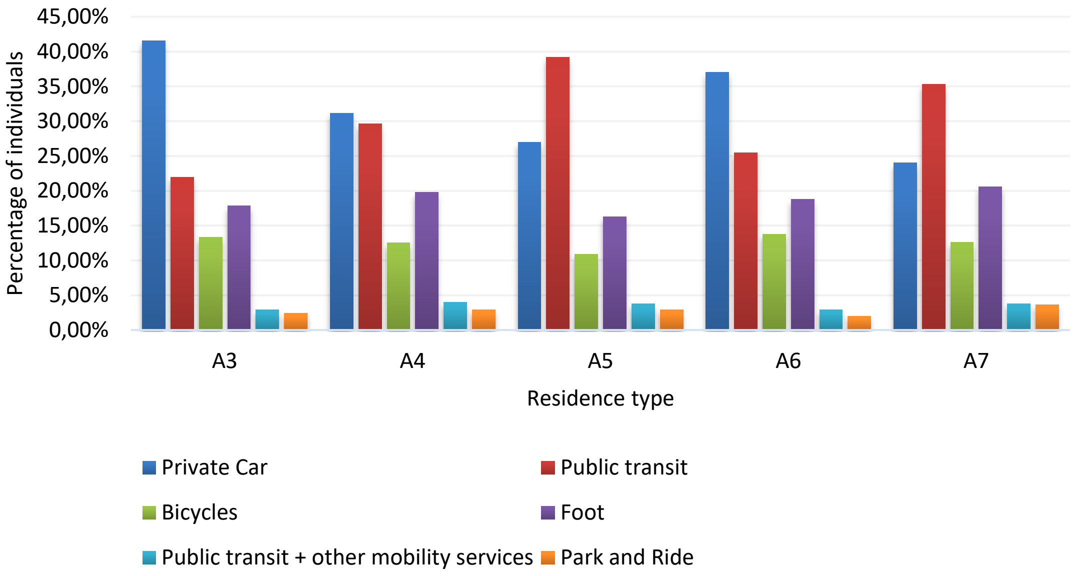

Fig. 1 - Transport modal distribution by residence type. Source: elaborated by author with data from Fraunhofer IAO 2021.

From this graph, it is notable that the size of the city impacts essentially on the preference for private car or public transportation, since the other means of transportation assume similar values and distributions. Looking back to what was mentioned in this chapter, the preference for public transit in cities with more than 3 million inhabitants (A7) is justified by the measures encouraging this modal, such as good coverage and offer, a reliable system, and the discourage of the use of individual transport in the city centres.

It can also be inferred, by looking at Fig. 1 that large cities with around 300 000 to 999 999 inhabitants (A5) present a behaviour that mirrors what happens in the great metropolis (A7), while the medium towns (A3) and the megacities (A6) are very similar between themselves. As of the cities with 100 000 to 299 999 inhabitants (A4), the percentual difference between choosing to use private car and public transport is around only 1%, which is irrelevant when compared to the other categories.

3.3. METHODOLOGICAL APPROACH

With the variables defined and having an overview of the transport conditions on the four countries where the survey was carried on, this section will present the steps that will lead to the results presented on the next chapter.

Aiming to identify the presence of any relationship between the modal choice and the ecological awareness of an individual, it was decided to begin with a cluster analysis of the data set. This analysis consists of an exploratory technique that allows to identify groups of individuals, in this case, that are similar to each other but different from those in other groups (Laudau, Chis Ster, 2010).

The software chosen to assist with all the analyses was IBM’s SPSS Statistical, which allows, when it comes to cluster analysis, to proceed with the hierarchical cluster analysis, k-means cluster, and two-step cluster, with the last one not being used on this work.

In cluster analysis there is no pre-classification, that is, it is not known which groups exist. Therefore, the data is grouped according to their similarities or distances and following one of the established clustering algorithms. On the development of the present work, the hierarchical cluster analysis, that creates a tree of clusters, with each observation starting in its own cluster and being grouped successively, followed the nearest neighbour algorithm, where the similarity between clusters is the shortest distance between any object in one cluster and any object in the other cluster. To calculate this distance, since all the variables used were continuous, the squared Euclidian distance was chosen.

The k-means method, on the other hand, starts from a pre-defined number of clusters (k), in this case defined by the hierarchical cluster analysis of a smaller sample, and adjusts the elements to the clusters, understanding the similarities between the groups. Thus, cluster analysis reveals patterns and trends in a data set, ensuring a division based on specific characteristics and helping decision-making based on clusters.

Following the methodology proposed, the Principal Component Analysis (PCA) aims to reduce the dimensionality of a data set by transforming the original variables into a new set of variables called principal components, that is, express a given set of data with other variables by identifying the most meaningful basis (Kurita, 2020). This way, a data set is simplified, eliminating redundancies, and preserving information. Reduce this data set using PCA allows to facilitate the visualization and interpretation of the data in other analyses. These components are linear combinations of the original variables and are organized so that the first principal component captures most of the variation present in the data, the second component captures most of the residual variation, and so on.

This analysis begins with standardizing the variables to have zero mean and unit variance. Then, both covariance and correlation matrixes are constructed, identifying how the variables relate to each other. At this stage, eigenvalues are identified, which show the amount of variance that each principal component captures, and eigenvectors represent the direction of the principal components. Finally, PCA orders the principal components based on the captured variance and the original variables are projected onto these new axes.

To finish the analytical part, it was chosen to perform several Multinomial Logistic Regression analyses, which studies the association between a categorical dependent variable – in this case, the number of the cluster and later the mode of transport – and a set of independent and explanatory variables – here only one, the first principal component of the previous analysis (Meloun, Militký, 2011).

4
RESULTS

4.1. CLUSTER ANALYSIS

After the selection of the questions and subsequently treatment of the data, already mentioned on the item 3.1, it was possible to follow to the cluster analysis. Since the sample was quite large, the first step was to select a random, smaller sample with 150 cases, which represents around 2% of the cases on the original data, making it possible to run the hierarchical clustering method.

The reason behind this process is to reduce the number of interactions to define the number of clusters for the next steps. The smaller sample was determined by randomly selecting 150 numbers between 1 and 7717 on Microsoft's Excel and extracting all the data needed from the original data set. After that, IBM's SPSS Statistical was used to run the hierarchical cluster analysis, with it providing the dendrogram helps choosing the numbers of clusters.

Part of the dendrogram, exhibited in Fig. 2, shows the number of clusters used on the next step, which consists, in this case, in saving the results for 5 to 14 clusters and running the ANOVA test for each one of them.

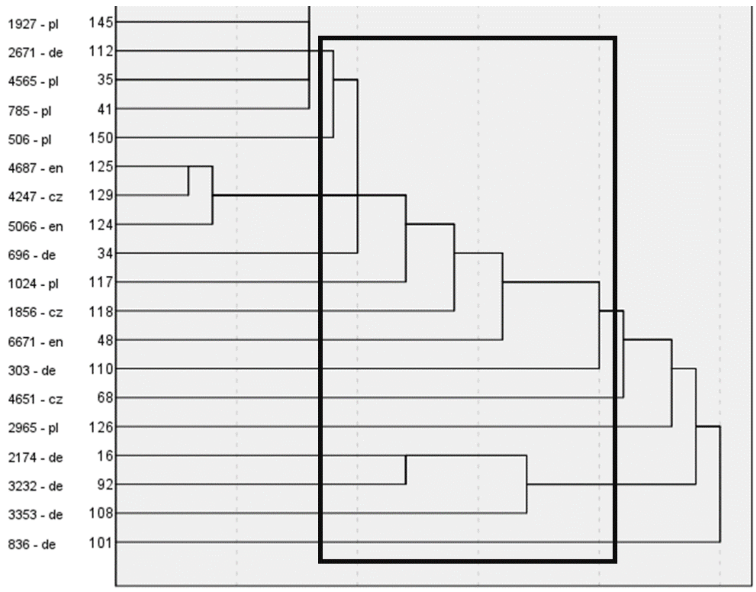

Fig. 2 - Part of the dendrogram for the smaller random sample. Source: elaborated by author with data from Fraunhofer IAO 2021.

From the ANOVA test results, it is possible to plot a graph where the number of clusters is on the horizontal axis, and the value for R^2 (1) is on the vertical axis.

$$R^2 = \frac{\sum R^2{}_{between\ groups}}{\sum R^2{}_{Total}} \tag{1}$$

The criteria to determine the number of clusters was the value that was preceded by a stabilization of the R^2 and succeed by a sudden change in the same indicator. The Fig. 3 below indicates the result of this procedure, with 7 clusters being chosen to continue with the analysis.

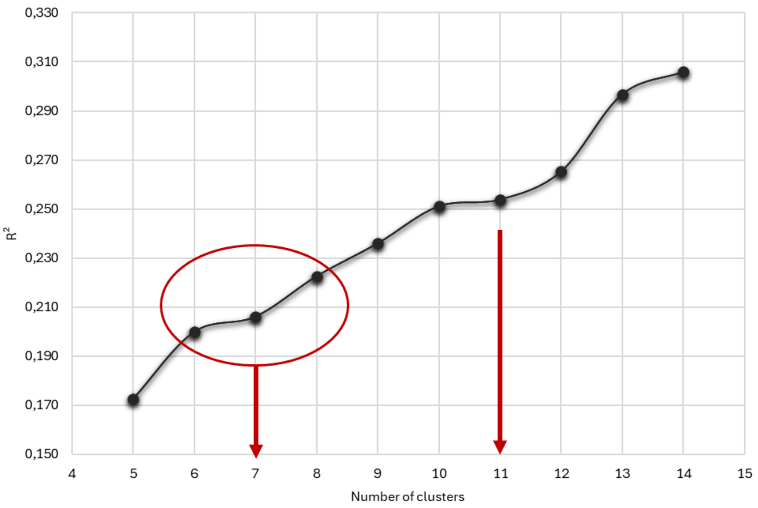

Fig. 3 - R^2 graph to determine the number of clusters. Source: elaborated by author with data from Fraunhofer IAO 2021.

With the number of clusters defined, it was possible to go back to the larger data set and run the k-means cluster analysis for 7 clusters. The results, depicted on Table 5, show the final cluster centres, or the mean value for each variable in each cluster, for the variables selected in the beginning of the process, as well as how far from the global mean each variable is in each cluster. Greener cells represent values above the average, while redder cells indicate values below the average, with whiter cells surrounding the average.

It is important to mention that, in the beginning, only the variables used for the cluster analysis were considered when trying to understand the behaviour of each group, other variables will be discussed later. With this approach, some of the clusters were not easily characterized, but this helped on giving an overview of the data set.

Table 5 - Final cluster centres. Source: elaborated by author with data from Fraunhofer IAO 2021.

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Demographic							
Age	34,35	39,68	35,97	41,14	40,29	29,72	32,12
HouseholdSize	2,58	2,38	2,40	2,58	2,87	2,87	3,21
Education	2,23	2,04	2,10	2,16	2,22	2,36	2,39
Profession	2,74	2,85	2,75	2,81	2,98	2,94	2,97

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Commute related							
AvgCommutingTime	2,98	3,53	3,72	2,95	2,91	3,10	3,26
AvgCommutingDistance	2,18	2,52	2,54	2,51	2,86	2,79	2,97
Use_Private_Car	6,45	4,89	5,85	12,38	45,00	30,35	41,91
Use_Car_Sharing	0,63	0,64	0,67	0,94	1,32	18,47	35,16
Use_Taxis	1,07	1,01	1,32	1,21	1,43	15,03	35,95
Use_Bus	8,82	38,73	42,16	5,38	3,20	16,42	37,23
Use_Subway	4,54	15,15	21,60	2,66	1,76	17,20	39,31
Use_Train	2,83	3,05	5,12	1,32	1,04	14,51	36,84
Use_EScooter	1,03	0,64	1,21	0,73	0,73	13,05	37,78
Use_Shared	0,58	0,54	0,62	0,69	0,51	13,35	36,42
Use_Foot_Bike	37,73	8,57	43,98	8,04	12,09	16,64	36,21
Ecollogical perception							
Collaborative_consumption_ save_natural_resources	3,89	3,78	3,99	3,76	3,87	3,97	4,61
Collaborative_consumption_ environmentally_friendly	4,21	4,29	4,40	4,21	4,29	3,97	4,55
New_technologies_solve_fossil _energies_shortage	3,59	3,59	3,67	3,54	3,74	3,91	4,58
Collaborative_consumption_ sustainability	3,75	3,60	3,83	3,62	3,73	3,96	4,65
Reduce_GHG	3,54	3,38	3,47	3,35	3,49	3,92	4,56
Safeguard_more_important_ environment_and_energy_ consumption	2,93	2,91	2,93	3,10	3,33	3,80	4,55
MaaS_helps_save_natural_ resources	3,69	3,60	3,80	3,64	3,73	3,95	4,40
MaaS_ecological	3,71	3,61	3,79	3,62	3,75	3,89	4,39
MaaS_environmentally_friendly	3,72	3,65	3,79	3,66	3,78	3,85	4,38
Collaborative_consumption_ ecological	3,84	3,75	3,90	3,71	3,83	3,88	4,49
Collaborative_consumption_ efficient_energy	3,82	3,67	3,87	3,67	3,79	3,91	4,49
Increase_energy_consumption _overstated_issue	2,57	2,76	2,71	2,68	3,01	3,72	4,40
Percentage of cases	15,8%	9,3%	7,6%	38,2%	21,7%	5,5%	2,0%

As shown on Table 5 above, cluster 7, despite being the smallest one, clearly stood out from the others. The group is composed of individuals with characteristics well above the average for all the variables, except for the age, representing the second youngest group. The variables regarding their ecological awareness indicate that this group is more inclined to take this factor into consideration when making choices. The ones that indicate the frequency of use of each mode of transport assume similar values, which may be a reflex of both their position towards the environment and the size of their household.

Cluster 6 also has a more positive response regarding the ecological awareness. As can be seen above, this group is characterized by the youngest individuals and with educational and professional levels close to the following cluster. Despite the similarities on what comes to the demographic variables, this group appears to be a little less ecologically aware, which reflects on the value for the frequency of use of private car being considerably higher when compared to the other modes.

Going back to the first cluster, it is likely composed by individuals with a high frequency of use of active modes of transport, such as foot and bicycle, although this seems like a reflex of the smaller distances and travel times registered in this group, as well as the fact that they show the smallest average value for professional level. On what comes to the ecological awareness, most of the variables related to this topic assumed values around the global average, showing that this theme might not have influence on this group's preferences.

Clusters 2 and 3 indicate a great predominance on the use of buses, although the latter differs from the former essentially on what comes to the frequency of use of active modes of transport. When comparing both groups, they present similar values for modal choices, despite cluster 3 having longer travel times, pointing towards a greater ecological awareness, suggesting that this factor might be a determinant for them to choose greener means of transportation.

The remaining clusters can also be compared between themselves, since they seem to represent quite opposite (between groups) and conflicting (within the group) behaviours. While cluster 4 presents the lowest values on the variables that describe the ecological awareness, the modal choices does not seem to be made based on this factor, since none of them assume values higher than the global average. On the other hand, cluster 5, despite having opinions indicating that they are more eco-friendly than the former, the mode of transport with higher frequency of use is the private car, suggesting that this choice is more likely to be influenced by other factors in both groups.

After this overview, the composition of each cluster was analysed observing how other variables that were not used for the definition of the clusters due to their nature were distributed within them, such as gender, income, country of residence, and the other variables that characterize the common ways of commuting.

Firstly, the gender distribution in each cluster is overall balanced, as seen on Fig. 4. The biggest difference is observed on cluster 7, where the number of male individuals is clearly higher. However, it is not enough to affirm that the gender of the individuals is a variable that would have an impact on the cluster they are more likely to be on.

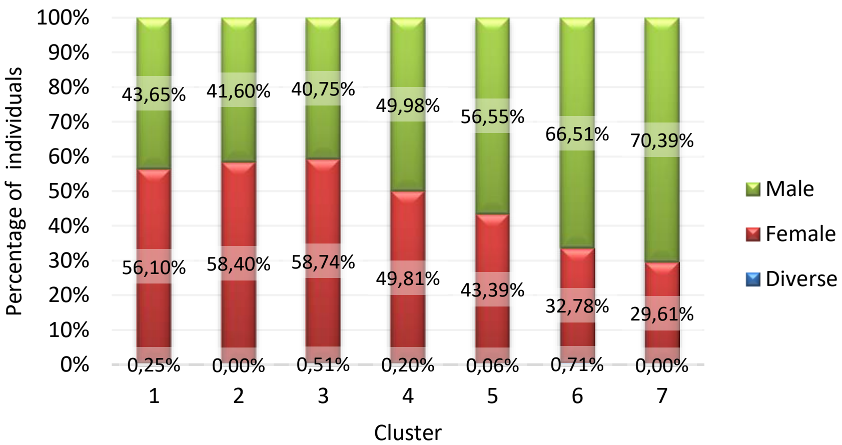

Fig. 4 - Gender distribution by cluster. Source: elaborated by author with data from Fraunhofer IAO 2021.

Other element that was contemplated when defining the clusters was the country of residence, which is shown on Fig. 5. Different from the previous characteristic, where the analysis was within cluster, the purpose here was to understand how the fact of an individual being a resident of each country would make them more likely to be a part of each cluster.

For example, people on cluster 7 – the one with individuals more inclined to be more ecologically aware –, are more distributed between Germany and the United Kingdom, which reinforces the assumption from the beginning of the data collection that they are countries well established in the field of multimodal and seamless mobility. Something similar happens to cluster 6, with the distribution between these two countries assuming values close to each other.

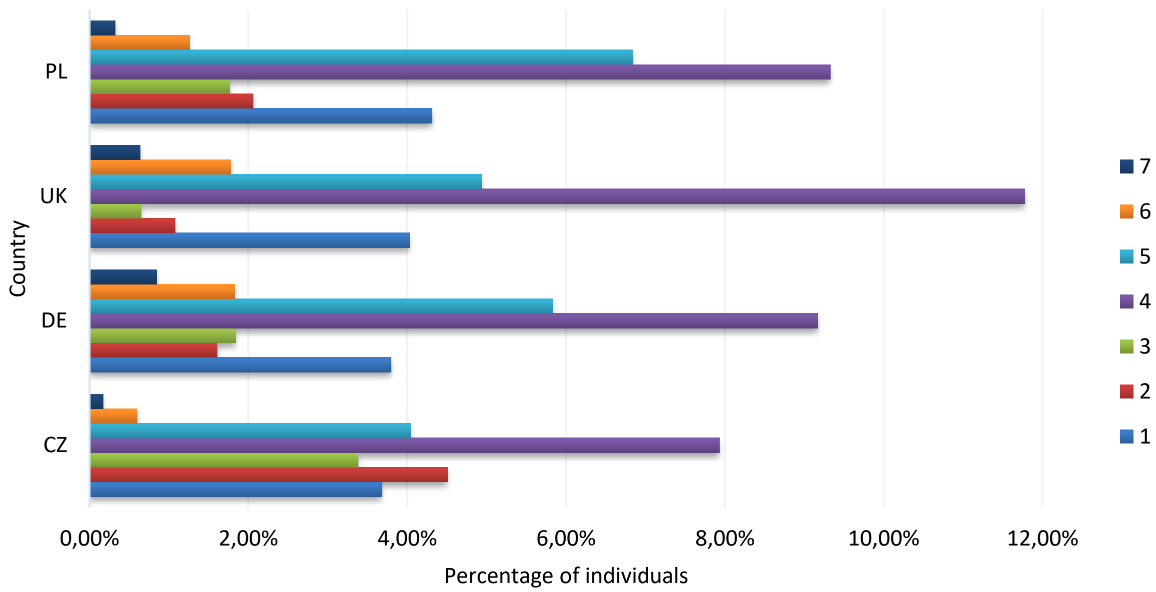

Fig. 5 - Percentage of individuals in each country by cluster. Source: elaborated by author with data from Fraunhofer IAO 2021.

Another idea reiterated by Fig. 5 is that clusters 4 and 5 are influenced by factors other than how eco-friendly are the individuals' ideals. These are the biggest clusters, so it is expected that they have bigger shares on all countries, but the idea is reinforced when regardless the country the shape of the distribution on both clusters remains the same.

For the next variable, the question related to it was which means of transportation the respondent use most of the time when commuting, with the possibility to select more than one mode. Because of that, the graph showed on Fig. 6 displays how each mean of transportation is distributed among the clusters.

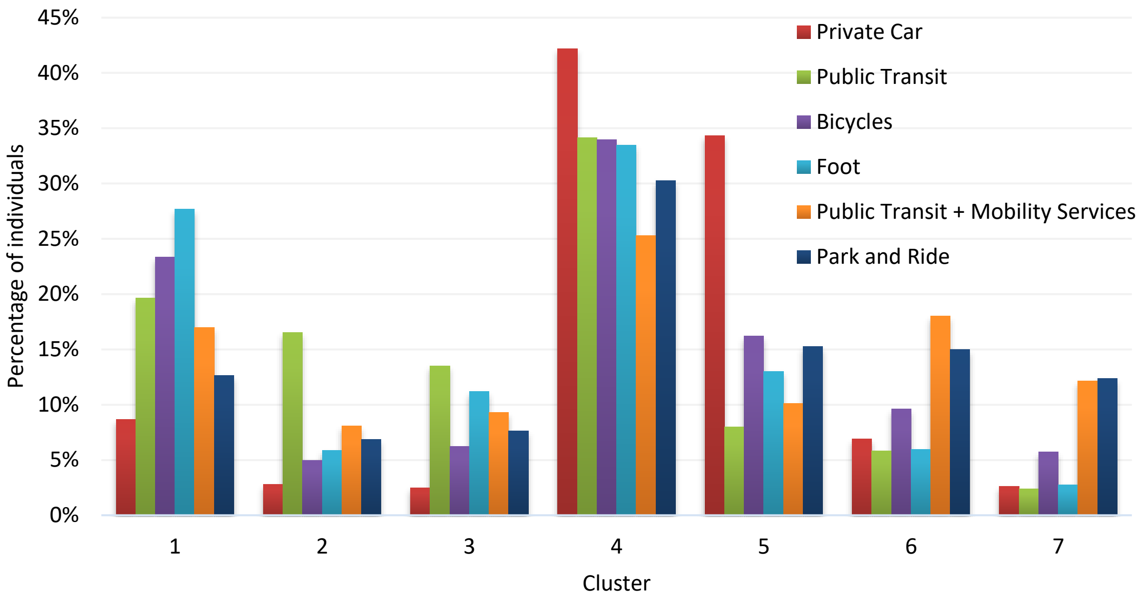

Fig. 6 - Distribution of means of transport by cluster. Source: elaborated by author with data from Fraunhofer IAO 2021.

The first point to catch the attention is how this distribution takes place in each cluster, which once again reiterates the analysis made with the final cluster centres' results. As discussed before, clusters 6 and 7 are the ones that indicate a higher ecological awareness and it is reflected in their transportation preferences, with shared means of transportation being the first choice in both cases. The shape of the distribution is also very similar, with bicycles being the third choice, private car the fourth, and public transport and traveling by foot sharing the fifth place.

It is also interesting to notice that only clusters 4 and 5, that were pointed out as groups where the modal choice was not influenced, at first, by one's ecological awareness, are the only with private car as first place, although they differ between themselves both on how close to this the other modes are and how they are distributed.

4.2. Principal components analysis and multinomial logistic regression

This section aims to present the results of the principal components analysis (PCA), ran in IBM's SPSS, which followed three different approaches. The first was to run the analysis with all the previously selected variables (questions) to each cluster and compare the results for the first component, to see if the ecological mindset was important in the definition of all the clusters. Later, a PCA was run with the same variables as before and only the first component was analysed, again to see if the environmental awareness would be the main definer of this component.

After that, the PCA was carried out with only the variables regarding the demographic characteristics and the two related to the context of the trips, average commuting time and average commuting distance, with the purpose of understanding the impact of the context of the trip on the modal choices. With the results for the first component in each of these PCAs, several multinomial regressions were tested, to try to understand the relation between them and the transport modal choice.

The first approach showed that the first four clusters were very similar regarding the first component of the PCA, as it seen on Table 6 below. For these clusters, the values of the factor loadings for the environmental variables were around the same, indicating an absence of heterogeneity on this subject, since the first principal component is mostly influenced by the variables related to the ecological awareness of the individual. For each cluster, the first principal component represents 18-20% of the total variance.

Table 6 - Factor loadings of the first components of PCA for each cluster ($PCA_{CLUSTER}$). Loadings <0,10 are shown as blank. Source: elaborated by author with data from Fraunhofer IAO 2021.

Variable	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
Age	-0,121	-0,146	-0,183	-0,106	-0,220	0,292	
HouseholdSize	0,129	0,105	0,147	0,189	0,185	0,291	
Education	0,253	0,122	0,162	0,210	0,210	0,175	
Profession						0,162	-0,103
AvgCommutingTime						0,253	-0,105
AvgCommutingDistance						0,139	
Use_Private_Car	0,140	0,140	0,163	0,103		0,278	0,376
Use_Car_Sharing		0,133	0,110				0,185
Use_Taxis		0,184	0,161		0,211	0,129	0,287
Use_Bus	0,139				0,169	0,286	0,347
Use_Subway					0,157	0,151	0,277
Use_Train			0,101		0,129	0,108	0,152
Use_EScooter			0,193		0,109	0,141	0,400
Use_Shared			0,173		0,138		0,235
Use_Foot_Bike				0,113	0,686	0,322	0,360
Collaborative_consumption_ save_natural_resources	0,711	0,713	0,704	0,729	0,317	0,596	0,630
Collaborative_consumption_ environmentally_friendly	0,368	0,374	0,341	0,369	0,567	0,581	0,565
New_technologies_solve_fossil _energies_shortage	0,489	0,490	0,595	0,539	0,695	0,610	0,616
Collaborative_consumption_ sustainability	0,709	0,763	0,737	0,722	0,569	0,588	0,561
Reduce_GHG	0,453	0,585	0,558	0,522	0,198	0,548	0,581
Safeguard_more_important_ environment_and_energy_ consumption					0,805	0,505	0,595
MaaS_helps_save_natural_ resources	0,807	0,808	0,794	0,802	0,802	0,624	0,511
MaaS_ecological	0,807	0,811	0,800	0,795	0,798	0,611	0,520
MaaS_environmentally_friendly	0,803	0,793	0,805	0,792	0,791	0,558	0,455
Collaborative_consumption_ ecological	0,778	0,812	0,773	0,783	0,783	0,599	0,617
Collaborative_consumption_ efficient_energy	0,747	0,806	0,759	0,784	0,194	0,610	0,607
Increase_energy_consumption _overstated_issue				-0,152		0,437	0,537

Other than that, Table 6 shows that the other clusters also had their first principal components highly influenced by the variables related to the ecological awareness. Since it was identified that it did not really matter the cluster in which the individual belonged, it was decided to follow to the second approach, running the PCA for the whole of the data set to see how it would behave.

The results for this second analysis can be found on Table 7 below, where the first principal component explains almost 21% of the total variance.

Table 7 - Factor loadings of the first components of PCA for the data set (PCA_{GLOBAL}). Source: elaborated by author with data from Fraunhofer IAO 2021.

Variable	Component 1
Age	-0,244
HouseholdSize	0,205
Education	0,202
Profession	0,070
AvgCommutingTime	0,112
AvgCommutingDistance	0,132
Use_Private_Car	0,215
Use_Car_Sharing	0,497
Use_Taxis	0,533
Use_Bus	0,244
Use_Subway	0,353
Use_Train	0,490
Use_EScooter	0,547
Use_Shared	0,536
Use_Foot_Bike	0,204
Collaborative_consumption_save_natural_resources	0,611
Collaborative_consumption_environmentally_friendly	0,261
New_technologies_solve_fossil_energies_shortage	0,534
Collaborative_consumption_sustainability	0,651
Reduce_GHG	0,538
Safeguard_more_important_environment_and_energy_consumption	0,240
MaaS_helps_save_natural_resources	0,683
MaaS_ecological	0,679
MaaS_environmentally_friendly	0,666
Collaborative_consumption_ecological	0,661
Collaborative_consumption_efficient_energy	0,664
Increase_energy_consumption_overstated_issue	0,229

With that new variable, explained to some extent by all the other variables, two different multinomial logistic regressions were performed. In both, the first principal component was introduced as the independent variable, while the dependent variable was changed in each case.

The first one, where the number of the cluster was the dependent variable, showed to be overall statistically significant and led to the results showed on Table 8, which has cluster 1 as the reference category.

Table 8 - Parameter coefficients for the multinomial logistic regression for clusters using PCA_{GLOBAL}. Source: elaborated by author with data from Fraunhofer IAO 2021.

Cluster case number		B	Error	Wald	df	Sig.	Exp(B)
2	Intercept	-0,544	0,048	130,588	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	-0,069	0,058	1,386	1	0,239	0,934
3	Intercept	-0,762	0,052	218,212	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	0,496	0,065	59,057	1	0,000	1,642
4	Intercept	0,824	0,035	560,523	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	-0,306	0,042	52,114	1	0,000	0,737
5	Intercept	0,319	0,038	71,053	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	0,076	0,047	2,613	1	0,106	1,079
6	Intercept	-2,181	0,100	477,699	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	2,077	0,091	526,522	1	0,000	7,979
7	Intercept	-12,490	1,058	139,389	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	6,125	0,430	203,323	1	0,000	457,135

To reinforce what has already been said, despite clusters 2 and 5 not having statistically significant results (Sig. < 0,05), the regression's parameters showed that clusters 2 and 4 are inversely related to clusters 1's behaviour, when using the first principal component mostly characterized by the ecological mindset as the independent variable. Also, as expected from the cluster analysis, clusters 3, 6 and 7 are directly related, with cluster 7 presenting the highest value for Exp(B), the ratio-change in the odds of the event of interest changing the predictor in one unit.

Later, the variable used as dependent was the modal choice, where 1 was private car; 2 was public transport; 3 was active modes, such as bicycle and by foot; and 4 was the combination of modes, both public transport and other mobility services, such as bike-sharing and scooter-sharing, and private car and public transport, also known as park and ride. The private car was the reference category this time, and the results were as shown on Table 9.

Table 9 - Parameter coefficients for the multinomial logistic regression for transport mode using PCA_{GLOBAL}. Source: elaborated by author with data from Fraunhofer IAO 2021.

Transport Mode		B	Error	Wald	df	Sig.	Exp(B)
2 (public transport)	Intercept	-0,484	0,035	185,985	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	0,078	0,038	4,191	1	0,041	1,081
3 (active mode)	Intercept	-1,786	0,059	922,664	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	-0,132	0,061	4,688	1	0,030	0,876
4 (combination)	Intercept	0,578	0,027	442,863	1	0,000	
	REGR factor score 1 for PCA_{GLOBAL}	0,436	0,030	214,178	1	0,000	1,546

This regression was also statistically significant, and the parameters displayed in Table 9 show that, when compared to those who use only private car in their daily trips, those who chose an active mode are the ones with a behaviour contrary to the reference category. Despite that, once again the values for the parameters analysed before, B and Exp(B), do not indicate a strong difference between the users who choose public transport and active mode, when compared to those who decide to use more than one mode of transport on their daily trips.

It is important to point out that the negative values of the parameters for the active mode were, at first, strange, since it is expected that the more one person is engaged with environmental issues and is aware of them, the more they will be likely to use transports that are more sustainable. However, the reference category is the private car, and as such the results imply a substitution of one mode by the other, which in this case could be more influenced by the length of the trips than other factors.

Therefore, the last PCA was undertaken with the so-called context variables, which are the demographic ones (age, household size, educational level and professional situation) along with the other two that describe the context of the trip (average commuting time and average commuting distance).

For this analysis, the first principal component explained about 27,5% of the total variance, and the factor loadings can be found on Table 10.

Table 10 - Factor loadings of the first components of PCA for the context variables ($PCA_{CONTEXT}$). Loadings <0,10 are shown as blank. Source: elaborated by author with data from Fraunhofer IAO 2021.

Variable	Component 1
Age	
HouseholdSize	0,191
Education	0,248
Profession	0,303
AvgCommutingTime	0,838
AvgCommutingDistance	0,867

These values indicate that, among the variables that characterize the context of the trip, the distance and the time taken to undertake a trip are the ones with the most impact when reducing it to only one variable.

With this last PCA, another multinomial logistic regression was conducted, with this as the independent variable and, once again, with the modal choice as the dependent variable and the private car as the reference category. The parameters obtained are displayed on Table 11.

Table 11 - Parameter coefficients for the multinomial logistic regression for transport mode using $PCA_{CONTEXT}$. Source: elaborated by author with data from Fraunhofer IAO 2021.

Transport Mode		B	Error	Wald	df	Sig.	Exp(B)
2 (public transport)	Intercept	-0,498	0,035	203,099	1	0,000	
	REGR factor score 1 for $PCA_{CONTEXT}$	0,015	0,035	0,171	1	0,679	1,015
3 (active mode)	Intercept	-2,041	0,069	863,193	1	0,000	
	REGR factor score 1 for $PCA_{CONTEXT}$	-0,847	0,064	175,425	1	0,000	0,429
4 (combination)	Intercept	0,573	0,027	454,341	1	0,000	
	REGR factor score 1 for $PCA_{CONTEXT}$	-0,026	0,027	0,952	1	0,329	0,974

The coefficients presented on Table 11 show that the results for both the choice of public transport and a combination of modes of transport are not statistically significant, indicating that the choice of these two modes is not influenced by the duration or the length of commuting. On the other hand, as initially thought, the longer the distance or the travel time, the less likely the individual is to change from private car to an active mode.

5
DISCUSSION

In this section it is intended to discuss the results based on all the analysis presented along this chapter, establishing a relation between all of them and indicating final thoughts. It is also intended to present how the clusters with less use of intelligent and sustainable mobility can change their behaviour, according to the PCA’s and regression’s results.

The cluster analysis indicates a relationship between being more inclined towards the environmental issues and a more intelligent modal choice, such as the option to frequently use more than one mode of transport on daily trips. Furthermore, the data analysis suggests that a city's transport offer is also relevant in this choice, that is, even if some individuals have a considered high level of environmental awareness, the conditions of the environment in which they are inserted also have its importance.

The relationship between a more intelligent modal choice and the degree of ecological awareness becomes visible mainly when observing individuals from clusters 6 and 7, who present values closer to the maximum in the third group of variables presented, as well as a high frequency of use of the different modes of transportation, which is even more visible for those that are part of cluster 7. Furthermore, 75% of the individuals of these groups reside either in Germany or the United Kingdom, where smart and seamless mobility is developed and well established.

Regarding the composition of the first cluster, it is not possible to confirm that the environmental factor is determining its modal choices, since the final cluster centres are close to the average value for the third set of variables, it presents the shortest travel distance when compared to the other groups (around 5 km), and the trips are more often carried out through active mobility, such as walking or cycling, suggesting a greater influence of other factors on the modal choice.

On the other hand, clusters 2 and 3 present almost antagonistic mindsets in terms of environmental awareness and differ from each other in the most frequent modal choices, corroborating with the assumption that the concern for the environment has the power to impact on the use of intelligent and more sustainable transport systems.

With this in mind, and moving on to the results of the PCAs, the first approach consisting of performing one PCA for each one of the clusters, showed that the first principal component was mainly related to environmental issues, regardless of the cluster. Given this, the decision taken was to run a new PCA, this time without cluster distinction and using all available data and the same variables used in the first analysis.

This second approach led to an interesting result that corroborates with the cluster analysis performed on the beginning of the data analysis. The PCA_{GLOBAL}, with the totality of the data set, indicated that the variables related to the ecological awareness have more impact on the composition of the first principal component and, therefore, can be used to analyse the individuals' characteristics and choices following a multinomial logistic regression, according to the methodological approach chosen.

The first regression indicated that, despite having outcomes not statistically significant for clusters 2 and 5, the result in general endorses what was inferred with the cluster analysis. When compared to cluster 1, the individuals belonging to the last cluster are around 450 times more likely to be ecologically aware, a result that differs greatly from the ones for the other clusters, and that indicates that cluster 7 is indeed the one with a more ecological mind.

With the characterization of the individuals being consolidated with both cluster analysis and the regression regarding the relationship between the ecological awareness, through the first principal component of the PCA_{GLOBAL}, and the group in which an individual is allocated, the following step was to relate this new variable with the modal choice of each person.

The data set utilised had two questions related to the modal choice. One was used on the analyses presented until this point and took into account the frequency of use of each mean of transportation, while the other considered the mostly used modal when commuting and was used on the regressions.

Although all the results were statistically significant this time, two of them were less trustworthy than the other. The only variable with the value of significance equal to zero was the use of a combination of means of transport, such as public transport and other mobility services (like scooter-sharing and bike-sharing) and private car and public transport, which also indicated that the more ecologically aware an individual is, based on the variable derived from the PCA_{GLOBAL}, the more likely they are to substitute the use of a private vehicle to combining public transit and other means of transportation.

As mentioned on the previous chapter, individuals more aware of the environmental issues were negatively inclined to change their mean of transportation from private car to an active mode, such as cycling or walking, which seems to be contradictory. The p-value obtained for this variable being lower than 0,05 but higher than 0,01 indicates that this result is not completely trustworthy, there is a chance of the value for the coefficient being zero of around 3%.

Moreover, it is also understandable that the travel distances could impact on this choice, since only about 10% of the people undertake trips with less than 10 km on their daily commuting routes. The percentage drops by half when the distance goes to up to 5 km.

With that in mind, the last PCA performed aimed to understand if the characteristics of the journeys would be more impactful than other variables that define the context of said trips, with the expectation that it could justify the negative values on the previous analysis.

As expected, to define the context of the trips, both average commuting time and average commuting distance presented the highest loading factors for the first principal component, which allowed to follow up on the methodology and perform the last multinomial logistic regression, now with this new variable based on the $PCA_{CONTEXT}$.

Once again using the modal choice as the dependent variable, and now aiming to understand the impact of the context of the trip on this choice, the regression indicated that the coefficients found for both public transport and combination of means of transportation were not statistically significant, that is, it is not possible to affirm that the length or the duration of the trip is something that influences a person to choose said mode.

On the other hand, when it comes to actives modes, the longer the trip, either in terms of time or distance, the less likely an individual is to change from commuting through private car to bicycle or by foot. This behaviour does make sense, since this model considers a “pure” exchange, but normally the active mode would be associated with other means of transportation, such as public transport or other shared mobility services.

The results presented lead us to believe that individuals more ecologically aware are in fact more likely to base their choices on the impact it has on the environment, although it is also important to highlight the need for an adequate supply of safe and reliable transport for the daily commutes.

The values for the factor loadings obtained on the PCA_{GLOBAL} for the variables related to the ecological awareness indicate that there is room for changing how people perceive these environmental issues and how their choices impact on the quality of life of both current and future generations. Changing the way people view this subject and providing means for habits changes may be the path to a more sustainable future, while also ensuring compliance with European and global agendas.

6
CONCLUSIONS

Summing up, transport systems have shown their importance to social development for over two thousand years. Despite being present in human's life for so long, the evolution on the sector is constant and it has both positive and negative impacts not only on the way people commute, but also on other areas of the society.

That means that the negative impacts, especially the ones related to GHG emissions should be diminished as soon as possible, since the European Union has the goal to reduce their emissions by 55% until 2030 and this sector alone is responsible for about 25% of the total emissions. And that is where the new technologies assume a key role in this change.

The importance of transport systems for the development of the city and society is undeniable and adapting the way people and goods move must follow global agendas that add sustainable measures to maintain natural and built resources. An urban sustainable mobility must provide democratic access to the urban environment, guarantee quality of life without harming future generations, as well as minimize impacts on the environment.

The use of technology in the development of transport promotes a change in perspective on the part of the user, who sees their demands met by the available mobility solutions, without the need to own a mean of transport.

Given these facts, this investigation began with a question: does ecological awareness influence modal choice?

To answer this question, an online survey carried out by Fraunhofer IAO within the EIT Urban Mobility Business plan 2020 project MaaS_together with citizens of four European countries (United Kingdom, Germany, Czech and Poland) was used, in which data was collected to comprehend to what extent citizens consider the impact that their modal choices generate on the environment.

Based on the information provided, three categories of data were used: demographic, commute related and ecological perception. On this last category, the respondents needed to define whether they agreed or not to sentences about how they perceive the relation between their modal choices and environmental issues.

The survey analyses showed that some people are inclined to base their choices on their environmental beliefs, but for that to be a reality the transportation system as a whole has to ensure that the change is beneficial not only to the world but also will not lead to a downgrade on people commutes.

Other than that, the study found out that there is room for improvement and, by changing the way people face the environmental issues and the impact of their choices on the wellbeing of the current and future generations, it opens space for changing behaviours towards the transport systems utilised.

It is also important that those in charge encourage public awareness of this issue and the impact the daily commutes have on the environment, promote the use of environmentally friendly means of transportation and reduce private car space, especially within the city.

BIBLIOGRAPHIC REFERENCES

Anable, J., Lane, B., & Kelay, T. (2006). *An evidence base review of public attitudes to climate change and transport behaviour.* Social Research in Transport (SORT) Clearinghouse. Retrieved July 10, 2024, from https://www.researchgate.net/publication/37183697

Banister, D., & Hickman, R. (2007). How to design a more sustainable and fairer built environment: Transport and communications. *Foresight Intelligent Infrastructure Systems Project*, pp. 276-291. Retrieved July 06, 2024, from https://www.researchgate.net/publication/3465179

Beim, M., & Haag, M. (2010). Freiburg's way to sustainability: the role of integrated urban and transport planning. *REAL CORP 2010: CITIES FOR EVERYONE. Liveable, Healthy, Prosperous*, (pp. 285-294). Vienna. Retrieved June 02, 2024, from https://www.academia.edu/522549/Freiburgs_way_to_sustainability_the_role_of_integrated_urban_and_transport_planning?auto=download

Boareto, R. (2003). A mobilidade urbana sustentável. *Revista dos Transportes Públicos - ANTP*, pp. 45-56.

Brinkhoff, T. (2024a). *Czech Republic: Regions and Major Cities*. Retrieved June 19, 2024, from City Population: https://citypopulation.de/en/czechrep/cities/

Brinkhoff, T. (2024b). *GERMANY: States and Major Cities*. Retrieved June 19, 2024, from City Population: https://citypopulation.de/en/germany/cities/

Brinkhoff, T. (2024c). *United Kingdom: Countries and Major Cities*. Retrieved June 19, 2024, from City Population: https://citypopulation.de/en/uk/cities/

Brinkhoff, T. (2024d). *Poland: Major Cities*. Retrieved June 19, 2024, from City Population: https://citypopulation.de/en/poland/cities/

Campos, V. B. (2006). Uma visão da mobilidade urbana sustentável. *Revista dos Transportes Públicos - ANTP*, pp. 99-106.

Department for Transport. (2023, July 25). *Rail passenger numbers and crowding on weekdays in major cities in England and Wales: 2022 (revised).* Retrieved May 20, 2024, from Department for Transport: https://www.gov.uk/government/statistics/rail-passenger-numbers-and-crowding-on-weekdays-in-major-cities-in-england-and-wales-2022/rail-passenger-numbers-and-crowding-on-weekdays-in-major-cities-in-england-and-wales-2022#rail-trends

Docherty, I., Marsden, G., & Anable, J. (2018). The governance of smart mobility. *Transportation Research Part A*, pp. 114-125. Retrieved July 10, 2024, from https://dspace.stir.ac.uk/handle/1893/29707

Dudek-Mańkowska , S., Grochowski, M., & Sitnik, K. (2024, June 05). Changes in the Characteristics of Suburbanization in the Warsaw Metropolitan Area in the First Decades of the 21st Century. *Sustainability*. Retrieved June 2024, 23, from https://doi.org/10.3390/su16114827

EIT Urban Mobility. (2020). *Become a partner*. Retrieved June 16, 2024, from EIT Urban Mobility: https://www.eiturbanmobility.eu/become-a-partner/

European Comission. (2020, September 17). *Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions.* Retrieved June 15, 2024, from EUR-Lex: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562

European Commission. (2008). *Communication from the commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions - Strategy for the internalisation of external costs.* Brussels. Retrieved July 02, 2024, from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0435:FIN:EN:PDF

European Environment Agency. (2023, October 24). *Greenhouse gas emissions from transport in Europe*. Retrieved May 25, 2024, from European Environment Agency: https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport?activeAccordion=546a7c35-9188-4d23-94ee-005d97c26f2b

Eurostat. (2022). *Key figures on European transport - 2022 edition.* Retrieved June 28, 2024, from https://ec.europa.eu/eurostat/web/products-key-figures/w/ks-07-22-523

Fitzová, H., & Markéta, M. (2020, February 25). Comparison of urban public transport systems in the Czech Republic and. *Research in Transportation Economics 81*. Retrieved June 11, 2024, from https://www.sciencedirect.com/science/article/pii/S0739885920300135?ref=pdf_download&fr=RR-2&rr=8c39a34f5dbe692a

Fraunhofer IAO. (2020). *MaaS_together*. Retrieved June 16, 2024, from Fraunhofer IAO: https://www.muse.iao.fraunhofer.de/de/projekte/maas_together.html

Gärling, T., & Schuitema, G. (2007, January 01). Travel demand management targeting reduced private car use: Effectiveness, public acceptability and political feasibility. *Journal of Social Issues, 63*(1), pp. 139-153. Retrieved July 03, 2024, from https://www.researchgate.net/publication/284903843

Gerber, P., Thériault, M., Enaux, C., & Carpentier-Postel, S. (2018). Modelling impacts of beliefs and attitudes on mode choices. Lessons from a survey of Luxembourg cross-border commute. *Transportation Research Procedia, 32*, pp. 513-523. Retrieved July 13, 2024, from https://doi.org/10.1016/j.trpro.2018.10.037

Hietanen, S. (2014). ITS & TRANSPORT MANAGEMENT SUPPLEMENT. *'Mobility as a Service' – the new transport model?, 12, 2*. Eurotransport. Retrieved July 13, 2024, from https://silo.tips/download/sampo-hietanen-ceo-its-finland#

Hoegh-Guldberg, O., Jacob, D., Taylor, M., Bindi, M., Brown, S., Camilloni, I., . . . Zhou, G. (2018). Impacts of 1.5ºC of global warming on natural and human systems. In IPCC.

IamExpat Media B.V. (2024). *Public transportation in Germany: U-Bahn, S-Bahn, tram & bus*. Retrieved June 11, 2024, from I AM EXPAT: https://www.iamexpat.de/expat-info/transportation/public-transportation-germany-sbahn-ubahn-tram-bus

Kurita, T. (2020). Principal Component Analysis (PCA). In *Computer Vision.* Springer, Cham. Retrieved July 15, 2024, from https://link.springer.com/referenceworkentry/10.1007/978-3-030-03243-2_649-1

Laudau, S., & Chis Ster, I. (2010). Cluster Analysis: Overview. In *International Encyclopedia of Education* (Third ed., pp. 72-83). Elsevier. Retrieved July 17, 2024, from https://www.researchgate.net/profile/Irina-Chis-Ster/publication/286854317_Cluster_Analysis_Overview/links/5e681a0292851c7ce05b0ae1/Cluster-Analysis-Overview.pdf

Meloun, M., & Militký, J. (2011). Statistical analysis of multivariate data. In *Statistical Data Analysis - A Practical Guide* (pp. 151-403). Woodhead Publishing India. Retrieved July 15, 2024, from https://www.sciencedirect.com/topics/mathematics/multinomial-logistic-regression

Prague Public Transit Company. (2024). *Timetables*. Retrieved July 07, 2024, from Prague Public Transit Company, joint-stock company: https://www.dpp.cz/en/timetables

Pucher, J., & Buehler, R. (2010, December). Walking and Cycling for Healthy Cities. *Built Environment*, pp. 391-414.

Rodrigue, J.-P., Comtois, C., & Slack, B. (2013). *The Geography of Transport.* Oxon: Routledge.

Sarasini, S., Sochor, J., & Arby, H. (2017). What characterises a sustainable MaaS business model? *1st International Conference on Mobility as a Service (ICOMaaS).* Tampere. Retrieved July 11, 2024, from https://www.researchgate.net/publication/320100540_What_characterises_a_sustainable_MaaS_business_model

Schikofsky, J., Dannewald, T., & Kowald, M. (2020, January). Exploring motivational mechanisms behind the intention to adopt mobility as a service (MaaS): Insights from Germany. *Transportation Research Part A: Policy and Practice*, pp. 296-312. Retrieved July 11, 2024, from https://www.sciencedirect.com/science/article/abs/pii/S0965856418309261?fr=RR-2&ref=pdf_download&rr=8ac118e08edc5be2

Shaheen, S., Cohen, A., & Zohdy, I. (2016). *Shared Mobility: Current Practices and Guiding Principles.* Washington: FHWA.

State of Berlin. (2024). *Public Transportation in Berlin*. Retrieved July 24, 2024, from The Official Website of Berlin: https://www.berlin.de/en/public-transportation/

Zarząd Transportu Miejskiego. (2024). *Public transport step by step*. Retrieved July 24, 2024, from Warszawski Transport Publiczny: https://www.wtp.waw.pl/en/public-transport-step-by-step/

ANNEX

Umfragen @ Fraunhofer IAO – MaaS Online Survey UK

Intro / Screening

1. In which special territory do you live? (Choose one of the following answers)
    - Village with less than 10.000 inhabitants
    - Small town with 10.000 to 79.999 inhabitants
    - Town with 80.000 to 99.999 inhabitants
    - City with 100.000 to 299.999 inhabitants
    - Large city with 300.000 to 999.999 inhabitants
    - Megacity with 1.000.000 to 3.000.000 inhabitants
    - Metropolis with more than 3.000.000 inhabitants

Demographics

2. Please pick your gender: (Choose one of the following answers)
    - Male
    - Female
    - Diverse
3. How old are you? (Your answer must be between 18 and 99) ________________ years old.
4. How many persons including you currently live in your household? (Choose one of the following answers)
    - 1 Person
    - 2 Persons
    - 3 Persons
    - 4 Persons
    - 5 or more Persons
5. What is the monthly net income (after all deductions) of your household? (Choose one of the following answers)
    - Up to 599£
    - 600£ to 1.199£
    - 1.200£ to 2.399£
    - 2.400£ to 3.599£
    - 3.600£ to 5.999£
    - 6.000£ or more

6. Please state your highest educational level. (Choose one of the following answers)
    - o General Certificate of Secondary Education
    - o General Certificate of Education Advanced Level (A-Levels)
    - o Foundation Degree
    - o Certificate or Diploma in HE or Higher National Diploma
    - o Bachelor or Master Degree
    - o Other graduation, such as: __________________
7. Which of the following options best describes your current employment status? (Choose one of the following answers)
    - o In training (pupil / student)
    - o Full-time employee
    - o Part-time employee
    - o Senior executive
    - o Self-employed
    - o Homemaker
    - o Retired
    - o Seeking work
    - o Other employment, such as: ________________
8. Please remember your regular, daily commuting routes such as the way to work, shopping or other appointments you have on a regular basis. Which of the following means of transport do you use most of the time when commuting? Please select all that applies.
    - □ Private Car
    - □ Public transit (e.g. bus, metro)
    - □ Bicycle
    - □ By foot
    - □ Combination of public transit and other mobility services (e.g. Bike-Sharing, Scooter-Sharing)
    - □ Combination of private car and public transit (Park and Ride)
    - □ Other: ________________________________
9. Please remember your regular, daily commuting routes such as the way to work, shopping or other appointments you have on a regular basis. How long is your average travel time per route? (This refers to only one way) (Choose one of the following answers)
    - o Less than 5 minutes
    - o 5 to 9 minutes
    - o 10 to 19 minutes

- 20 to 29 minutes
- 30 to 44 minutes
- 45 to 60 minutes
- More than 60 minutes

10. Please remember your regular, daily commuting routes such as the way to work, shopping or other appointments you have on a regular basis. How long is your average travel distance per route? (This refers to only one way) (Choose one of the following answers)
    - Less than 3 miles
    - 3 to 6 miles
    - 6 to 15 miles
    - 15 to 30 miles
    - More than 30 miles

11. Please think about your average month. How often do you use the following means of transport? (Please choose the appropriate response for each item:)

	Several times per day	At least once a day	Several times per week	At least once a week	Several times per month	Once a month	Rather than that
Private car	○	○	○	○	○	○	○
Car sharing, rental car	○	○	○	○	○	○	○
Taxicab, mability service provider (e.g. Uber)	○	○	○	○	○	○	○
Bus, streetcar	○	○	○	○	○	○	○
Subway, city train	○	○	○	○	○	○	○
Local train, long distance train	○	○	○	○	○	○	○
Electric Scooter / E-Kick-Scooter	○	○	○	○	○	○	○
Shared On-Demand-Shuttels (Ride-pooling, Ride-hailing systems)	○	○	○	○	○	○	○
On foot, bike, other means of transport	○	○	○	○	○	○	○

Latent One

12. In the following we will show you some statements concerning your personality. Please state how much you agree or disagree with the following statements. (Please choose the appropriate response for each item:)

	Strongly agree	Rather agree	Neutral	Rather disagree	Strongly disagree
Collaborative consumption helps save natural resources	○	○	○	○	○
Collaborative consumption is environmentally friendly	○	○	○	○	○
New technologies will solve the problem of fossil energies shortage	○	○	○	○	○

Latent Two

13. Here you will find again some statements about your characteristics. Please state how much you agree or disagree with the following statements. (Please choose the appropriate response for each item:)

	Strongly agree	Rather agree	Neutral	Rather disagree	Strongly disagree
Collaborative consumption is a sustainable mode of consumption	○	○	○	○	○
When travelling, I try to reduce my GHG (greenhouse gas emissions)	○	○	○	○	○
Safeguard my lifestyle is more important than environment and energy consumption	○	○	○	○	○

TAM MaaS

14. Please state how much you agree or disagree with the following statements. (Please choose the appropriate response for each item:)

	Strongly agree	Rather agree	Neutral	Rather disagree	Strongly disagree
Using Mobility-as-a-Service helps save natural resources	○	○	○	○	○
Using Mobility-as-a-Service is ecological	○	○	○	○	○
Using Mobility-as-a-Service is environmentally friendly	○	○	○	○	○

Latent Three

15. Finally, we will provide again some statements concerning your personality. Please state how much you agree or disagree with the following statements. (Please choose the appropriate response for each item:)

	Strongly agree	Rather agree	Neutral	Rather disagree	Strongly disagree
Collaborative consumption is ecological	○	○	○	○	○
Collaborative consumption is efficient in terms of using energy	○	○	○	○	○
Increase of energy consumption is an overstated issue	○	○	○	○	○