Master of Science in Civil Engineering

Modelling the impact of neighbourhood effects and psychosocial factors on commuting travel behaviour: an application in the metropolitan city of Cagliari

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Academic year: 2021/2022
October 2022

AKNOWLEDGEMENT

I feel compelled to dedicate this page of this thesis to the people who contributed and supported me in drafting it.

First of all, I would like to express my deepest gratitude to my supervisor Prof. Marco Diana for his infinite availability and promptness to my every request. Thank you so much for giving me the opportunity to work on this master's thesis.

Thanks also to my co-supervisor Prof. Italo Meloni for the opportunity to work and contribute to the development of my beloved island. Special thanks go to Eng. Francesco Piras for his immense availability and for helping me to conduct the research, subject of the report.

I thank my parents infinitely, without their support I would never have been able to get this far. I would also like to thank my boyfriend Andrea, my brother Luca, my grandparents, and my friends who have always been close to me during my university career.

Finally, I would like to dedicate this great achievement to myself, to my sacrifices and my tenacity. Nothing is impossible if you really want it!

ABSTRACT

In recent years, studies have found that individuals' choice of transportation mode is influenced not only by the level of service and socioeconomic variables but also by spatial and social interactions effects, also known as neighbourhood effect in which the individual's behaviour is influenced by the relational effects of the people living in his neighbourhood.

However, past research has only focused on topics such as children's travel behaviour, bicycle use, choice of residence place, and have not considered the presence of a neighbourhood effect when analysing commuting travel behaviour. Moreover, the majority of previous works have investigated neighbourhood effects only in places of residence, while it would be important to understand the presence of these effects even in places of destination. Another issue with most of the aforementioned papers who have analysed the effect of individuals' spatial interactions, is that they neglected the impact of psycho-attitudinal variables which, in the last 20 years, they have been recognized as having influence on individuals' travel behaviour.

Given the above background, the object of the current thesis is the analysis of the spatial and social interactions and psychosocial factors that may affect individuals' decision process when choosing a transport mode for their home - work and home - study trips.

To this end, a spatial probit model is specified and estimated, modelling the probability of individuals choosing to use a sustainable means of transport. The utility function of the estimated model include: 1) the effect of the level of service variables and household characteristics; 2) the psychosocial variables' effect, whose values were calculated by computing factor scores; 3) spatial interactions effects. The spatial effect is computed for both the place of origin (residence) and destination (work or study address).

The model is applied to a sample of students and workers (3251 individuals), who participated in 2019 to a survey conducted by the Interuniversity Centre for Economic Research and Mobility (CIREM) of the University of Cagliari (Sardinia) in the metropolitan city of Cagliari.

Model results shows that spatial (social) effects are statistically relevant in explaining commuters' travel behaviour, both when analysing travel behaviour of individuals living in the same neighbourhood and when considering travel behaviour in the working/studying place. Another important finding is that individual decision-making process in choosing the mode of transportation is influenced not only by socioeconomic characteristics and spatial interactions, but also by psychosocial effects. In particular, it is found that the intentions to adopt a sustainable travel behaviour of transport and the perceived behavioural control of using a sustainable means of transport positively influence the choice to use the active mobility and transit service.

Finally, the results suggest that ignoring these spatial effects may lead to biased estimates of the model parameter values, and consequently, to the underestimation of the impacts of policies and strategies aimed at favouring sustainable mobility.

Keywords: transport mode choice, commuting travel behaviour, spatial and social interactions, neighbourhood effects, psychosocial factors, spatial probit model, sustainable means of transport.

Modellazione dell'impatto degli effetti di vicinato e dei fattori psicosociali sui comportamenti negli spostamenti pendolari: un'applicazione nella città metropolitana di Cagliari

SINTESI

Negli ultimi anni, alcuni studi hanno scoperto che la scelta del modo di trasporto degli individui è influenzata non solo dal livello di servizio e dalle variabili socioeconomiche, ma anche dagli effetti delle interazioni spaziali e sociali, noti anche come effetto di vicinato, in cui il comportamento dell'individuo è influenzato dagli effetti relazionali delle persone che vivono nel suo vicinato.

Tuttavia, i lavori svolti si sono concentrati solo su argomenti come il comportamento di viaggio dei bambini, l'uso della bicicletta, la scelta del luogo di residenza e non hanno considerato la presenza di un effetto di vicinato nell'analisi del comportamento di viaggio pendolare. Inoltre, la maggior parte dei lavori precedenti ha indagato sugli effetti di vicinato solo per il luogo di residenza, mentre sarebbe importante comprendere la presenza di questi effetti anche per il luogo di destinazione. Un altro problema della maggior parte degli articoli che hanno analizzato l'effetto delle interazioni spaziali degli individui, è quello di aver trascurato l'impatto delle variabili psicoattitudinali che, negli ultimi 20 anni, hanno dimostrato di svolgere un ruolo fondamentale nel comportamento di viaggio degli individui.

Alla luce di quanto sopra, l'oggetto della presente tesi è l'analisi delle interazioni spaziali e sociali e dei fattori psicosociali che possono influenzare il processo decisionale degli individui nella scelta di una modalità di trasporto per i propri viaggi casa - lavoro e casa - studio.

A tal fine, viene specificato e stimato un modello probit spaziale, modellando la probabilità di scelta degli individui di utilizzare un mezzo di trasporto sostenibile. La funzione di utilità del modello stimato comprende: 1) l'effetto delle variabili del livello di servizio e delle caratteristiche del nucleo familiare; 2) l'effetto delle

variabili psicosociali, i cui valori sono stati calcolati attraverso il calcolo dei punteggi fattoriali; 3) effetti di interazioni spaziali. L'effetto spaziale è calcolato sia per il luogo di origine (residenza) che per il luogo di destinazione (indirizzo di lavoro o di studio).

Il modello è applicato ad un campione di studenti e lavoratori (3251 individui), che hanno partecipato nel 2019 ad un'indagine condotta dal Centro Interuniversitario per la Ricerca Economica e la Mobilità (CIREM) dell'Università di Cagliari (Sardegna) nella città metropolitana di Cagliari.

I risultati del modello mostrano che gli effetti spaziali (sociali) sono statisticamente rilevanti per spiegare il comportamento di viaggio dei pendolari, sia quando si considera il comportamento di viaggio degli individui che vivono vicino al luogo di residenza, sia quando si lavora/studia vicino al luogo di destinazione. Un'altra importante scoperta è che il processo decisionale individuale nella scelta del modo di trasporto è influenzato non solo dalle caratteristiche socioeconomiche e dalle interazioni spaziali, ma anche dagli effetti psicosociali. In particolare, si rileva che le intenzioni di adottare un comportamento di viaggio sostenibile del trasporto e il controllo comportamentale percepito nell'utilizzo di un mezzo di trasporto sostenibile influenzano positivamente la scelta di utilizzare il servizio di mobilità attiva e di transito.

Infine, i risultati suggeriscono che ignorare questi effetti spaziali può portare a stime dei valori dei parametri del modello distorte e, di conseguenza, alla sottovalutazione degli impatti di politiche e strategie volte a favorire la mobilità sostenibile.

Parole chiave: scelta della modalità di trasporto, comportamento negli spostamenti pendolari, interazioni spaziali e sociali, effetti di vicinato, fattori psicosociali, modello spaziale probit, mezzi di trasporto sostenibili.

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1 INTRODUCTION

Transportation problems are constantly increasing in everyday life; that is why the interest in reducing the use of car for commuting has also grown.

For most of the twentieth century, nations responded to the increasing demand for road travel and to the problem of traffic congestion by building more roads. However, nowadays, this has not proved to be a good policy: the continuous growth in transport demand and the use of private cars are responsible for many problems such as pollution, people's health deterioration, road congestion and space problems to accommodate an increasing number of private cars. This is precisely why more and more transport planners are called upon to address these issues.

Since the 1990s, transport planning has begun to take account of environmental issues, which still have an impact on transportation policy. Today, one of the major sources of environmental pollution is road transport. To counter this problem, transport policies have been directed towards finding both alternative means of transport to private cars and ways of limiting travel demand. For this reason, in the recent years, numerous information campaigns have been caried out with the aim of raising public awareness of environmental issues and promoting the use of sustainable transport.

In order to implement effective policy measures to achieve more sustainable mobility, a detailed analysis of people's actual travel behaviour and their modal preferences is required.

The choice of the means of transport is a complex decision-making process and is influenced by a multiplicity of factors from different disciplines such as economy, geography, psychology, and sociology, for this reason it is important to identify the determinants which may play a role in the modal choice decision process. The main assumption is that travellers make decisions based on utility maximization concept, choosing the alternative with the highest utility (Ortuzar and Willumsen, 2011).

Recent research has shown that individuals' choice of transportation mode is influenced not only by variables such as the level of service, socioeconomic and psycho-attitudinal characteristics, but also by the effect of spatial and social interactions. Individuals have the ability to observe or exchange information about the choices made by other individuals close to them, therefore their behaviour may be influenced by the behaviour of those close to them. This is called spatial lag effect, also known as neighbourhood effect. It is demonstrated (Bhat, 2015) that ignoring spatial dependence when it is actually present leads to bias in parameter estimation.

Past research on the effects of spatial interaction has focused more on issues such as children's travel behaviour, bicycle use, residential location choice, and did not deepen the presence of the neighbourhood effect when analysing the commuting behaviour. Furthermore, most of previous studies investigated the neighbourhood effects only for places of residence, even though it would be important to know the presence of these effects also for the place of destination. Another problem with most of the papers is that, by analysing the effect of individuals’ spatial interactions, they have overlooked the impact of psycho-attitudinal variables that are crucial in individuals’ travel behaviour.

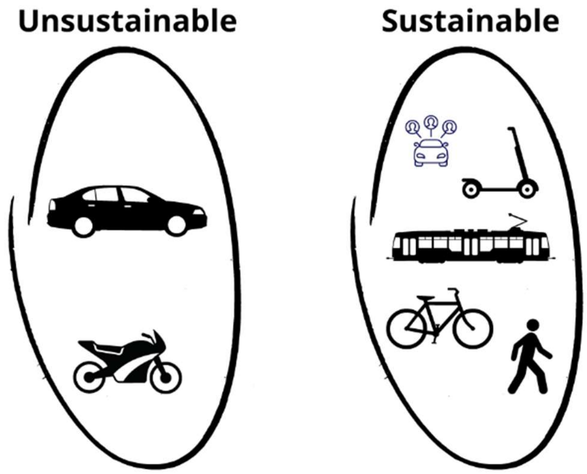
In this thesis an analysis of the decision-making process of modal choice is conducted, aimed at capturing those sociodemographic and psychological factors, but above all to verify if there are spatial and social factors that influence individuals’ decision-making process in choosing a means of transport for their commuting trips.

In order to analyse the probability of choosing a sustainable or unsustainable means of transport, for commuting trips, two different models are estimated:

1) an independent binomial probit model that captures the significant variables to be adopted in the model specification;
2) a binomial spatial probit model (LeSage, 2009) which captures the spatial lag effect.

The category of unsustainable means of transport (Figure 1.1) includes: car driver, car passenger and motorcycle; while the category of sustainable means of transport includes: cycling, walking, public transport, micromobility, car sharing, carpooling and car plus public transport. Both, sustainable and unsustainable alternatives, are assumed to be available to all individuals.

Figure 1.1 - Unsustainable and sustainable means of transport



In the model utility function are included:

1) the effects of the level of service and sociodemographic variables,
2) the effects of the psychosocial variables whose values were calculated through a factor analysis,
3) the effects of spatial interactions that have been inserted through a variable of the lag type. A spatial lag of the dependent variable is an explanatory variable vector constructed using an average of values from neighbouring observations (LeSage, 2009).

In addition, the presence of spatial effects is verified both in the place of production and in the place of attraction, estimating two different spatial probit models. In the first model, the coordinates relating to the residential places (origin), considered as the place of production, were inserted into the spatial matrix. In the second model, were entered the coordinates relating to the workplace (destination), considered as a place of attraction.

The dataset used is based on the Svolta's survey conducted in 2019 by the Interuniversity Centre for Economic Research and Mobility (CIREM) of the University of Cagliari in which workers and students were interviewed about their commuting home-work and home-study trips from or to the metropolitan area of Cagliari. The survey dataset includes detailed information about individual's socioeconomic, trip characteristics and psychosocial characteristics. The entire dataset includes all those observations with a covered distance of

105 km or less. In order to capture the spatial effects among observations, this distance may be inappropriate because there may be substantial geographical and built environmental differences across the region; for this reason, it was decided to limit the geographical boundaries by excluding all those observations with a home-work distance greater than 20 km, obtaining a final sample consisting of 3251 individuals.

The results obtained suggest that spatial and social effects are present at the neighbourhood level. It is also possible to predict the total effects on modal choices by modifying one exogenous variable at a time. By modifying a variable for the single individual, both the probability of modal choice of the individual (direct effect), and the probability of modal choice of other individuals (indirect effect) will change. Therefore, public policy programs aimed at promoting sustainable mobility can have a greater impact when targeted at local areas rather than more widespread areas.

The next section provides an overview of literature. The third section provides a description of the dataset used; the fourth section presents the modelling methodology adopted. The fifth section summarizes model estimation results and the final section offers conclusive reflections and directions for further research.

2 STATE OF THE ART

In this section it is provided an investigation on the literature review on the concepts of sustainable mobility, socioeconomic variables which influence the mode choice behaviour, role of psychosocial variables and neighbourhood effect.

2.1 The concept of sustainable mobility

About thirty years have passed since the concept of sustainable mobility first appeared. This concept was introduced in 1992 in an EU green paper: “Green Paper on the Impact of Transport on the Environment. A Community Strategy for Sustainable Mobility”. In this book, the negative impacts of transport on the environment have been explained and a common strategy has been provided to contain these harmful effects through the use of a sustainable mobility (EU, 1992).

There are several definitions of sustainable mobility, according to the World Commission on Environment and Development (WCED, 1987), sustainable mobility can be defined as the mobility that “satisfies the needs of present generations without compromising future generations’ ability to satisfy their own needs”.

Road transport is now one of the major contributors to greenhouse gas emissions, having negative impacts on environment and health, including climate change, air pollution, noise and congestion.

Since 2016, the United Nations (UN) presented the “The 2030 Agenda for Sustainable Development” with 17 Sustainable Development Goals (SDGs). The 11^{th} SDG does not specifically include sustainable mobility but affirms the goal of “Make cities and human settlements inclusive, safe, resilient and sustainable”. This implies that the population is constantly increasing, and there is a need for sustainable cities, with smart urban planning that creates safe, affordable and resilient cities with green and culturally stimulating living conditions (UN, 2015).

In recent years, various measures have been taken to reduce environmental impacts. Menendez and Ambühl (2022) provided an overview of operational measures for sustainable mobility classifying them into: measures discouraging private motorized transport (such as parking policies and speed traffic calming policies), measures encouraging public transport (providing dedicated public transport lines and curb-side stops of bus and tram) and measures encouraging human-powered mobility (cycle lanes, comfort routes and public bike-sharing system).

It should also be emphasized that using some sustainable means of transport has a beneficial effect on human health, just think on the active mobility of walking and cycling, these have social and environmental effects. For example, cycling has reduced transportation costs and helps improve people's lifestyle (Wang et al., 2015).

A study conducted by Cooper et al. (2003), showed that children walking to and from school were more active during other periods of the day than those who use inactive modes of transportation, thus increasing their overall physical and mental well-being. Furthermore, the active use of modes of transport would substantially help fight obesity.

2.2 Importance of sociodemographic variables in transportation mode-choice

Modal choice is determined by a variety of factors. Concerning sociodemographic variables, De Witte et al. (2013) provides an overview of the travel behaviour and the modal choice. They found that car availability was mentioned as a determinant in the 47% of the papers analysed and in those, it was significant in the 78% of the cases. Other variables often studied and having significant influence on the modal choice decision are income, household composition and age. Variables often studied but rarely found significant are gender, employment, travel cost and travel time, finally the least studied and rarely significant variables are education level, departure time and distance.

Contrary, different studies found that travel distance and travel time have a great influence on student's travel mode choice (Ribeiro et al. 2022, Sidharthan et al. 2011). Additionally, different students may choose different modes for travelling the same distance, for example, Ribeiro et al. (2022) found that in a survey conducted at the University of Minho (Portugal) there were more male students driving and more female students walking and traveling by bus. Furthermore, the mode choice for children's trips to and from school is correlated to characteristics of the built environment in the neighbourhood, attitudes and perceptions of safety, income, and number of cars available in the household. Higher household income and vehicle ownership is associated with a greater propensity to use cars and less utility for school buses and walks (Sidharthan et al. 2011).

Regarding sociodemographic variables that affect workers' propensity to cycle, these are household income, number of vehicles in the individual's household, education level, full-time work status (Bhat et al., 2016). Having less vehicles in the household, higher income, highly educated and non-full-time workers increases the propensity to use the bicycle to go to work.

2.3 Importance of psychosocial variables in transportation mode-choice

It is widely known that the reason for choosing one mode of transport over another, strongly depends on the travel behaviour. Nowadays, most people are highly dependent on car travel (Anable, 2005), so it is useful to understand what psychosocial variables may contribute to explaining individual behaviour to shift car drivers toward sustainable means of transport.

Different studies states that the choice of travel mode is a reasoned decision related particularly to intentions and perceived behavioural control (Anable, 2005). However, according to other studies, many people's daily travel mode choices are based on habit and are usually not preceded by alternatives considerations (Bamberg et al., 2003).

Anable (2005) demonstrates how the same behaviour can occur for numerous reasons and that the same attitudes can lead to different behaviours. Instead, people must be dealt in distinct ways since they are motivated by several variables and are affected in different ways by policy. For this reason, she categorized different mobility styles based on attitudes towards alternative transport modes and lifestyle attributes. Indeed, Beirao et al. (2007) found that the mode choice is influenced by one's attitude toward transportation. In particular they found that car users have lower perceptions of public transport than public transport users, which means that in reality the public transport service is better than they think. The propensity to switch modes revealed by car users demonstrates how a better public image and higher service levels can attract new customers to the public transportation system. Conversely, people are more inclined to switch to car use if public transportation is unreliable, has a low frequency, or uncomfortable because they do not perceive it as a credible alternative to them.

The same study also found that respondents' travel mode choice did not appear to be influenced by environmental concerns regarding car use. This is in line with studies indicating that although having information on the harmful effects of car use on the environment may increase awareness, this is typically insufficient to modify behaviour (Anable, 2005). Nevertheless, there is some evidence that adding measures on environmental concern provide additional beliefs that can be target in order to change behaviour (Anable, 2005).

Concerning public transport, it is noted that intentions have the greatest total effect on behaviour, so the attitude of public transport plays a decisive role with great effects on intentions, habits, and satisfactions. (Fu et al., 2017).

As for the attitude towards cycling, people with a greater perception of the benefits of cycling tend to be more likely to choose a bicycle as a mode for commuting trips (Piras et al., 2021).

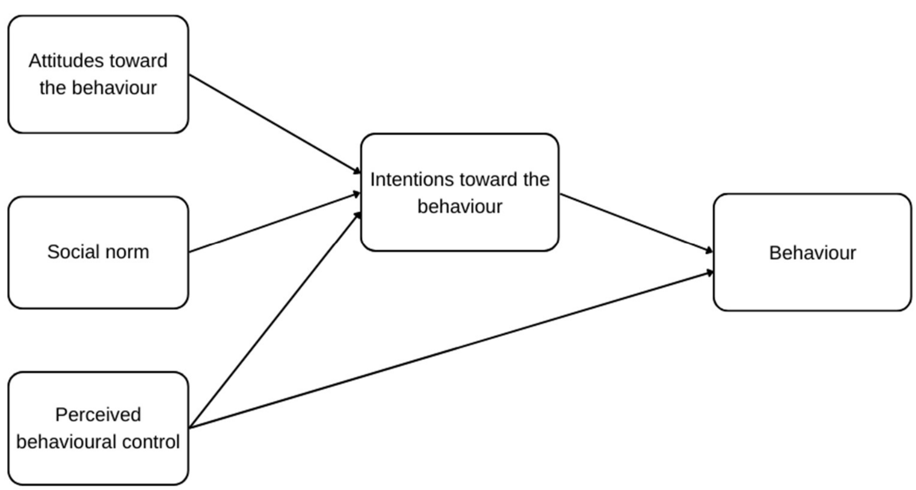
In the previous mentioned studies, intentions, attitudes, and perceptions influence travel behaviour. These notions are further reinforced by theories in social psychology.

2.3.1 Theory of planned behaviour

There are many theoretically frameworks developed to capture the relationship between psychosocial variables and travel behaviour, the best-known behavioural theory for predicting mode choice is the Theory of Planned Behaviour (TPB; Ajzen, 1991).

In TPB (Figure 2.1) it is assumed that people form behavioural intentions based on their attitudes, subjective norms, and perceptions of behavioural control, and that these intentions, together with perceptions of behavioural control, are the immediate determinants of behaviour (Ajzen, 1991).
The first factor that determines intentions is the attitude toward the behaviour, which describes how positively or negatively they view the behaviour in question. The second predictor, social norm, relates to the perceived social pressure to perform or not the behaviour. The perception of behavioural control refers to the perceived ease or difficulty in performing the behaviour and is the third antecedent of intention. Perceived behavioural control is assumed to reflect past experiences. Finally, intentions are assumed to capture the motivational factors that influence the behaviour (Ajzen, 1991).

Figure 2.1 - Theory of planned behaviour



Different behaviours and situations will affect the prediction of intentions based on the relative weight of attitude, subjective norm, and perceived behavioural control. As a result, it may be found that in some applications only attitudes have a greater influence on intentions, in others, attitudes and perceived behavioural control are sufficient to explain intentions, and in still others, all three predictors contribute independently. According to the theory of planned behaviour, perceived behavioural control, together with intention, can be used directly to predict the behaviour (Ajzen, 1991).

By analysing travel behaviour, which is a complex behaviour, the literature identifies inadequacies in this theory. This requires the use of psychometric measurement theoretically derived and post hoc analytical methods.

2.3.2 Other behavioural theories

In the last twenty years, different studies and works extended the formulation of the theory of Planned Behaviour by including new psychological constructs.

Conner and Armitage (1998) proposed to assess six additional variables to the TPB, they are belief salience, past behaviour/habit, perceived behavioural control versus self-efficacy, moral norms, self-identity, and affective beliefs. In particular, moral norms are considered as an individual’s perception of the moral correctness or incorrectness of performing a behaviour (Ajzen, 1991). They found that moral norm would give a useful contribution to the perceived behavioural control, at least for those actions where moral considerations are likely to be significant. (Cooner and Armitage, 1998).

Carrus et al. (2008) found that emotions measured as anticipated emotions, thus thought about future feelings after attaining a specific goal, gives an important contribution in capturing the pro-environmental orientation. In particular, they can induce certain modal choices when associated to positive or negative experiences while travelling. Moreover, emotions can be fed by cultural and symbolic patterns which can influence the attitudes (Steg, 2005).

Environmental awareness is found to be another important predictor on attitude and perceived behavioural control. The awareness that one's personal car use contributes significantly to environmental issues seems to induce guilt and to adopt more ecologically friendly modes of transportation (Bamberg et al., 2007).

2.4 Neighbourhood effect

The first law of geography is the fundamental assumption used in all spatial analysis, where, according to Tobler (1970): "Everything is related to everything else, but near things are more related than distant things".

Spatial models have not been so used until the last years in modelling travel behaviours. Nowadays, there is increasing interest and attention in discrete choice modelling on recognizing spatial dependence among decision makers. Bhat (2015) demonstrated that ignoring spatial dependence when it is actually present leads to bias in parameter estimation.

The main difference between standard econometrics and spatial econometrics lies in the fact that, standard econometrics consider the observed values of the economic variables whereas spatial econometric refers not only to the value of economic variables, but also to the location where these variables were observed and to the various links of proximity between all spatial observations (Arbia, 2014).

The spatial and social effects, also known as neighbourhood effect, may occur across spatial units (zones, neighbourhoods) closer to each other as they share common unobserved attributes, and across behavioural units (individuals, household) closer to each other in space as they can share common unobserved attributes that affect how they behave (Sidharthan et al., 2011). People interact with each other as an inevitable part of living in a society. Individuals observe or exchange information about characteristics of different modes with other people in close proximity to themselves, modelling their behavioural choices according to that of the nearest neighbours. For example, if a lot of people in the neighbourhood take a bus to go to work, other people in the same neighbourhood might consider using the bus to go to work as well. The main assumption is that the more a commuting mode is used inside a neighbourhood, the more attractive it will become to all commuters in that neighbourhood (Goetzke et al., 2008).

In spatial econometrics terms, this is called spatial lag effect, which is defined as the endogenous interaction effect, and it can occur due to observable and unobservable factors. In fact, it is not known if the choice of a means of transport is influenced only by the relational effects of the closest people or also by some cultural characteristics or level of services in the residence or destination trip area. The spatial lag effect can have “spurious” sources that can be unobserved correlation effects and/or exogenous interaction effects. An example of the first sources can be that two spatially proximate neighbourhoods may both have good continuous bicycle pathways and/or seating areas along walking pathways. If these detailed bicycle/pedestrian infrastructure characteristics are not accounted for, the resulting unobserved correlation would get manifested as a spurious social/spatial interaction effect (Bhat, 2015). The second spurious source relates to the exogenous variables of one individual directly impacting the decision-making of a neighbouring individual. For instance, this may occur if the pedestrian facilities in one neighbourhood affect the decision of an individual in an adjacent neighbourhood to walk more (Bhat, 2015). Also, if the residential self-selection is ignored, it can incorrectly manifest spatial lag effect based in dyadic interactions and/or built environment effects.

To capture this dependence, the spatial drift effect needs to be estimated, which capture the unobserved preferences and response sensitivity of individual (Bhat, 2015). Spatial drift effect is a very complex procedure that is almost never estimated.

In this thesis, the spatial probit model considered only the spatial lag effect.

2.4.1 Importance of spatial effects in transportation mode-choice

Travel means choice involves a set of alternatives that can be spatially correlated with each other due to unobserved factors. There are different studies accounting for spatial interaction effects in the transportation sector, in particular in residential location choice, school travel mode choice and commuting trips with bicycle.

Concerning residential location choice, often it is associated with sociodemographic characteristics and environmental factors (Sener et al. 2011). Households tend to locate in areas with similar income levels and household sizes. Furthermore, residential location choice is positively affected by the availability of transit between the home and work zones. Sener et al. (2011) demonstrated that, apart from these variables, residential location choice alternatives are correlated with one another due to unobserved spatial and demographic factors that lead to a spatial correlation. In that case, since there was a correlation between choice alternatives over space, it has been proved that the hypothesis of independence of choice alternatives intrinsic to the classical multinomial logit model was violated and the estimated parameters of the standard logit models were biased and inconsistent.

On the other hand, Sidharthan et al. (2011) examined the unobserved spatial and social interaction effects that may influence household decision making in choosing a mode of transportation for children's' school trip. The result obtained from this research state that spatial correlation effects are statistically significant, therefore a household's decision may be influenced by interactions with other households and individuals that are geographically close together in a neighbourhood. For example, if many neighbourhood children walk to school, parents may feel comfortable with their own child walking to school.

Additionally, an important commuting alternative means of transport for school trips is the bicycle. A study conducted at Ohio State University found that students and males are more likely to cycle to campus, the probability of cycling decreases with distance from home to campus, proximity to bicycle infrastructures encourages people to ride bicycles and that crime and traffic safety and environmental concerns have a significant impact on individuals' bicycling choices (Wang et al. 2015). The estimation of a spatial probit model for cycling versus non-cycling choices conducted by Wang et al. (2015) demonstrates the existence of spatial autocorrelation in bicycle commuting choices. The more bicycle riders, the more attractive the bicycle become to all commuters in a neighbourhood. Therefore, when these neighbourhood effects are considerable, strategies to increase cycling choice should concentrate not only on enhancing related facilities but also on promoting a cycling culture.

Moreover, in this smart mobility area, car sharing services are another alternative mode of transport. Carsharing services, which are hourly or minutely car-rentals, may offer consumers potential benefits such as efficient mobility with lower car ownership levels, lower parking demand, and lower purchase and use costs. Vinayak et al. (2018) proposed an econometric methodology capable of simultaneously considering both spatial (geographical) and non-spatial (attitudinal) dependency effects by modelling the frequency of using shared mobility services. They extend the concept of proximity-based dyadic interactions by introducing the idea of attitudes, habits and preferences as a new dimension and measure of proximity. To account for attitudinal dependency effects, pro-environmental attitude and preference for a neo-urban lifestyle are considered as latent constructs. While to consider spatial effects, a spatial ordered response model is applied using a composite weight matrix that includes both spatial and attitudinal components. In general, frequent users of shared mobility services are younger, more educated, full-time workers, and residents in higher income households. While lower frequency of the shared mobility service is correlated with higher levels of vehicle ownership (Vinayak et al., 2018). The results of the model estimation show that both spatial and non-spatial (attitudinal) dependency effects are significant in explaining the use of emerging shared mobility services and both of these effects are of comparable magnitude. In comparison to models that neglected one or both types of dependency, the model that simultaneously accounted for both sources of dependency provided statistically better goodness-of-fit. This suggests that, as more people use shared mobility services, the more visible they become to the rest of the population, both from a spatial and a social (attitudinal and lifestyle) point of view.

Furthermore, Goetzke (2008) applied a spatial autoregressive logit mode choice model to see the social effect in transit use. Also in this case, positive social effects exist, in fact people prefer to use transit together with other people as a result of social spill-over.

Although these studies account for spatial interactions effects in different discrete choices, they do not explicitly account for spatial and social interactions effects on the place of destination of commuting trips.

This thesis presents a framework for modelling the choice of the means of transport for commuting trips, capable of accounting for spatial correlation both in the place of production and in the place of attraction.

We will refer to social and spatial interactions as a form of dyadic interaction between individuals located in close social or spatial proximity of one another.

In the rest of the text, it will be used the term neighbourhood effect and social and spatial effect interchangeably.

3 THE CASE STUDY

3.1 Territorial context of the metropolitan city of Cagliari

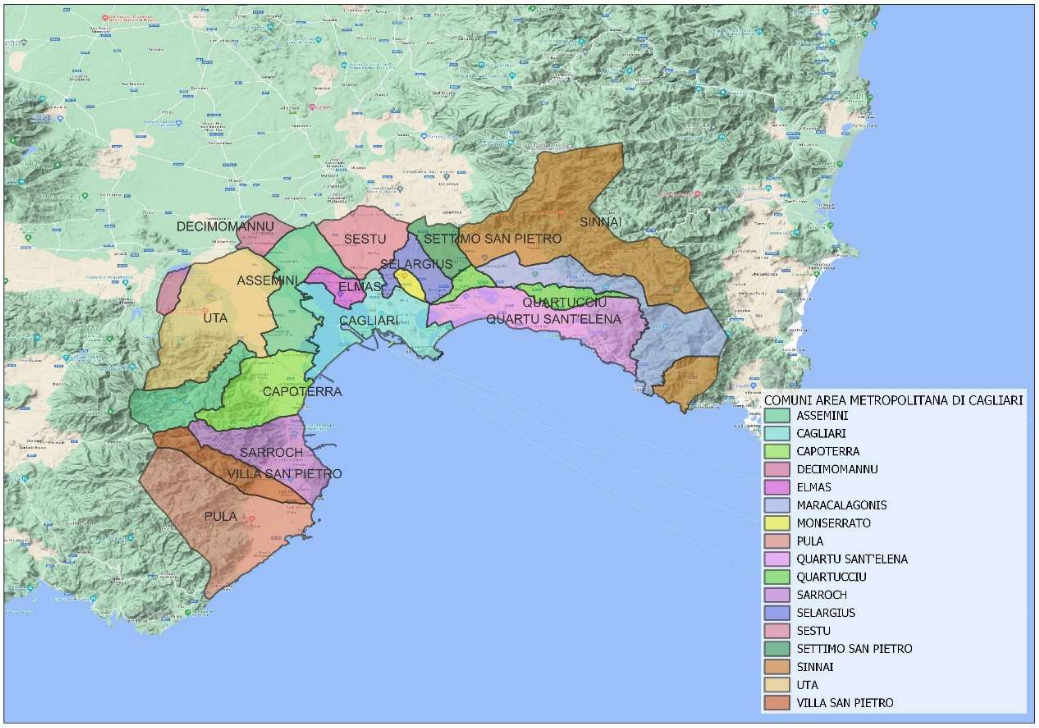
The Metropolitan City of Cagliari was established by regional law no. 2 of 2016 and became fully operational on 1st January 2017. It is composed, in addition to the capital, Cagliari, of sixteen municipalities (Figure 3.1): the conurbated ones (Monserrato, Quartu Sant'Elena, Quartucciu and Selargius) plus a part of those of the so-called first band of gravitation (Assemini, Capoterra, Decimomannu, Elmas, Maracalagonis, Pula, Sarroch, Sestu, Settimo San Pietro, Sinnai, Uta and Villa San Pietro). It has a population of over 420,117[1] inhabitants and covers an area of 1,248.71 km^2 with a population density of 336.63 inhabitants / km^2. The most populous municipality is that of Cagliari with 149,474 inhabitants, while the second is Quartu Sant'Elena with 67,831 inhabitants.

In recent years there has been a progressive increase in individual mobility on private cars, also following an increase in mobility for discretionary reasons and the improvement of economic conditions, which have led to a progressive increase in the motorization rate, which in 2019 it reached the value of 62.4 cars per 100 inhabitants[2] (Cagliari city 67.8).

[1] Source: ISTAT, resident population at the 1 January 2021

[2] Source: ISTAT, motorization rate updated to 2019

Figure 3.1 - Metropolitan city of Cagliari



The main regional infrastructural lines, both road and rail, converge in the city of Cagliari, there is an international airport (about 4,700,000 pax / year in 2019), and a commercial passenger port (passenger cabotage lines, 320,000 and cruise passengers 275,000 pax / year 2019).

Access to the Metropolitan City of Cagliari occurs mainly from four main routes (Figure 3.2). The first is the SS 131 "Carlo Felice" longitudinal director and main road of the regional road network that connects the Metropolitan City with Oristano, Sassari and Porto Torres and, through its branches, with Nuoro and Olbia (SS 131 dcn) and Alghero SS (SS 291 var).

The second main route is the SS 130 which connects the Metropolitan City with Sulcis - Iglesiente.

Access from the southwest coast is guaranteed by the SS 195 while the connection with the east coast is via the New SS 125.

The radial routes penetrate the Metropolitan City by connecting to the SS 554 which serves as a bypass route for the municipalities of Cagliari and its conurbated area. From the SS 554, and directly connected to the SS 131 via the SS 131dir, the Median Axis of Scrolling, an important and recent Cagliari ring road, develops.

Figure 3.2 - Road infrastructure system of the Metropolitan City of Cagliari

The transport system, in addition to connecting the metropolitan city with the outside world, must satisfy the movements of over 425,000 inhabitants and 148,500 employees who generate traffic mainly concentrated on Cagliari and its conurbation (Cagliari, Monserrato, Selargius, Quartucciu and Quartu Sant'Elena).

3.1.1 The mobility demand in the metropolitan area

Commuter journeys (work and study) that daily affect the Metropolitan City of Cagliari, with origin or destination in one of the municipalities belonging to it, are approximately 204,360[3]. Half of these trips are conducted by residents in the

[3] Source: ISTAT, 2019 census

municipalities of Cagliari and Quartu Sant'Elena, respectively 34% (69,817) and 16% (31,938).

According to the Istat permanent census of 2011, which provides the commuting matrix for municipalities throughout Italy, the number of trips made within the Metropolitan City of Cagliari with motivation for work / study daily and with destination the city of Cagliari was equal to 103,363. Of these, about 53% are internal movements in the capital. Still according to the data provided by the 2011 census, the modal split within the Metropolitan City, for work / study reasons, was as follows: private car 66.7%; public transport 13.4%; feet 16.5%; motorcycle 2.8%; 0.6% other.

Finally, from the analysis of the data collected from the relevant sections of the traffic flows in the city of Cagliari, it emerged that on an average weekday there are 166,000 incoming vehicle passes in Cagliari for work / study and discretionary reasons[4].

3.1.2 The supply system in the metropolitan area

An attempt has been made to remedy the growth in mobility, with the consequent increase in road congestion, above all with interventions to enhance the viability. More recently, the transport and mobility system has been affected by a series of planning and infrastructural interventions aimed at encouraging the still too scarce use of public transport (light metro line, info mobility system, renewal of the bus fleet, preferential lanes) and sustainable modes of transport (car and bike sharing with cycle paths and lanes).

3.1.2.1 Public transport

Urban public transport operator (CTM - Transport and Mobility Consortium) recorded 46,223,932[5] passengers transported in 2019. The urban public transport service of the metropolitan city of Cagliari involves, in addition to the capital, the cities of Quartu Sant'Elena, Quartucciu, Monserrato, Selargius,

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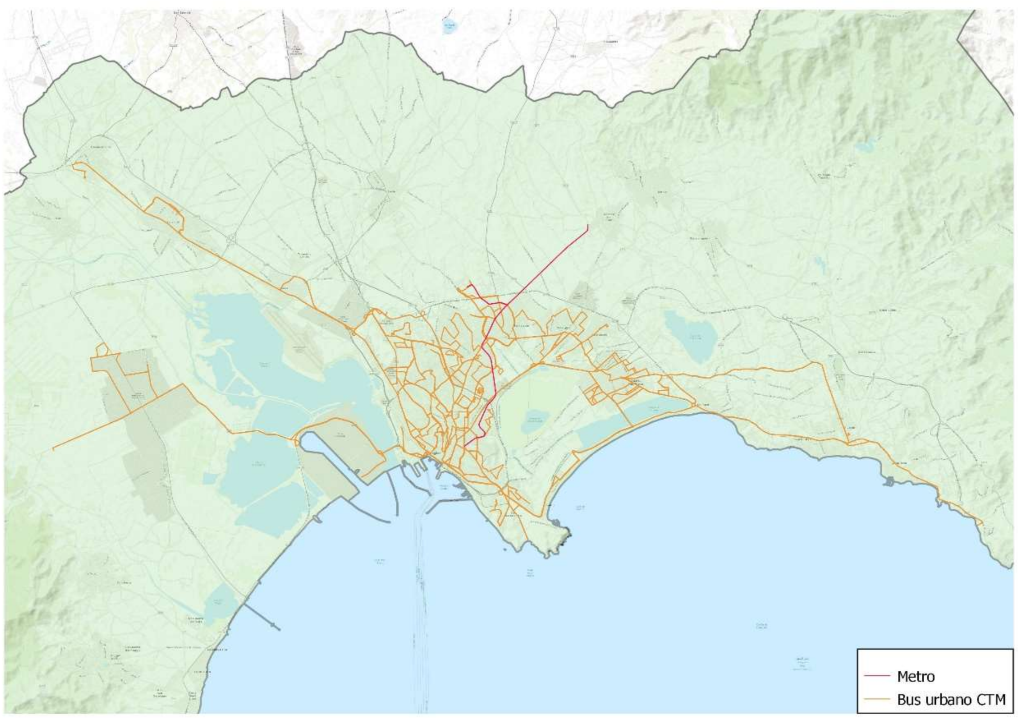
[4] Source: ITS, Metropolitan City of Cagliari 2020. https://cittametropolitanacagliari.it/web/cmdca/-/coronavirus-viabilita-a-cagliari-calo-del-traffico-fra-il-60-e-il-70-per-cento

[5] All data relating to the CTM service refer to the Mobility Charter 2020/21

Elmas, Assemini and Decimomannu. It mainly consists of road services managed by the CTM and a rail transport line, such as light rail, managed by ARST. Added to these are the metropolitan rail services operated by Trenitalia on the Decimomannu-Cagliari line, which have a single hub in Piazza Matteotti in the city of Cagliari.

The CTM service is carried out by bus and trolleybus, spread over a network of about 306 km (Figure 3.3) consisting of 29 active lines, 3 of which are trolleybuses. The CTM fleet (updated to 2018) consists of 271 vehicles: including buses, trolley buses and minibuses. Along the entire network there are 989 stops, all equipped with poles indicating the transit lines, the routes followed and the transit interval of the vehicles.

Figure 3.3 - Urban public transport network (CTM)



During the summer, the service dedicated to reaching the Poetto beach in Cagliari and Quartu Sant'Elena is strengthened, with the addition of supplements or changes to the lines in normal operation throughout the year and the activation of a further 5 lines. The Amico Bus service is also active, a "door to door" service on call, dedicated to people with disabilities or limited in the use of ordinary services.

In addition to the road services operated by the CTM, in 2015 two lines of the tramway network (managed by ARST) came into operation, serving the municipalities of Cagliari, Monserrato, Selargius and Settimo San Pietro (Figure 3.4). Line 1 connects Piazza Repubblica (Cagliari) to the Monserrato University Hospital (2.5 million passengers / year transported). Line 2 connects the Monserrato San Gottardo station with the municipality of Settimo San Pietro. The frequency on both lines is 10 minutes for the entire day[6]. The network is spread over an itinerary of 12.3 km with 12 stops.

Figure 3.4 - Light metro lines (MetroCagliari)

In March 2021, works began for the extension of line 1 from Piazza della Repubblica to Piazza Matteotti (Figure 3.5), the main hub of interchange and access to Cagliari for most tourists and commuters.

[6] Source: ARST Annual Report 2019

Figure 3.5 - Extension of the light rail line

3.1.2.2 The cycle network

The metropolitan city of Cagliari, in addition to strengthening the public transport offer system, has among its objectives that of promoting cycling mobility, through the progressive extension of the existing cycle network. To date there are 78 km of slopes, of which 41 km in the capital and the remaining 37 km distributed between the municipalities of Quartu Sant'Elena, Monserrato, Selargius, Quartucciu, Elmas, Assemini and Decimomannu.

3.1.2.3 Car sharing and bike sharing

Playcar s.r.l. is the company that since 2014 only manages the car sharing service in Cagliari. The car sharing service is provided in two different ways: free floating and round trip[7]. The first is designed for short one-way journeys, so once the journey is complete, it is possible to park the car in a different location to that of the pick-up; the second, ideal for both short trips around the city and for trips out of town, requires the car to always be returned to the departure station. The fleet consists of a total of 99 vehicles. In Cagliari in 2020 there was an average of about 55 average daily vehicle rentals in free floating mode and

[7] Source: website www.playcar.net

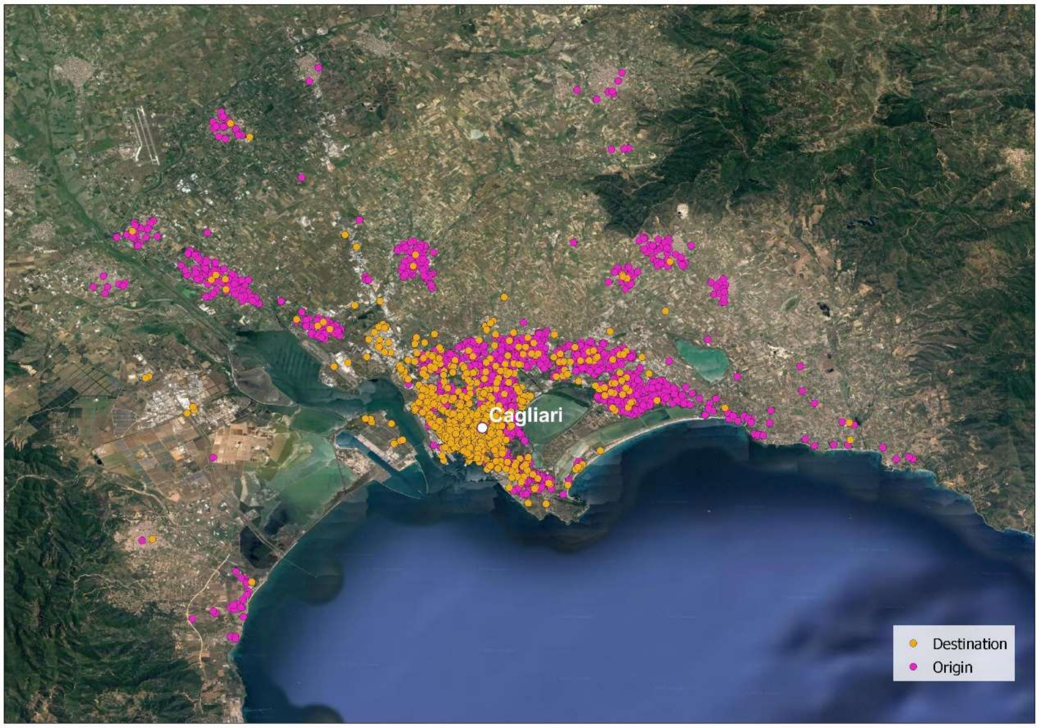
about 60 in round trip mode (period February-October 2020)[8]. It should be noted that this figure is strongly influenced by the COVID-19 pandemic.
In 2017 Playcar also took over the bike sharing service and from February 2021 provides the full integration of the two modes, car sharing and bike-sharing, in a single App, making Cagliari the only reality in Italy where this integration is operative. In this way, Cagliari citizens can switch from shared cars (including electric ones) to bicycles for the last mile. The bike sharing service uses the one-way mode[9], which allows the pick-up and return of the bicycle in each of the 7 stations in the city. Playcar offers 70 pedal assisted bicycle[10].

3.2 The Svolta's survey

The data used in the analysis is based on the Svolta's survey conducted from 2019 to 2020 by the Interuniversity Centre for Economic Research and Mobility (CIREM) of the University of Cagliari in the metropolitan area of Cagliari. The aim of the SVOLTA's program was to promote the use of sustainable modes of transport to replace the private car for home-work trips and home-study trips. The survey collected information on the mode transport choice of systematic trips among individuals working and studying in the municipality of Cagliari. As mentioned in section 1, during this thesis we will talk about origin as the place of production and destination as a place of attraction (Figure 3.6).

[8] Source: National sharing mobility report 2020
[9] Source: website www.playcar.net
[10] Source: website www.comune.cagliari.it

Figure 3.6 – Origins and destinations of the survey



The information collected by the questionnaire concerns three different sections:

- *socioeconomic characteristics*: age, gender, employment status, education level, number of household members, number of children, number of children with an age between 0 and 10 years, driving license, car ownership, number of household vehicles, individual income.
- *characteristics of the home to work trip*: origin, destination, distance, means of transportation used, alternative mode of transportation available, yearly frequency, start time of the trip, availability of bike parking in the workplace, car classification, car fuel
- *psychosocial characteristics*: choice, social norm, emotions, environmental responsibility, environmental awareness, place identity, habits, intentions, attitudes toward sustainable mobility, perceived behavioural control. They will be discussed in section 3.4.3

In addition to the dataset from the Svolta's survey, other characteristics were extracted to obtain information concerning built environment and available alternatives. From the GIS open data of Sardegna it was possible to compute another variable to be included in the model specification through the use of the QGIS software. This variable is the number of TPL's stops in an area with a buffer of 300 meters from the point of origin and from the point of destination of the individual trip. The two variables generated are: Stop_origin and Stop_destination.

Additionally, the available alternatives were asked in the questionnaire and, in order to check whether an individual has a means of transport available or not, certain rules are applied.

Rules for the bike mode availability

- He must declare to have the bike available
- Among those who declare to have the bike available and do not use it must result:
  - Distance from home to work <15 km
  - The route must not include extra-urban roads
  - Average slope uphill less than 2.5%

Rules for the foot mode availability

- He must declare to have the feet available
- Among those who claim to have their feet available and do not use them must result:
  - Distance from home to work ≤ 5 km
  - The route must not include extra-urban roads

Rules for the car driver mode availability

- He must declare to have the car as driver available
- Those who declare that they have the car available must include:
  - Driving license
  - Ownership of at least one car in the family

Rules for the public transport mode availability

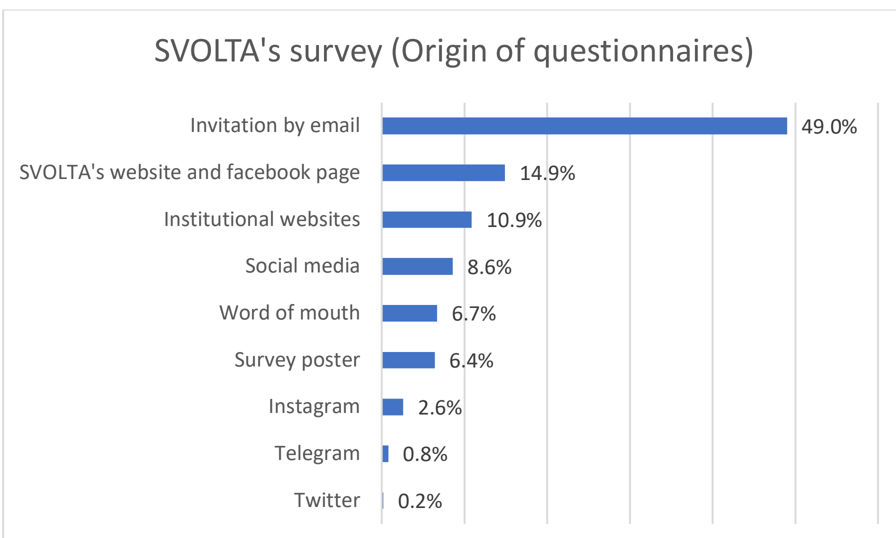
- He must declare that public transport is available
- Those who claim to have public transport available and do not use it must include:
    - Distance home-stop and stop-work <2 km
    - Headway (Waiting time between one bus and another) < 30 min

3.3 Data collection and data cleaning

During the survey, conducted from November 2019 to February 2020, 36,000 people were contacted (including 24,000 students from the University of Cagliari and 12,000 partner employees). Potential participants between staff and students at the University of Cagliari, employers at the Regional Government of Sardinia and at the municipality of Cagliari were reached by sending emails and through a promotional campaign conducted via traditional communication channels (TV, radio, posters, and postcards) and social media (Facebook, Instagram, Twitter).

Figure 3.7 shows the origin of the questionnaires in which almost half of the people were contacted by email.

Figure 3.7 – Origin of questionnaires of Svolta's survey



In Table 3.1 it is summarized the sample size. At the end of the survey, 11,495 questionnaires were collected, of which 5,006 complete with all information and 6,489 incompletes. From the analysis of the responses, 92.2% of the complete questionnaires (4,616 individuals) were georeferenced and it was possible to accurately identify the coordinates of the home and workplace.

However, among these, 4,311 compilations (86.1%) were useful for the purposes of the Svolta program. In fact, users with a home-work distance greater than 105 km (68 individuals), users under the age of 18 (37 individuals), those who had a destination other than the city of Cagliari, or the University Citadel (200 individuals) were removed. As introduced before in section 1, to conduct the analysis, there were considered only those observations that had available both the sustainable transport alternative (cycling, walking, public transport, micromobility, car sharing and carpooling and car plus public transport) and the unsustainable transport alternative (car driver, car passenger, motorcycle), removing 399 observations. Furthermore, observations with a home-work distance greater than 20 km were not considered to have the spatial correlation effects more localized (section 1), with a final data sample of 3251 observations.

Table 3.1 - Sample size

	N.	[%]
Total questionnaires	11495	100.0%
Complete questionnaires	5006	43.5%
Complete and georeferenced questionnaires	4617	40.2%
Complete questionnaires useful for the purpose of the survey	4311	37.5%
Final data sample	3251	28.3%

Subsequent analysis will refer to the sample of 3251 individuals.

3.4 Sample characteristics

3.4.1 Socioeconomic characteristics

Table 3.2 summarizes the socioeconomic characteristics of the sample. The sample includes a percentage of women of 54% and men of 46%, the average age of the sample is 39 years old, with the majority of individuals (41%) between 41-60 years, with 37.5% in the 18-30 year age group, 15% in the 31-40 year age group, and a lower percentage of 6.3% of people with an age over 60 years. The 34.6% are students, while the 62% are workers (PhD, employee, employer). A high percentage had attained a high school degree (45%) or a bachelor's or master's degree (34%) education, with relatively low percentages of individuals with some postgraduate degree (17%). 55% of the individuals reported a number of household members of 3 / 4 people with an average of 3 members, 70% of the respondents have no children and 14% stated having at least one child younger than 10 years in the household. 94% own the driving license, 50% of the sample declare to possess a bicycle and 83% own a car. The average number of cars in the household is 1.7 while the average monthly income is € 1349, with 26.4% of individuals earning between € 0 - 500.

Table 3.2 – Socioeconomic variables of the sample

Socioeconomic Variables		**N.**	**[%]**	Average
Total sample		3251	100	
Variable's name	*Variable's description*			
Gender	*Gender*			
	Male	1498	46.1	
	Female	1753	53.9	
Age	*Age*			39
	18-30	1218	37.5	
	31-40	483	14.9	
	41-60	1345	41.4	
	>60	205	6.3	
Employment	*Employment*			
	Student	1097	33.7	
	Student_worker	30	0.9	
	PhD	139	4.3	
	Employee	1674	51.5	
	Employer	206	6.3	
	Unemployed	54	1.7	

	Housewife	13	0.4	
	Retired	38	1.2	
Educational level				
	Primary or secondary school diploma	83	2.6	
	High school degree	1458	44.8	
	Professional degree	57	1.8	
	Bachelor or master's degree	1104	34.0	
	Postgraduate degree	549	16.9	
Graduate	*Graduate*			
	Yes	1653	50.85%	
	No	1598	49.15%	
N_household	*Number of household members*			3.0
	1	467	14.4	
	2	672	20.7	
	3 or 4	1775	54.6	
	5 or more	337	10.4	
N_children	*Number of children*			0.5
	0	2270	69.8	
	1	478	14.7	
	2 or more	503	15.5	
N_children10	*Number of children younger than 10 years*			0.2
	0	2791	85.9	
	1	327	10.1	
	2 or more	133	4.1	
Driving_license	*Driving License ownership*			
	Yes	3047	93.7	
	No	204	6.3	
Bicycle	*Bicycle ownership*			
	Yes	1616	49.7	
	No	1635	50.3	
Own_car	*Car ownership*			
	Yes	2707	83.3	
	No	544	16.7	
N_car	*Number of household vehicles*			1.7
	0	86	2.6	
	1	1225	37.7	
	2	1504	46.3	
	3 or more	436	13.4	
Income	*Individual income*			1349
	0-500€	859	26.4	
	500-1000€	323	9.9	
	1000-1500€	757	23.3	
	1500-2000€	729	22.4	
	2000-3000€	333	10.2	
	>3000 €	250	7.7	

3.4.2 Travel demand characteristics

In Table 3.3 it is possible to see the different means of transport used by the sample for the commuting trips. The survey recorded that 45.6% of the individuals use the car to move from home to work, 33.1% use public transport, 9.5% walk while only 3.3% use the bicycle. From the results, slightly more than half of people use unsustainable transport means.

Table 3.3 – Means of transport count

Trip Variables		**N.**	**[%]**
Total sample		3251	100
Means of transport			
Unsustainable	Car driver	1484	45.6
	Passenger car	92	2.8
	Motorcycle	97	3.0
Total unsustainable		**1673**	**51.5**
Sustainable	Walk	309	9.5
	Bike	107	3.3
	Public transport	1076	33.1
	Micromobility	12	0.4
	Car sharing/Car pooling	8	0.2
	Car + public transport	66	2.0
Total sustainable		**1578**	**48.5**

Table 3.4 shows the commuting distance. The mean distance is about 7 km, with a majority of individuals (43%) travelling between 1 to 5 km.

Table 3.4 – Commuting distance

Trip Variables		**N.**	**[%]**	Average
Total sample		3251	100	
Distance				6.87
	0-1 km	70	2.2	
	1-5 km	1412	43.4	
	5-10 km	1015	31.2	
	10-20 km	754	23.2	

From the origin / destination matrix (Table 3.5) it is possible to see that the majority of the trips are made within the city of Cagliari (53%), followed by the trips from the metropolitan area to Cagliari's city (26%), while a lower percentage of trips are made from Cagliari to the metropolitan area (12.5%).

Table 3.5 - Origin / Destination matrix

		DESTINATION							
		Metropolitan area of Cagliari		Cagliari		Sud Sardegna		Total	
		N.	[%]	N.	[%]	N.	[%]	N.	[%]
ORIGIN	Metropolitan area of Cagliari	150	4.6%	845	26.0%	0	0.0%	995	30.6%
	Cagliari	408	12.5%	1724	53.0%	2	0.1%	2134	65.6%
	Sud Sardegna	22	0.7%	100	3.1%	0	0.0%	122	3.8%
	Total	580	17.8%	2669	82.1%	2	0.1%	3251	100.0%

3.4.3 Psychosocial variables

The SVOLTA survey includes a set of attitudinal variables that capture individual attitudes, perceptions, and intentions to use sustainable mobility. It was used an inductive scale development approach to generate the items following the Theory of Planned Behaviour (Ajzen, 1991). More specifically, the Interuniversity Centre for Economic Research and Mobility (CIREM) of the University of Cagliari, have conducted a thorough review of the literature and have identified which items, among the ones adopted in previous studies, were more suitable given the context and aim of the program. At the end, they were able to identify the following items, using a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5). The questions formulated are the following:

- *Choice:* personal motivations that influence the choice to perform the behaviour. Choice was formulated ad hoc only for people who already use sustainable means of transport in order to assess what motivations could lead people to use sustainable means of transport. Choice was measured by fourth items concerning to the motivation to use sustainable means.
- *Social norm*: explicit and objective influences of others on oneself. It refers to the perceived social pressure to perform or not to perform the

behaviour (Ajzen, 1991). If an individual feels part of a group, he is influenced by the group's norms.

This was measured by two items (adapted from Fornara *et al.*, 2016) that pertained to whether or not friends, relatives, and neighbours use sustainable means of transport or think it would be important to use them.

- *Moral norm*: a feeling of personal obligation or commitment to perform, or refuse to perform, a certain behaviour (Ajzen, 1991).

  This was measured using the following item: "I feel morally obligated to use sustainable means of transport regardless of what others are doing."

- *Emotions*: they are related to mode choice; emotions are thoughts about future feelings after reaching a specific goal.

  Emotions were measured by three items (adapted from Carrus *et al.*, 2008) introduced by the following question: "If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel…". The items featured the following emotions: "guilty, proud, indifferent".

- *Environmental responsibility*: feeling of personal responsibility for the environmental consequences of their own decisions.

  Environmental responsibility was assessed using the following two items (adapted from Bamberg and Schmidt, 2003): "I feel personally responsible for the environmental problems resulting from the choice of my means of transport"; "I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city".

- *Environmental awareness*: feeling of personal awareness for the environmental consequences of their own decisions.

Environmental awareness was measured through the following two items (adapted from Bamber et al., 2007) concerning individuals' awareness of environmental issues generated by the use of the car: "I am aware that the use of private car has negative impacts on the environment and people's health"; "I am aware that I can personally contribute (by using the car less) to reduce pollution".

- *Place identity:* personal identity of belonging to a specific place.
  Place identity was measured by three items (adapted from Hernandez *et al.*, 2007) assessing individuals' degree of identification with place, feeling of belonging, etc.

- *Habits*: they cannot be considered a psychosocial determinant but can be very strong in activating a travel behaviour because a behaviour can become habitual. The TPB (Ajzen, 1991) states that past behaviour does influence future intentions, but the effect is indirect and mediated by attitudes and subjective norms.
  Habits were measured in a 5-point Likert scale, ranging from never (1) to every day (5). They have been formulated ad hoc to evaluate the transport mode choice used for trips other than home-work and home-study.

- *Intentions:* they capture the motivational factors that influence a behaviour (Ajzen, 1991).
  This was measured through three items (Manca and Fornara, 2019): "In the next two weeks I do not have any interest in using sustainable means of transport"; "During the next two weeks I intend to use the car"; "In the next two weeks I do not have any interest in using sustainable means of transport".

- *Attitudes:* they are not directly observable; they are hidden psychological states of an individual that can be measured through some feeling. They reflect an individual's evaluation toward the target behaviour, service, or product.

Attitudes were measured through three items introduced by the following statement: "I find that using sustainable means of transport instead of a private car is …". For the three items the following adjectives were used: "useful", "pleasant" and "right".

- *Perceived behavioural control*: it refers to people's perception of the ease or difficulty of performing the behaviour of interest (Ajzen, 1991).

  Perceived behavioural control was measured through three items (adapted from Klöckner and Friedrichsmeier, 2011; Bamberg *et al.*, 2007), by asking respondents to rate how easy and possible it was for them to use sustainable means of transport.

The choice to focus on psychosocial constructs related to sustainable mobility was because the object of the survey was to understand the facilitators and deterrents to the use of an environmental-friendly transport alternative.

Table 3.6 summarizes the percentage response and the average for each item. About 75% of the sample declared that the choice to use sustainable transport is motivated by a specific desire to do good for the environment and because it is more convenient in terms of time and costs. For 60% of individuals, this choice is due to the fact that it allows to do physical activity. 58% of individuals think they feel proud if during the next two weeks use sustainable means of transport instead of the car, but 48% think they will not feel guilty if during the next two weeks they will use the car instead of sustainable means of transport. About 60% feel personally responsible for the environmental problems deriving from the choice of their own means of transport, while only 40% feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in his city. Approximately 90% of individuals are aware that the use of a private car has negative impacts on the environment and people's health, and they can personally contribute, by using the car less, to reducing pollution. More or less 85% feel at home in Cagliari's city and must contribute to make it a better place and to respect it. Around 50% say they intend to use sustainable means of transport instead the car during the next two weeks, and about 70% are interested in using sustainable means of transport in the next two weeks. For 80% of individuals, it is useful and right to use sustainable means of transport instead of private cars, while only for 60% it is also pleasant. More or less half of the sample say it would be easy to use sustainable means of transport and are confident that in the next week they will be able to use sustainable means of transport.

Concerning trips different from work / school, 38% of individuals walk every day and 38% use the private car every day, while only 25% use public transport. 65% of individuals declare that they never use the bicycle for trips other than work or school.

Table 3.6 - Psychosocial variables

	Item	1 (Strongly disagree)	2 (Disagree)	3 (Neither agree nor disagree)	4 (Agree)	5 (Strongly agree)	AVERAGE
CH1	My choice to use sustainable transport is consciously and intentionally motivated by a specific desire to do good for the environment.	9.3%	4.1%	15.4%	37.2%	34.1%	3.83
CH2	My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).	3.7%	6.1%	14.9%	33.2%	42.2%	4.04
CH3	My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.	8.9%	10.0%	22.1%	27.8%	31.3%	3.63
CH4	My choice to use sustainable transport is obliged by the fact that I have no alternative	34.4%	16.5%	18.3%	14.3%	16.5%	2.62
NS1	Most of the people I know think I should use sustainable means of transport instead of the car.	24.4%	20.1%	32.9%	15.3%	7.3%	2.61
NS2	Most of the people I know use sustainable means of transport instead of the car.	32.0%	33.1%	16.7%	12.0%	6.2%	2.27
NM1	I feel morally obligated to use sustainable means of transport regardless of what others are doing.	8.8%	9.9%	25.3%	30.5%	25.5%	3.54
EM1	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	26.7%	20.9%	29.5%	16.8%	6.1%	2.55
EM2	If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	9.8%	7.8%	24.1%	34.6%	23.7%	3.55
EM3	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	16.4%	22.8%	31.8%	18.2%	10.9%	2.84
RESP1	I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	8.0%	11.7%	19.3%	41.6%	19.4%	3.53
RESP2	I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.	21.2%	19.2%	20.4%	25.7%	13.5%	2.91
AWA1	I am aware that the use of private car has negative impacts on the environment and people’s health.	1.0%	1.8%	4.9%	36.9%	55.4%	4.44
AWA2	I am aware that I can personally contribute (by using the car less) to reducing pollution.	1.5%	2.2%	6.8%	35.5%	54.0%	4.38
LOC1	This city is part of my identity and therefore I respect it.	0.8%	1.2%	6.5%	34.4%	57.1%	4.46

LOC2	I feel at home in this city.	2.1%	3.8%	9.4%	32.5%	52.2%	4.29
LOC3	I feel I belong to this city and therefore I must contribute to make it a better place.	1.6%	2.4%	12.0%	33.2%	50.8%	4.29
HABIT _W	Frequency of walking for trips different from work	10.2%	7.2%	15.3%	29.0%	38.3%	3.78
HABIT _B	Frequency of bicycle use for trips different from work	64.7%	18.0%	8.5%	5.4%	3.4%	1.65
HABIT _PT	Frequency of public transport use for trips different from work	12.9%	25.6%	19.7%	16.8%	24.9%	3.15
HABIT _CAR	Frequency of car use for trips different from work	7.2%	6.6%	17.9%	29.4%	38.8%	3.86
INT1	During the next two weeks, I intend to use sustainable means of transport instead of the car	14.6%	13.4%	19.2%	24.7%	28.1%	3.38
INT2	During the next two weeks, I intend to use the car.	16.9%	12.2%	19.4%	27.1%	24.3%	3.30
INT3	In the next two weeks, I do not have any interest in using sustainable means of transport.	48.1%	20.0%	21.2%	5.6%	5.1%	2.00
ATT1	I find that using sustainable means of transport instead of the private car is useful.	3.4%	5.0%	10.2%	34.2%	47.1%	4.17
ATT2	I find that using sustainable means of transport instead of the private car is pleasant.	8.1%	12.2%	20.7%	31.2%	27.8%	3.58
ATT3	I find that using sustainable means of transport instead of the private car is right.	1.4%	2.4%	13.8%	34.2%	48.2%	4.25
PBC1	It would be easy for me to use sustainable means of transport.	18.2%	18.9%	13.5%	25.5%	23.8%	3.18
PBC2	I am sure that in the next week I can use sustainable means of transport.	19.2%	14.4%	12.6%	19.6%	34.2%	3.35
PBC3	For me using sustainable means of transport is impossible.	46.7%	16.6%	13.2%	13.8%	9.7%	2.23

3.4.4 Alternatives available

Table 3.7 shows the availability of alternatives means of transport to compute the commuting trips. Considering the dataset composed by 3251 individuals, 81% of people have the possibility to use their private car to go to work/school, while only 51% can ride a bike and 42% can make the home to work trip on foot.

Table 3.7 – Availability of alternatives

		Yes		No	
Alternatives		N.	[%]	N.	[%]
Unsustainable	Car driver	2629	80.9	622	19.1
	Car passenger	2728	83.9	523	16.1
	Motorcycle	1806	55.6	1445	44.4
Sustainable	Walk	1352	41.6	1899	58.4
	Bike	1667	51.3	1584	48.7
	Public transport	2811	86.5	440	13.5
	Car sharing / Car pooling	2167	66.7	1084	33.3

3.4.5 Descriptive statistics

An association between distances and modal split was made, and it is presented in Table 3.8. Walking is the predominant choice (69%) of mode at very short distances (0 to 1 km) and about 17% individuals travel by car. However, 11% use public transport and only 1.4% ride a bicycle. There is a substantial increase in car mode use as distance increases, the car mode double to 35.2% for distances between 1 to 5 km. The use of the car still increases up to 58.5% for distances between 10 to 20 km. The use of the bus also increases with distance (about 36% for distances between 5 and 10 km), up to the category of 10 to 20 km where there is a slightly decrease up to 29.3%. The walking mode decreases from 69% to 18% for distances between 1 and 5 km, and it is almost zero for distances greater than 5 km. For the bike mode there is an increase in the category 1-5 km (5.7%) to decrease again to 0.7% for distances between 10 to 20 km.

For home - work distances less than 5 km, the use of sustainable means of transport is preferred (83% for 0-1 km and 59% for 1-5 km), for distances greater than 5 km, people prefer the use of unsustainable means of transport (about 60%).

Table 3.8 - Modal split distribution by distance from home to work / school

		Distance to work / school			
	Mode	0 - 1 km	1 - 5 km	5 - 10 km	10 - 20 km
Unsustainable	Car driver	17.1%	35.2%	52.6%	58.5%
	Passenger car	NA	2.3%	3.3%	3.3%
	Motorcycle	NA	3.2%	3.5%	2.1%
		17.1%	40.7%	59.5%	63.9%
Sustainable	Walk	68.6%	17.9%	0.8%	NA
	Bike	1.4%	5.7%	2.1%	0.7%
	Public transport	11.4%	34.3%	35.8%	29.3%
	Micromobility	1.4%	0.7%	0.1%	NA
	Car sharing/Car pooling	NA	0.1%	0.3%	0.4%
	Car + public transport	NA	0.6%	1.5%	5.7%
		82.9%	59.3%	40.5%	36.1%

NA = not applicable

Another comparison is made by analysing in detail the responses to the psychosocial variables between respondents who use sustainable means of transport and those who did not. It is possible to notice some interesting dissimilarities and to detect any differences in socio-psychological variables between these two groups, the mean of each item for the two subsamples is first calculated and then determined whether the means of the two subsamples are statistically different from each other using z-test (Table 3.9).

A statistically significant difference can be observed between the two subsamples. The items related to the choice to use sustainable means of transport, as mentioned before (section 3.4.3), were asked only to those who use sustainable means, for this reason the Z-stat shows very high values. Sustainable individuals are more influenced by the thought of people who are important for them, and also feel prouder of using sustainable means of transport than those who do not.

People using sustainable means of transport showed a higher level of environmental concern (responsibility and awareness) feeling more responsible for the environmental problems due to the use of the car, apart for the problems resulting from road congestion, space occupancy and car accidents in which both categories show the same behaviour.

Particularly interesting is that no differences were found for the items concerning the place identity; both subsamples show the same feelings for their city. Another particular finding is that unsustainable individuals are less intentioned to use sustainable means than individuals who use them.

Regarding attitudes, respondents generally agree that using sustainable means of transport is useful and right, but again, there is a statistical difference between the means of the two subsamples. With regard to perceived behavioural control, sustainable individuals find it is easy to use sustainable means of transport with high significant difference with those who do not use them.

Table 3.9 - Average of psychosocial variables between who use sustainable means of transport and who did not

	AVG total	AVG sustainable	AVG unsustainable	Difference	Z*	
CH1	3.83	3.82	0.00	3.82	125.08	*
CH2	4.04	4.04	0.00	4.04	149.33	*
CH3	3.63	3.62	0.00	3.62	113.74	*
CH4	2.62	2.62	0.00	2.62	70.14	*
NS1	2.61	2.70	2.53	0.17	4.11	*
NS2	2.27	2.58	1.99	0.59	14.35	*
NM1	3.54	3.77	3.33	0.44	10.47	*
EM1	2.55	2.77	2.34	0.42	10.05	*
EM2	3.55	3.60	3.50	0.10	2.32	*
EM3	2.84	2.75	2.93	-0.18	-4.27	*
RESP1	3.53	3.70	3.37	0.34	8.30	*
RESP2	2.91	2.89	2.93	-0.04	-0.74	
AWA1	4.44	4.55	4.33	0.23	8.60	*
AWA2	4.38	4.56	4.21	0.35	12.45	*
LOC1	4.46	4.46	4.46	0.00	-0.15	
LOC2	4.29	4.26	4.32	-0.05	-1.57	
LOC3	4.29	4.28	4.30	-0.02	-0.50	
HABIT_W	3.78	4.21	3.37	0.84	19.50	*
HABIT_B	1.65	1.66	1.63	0.04	0.94	
HABIT_PT	3.15	4.05	2.31	1.74	46.00	*

HABIT_CAR	3.86	3.12	4.56	-1.44	-41.68	*
INT1	3.38	4.30	2.52	1.78	47.77	*
INT2	3.30	2.41	4.13	-1.72	-44.22	*
INT3	2.00	1.58	2.39	-0.81	-21.02	*
ATT1	4.17	4.43	3.92	0.51	14.58	*
ATT2	3.58	3.69	3.49	0.20	4.61	*
ATT3	4.25	4.38	4.14	0.24	7.69	*
PCB1	3.18	4.14	2.28	1.86	48.05	*
PCB2	3.35	4.47	2.30	2.16	57.33	*
PCB3	2.23	1.42	3.00	-1.59	-39.58	*

** Significant at 95% confidence*

Other descriptive statistics are presented in APPENDIX A: Descriptive statistics of Svolta's survey dataset, using the whole dataset composed by 4311 observations.

4 METHODOLOGY

In the current thesis, a discrete choice model has been developed in order to analyse the factors that can influence the individuals' modal choice for their commuting trips. In particular, the probability that individuals choose a sustainable means for this type of trips is analysed. Two different models have been estimated: the first is a simple probit model and takes into account the socioeconomic and psychosocial characteristics that influence the modal choice of individuals. The second model estimated is a spatial probit model, where through a spatial weight matrix it is also able to capture the spatial dependence of this choice. As previously mentioned, spatial dependence implies that the individuals' choice of transportation mode can be influenced by the choice of individuals close to them.

After testing a large number of variables, only those statistically significant and consistent with the behavioural interpretation were adopted for the final specification of the model.

This section presents an overview of discrete choice models and in particular the simple probit model and the spatial probit model which includes the Bayesian estimation, the spatial weight matrix, and the marginal effects.

Furthermore, the model specifications and the tests to which the two models have been subjected are presented, such as maximum likelihood method, t-test, and likelihood ratio test.

Finally, the factor analysis used to transform the psychosocial variables into latent constructs is presented.

4.1 Overview of discrete-choice models

This section provides an introduction to discrete choice models, in particular, the simple probit and the spatial probit models are described.

The observed choices are made at individual level, so it deals with a disaggregated demand model that allow for a more realistic model, compared to aggregate models.

A discrete-choice model is applied when individuals have to select an option from a finite set of alternatives and is based on the concept of utility maximization in which individuals choose the alternative which has the highest utility (Ortuzar and Willumsen, 2011).

The theoretical framework that applies to discrete choice models is based on consumer theory (Ortuzar and Willumsen, 2011), in which:

1) *Individuals belong to a given homogeneous population Q*
2) *Perfect rationality of decision makers*
3) *Perfect knowledge of the alternatives*
4) *The choice set is the same for all individuals and is predetermined*

   The choice set is the set of travel means alternatives, this is predetermined before people start the evaluation process, meaning that all individuals face with the same constraints and these constraints do not affect the selection process among the available alternatives.
5) *The utilities can be analytically expressed*
6) *Distinction between net utility and systematic utility.*

   Each alternative i has associated a net utility U_{iq} for each individual q. Net utility represents all the elements considered by the individual making a choice and this is not directly observable. It is composed by two elements: a measurable systematic utility V_{iq}, function of the measured attributes x, and a random part ε_{iq} which express the error term. ε_{iq} has a mean 0 and a certain probability distribution. The net utility is equal to:

   $$U_{iq} = V_{iq} + \varepsilon_{iq}, \qquad \forall i$$

   This formula implies that two individuals with the same attributes and facing the same choice set may select different options, and that some individuals may not always select what appears to be the best alternative (Ortuzar and Willumsen, 2011).

   The observable utility is a linear combination of variables:

   $$V_{iq} = ASC + \sum_k \beta_{ki} * x_{ikq}$$

   Where:

V_i is the systematic utility of option i, *ASC* is the alternative specific constant, and it represents the influence of all characteristics of the individual not observed or not explicitly included.

β is the relative influence of the k-th attribute, they are constant parameters for all individuals, also called specified utilities, while *x* are the attributes of the traveller.

7) *Maximisation of the utility*

The individual q chooses the option that maximise its utility, he chooses j if and only if:

$$U_{jq} \geq U_{iq}$$

That is equal to write:

$$V_{jq} - V_{iq} \geq \varepsilon_{iq} - \varepsilon_{jq}$$

To understand if an alternative will be chosen, the utility must be transformed into a probability value between 0 and 1. Thus the probability of choosing option j is given by:

$$P_{jq} = Prob\{\varepsilon_{iq} \leq \varepsilon_{jq} + (V_{jq} - V_{iq})\}$$

In this thesis a binomial model has been applied, analysing the probability of choosing a sustainable or unsustainable means of transport. The probability of choosing an alternative does not depend on the value of the systematic utility of that option, but it depends on the difference between the two systematic utilities (V_s – V_{ns}) (Ortuzar and Willumsen, 2011). For this reason, in defining the systematic utilities, it is necessary to satisfy some constraints, otherwise identification problems may arise. To avoid the identification problems, in a binomial model, the ASC and the variables related to individual characteristics need to be added only in one of the two alternatives. In this case, the unsustainable and sustainable alternatives were defined as:

$$V_{ns} = 0$$

$$V_s = ASC + \sum_k \beta_k * x_k$$

4.2 Probit model

In the probit model the error terms ε are normally distributed (instead of independent and identically distributed of the logit model) with zero mean and an arbitrary covariance matrix. This does not allow to write the choice probability in a closed form as in the logit model (except for the binary case), because it is necessary to solve an integral, therefore approximations or numerically simulations are necessary (Ortuzar and Willumsen, 2011). The choice probability in the probit model, for alternative 1, become:

$$P_1 = \int_{-\infty}^{\infty} \int_{-\infty}^{V_1 - V_2 + x_1} \frac{exp\left\{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{x_1}{\sigma_1}\right)^2 - \frac{2\rho x_1 x_2}{\sigma_1 \sigma_2} + \left(\frac{x^2}{\sigma^2}\right)^2\right]\right\}}{2\pi\sigma_1\sigma_2\sqrt{(1-\rho^2)}} dx_2\, dx_1$$

In which the general variance-covariance matrix of the normal distribution of the error terms, applied to a binomial model, is:

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

Where σ_1^2 and σ_2^2 are the variance and σ_1 σ_2 is the covariance.

It allows for correlation ($\rho \neq 0$) and heteroskedasticity ($\sigma_1^2 \neq \sigma_2^2$) among alternatives.

4.3 Spatial probit model

Spatial interaction effects may exist across discrete choice alternatives. The spatial analysis allows to determine the spatial relationship between observations close to each other. With a spatial probit model based on random utility theory it is possible to capture the neighbourhood effect as explained in section 2.4.

Consider *q* (*q = 1, 2, …, Q*) as an index to represent the observations of a sample of Q decision makers. The $\tilde{y}_q$ represents the latent unobservable utility of the q-th observation. The equation system for the spatial lag model then takes the following form (LeSage and Pace, 2009):

$$\tilde{y}_q = \rho \sum_{q'=1}^{Q} w_{qq'}\tilde{y}_{q'} + \beta' x_q + \varepsilon_q,$$

Where:

ρ is the spatial autoregressive parameter ($0 < \rho < 1$).

$w_{qq'}$ is the element of the row-normalized spatial weight matrix W ($Q\ x\ Q$) corresponding to observations q and q' with zeros on the diagonal and 1 if the observations q and q' are adjacent $\left(w_{qq} = 0 \text{ and } \sum_{q \neq q'}^{Q} w_{qq'} = 1\right)$.

β' is the vector ($A\ x\ 1$) of coefficients associated with the x_q ($A\ x\ 1$) vector of exogenous attributes (excluding the constant).

ε_q is the error term, standard normally distributed and independently and identically distributed across decision makers which captures the effects of unobserved factors on latent propensity.

In the vector notation, the formulation for all individuals Q is given as:

$$\tilde{y} = \rho W \tilde{y} + X\beta + \varepsilon$$

where $\tilde{y}$ and ε are ($Q\ x\ 1$) vectors, W is the spatial weight matrix ($Q\ x\ Q$) which capture the spatial autocorrelation, X is ($Q\ x\ A$) matrix of exogenous variables A for all Q individuals and β is (A x 1) vector of associated parameters.

In other words, the utility of choosing sustainable means of transport is not affected only by exogenous variables but also by the neighbourhood effects represented by the spatial lag term $W\tilde{y}$.

ρ is expected to be positive because attitudes/preferences are likely to strengthen through social interactions.

The code of the independent probit model and spatial probit model are reported in APPENDIX B: R script to estimate models.

4.3.1 Spatial weight matrix (W)

The neighbourhood effects on each respondent's choice are represented by the spatial lag term $W\tilde{y}$. The spatial weight matrix W is a table where the information about the dependencies between object i and object j are stored.

The spatial weight matrix has dimension Q x Q, where Q is the number of observations. The elements in the matrix follow the conditions under which (LeSage and Pace, 2009):

- ω_{ij} = 1 if individual i is a neighbour of individual j
- ω_{ij} = 0 if individual i is not a neighbour of individual j
- ω_{ij} = 0 diagonal elements

The spatial matrix is based on the k-nearest neighbours where each row contains the k-nearest neighbours of the corresponding observation.

To illustrate this, consider the longitude and latitude of the origin place of ten individuals. Consider also that we want to see the interaction effects with the three closest neighbours. In row one, we see that individual 4, 9 and 10 are the closest neighbours of individual 1. All other elements of row one are equal to 0 because they are not closest neighbours. It is also possible to see that the diagonal elements of the matrix are zero, because individuals are not neighbour of themselves.

$$W' = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}$$

In order to normalize the matrix, each row need to sum to 1. The standard spatial weight matrix is defined as 1 over the number of neighbours within the row (1/k).This method treats every neighbour's effect equally. Concerning the previous example, the standard spatial weight matrix becomes:

$$
W = \begin{pmatrix}
0 & 0 & 0 & 1/3 & 0 & 0 & 0 & 0 & 1/3 & 1/3 \\
0 & 0 & 0 & 0 & 0 & 1/3 & 1/3 & 1/3 & 0 & 0 \\
1/3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1/3 & 1/3 \\
1/3 & 0 & 0 & 0 & 1/3 & 0 & 0 & 0 & 0 & 1/3 \\
1/3 & 0 & 0 & 1/3 & 0 & 0 & 0 & 0 & 0 & 1/3 \\
0 & 1/3 & 0 & 0 & 0 & 0 & 1/3 & 1/3 & 0 & 0 \\
0 & 1/3 & 0 & 0 & 0 & 1/3 & 0 & 1/3 & 0 & 0 \\
0 & 1/3 & 0 & 0 & 0 & 1/3 & 1/3 & 0 & 0 & 0 \\
1/3 & 0 & 1/3 & 0 & 0 & 0 & 0 & 0 & 0 & 1/3 \\
1/3 & 0 & 1/3 & 0 & 0 & 0 & 0 & 0 & 1/3 & 0
\end{pmatrix}
$$

4.3.2 Bayesian estimation

To estimate the parameters of the spatial probit model, the “spatialprobit” package, implemented in RStudio is used. It estimates spatial models using the Bayesian Markov Chain Monte Carlo (MCMC) approach (LeSage and Pace, 2009). This approach allows to estimate complex functional forms that are difficult to estimate using the maximum likelihoods method. The basic idea of this approach is to examine a large random sample estimating the parameters from a posterior distribution, knowing the data of the observable binary variables y, and some prior distributions $p(\tilde{y})$, $p(\beta)$, $p(\rho)$.

This sampling for the posterior distribution $p(\tilde{y}, \beta, \rho)$, can be performed by a Markov Chain Monte Carlo and Gibbs sampling scheme, where, from the conditional distribution associated with the first parameter, it proceeds sequentially with each parameter until all parameters have been drawn. The sampling starts from the following three conditional densities $p(\tilde{y}|\beta, \rho)$, $p(\beta|\tilde{y}, \rho)$ and $p(\rho|\tilde{y}, \beta)$ *(Wilhelm, 2013)*:

1. Given the observed variables y and parameters β and ρ, we have $p(\tilde{y}|\beta, \rho)$ as a truncated multinormal distribution:

   $$\tilde{y} = \left(I_Q - \rho W\right)^{-1} X\beta + \left(I_Q - \rho W\right)^{-1} \varepsilon$$

   subject to $\tilde{y}_i \geq 0$ for $y_i = 1$ and $\tilde{y}_i < 0$ for $y_i = 0$.

2. For a normal prior $\beta \sim N(c, T)$, and a uniform prior for the parameter ρ, we can sample $p(\beta|\rho, \tilde{y})$ from a multivariate normal as:

   $$p\,(\beta|\rho, \tilde{y}) \propto N\,(c^*, T^*)$$

$$c^* = (X'X + T^{-1})^{-1}(X'S\tilde{y} + T^{-1}c)$$
$$T^* = (X'X + T^{-1})^{-1}$$
$$S = (I_Q - \rho W)$$

3. The conditional density for the parameter ρ can be sampled from $p(\rho|\beta, \tilde{y})$:

$$p\,(\rho|\beta, \tilde{y}) \propto |I_Q - \rho W| \exp\left(-\frac{1}{2}(S\tilde{y} - X\beta)'(S\tilde{y} - X\beta)\right)$$

The MCMC model converge when the sampled parameters have reached stationarity.

4.3.3 Marginal effects

From the "spatialprobit" package of RStudio software it is possible to compute the marginal effects with respect to the independent variables of the spatial probit model. Marginal effects indicate how a dependent variable changes when a specific independent variable changes. The other variables are assumed to be kept constant. The marginal effects can be direct, indirect, and total effects.

The direct effect measures how individual behaviour can change if something changes in the variables. For instance, if the age is incremented by one year, how much does the probability of the individual choosing the sustainable means of transport change?

The indirect effect measures how individual behaviour can change if the behaviour of the neighbours' changes. For instance, if the age of the neighbours increases by 1%, how much does the probability of the individual choosing the sustainable means of transport change?

The total effect is the sum of the direct and indirect effects. For instance, if the age of the individual and that of the neighbour's change, how much does the probability of the individual choosing the sustainable means of transport change?

Summarizing, for any individual, an increase (decrease) in the utility of each alternative for his or her geographic neighbours would positively (negatively) influence the utility of corresponding alternative for that individual (spatial interdependence).

4.4 Probit model specification

The sample was initially composed of 4311 observations (as mentioned in section 3.3), to ensure that all individuals have both, the sustainable and unsustainable alternatives available, those observations that did not meet this criterion were eliminated, obtaining a final sample consisting of 3912 observations.

The binary endogenous variable y is defined taking the choice of the unsustainable means (ns) as reference category:

$$y = 0 \; if \; ns \; is \; used \qquad\qquad y = 1 \; if \; s \; is \; used$$

For the model specification the attributes of the trip considered are:

- *Bike_parking: it* is the availability of bike parking in the workplace, it is equal to 1 if it is available and 0 otherwise. Computing the utility of the sustainable alternative, this variable should be positive.
- *Distance:* it was considered the distance between the origin and the destination of the work or study trip in different ways:
    - *Categoric distance:* class 1: 0 - 1km; class 2: 1 – 5km, class 3: 5 – 10km, class 4: 10 – 20km, class 5: 20 – 40km and class 6: >40km.
    - *Continuous distance:* increasing the distance faster travel modes are preferred, hence the utility of the sustainable means should decrease, and the correct value should be negative. Since in the model specification the continuous distance became positive, it was decided to adopt the logarithmic distance and to consider only those observations with a distance equal to or less than 20 km.
    - *Logarithmic distance:* using the logarithm of the distance the curve is flattened, for this reason, long trips have no significant effects unlike medium distance trips.
- *Frequency:* is the yearly frequency of the trip. The correct sign should be negative.

- *Peak_hour:* it goes from 7:30 a.m. to 9:30 a.m., is equal to 1 if the trip is made in this period, 0 otherwise. For people who walk or cycle, this variable should be positive because they do not want to waste time congested in traffic. In the other hand, for those who use the bus, this variable should have a negative sign as using it during rush hour is not comfortable as it is generally crowded. Since most people in the sample use public transport, the correct sign of this variable should be negative.
- *Origin_metropolitan_other:* if the origin of the trip is not in the city of Cagliari, this variable is equal to 1. Taking as reference the trips originating in Cagliari, the sustainable utility decreases if the trip origin is in other locations, therefore this variable should be negative.
- *Destination_metropolitan_other:* if the trip destination is not in the city of Cagliari, this variable is equal to 1. Taking as reference the trips with destination in Cagliari, the sustainable utility decreases if the trip destination is in other locations, hence this variable should be negative.
- *Stop_origin:* is the number of public transports stops 300 meters from the point of origin of the trip. The availability of a public transport stop increases the public transport use (Limtanakool et al., 2006), so increasing the number of stops, the sustainable utility increases and the correct sign should be positive.
- *Stop_destination:* is the number of public transports stops 300 meters from the point of destination of the trip. By increasing the number of stops, the sustainable utility increases, hence the correct sign should be positive. Proximity to a public transport stop at the place of destination has been found to be more important than at the place of origin (Limtanakool et al., 2006).

Then, the socioeconomic characteristics were considered:

- *Age:* is the age of the individual. The logarithmic value of age was considered to have no significant differences in sustainable utility for old people. According to the literature, the car use increases together with age (Habib et al., 2009), hence the correct sign should be negative.

- *Gender:* is the gender of individuals. It is equal to 1 for men and equal to 0 for women. Some studies found that men tend to use the car more than women (Limtanakool et al., 2006), hence the sustainable utility for men is assumed to be lower than for women, so the sign should be negative.
- *Employment:* it is considered 0 for students and 1 for workers. The assumption is that workers tend to have higher income levels, resulting more prone to use the car and so using less sustainable means with respect to students, hence the sign should be negative.
- *Graduate:* it is equal to 1 for persons who have university degrees, 0 otherwise. It is assumed that those who have the degree are workers and those who do not have it are still students. For the assumption described above, the correct sign should be negative.
- *N_household:* number of household members. It is assumed that as the number of households increases, the sustainable utility increases, hence the correct sign should be positive.
- *N_children:* number of children. According to literature, the presence of children increases the utility of car use (Limtanakool et al., 2006) as the number of children increases, sustainable utility decreases, hence the sign should be negative.
- *Driving_license:* this variable is equal to 1 for driving license holders, 0 otherwise. For people who own the driving license, the sustainable utility decreases, hence the correct sign should be negative.
- *Bicycle:* it is equal to 1 for bicycle owners, 0 otherwise. In this case the sustainable utility should increase, therefore the sign should be positive.
- *Own_car:* it is equal to 1 for car ownership, 0 otherwise. For these people, the sustainable utility decreases because when a car is available, it will be used to travel (De Witte et al., 2013), thus the correct sign should be negative.
- *N_car:* it is the number of household vehicles. Increasing the number of available cars in a household, increases the probability of selecting a car for travel (Limtanakool et al., 2006), decreasing the sustainable utility, for this reason se sign should be negative.

- *Income:* is the individual income. It is found that income has an inverse relationship with usage of public transportation and a positive association with use of cars (Hensher et al., 2007), it means that increasing the income, the sustainable utility decreases, hence the correct sign should be negative. Moreover, there were considered 4 classes of income: class 1: 0 – 1000€, class 2: 1000 – 2000€, class 3: 2000 – 3000€ and class 4: >3000€, where the value of the parameter should increase as the income decreases.

Excluding observations with a distance greater than 20km, the final sample is composed of 3251 observations as mentioned in section 3.3.
The model specification has been computed with the RStudio software which allows to estimate the maximum likelihood of the model, the t-test related to variables and the likelihood ratio test (APPENDIX B: R script to estimate models).

4.4.1 Maximum likelihood method

For estimating the model parameters, the maximum likelihood method is the most used method. It estimates the parameters that maximise the probability of observing the choices made by the individuals. The observations of the sample are statistically independent, and the likelihood function is the product of the probabilities that each individual chooses the alternative actually chosen (Ortuzar and Willumsen, 2011):

$$L(\beta) = \prod_{q=1}^{Q} \prod_{j} \left(P_{jq}\right)^{g_{jq}}$$

Where Q are the individuals of the sample, j is the alternative and g_{jq} is a dummy variable, it is equal to 1 if the alternative j is chosen by the individual q and equal to 0 otherwise, β is the vector containing the parameters of the model.

Compared to the likelihood function, it is simpler to calculate its natural logarithm:

$$LL(\beta) = log\ L(\beta) = \sum_{q=1}^{Q} \sum_{j} g_{jq} log P_{jq}$$

To maximise the log likelihood function, LL(β) is partially differentiated with respect to the parameters and equating the derivative to zero.

$$\frac{dLL(\beta)}{d\beta} = 0$$

The log likelihood value is always negative because it is a probability between 0 and 1 and the logarithm function between 0 and 1 is always negative. After maximising LL(β), a set of estimated parameters β is obtained which are asymptotically distributed normally.

4.4.2 T-test

To verify the significance of the estimated parameters, the students t-test is applied where the null hypothesis is that the estimated parameter β_k is equal to zero (Ortuzar and Willumsen, 2011):

$$t = \frac{\beta_k}{s_{kk}}$$

Where β_k is the coefficient of the k-th attribute and s_{kk} is the standard error of that attribute. The t-test has a standard normal distribution, and it is possible to check whether the β_k coefficient is significantly different from zero. If the value is $t > 1.96$ (for 95% confidence level) it is possible to reject the null hypothesis ($\beta_k = 0$), hence it has a significant effect on the model specification. Generally, it is better to reject a variable that is not significant at least at the 80% level ($t \geq 1.282$) even if it has a correct sign. Variables with wrong sign are always rejected.

4.4.3 Likelihood ratio test

The likelihood ratio (LR) test evaluates the overall significance of the models. It compares the log-likelihood at convergence of two models that are one the restricted (r) version of the other. The LR is equal to twice the difference in the maximum values (Ortuzar and Willumsen, 2011):

$$LR(\beta) = -2\{LL(\beta_r) - LL(\beta)\}$$

Which is asymptotically distributed as a chi-squared variable with degrees of freedom equal to the number of linear restrictions. If this value exceeds the critical value of χ^2 associated with those degree of freedom, then the null hypothesis is rejected. The rejection of the null hypothesis implies that the restricted model is erroneous.

4.5 Psychosocial variables

As already mentioned in section 3.4.3, questions related to psychosocial variables asked to individuals are measured on a 5-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

These psychosocial latent variables are dependent variables not directly observable and are approximated with one or more surrogate variables through a factor analysis.

In factor analysis, different items are approximated into a single specific factor, so the states of the items must be consistent. For this reason, the items relating to intentions and perceived behavioural control need to be modified to be consistent with the other items belonging to these two groups.

Regarding intentions, the INT1 question (Table 3.6) was formulated with the intention of using sustainable transport, while INT2 and INT3 are formulated with the intention of using the private car. It was, therefore, decided to modify the sentence relating to INT1 in favour of the car ("During the next two weeks, I do not intend to use sustainable means of transport instead of the car."), also modifying the 5-point Likert scale, strongly disagree (1) become strongly agree (5) and so on. For this reason, the variable relating to intention in the model specification, must have a negative sign.

Instead, in perceived behavioural control, the third sentence PCB3 (Table 3.6) was changed to "For me using sustainable means of transport is possible.", changing the values of the scale as for INT1.

All psycho-attitudinal variables, except intentions, are formulated in support of sustainable mobility, therefore according to the specification of the sustainable utility they must have a positive sign.

The items relating to habits were not considered because test the transport mode choice used for trips other than home-work and home-study. Furthermore, the moral norm was not considered because as it is not possible to generate a factor with only one element.

4.5.1 Exploratory - Confirmative factor analysis

Exploratory factor analysis is suitable for variables measured on ratio scale as in this case. It is a statistical approach involving sequential steps, in which the objective is to reduce a large number of items into a set of variables (factors), establishing underlying dimensions between measured variables and latent constructs. The exploratory factor analysis allows to investigate the main dimensions to develop a model from a relatively large set of latent constructs.

To assess the suitability of the dataset for factor analysis, it is necessary to perform some tests such as Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity. The KMO index is a value between 0 and 1, and it needs to be greater than 0.50 to consider the sampling as adequate, while the Bartlett's Test of Sphericity is significant when $p < 0.05$.

The method used to extract the factor loadings is the Principal Axis Factoring (PAF) in which the cumulative percentage of variance and factors having an eigenvalue > 1 are computed.

To better interpret results, it is necessary to rotate them. The rotation maximises high item loadings and minimises low item loadings. In this case Varimax orthogonal rotation is used which produces uncorrelated factor structures.

Then, it is possible to examine which variables are attributable to a factor. To have a meaningful interpretation, at least two or three variables, with a value greater than 0.5, must load on a factor and these constructs should reflect the theoretical intent. In addition, another indicator is the Cronbach's alpha used to assess the degree of internal consistency. This parameter needs to be greater than 0.7 to consider the dataset reliable and acceptable.

The exploratory factor analysis was performed with Statistical Program for Social Sciences SPSS (IBM Corp. 2021).

It is necessary to clarify that, as it was mentioned previously (section 3.4.3), psychosocial factors were defined following the widely consolidated Theory of Planned Behaviour, in reality even if the tool used is typical of exploratory analysis in which there is no hypothesis about latent constructs, in fact, this tool it is used with a confirmatory perspective, verifying that the results obtained supports the existence of latent variables as foreseen by the TPB.

5 RESULTS

In this section are presented the results obtained, which as mentioned in section 1, a simple probit model was adopted as the first approach to verify which were the significant variables to be used in the specification of the model, then a spatial probit model, which analyse the spatial effects, was estimated. To arrive at the final specification of the model, the variables were gradually inserted and verified for their statistical significance and intuitive behavioural interpretation.

5.1 Simple probit results

Table 5.1 shows the results of the simple probit model estimated through the RStudio software including socioeconomic, trip and environmental characteristics that resulted statistically significant. The second column (estimate) represent the estimates of the β vector elements that characterize the propensity to use sustainable means of transport. For continuous variables such as age and distance, it was attempted a variety of functional forms, including the continuous value, the categoric function, and the logarithmic variable specification. In the end, the logarithmic variable specification was the best for both the age and distance variables. For income, the best form was to consider the dummy variable specification.

The statistical significance of the variables is indicated in the following way:

- (***) for level of significance equal to 0.001 and 99.9% confidence level
- (**) for level of significance equal to 0.01 and 99% confidence level
- (*) for level of significance equal to 0.05 and 95% confidence level
- (.) for level of significance equal to 0.1 and 90% confidence level

The variables resulted to be not statistically significant at the 95% confidence level ($t < 1.96$) are the driving licence, the graduate variable, the income 2000_3000, the trip yearly frequency, the variables relating to origins and destinations different from the city of Cagliari and the bike parking variable. Let us comment these variables:

- *Driving license* and *graduate variables*: these two variables are not significant at the 95% confidence level, but it is decided to continue to consider them in the model because they are statistically significant at the 80% and 85% confidence level.
- *Income2000_3000*: income greater than € 3000 is considered as the basis, for this reason the sustainable utility increases as the income decreases. The income2000_3000 is not statistically significant, so it is decided to consider income greater than € 2000 as a basis.
- *Frequency, origins, and destinations different from the city of Cagliari*: they are no longer considered in the model specification because not statistically significant.
- *Bike parking*: from the results, the presence of the bike parking in the workplace decreases the utility to use sustainable means of transport, this is not consistent with the assumption described before, because the possibility of parking the bike in the workplace should increase sustainable utility. This variable is wrong in sign and not statistically significant, for this reason it is no longer considered in the model specification.

On the other hand, the individual characteristics that affect the propensity to use sustainable means of transport are age, bicycle owners, driving license, employment status, gender, graduate owners, income, number of household vehicles, number of children, number of household members and car ownership.

According to the results:

- Older people have a lower propensity to use sustainable means of transport than young people.
- Being a bicycle owner increases the sustainable utility.
- Driving license holders are less inclined to use sustainable means of transport than those who do not.
- Since students are the base category, workers are less inclined to use sustainable means of transport.

- Men have a lower propensity to use sustainable means of transport than women.
- For graduates, the utility to use sustainable means of transport decreases.
- Individuals with income between € 0 and 1000 have a greater propensity to use sustainable means of transport than those belonging to other income groups.
- Individuals living in household with more vehicles have a lower propensity to use sustainable means of transport.
- The presence of children in the household also reduces the propensity to use sustainable means of transport.
- By increasing the number of household members, increases the propensity to use sustainable means of transport.
- People who own cars are less inclined to use sustainable means of transport than those who do not.

The trip characteristics that affect the propensity to use sustainable means of transport are the distance and the peak hour variable: increasing the distance from home to work, decreases the propensity to use sustainable means of transport. The same thing happens if we are in the peak hour.

Finally, the environmental characteristics that affect the propensity to use sustainable means of transport are the number of public transports stops in area with a radius of 300m from the place of origin and from the place of destination, which increase the sustainable utility. They are both positive and this is not surprising, because more bus stops, encourages people to take public transports and therefore a sustainable means of transport.

Table 5.1 – Probit model 1

Variables	Probit model 1 Estimate	Std. Dev	p-level	t-value	
Alternative specific constant					
Sustainable means of transport	3.12	0.50	0.00	6.23	***
Individual characteristics					
log(Age)	-0.32	0.12	0.01	-2.67	**
Bicycle	0.11	0.05	0.03	2.14	*
Driving_license	-0.27	0.22	0.22	-1.24	
Employment	-0.35	0.10	0.00	-3.65	***
Gender	-0.20	0.05	0.00	-3.77	***
Graduate	-0.08	0.06	0.15	-1.44	
Income0_1000	0.22	0.09	0.01	2.44	*
Income1000_2000	0.19	0.07	0.01	2.57	*
N_car	-0.46	0.04	0.00	-11.01	***
N_children	-0.36	0.05	0.00	-7.48	***
N_household	0.29	0.03	0.00	8.43	***
Own_car	-1.24	0.12	0.00	-10.37	***
Trip characteristics					
log(Distance)	-0.46	0.04	0.00	-11.91	***
Peakhour	-0.16	0.06	0.01	-2.64	**
Environmental characteristics					
Stop_destination	0.04	0.01	0.00	5.77	***
Stop_origin	0.02	0.01	0.00	3.33	***
Final log likelihood		-1576.786			
Number of parameters estimated		17			
Number of observations		3251			

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

5.2 Exploratory - Confirmative factor analysis

In order to include psychosocial variables in the model specification, an exploratory factor analysis is conducted in which the set of attitudinal statements measured in a ratio scale, are transformed into latent constructs.

Through the IBM SPSS software it was possible to assess the suitability of the data by verifying the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and the Bartlett’s test of sphericity by considering all the 22 variables. As shown in Table 5.2, the KMO of the dataset is equal to 0.891, thus the sampling is adequate to perform the factor analysis as it is greater than 0.5. The significance of the Bartlett’s test is p = 0.000 which is lower than the threshold of 0.05, also in this case is possible to confirm that the dataset is suitable for the exploratory factor analysis.

Table 5.2 – KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.891
Bartlett's Test of Sphericity	Approx. Chi-Square	33068.429
	Degrees of freedom	231
	Significance	0.000

Then, it is possible to see the total variance explained using the Principal Axis Factoring as extraction method (Table 5.3). The cumulative percentage of variance is 17.02% and the latent factors suitable for the modelling analysis, having an eigenvalue greater than one, are five.

Table 5.3 – Total variance explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.64	30.17	30.17	6.20	28.17	28.17	3.75	17.02	17.02
2	2.92	13.27	43.43	2.56	11.63	39.80	2.49	11.30	28.32
3	1.81	8.25	51.68	1.45	6.59	46.39	2.23	10.15	38.48
4	1.32	6.02	57.70	0.75	3.40	49.79	1.59	7.23	45.70
5	1.11	5.06	62.77	0.59	2.69	52.48	1.49	6.78	52.48
6	0.99	4.49	67.26						
7	0.90	4.08	71.34						
8	0.67	3.06	74.40						
9	0.61	2.77	77.17						
10	0.58	2.66	79.83						
11	0.54	2.45	82.29						
12	0.53	2.42	84.71						
13	0.49	2.22	86.92						
14	0.44	2.02	88.94						
15	0.41	1.84	90.78						
16	0.38	1.74	92.52						
17	0.36	1.63	94.14						
18	0.33	1.50	95.65						
19	0.31	1.41	97.06						
20	0.27	1.21	98.27						
21	0.21	0.97	99.24						
22	0.17	0.76	100.00						

By rotating the results with the Varimax method, it is possible to compute the rotated factor matrix. The rotation converged with seven iterations. The results of the exploratory factor analysis and the reliability of each group of variables, calculated using the Cronbach's alpha, are shown in Table 5.4:

Table 5.4 – Rotated factor matrix

Factor	1	2	3	4	5	Cronbach's Alpha
NS1	0.239	0.389	0.069	-0.061	-0.070	0.530
NS2	0.365	0.186	-0.012	-0.045	-0.178	
EM1	0.239	0.686	0.041	0.095	0.110	0.718
EM2	0.073	0.560	0.155	0.177	0.245	
EM3	0.079	0.463	0.071	0.092	0.271	
RESP1	0.093	0.550	0.076	0.398	0.134	0.684
RESP2	-0.042	0.451	0.125	0.172	0.121	
AWA1	0.093	0.193	0.128	0.712	0.138	0.766
AWA2	0.190	0.260	0.154	0.696	0.149	
LOC1	0.030	0.131	0.767	0.141	0.134	0.881
LOC2	0.027	0.091	0.822	0.064	0.059	
LOC3	0.042	0.181	0.886	0.105	0.143	
INT1	-0.789	-0.214	-0.048	-0.117	-0.206	0.761
INT2	-0.690	-0.117	0.036	-0.053	-0.121	
INT3	-0.403	-0.192	-0.052	-0.172	-0.349	
ATT1	0.293	0.185	0.115	0.191	0.536	0.713
ATT2	0.084	0.277	0.176	0.027	0.575	
ATT3	0.101	0.327	0.144	0.359	0.551	
PBC1	0.818	0.104	0.084	0.055	0.138	0.887
PBC2	0.897	0.076	0.040	0.105	0.104	
PBC3	0.747	0.010	0.028	0.122	0.084	

As can be seen from Table 5.4 the two items of the social norm do not go in the same latent construct, moreover their value is less than 0.5 and also the Cronbach's alpha is smaller than the 0.7 threshold, so these two items are not reliable. Environmental responsibilities are also unreliable because Cronbach's alpha is equal to 0.68, while all other variables are reliable with a Cronbach's alpha greater than 0.7.

The results present an issue: intentions are in the same latent construct of perceived behavioural control that is not consistent with the theory of planned behaviour in which they separately concur in understanding travel behaviour.

Considering a confirmatory perspective based on TPB, intentions and perceived behavioural control in the model specification will be considered separately.
All the reliable latent constructs were added in the model specification but only those statistically significant and with the correct sign are presented in Table 5.5. By analysing the results, it was possible to notice some inconsistencies:

- Bicycle: this variable becomes not significant, hence it is no longer considered in the model specification.
- Driving license: it is statistically significant at the 90% level of confidence, so it is decided to continue to consider it.
- Graduate: it has become positive, which is not coherent with the assumption described before in which graduate people are considered as workers and so the sustainable utility should decrease, moreover this variable is no longer statistically significant, for this reason it is no longer considered.
- Income: this variable should increase by decreasing the income, this is not what happen in this model specification because the value of income1000_2000 should be less than income0_1000, For this reason it is decided to consider a single variable that includes the two income classes (Income 0_2000).
- Psychosocial variables: attitudes, emotions and place identity resulted to be wrong in sign as they should be positive, differently awareness is correct in sign but not statistically significant at the 95% confidence level. Several trials have been carried out to find a correct combination for these variables, but in the end only intentions and perceived behavioural control were statistically significant and with correct sign. Perceived behavioural control increases the propensity to use the sustainable means of transport, while intentions (which are based on the use of the car) decrease the propensity to use sustainable means.
- The number of public transports stops in the origin place increases the propensity to use sustainable means of transport but becomes not statistically significant. It was decided to leave this variable in the model specification because it can be seen that people probably do not choose

to live in a specific place because there is the presence of TPL stops, but the residential location choice does not depend on this variable.

Table 5.5 – Probit model 2

	Probit model 2				
Variables	Estimate	Std. Dev	p-level	t-value	
Alternative specific constant					
Sustainable means of transport	3.01	0.63	0.00	4.79	***
Individual characteristics					
log(Age)	-0.39	0.15	0.01	-2.58	**
Driving_license	-0.51	0.28	0.07	-1.82	.
Employment	-0.35	0.12	0.00	-2.97	**
Gender	-0.17	0.07	0.01	-2.57	*
Income0_2000	0.15	0.09	0.11	1.62	
N_car	-0.30	0.05	0.00	-5.64	***
N_children	-0.20	0.06	0.00	-3.28	**
N_household	0.23	0.04	0.00	5.34	***
Own_car	-0.91	0.15	0.00	-6.25	***
Trip characteristics					
log(Distance)	-0.32	0.05	0.00	-6.50	***
Peakhour	-0.19	0.08	0.01	-2.50	*
Psychosocial variables					
INT	-0.63	0.06	0.00	-10.99	***
PBC	0.92	0.06	0.00	16.09	***
Environmental characteristics					
Stop_destination	0.03	0.01	0.00	3.58	***
Stop_origin	0.00	0.01	0.85	0.19	
Final log likelihood	-901.94				
Number of parameters estimated	16				
Number of observations	3251				

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

5.3 Spatial probit model results

In order to estimate the spatial effects, a spatial probit model was applied by using the 'spatialprobit' package in RStudio software. These effects are estimated considering a spatial weight matrix with 80 nearest neighbours which provide the best log likelihood value for both origin and destination models.

At the end we want to compare the spatial probit models with the simple probit model that does not account for spatial interactions effects, in order to provide evidence in favour of the spatial dependence theory. To compare the two models, the likelihood ratio test is performed.

Considering the effects in the origin place, the estimation results are listed in Table 5.6. At first glance is possible to notice that all the variables, in both models, have the correct sign, consistent with the behavioural interpretation.

The alternative specific constant in the spatial model is slightly lower than the ASC of the independent model, indicating that ignoring spatial interactions effects can lead to an inaccurate estimation.

In both independent and spatial dependent models, the variables that most influences the utility of using sustainable means of transport are the perceived behavioural control ($\beta = 0.92$ and $\beta = 0.91$ respectively) and the ownership of the car ($\beta = -0.91$ and $\beta = -0.89$ respectively). An interesting thing is that the number of stops in the origin place becomes negative in the spatial probit model, this is not consistent with the assumption previously explained.

The spatial dependency parameter is moderate in magnitude (0.20), positive and highly statistically significant (t-stat = 3.82), supporting the hypothesis that the propensity to use sustainable means of transport is positively correlated by individuals located in close proximity of each other.

Table 5.6 - Comparison between independent probit and spatial probit (origin) models

	Independent probit					Spatial probit (origin)				
Variables	Estimate	Std. Dev	p-level	t-value		Estimate	Std. Dev	p-level	t-value	
Alternative specific constant										
Sustainable means of transport	3.01	0.63	0.00	4.79	***	2.93	0.58	0.00	5.02	***
Individual characteristics										
log(Age)	-0.39	0.15	0.01	-2.58	**	-0.37	0.14	0.00	-2.65	**
Driving_license	-0.51	0.28	0.07	-1.82	.	-0.63	0.32	0.02	-1.97	*
Employment	-0.35	0.12	0.00	-2.97	**	-0.34	0.12	0.01	-2.91	**
Gender	-0.17	0.07	0.01	-2.57	*	-0.17	0.06	0.00	-2.66	**
Income0_2000	0.15	0.09	0.11	1.62		0.15	0.09	0.06	1.57	
N_car	-0.30	0.05	0.00	-5.64	***	-0.30	0.05	0.00	-6.12	***
N_children	-0.20	0.06	0.00	-3.28	**	-0.19	0.06	0.00	-3.22	**
N_household	0.23	0.04	0.00	5.34	***	0.23	0.04	0.00	5.46	***
Own_car	-0.91	0.15	0.00	-6.25	***	-0.89	0.14	0.00	-6.59	***
Trip characteristics										
log(Distance)	-0.32	0.05	0.00	-6.50	***	-0.23	0.05	0.00	-4.50	***
Peakhour	-0.19	0.08	0.01	-2.50	*	-0.18	0.07	0.01	-2.49	*
Psychosocial variables										
INT	-0.63	0.06	0.00	-10.99	***	-0.63	0.06	0.00	-10.73	***
PBC	0.92	0.06	0.00	16.09	***	0.91	0.06	0.00	15.38	***
Environmental characteristics										
Stop_destination	0.03	0.01	0.00	3.58	***	0.03	0.01	0.00	3.76	***
Stop_origin	0.00	0.01	0.85	0.19		-0.01	0.01	0.15	-1.03	
Spatial parameter ρ	NA					0.20	0.05	0.00	3.82	***
Final log likelihood	-901.94					-896.84				
Number of parameters estimated	16					17				
Number of observations	3251					3251				
Number of nearest neighbours	NA					80				

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

The spatial probit model is capturing the spatial correlation effect that is completely ignored in the independent probit model. The spatial probit model is also found to offer a statistically superior goodness-of-fit in comparison to the independent probit model. In particular, as can be seen in Table 5.7, the likelihood ratio test comparing independent probit and spatial probit models for the origin place is 10.211, which is statistically significant at the 0.001 level of significance compared to the chi-square distribution with one degree of freedom. This indicates the superiority of the spatial probit model over the independent probit model.

Table 5.7 – Likelihood ratio test (origin)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)	
Probit	16	-901.94				
Spatial Probit (origin)	17	-896.84	1	10.211	0.001396	**

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

Then a comparison between the spatial probit model in the origin place and the spatial probit in the destination place is made. The results are presented in Table 5.8. It can be seen that the estimated parameters are very similar in both models. The variables that most influences the utility of using sustainable means of transport at the destination, as in the origin place, is the perceived behavioural control with a β value of 0.91, followed by the car ownership with a β value equal to -0.91. The three other more important variables are intentions (-.064), driving license (-0.54), and age (-0.37). While the variables that have the least impact on the use of sustainable means of transport are the TPL stops in the origin and destination place, the income, and the gender variable.
The spatial dependence parameter is positive and slightly less than the origin place (0.16), it is highly statistically significant (t-stat = 3.22), supporting, again, the hypothesis that the propensity to use sustainable means of transport is positively correlated by individuals who are in close proximity to one another.

Table 5.8 – Comparison between spatial probit models in origin and destination

	Spatial probit (origin)					Spatial probit (destination)				
Variables	Estimate	Std. Dev	p-level	t-value		Estimate	Std. Dev	p-level	t-value	
Alternative specific constant										
Sustainable means of transport	2.93	0.58	0.00	5.02	***	2.92	0.61	0.00	4.75	***
Individual characteristics										
log(Age)	-0.37	0.14	0.00	-2.65	**	-0.37	0.15	0.01	-2.43	*
Driving_license	-0.63	0.32	0.02	-1.97	*	-0.54	0.25	0.00	-2.17	*
Employment	-0.34	0.12	0.01	-2.91	**	-0.25	0.12	0.02	-2.09	*
Gender	-0.17	0.06	0.00	-2.66	**	-0.14	0.07	0.03	-1.97	*
Income0_2000	0.15	0.09	0.06	1.57		0.18	0.10	0.04	1.81	.
N_car	-0.30	0.05	0.00	-6.12	***	-0.28	0.05	0.00	-5.27	***
N_children	-0.19	0.06	0.00	-3.22	**	-0.19	0.05	0.00	-3.48	***
N_household	0.23	0.04	0.00	5.46	***	0.22	0.04	0.00	5.10	***
Own_car	-0.89	0.14	0.00	-6.59	***	-0.91	0.15	0.00	-6.02	***
Trip characteristics										
log(Distance)	-0.23	0.05	0.00	-4.50	***	-0.30	0.05	0.00	-6.06	***

Peakhour	-0.18	0.07	0.01	-2.49 *	-0.20	0.08	0.00	-2.55 *
Psychosocial variables								
INT	-0.63	0.06	0.00	-10.73 ***	-0.64	0.06	0.00	-11.05 ***
PBC	0.91	0.06	0.00	15.38 ***	0.91	0.06	0.00	15.11 ***
Environmental characteristics								
Stop_destination	0.03	0.01	0.00	3.76 ***	0.02	0.01	0.00	2.78 **
Stop_origin	-0.01	0.01	0.15	-1.03	0.00	0.01	0.35	0.37
Spatial parameter ρ	0.20	0.05	0.00	3.82 ***	0.16	0.05	0.00	3.22 **
Final log likelihood		-896.84				-897.56		
Number of parameters estimated		17				17		
Number of observations		3251				3251		
Number of nearest neighbours		80				80		

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

The likelihood ratio test comparing the independent probit and the spatial probit model for the destination place is presented in Table 5.9 and is equal to 8.764, which is statistically significant at the 0.001 level of significance. As before, this indicates the superiority of the spatial probit model over the independent probit model.

Table 5.9 – Likelihood ratio test (destination)

Model	#Df	LogLik	Df	Chisq	Pr(>Chisq)	
Probit	16	-901.94				
Spatial Probit (destination)	17	-897.56	1	8.764	0.003073	**

Level of significance: (***) = 0,001; (**) = 0.01; (*) = 0.05; (.) = 0.1; ( ) = 1

5.4 Marginal effects analysis

Table 5.10 presents the direct, indirect, and total mean effects resulting from changes in the continuous independent variables in the origin place.

With an increase in individual's age of 1%, the probability that the individual chooses the sustainable means of transport decreases by 5.9%, if the age of the neighbours increases, the probability that the individual chooses the sustainable means of transport decreases by 1.4%.

A 1% of increase in the number of household members of the individual would increase his or her probability of choosing sustainable means of transport (3.6%) and the indirect effect through his neighbours' choice would also cause a probability increases (0.8%).

An increase in the number of children would decrease both directly (-3%) and indirectly (-0.7%) his probability of choosing sustainable means. Similarly, with regard to the number of cars in the household and the ownership of cars, the probability of choosing sustainable means decreases.
An increase of 1 km in an individual's residence location away from the workplace would directly reduce his or her probability of choosing sustainability (-3.6%) and the indirect effect would also cause a probability decline (-0.8%).
As the number of bus stops at the destination place increases, there is an increase in the direct and indirect effect, while the TPL stops at the origin place have almost no effect on the results.
An increase in the perceived behavioural control means an increase in choosing sustainable means of transport in both direct (14.4%) and indirect (3.3%) effects.
However, an increase in the intentions, as related to the use of the car, leads to a decrease in the probability to use sustainable means.

Table 5.10 – Impacts spatial probit (origin)

Variable	Direct effects	Indirect effects	Total effects
Age	-0.059	-0.014	-0.072
Driving_license	-0.099	-0.022	-0.122
Employment	-0.054	-0.013	-0.066
Gender	-0.027	-0.006	-0.033
Income0_2000	0.023	0.005	0.028
N_car	-0.047	-0.011	-0.057
N_children	-0.030	-0.007	-0.037
N_household	0.036	0.008	0.044
Own_car	-0.140	-0.033	-0.172
Distance	-0.036	-0.008	-0.044
Peakhour	-0.028	-0.007	-0.035
INT	-0.099	-0.023	-0.122
PBC	0.144	0.033	0.177
Stop_destination	0.005	0.001	0.007
Stop_origin	-0.001	0.000	-0.002

The greatest impacts are found in perceived behavioural control and in car ownership for both direct and indirect effects.

The direct effects are stronger than the indirect effects, it means that even if the choice of the individual is affected by neighbours' choice, this choice is more influenced by his own characteristics.

The results for the impacts related to the spatial probit at the destination place are very similar with respect to the spatial probit at the origin place and they are presented in Table 5.11. As for the origin place, the greatest impacts are due to perceived behavioural control and car ownership for both, direct and indirect effects. While the less significant impacts are due to the increase of TPL stops in the origin and destination locations.

Table 5.11 – Impact spatial probit (destination)

Variable	Direct effects	Indirect effects	Total effects
Age	-0.057	-0.011	-0.068
Driving_license	-0.084	-0.016	-0.101
Employment	-0.038	-0.007	-0.046
Gender	-0.023	-0.004	-0.027
Income0_2000	0.028	0.006	0.033
N_car	-0.044	-0.009	-0.053
N_children	-0.030	-0.006	-0.036
N_household	0.034	0.007	0.041
Own_car	-0.142	-0.028	-0.169
Distance	-0.047	-0.009	-0.057
Peakhour	-0.031	-0.006	-0.037
INT	-0.099	-0.019	-0.118
PBC	0.142	0.028	0.170
Stop_destination	0.004	0.001	0.004
Stop_origin	0.000	0.000	0.001

6 CONCLUSIONS

The present thesis develops a framework for incorporating spatial dependencies and psychosocial effects when modelling commuting trip mode choice behaviour. Spatial effects may arise due to interactions between individuals geographically close to each other. In order to capture these dependences, two models are estimated, an independent probit model that does not take into account the effects of spatial interaction and a spatial probit model which allows to determine whether the spatial interaction effects are significant and present. When such interaction effects are present, the assumption of independence of choice alternatives, intrinsic to the traditional discrete choice model, is violated and the parameters estimated with the simple model can be biased and inconsistent.

The two models analyse the probability of choosing a sustainable or unsustainable means of transport of 3251 commuters in the metropolitan area of Cagliari (Sardinia), by exploring individual, trip and environmental characteristics and the psychosocial variables related to the use of sustainable mode of transportation for their home to work/study trips. Environmental characteristics, which include spatial and social effects, are analysed both in the place of production and attraction.

By carrying out the analysis, the results can be commented by separately considering the following four aspects: individual characteristics, trip characteristics, psychosocial variables, and environmental characteristics.

Regarding individual characteristics, it has been observed that being young, a student or a woman increases the probability of using sustainable means of transport. Also, this probability increases as the number of members in the household increases. The probability of using sustainable means of transport, on the other hand decreases in the presence of children in the household, for driving license holders and owners of private cars; it also decreases as the number of cars in the household increases.

From the results it is possible to note that the variables relating to car ownership and driving license holding have an important weight in the probability of choosing a sustainable means of transport; in particular, the car ownership variable has a value around β = -0.90 and t-test around 6, both in the spatial probit model at the place of production and in the spatial probit model at the place of attraction.

With regard to trip characteristics, it is observed that as the distance from home to the place of work or study increases, the probability of using sustainable means of transport decreases. Moving during rush hour is another variable that decreases the probability of choosing a sustainable mode of transportation.

Concerning the psychosocial variables, they are estimated through a factor analysis that reduces the number of items into a set of variables (factors). Through this it is possible to note how the intentions to use the private car, as expected, reduces the probability of using sustainable means of transport. While, perceived behavioural control, which is related to the ease and possibility of using a sustainable means of transport, increases the sustainable utility and is an important determinant for the mode choice both in residential (β = 0.91, t-test = 15.38) and in work/study (β = 0.91, t-test = 15.11) addresses.

Finally, regarding environmental characteristics, the number of public transports stops near the work/study address increases the probability of using sustainable means, while the number of public transports stops near the residential address has almost no effect. One possible explanation could be that people do not choose to live in a specific location because of public transport stops, but the choice of residential location is due to other factors.

Concerning the spatial and social dependence in the transport mode choice for commuter trips, we can say that this has been verified, through the spatial autoregressive probit model, with positive results and high statistical significance. There are spatial effects both in the residential (ρ = 0.20, t-test = 3.82) and in the work/study (ρ = 0.16, t-test = 3.22) addresses, arising from interactions among individuals that are close to each other. These effects are also called neighbourhood effects.

The estimated spatial probit model considers the spatial lag effect that captures the effects caused by interactions between individuals who are geographically close to each other, which may influence the way the individual behaves; however, unobserved correlation effects may be present. The spatial effects can be slightly overestimated at the place of production because the unobserved effects may be due to the choice of the residential location near people with the same propensity for sustainable mobility, while in the place of attraction it is difficult that these unobserved effects are present as the workplace is not a recreational destination that can be chosen.

The findings obtained can be used by policy makers to develop strategies for encouraging citizens to use a more sustainable means of transport, such as the active mobility and public transport, for their commuting trips. More specifically, policy-makers, planners, and practitioners, in their aim of reducing the use of the private vehicles should focus on three macro-areas: policies that affect the psycho-attitudinal characteristics of individuals, policies against car ownership and policies that integrate the effects of spatial interaction between individuals. As for the psycho-attitudinal characteristics, model results indicate that the perceived behavioural control (PBC) and the intention to use the car are among the variables that most affect the choice of using a sustainable mode of transport. Perceived behavioural control positively influences this choice, while the intention, centred on private car use, negatively affects the use of sustainable means. From a policy standpoint, these findings suggest that the implementation of an infrastructural measure, like the introduction of a new transit line or the construction of a new cycle path, is a necessary but not sufficient condition for the long road leading to the decarbonisation of private transport. In fact, an aspect that should not be neglected is how individuals perceive this new infrastructure and if they consider it more convenient and easier to use compared to the private car alternative.

For example, the construction of a new light rail line, characterized by the presence of few stops and not connected to other public transport, would hardly change people's PBC and therefore their intention to use public transport. It is necessary that this new line will be easy to use for all potential passengers and therefore it should be planned to have the right distance among stops, as well as the presence of a sufficient number of interconnections with other transit lines and/or sharing mobility stations, and a good level of walking accessibility guaranteed. A different kind of strategy is the deployment of an information campaign, both at individual and general level, aimed at changing perceived behavioural control toward the use of sustainable mobility. An example of these measures are the Personalized Travel Plans, which inform citizens about the sustainable travel alternatives available to them for their commuting trips and provide them with useful information (e.g., the position of the transit stop where to take/get off the bus, the number of the transit line they need to take) to facilitate the use of sustainable means of transport.

Another variable that strongly affects the likelihood to choose to commute by sustainable mobility is car ownership, which negatively influences the utility function associated with this choice. Indeed, it is observed that, on average, the possession of a car decreases the probability of using a sustainable travel alternative by approximately 14% (direct effect). Hence, measures aimed at discouraging the purchase of the car, such as the introduction of a congestion charge or the increase of parking feed, are among the strategies that policy-makers should consider if they wish to induce a travel behaviour change among citizens. Another possible measure in policy-makers tool-box is the implementation of Mobility as a Service (MaaS), a system whose main purpose is to develop efficient, integrated, and personalized mobility services (Smith and Hensher, 2020). One of the promises of MaaS is the reduction in the level of car ownership, since citizens will be able to conclude a single subscription plan that will allow them easy and convenient access to different modal transport services (car sharing, bike sharing, scooter sharing, transit) (Hensher et al., 2020).

Regarding the spatial and social interaction effects present at both the place of production and the place of attraction, policy makers can develop strategies directed towards local areas rather than more widespread areas.

In the place of production, policies can be implemented at the neighbourhood level: for example, building a new bike path that connects that neighbourhood to a strategic point in the city. Initially only a few people will use the bike to make that movement, as other people observe and interact with them, they will also start to use the bicycle.

Another type of policy can be implemented at the place of attraction, which is to say in the workplace or where educational activities are carried out: for example guarded parking for bicycles or public transport incentives for employees of certain institutions or students of a certain university. In this way, more and more people interacting and observing the choices of others, will be more inclined to use the bike or bus instead of the car which would require higher costs.

though these important results and political implications, the present thesis has some limitations. Firstly, the model does not take into account travel times and travel costs of the different means of transport, which can strongly influence the results. Using disaggregated data at individual level it is not easy to include time and cost and this can affect the interpretation of the results. For future research, a model could also be built using travel times and travel costs of the different means of transport.

Secondly, a binomial model was considered by analysing the probability of using a sustainable or unsustainable means of transport as it is complex to build a multinomial model that includes the effect of spatial lag. For future research, a trinomial spatial model could be constructed taking into consideration the choice between cars, public transport, and active mobility.

Thirdly, the spatial weight matrix used is based on the k-nearest neighbours. In some cases, some of these closest neighbours may be quite far away, thus their effects may negligible or inexistent. For future research, the distance-based spatial matrix could be used in which it is possible to decide a distance threshold to also see the different effects in the different neighbourhood of the city.

Despite these limitations, the estimated models have been useful in confirming that the probability of choosing a means of transport for individual commuting trips is influenced by the effects of interaction between individuals that are closer together, and that psychosocial variables such as intentions and perceived behavioural control play a significant role in the choice of travel means. After these considerations, it is possible to confirm that ignoring spatial and social interactions effects can lead to potential bias in the estimated parameters, inferior data fit and underestimation of policy impacts.

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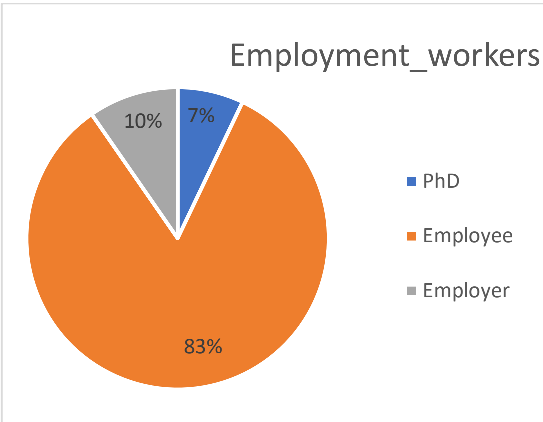
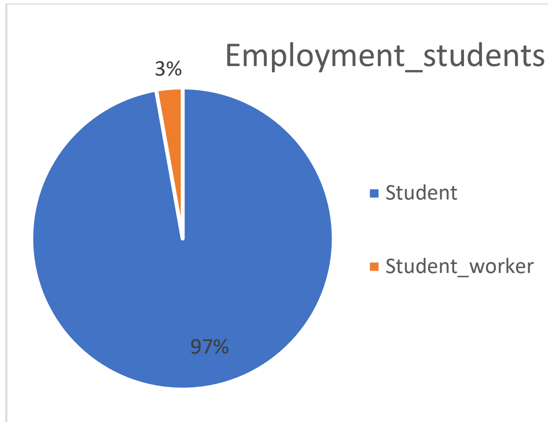
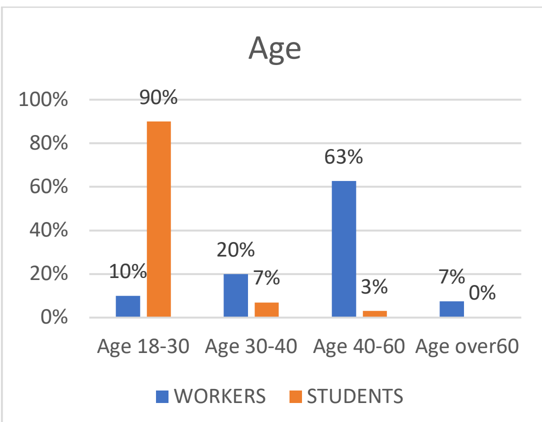
APPENDIX A: Descriptive statistics of Svolta's survey dataset

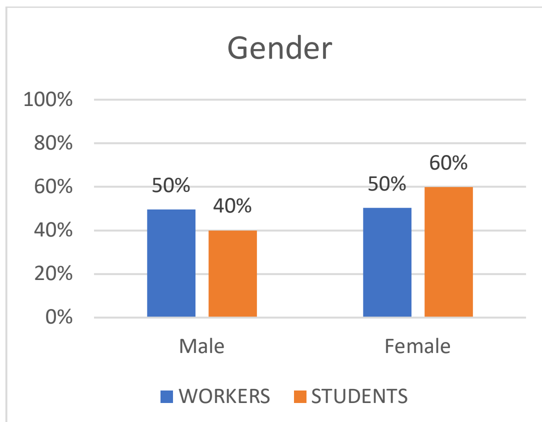
A.1 WORKERS vs STUDENTS

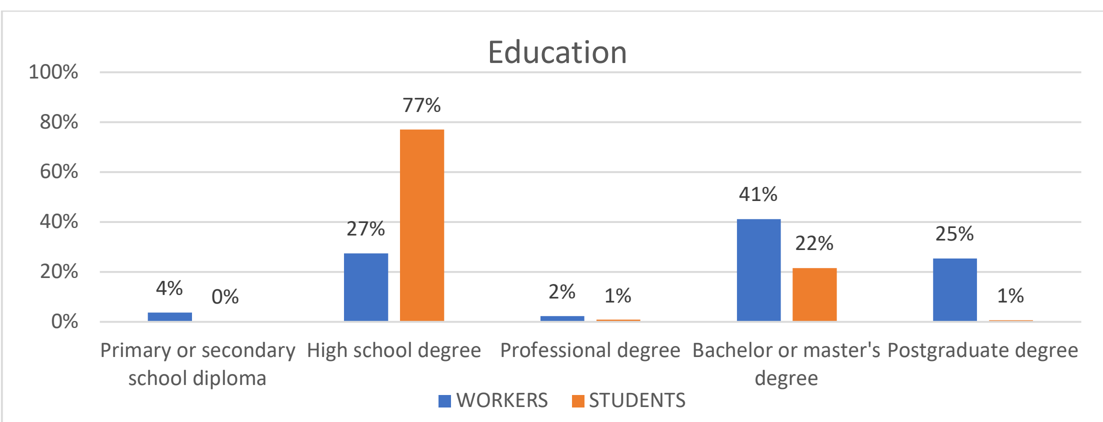
A.1.1 Socioeconomic characteristics

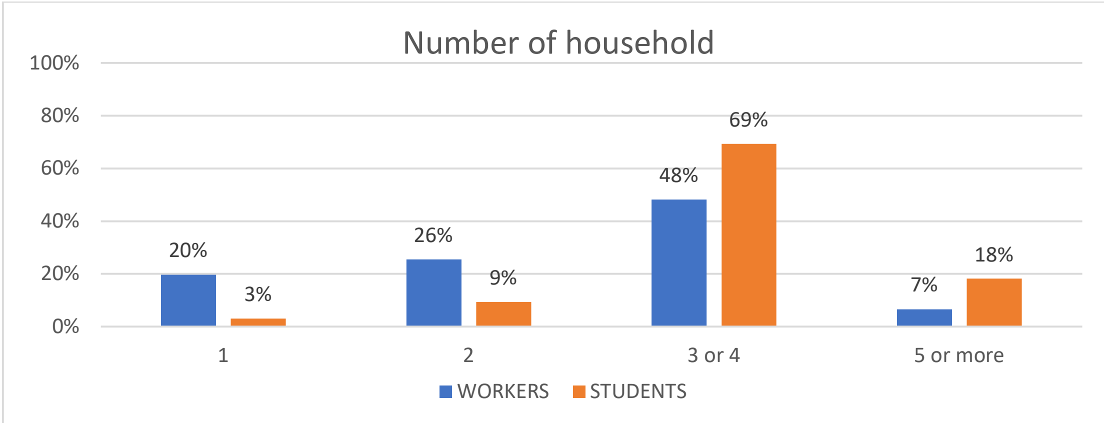


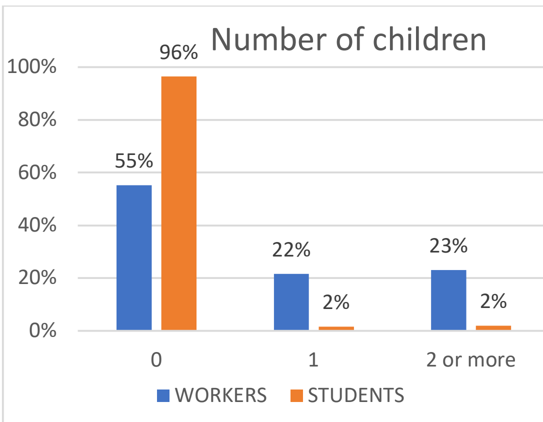


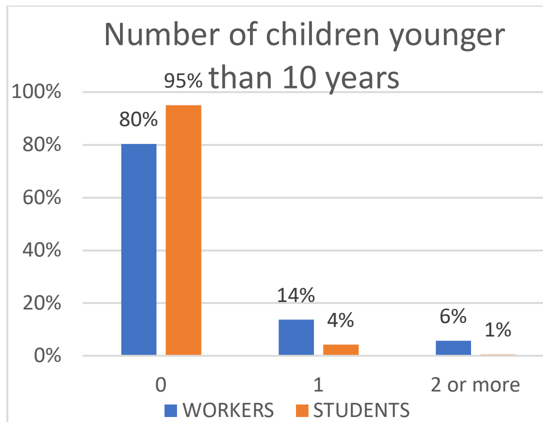


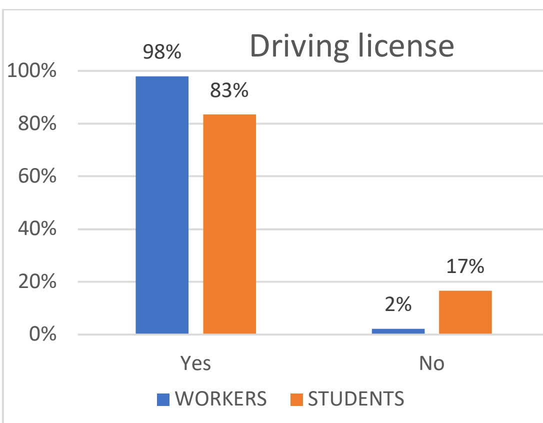


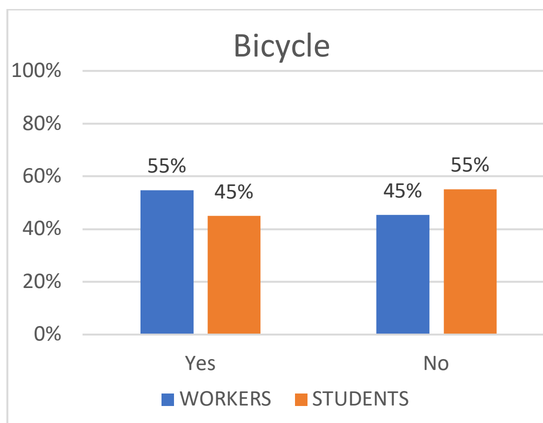


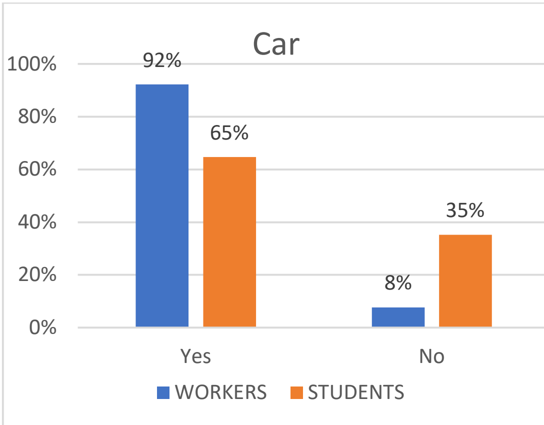

Number of household
100%
80%
60%
40%
20%
0%
20%
3%
26%
9%
48%
69%
7%
18%
1
2
3 or 4
5 or more
WORKERS
STUDENTS

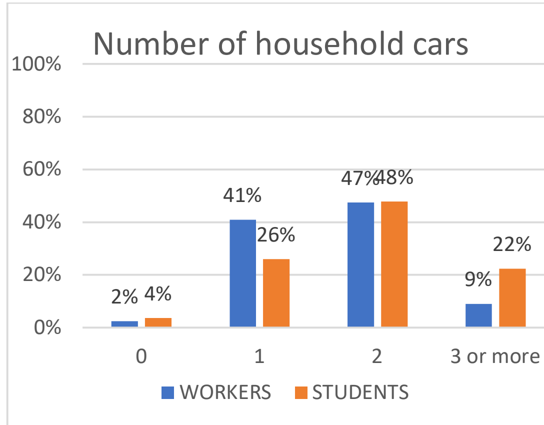

Number of children
100%
80%
60%
40%
20%
0%
55%
96%
22%
2%
23%
2%
0
1
2 or more
WORKERS
STUDENTS

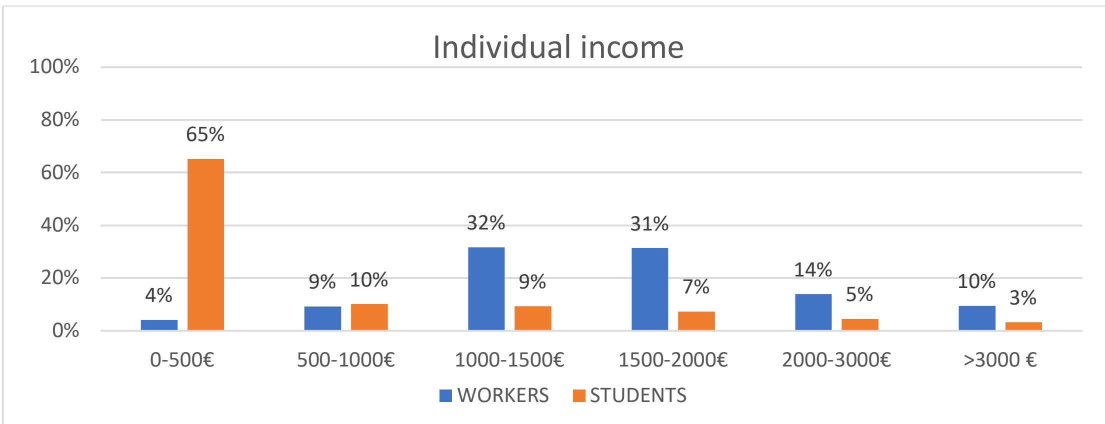

Number of children younger than 10 years
100%
80%
60%
40%
20%
0%
80%
95%
14%
4%
6%
1%
0
1
2 or more
WORKERS
STUDENTS


Driving license
100%
80%
60%
40%
20%
0%
98%
83%
2%
17%
Yes
No
WORKERS
STUDENTS


Bicycle
100%
80%
60%
40%
20%
0%
55%
45%
45%
55%
Yes
No
WORKERS
STUDENTS



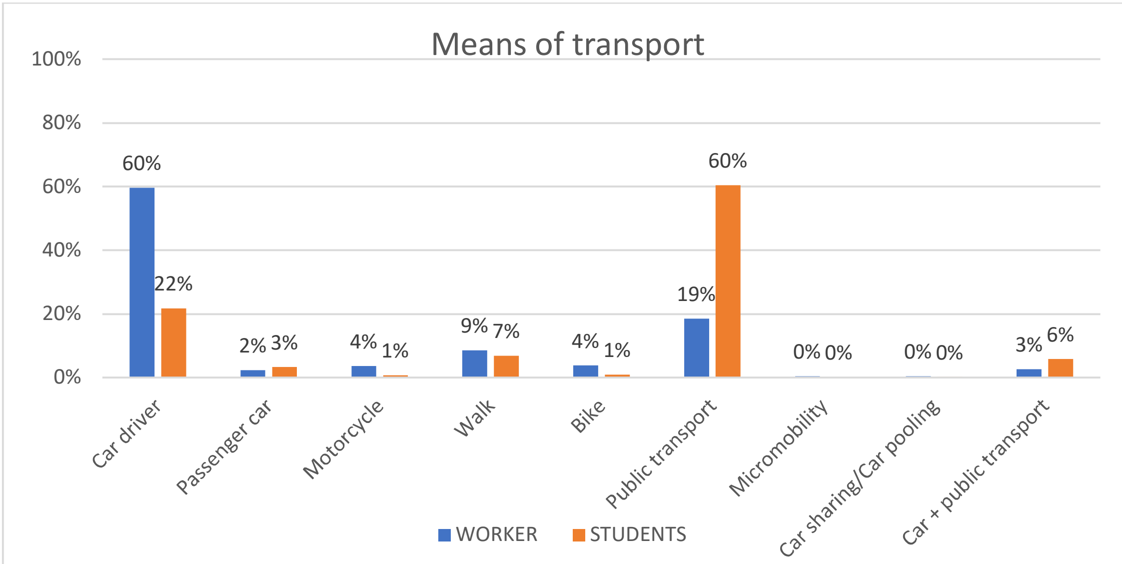


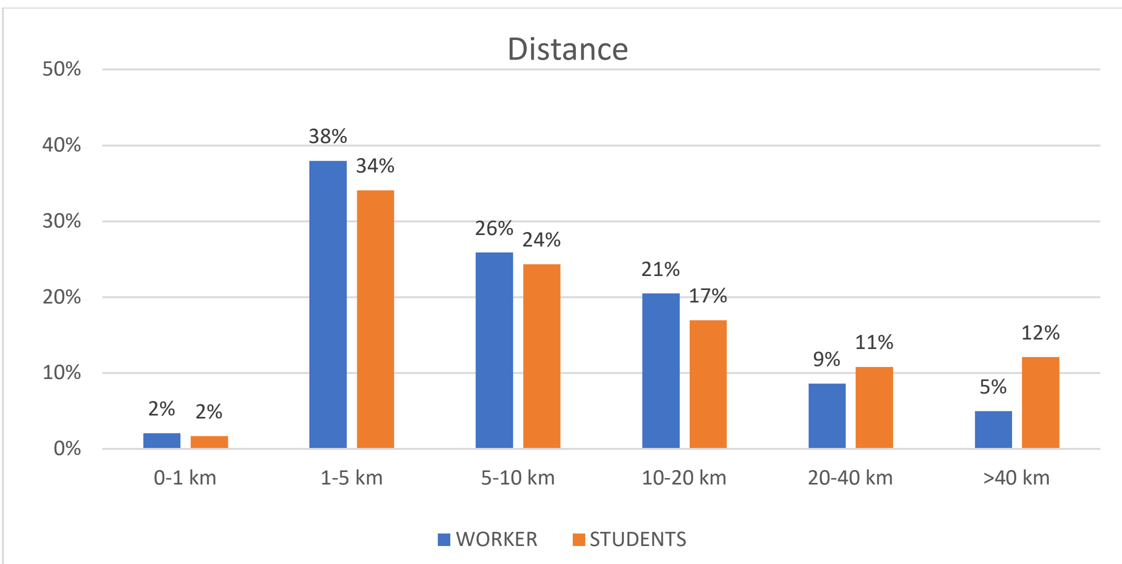


	Average Workers	Average Students	Difference	Z* stat	
Age	45.9	24.1	21.7	85.48	*
N_household	2.7	3.7	-1.0	-26.75	*
N_children	0.7	0.1	0.7	32.20	*
N_children10	0.3	0.1	0.2	15.67	*
N_car	1.7	1.9	-0.3	-11.00	*
Income	3.7	1.9	1.8	44.24	*

** Significant at 95% confidence level*

A.1.2 Trip characteristics

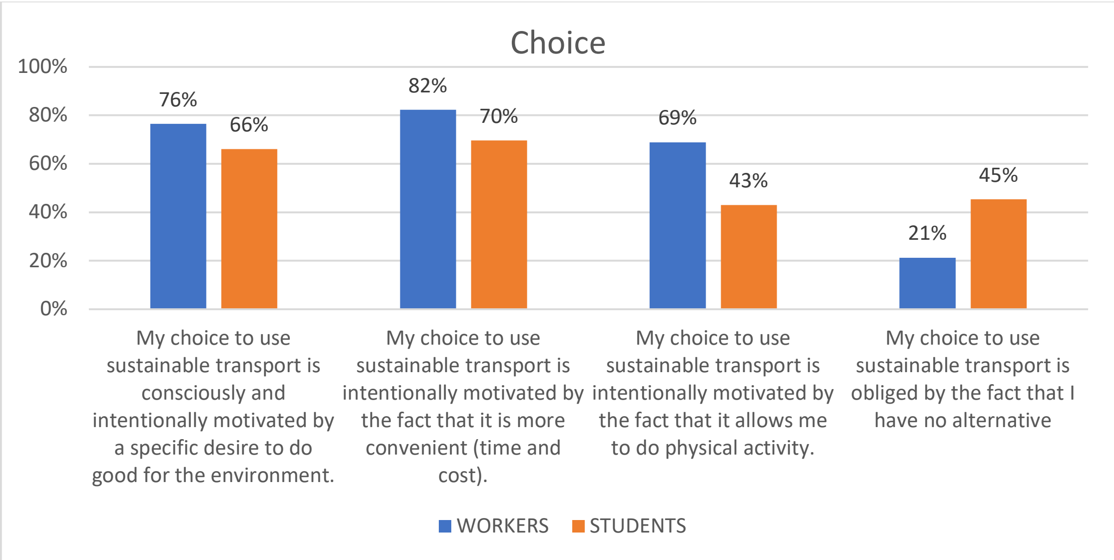


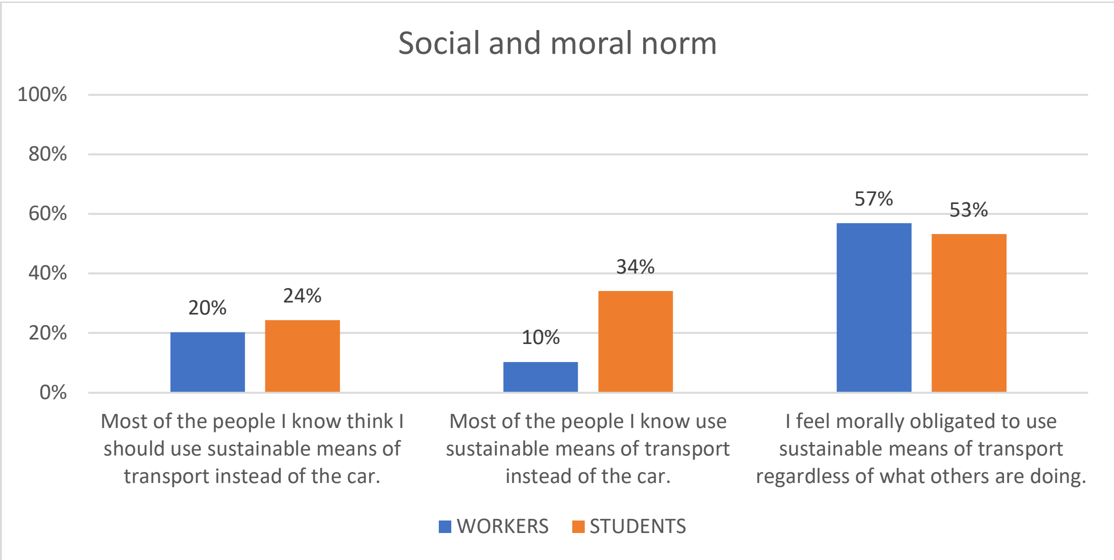


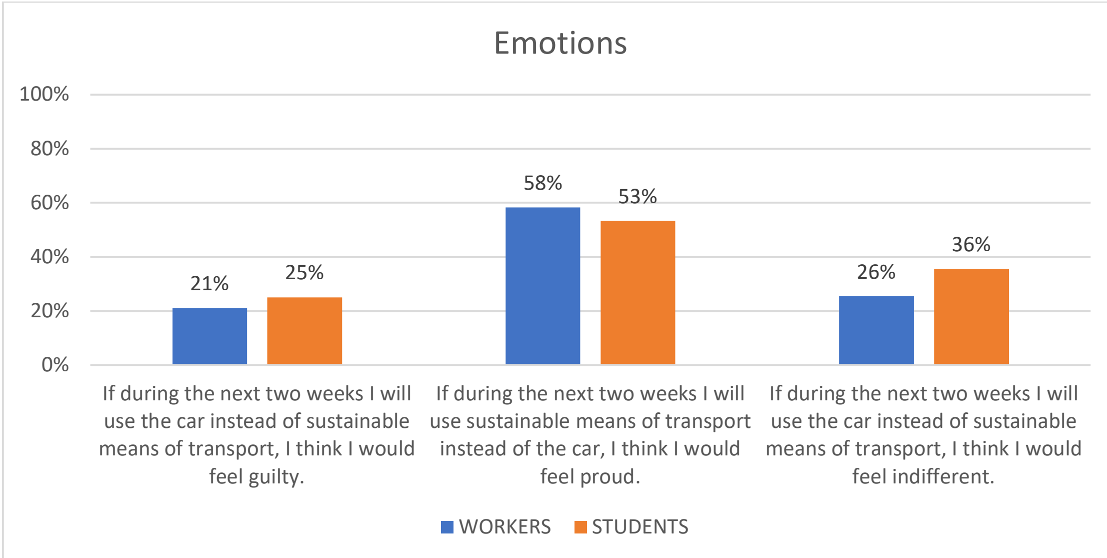
ORIGIN/DESTINATION WORKERS	AREA METROPOLITANA CAGLIARI		CAGLIARI		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	59	2.4%	661	26.8%	0	0%	720
CAGLIARI	216	8.8%	1224	49.6%	18	0.7%	1458
ORISTANO	2	0.1%	10	0.4%	0	0%	12
SUD SARDEGNA	20	0.8%	258	10.5%	0	0%	278
Total	297	12.0%	2153	87.2%	18	0.7%	2468

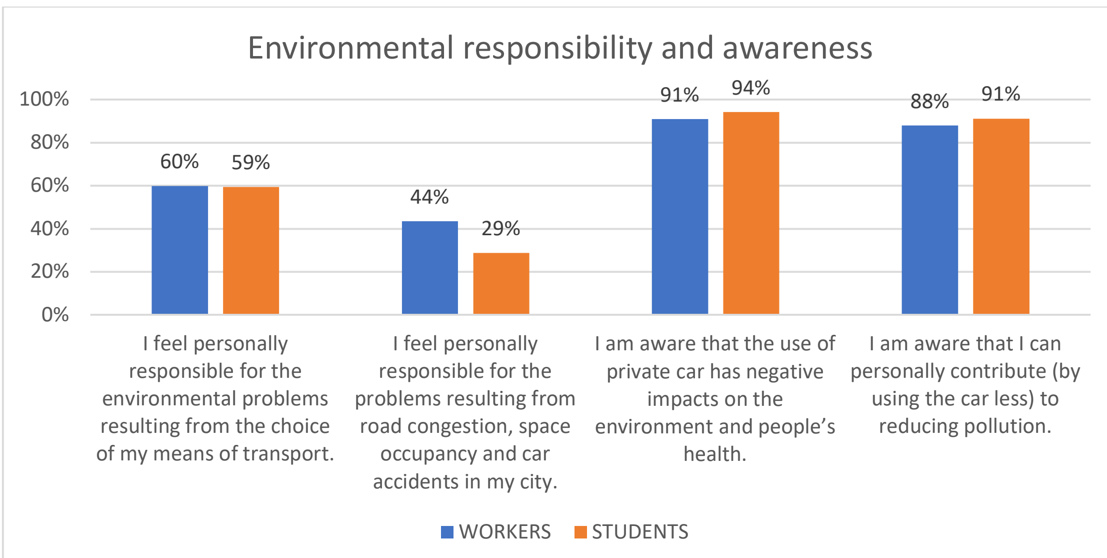
ORIGIN/DESTINATION STUDENTS	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	140	8.2%	347	20.2%	0	0%	0	0%	487
CAGLIARI	245	14.3%	622	36.2%	3	0.2%	3	0.2%	873
NUORO	0	0%	1	0.1%	0	0%	0	0%	1
ORISTANO	4	0.2%	25	1.5%	0	0%	0	0%	29
SUD SARDEGNA	68	4.0%	259	15.1%	0	0%	0	0%	327
Total	457	26.6%	1254	73.0%	3	0.2%	3	0.2%	1717

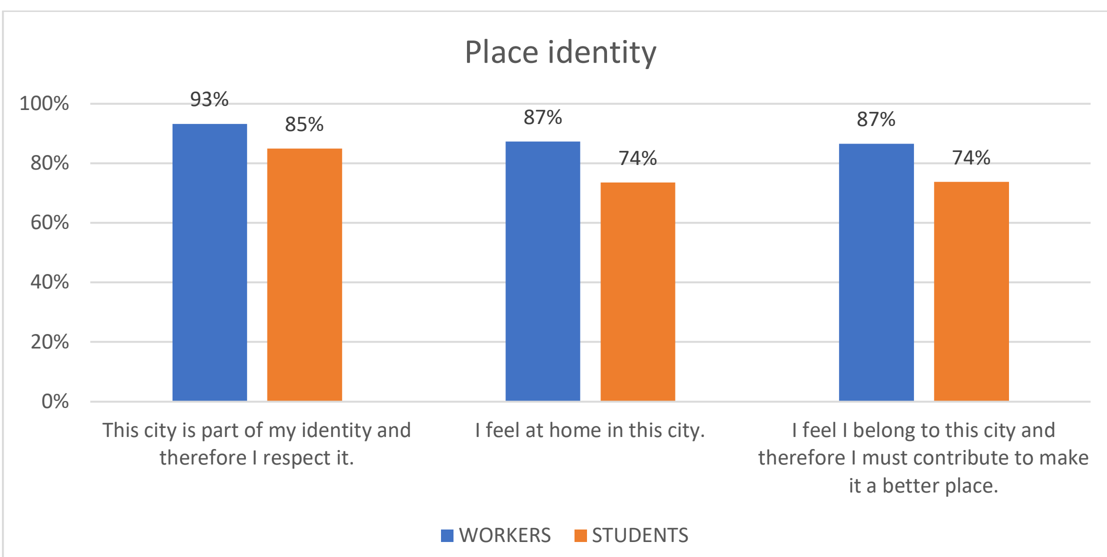
A.1.3 Psychosocial characteristics

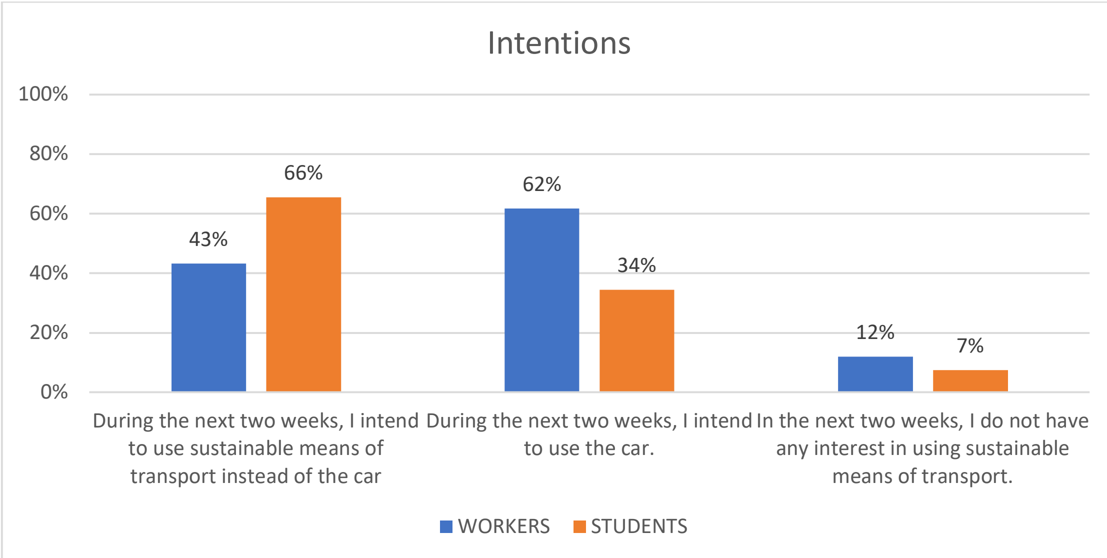


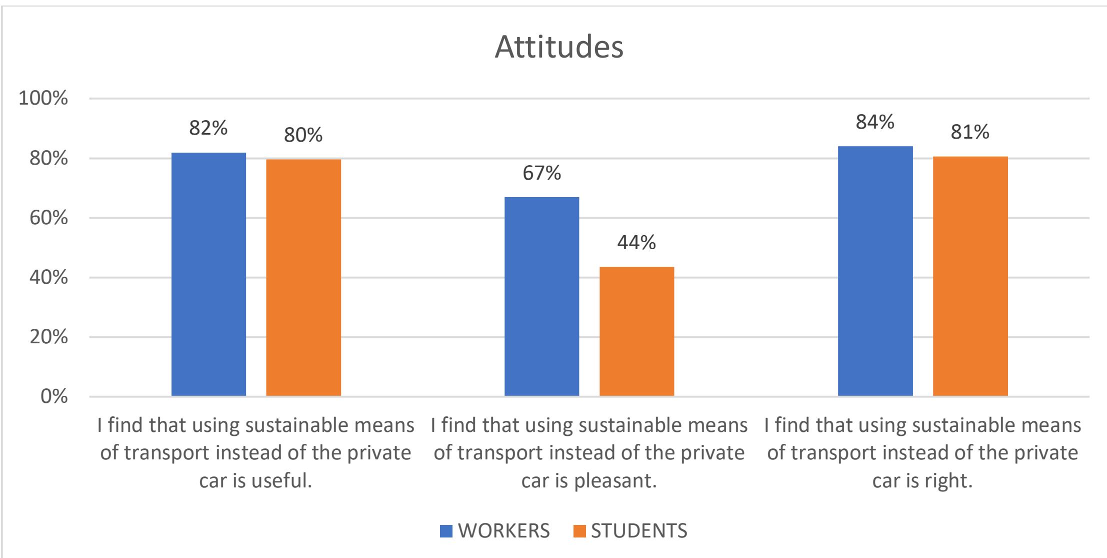


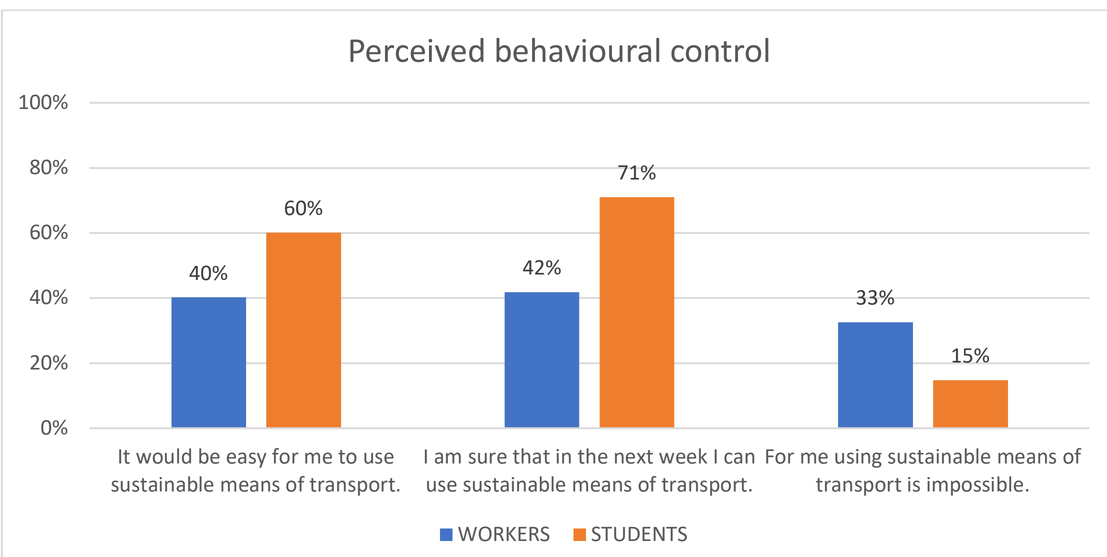

Emotions
100%
80%
60%
40%
20%
0%
21%
25%
58%
53%
26%
36%
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.
If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.
WORKERS
STUDENTS

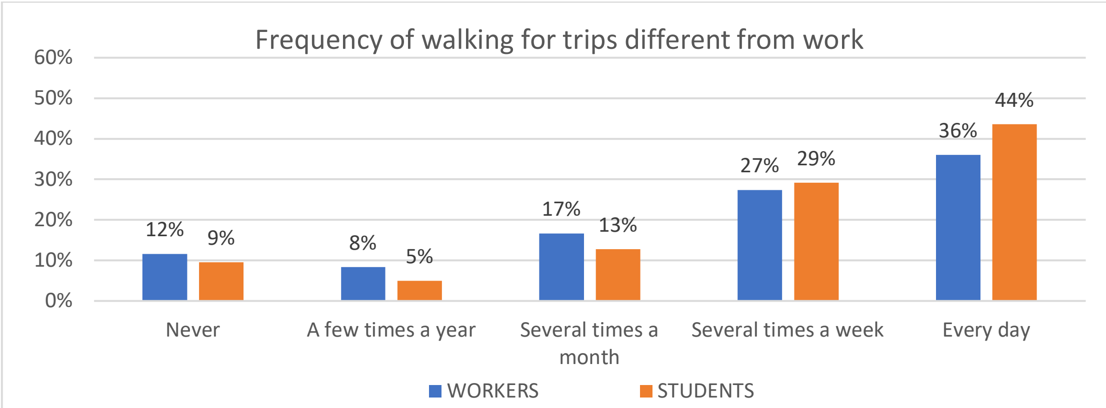

Environmental responsibility and awareness
100%
80%
60%
40%
20%
0%
60%
59%
44%
29%
91%
94%
88%
91%
I feel personally responsible for the environmental problems resulting from the choice of my means of transport.
I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.
I am aware that the use of private car has negative impacts on the environment and people's health.
I am aware that I can personally contribute (by using the car less) to reducing pollution.
WORKERS
STUDENTS

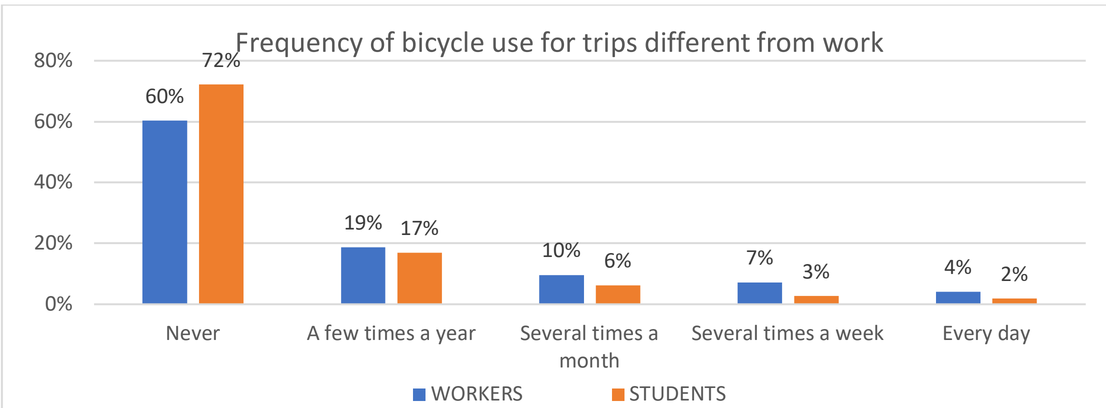

Place identity
100%
80%
60%
40%
20%
0%
93%
85%
87%
74%
87%
74%
This city is part of my identity and therefore I respect it.
I feel at home in this city.
I feel I belong to this city and therefore I must contribute to make it a better place.
WORKERS
STUDENTS

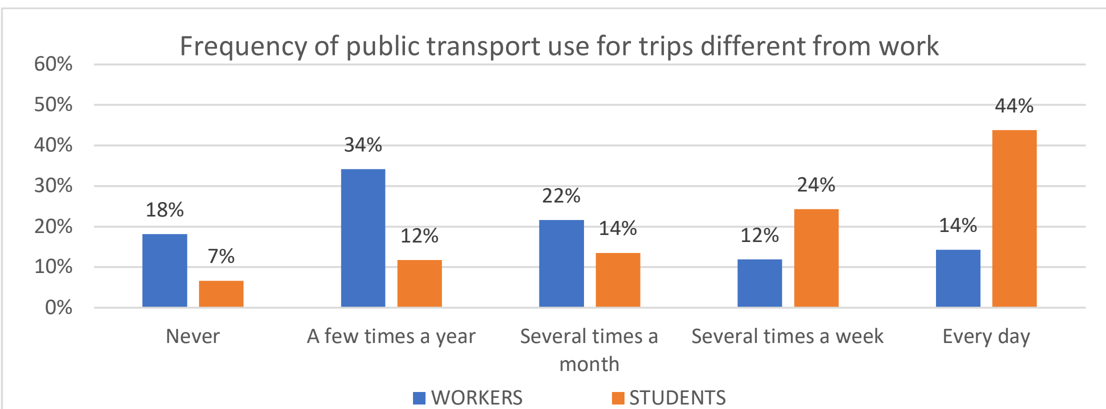

Intentions
100%
80%
60%
40%
20%
0%
43%
66%
62%
34%
12%
7%
During the next two weeks, I intend to use sustainable means of transport instead of the car
During the next two weeks, I intend to use the car.
In the next two weeks, I do not have any interest in using sustainable means of transport.
WORKERS
STUDENTS

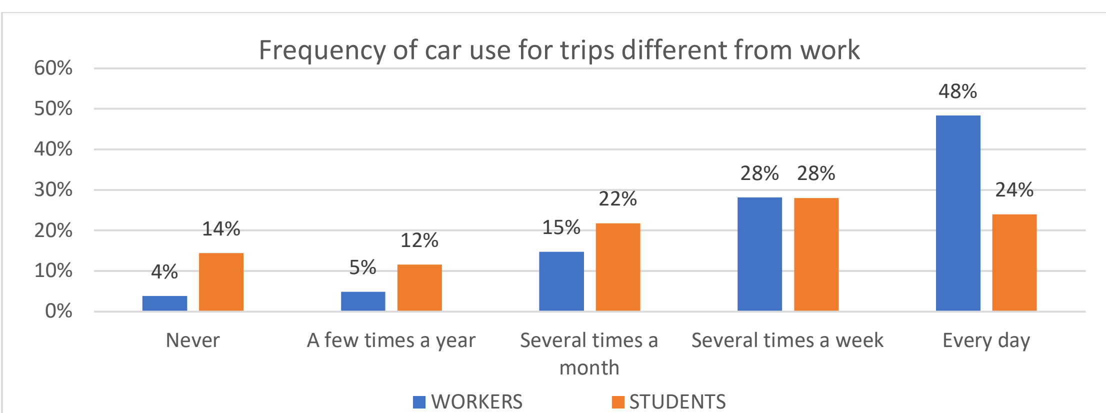

Attitudes
100%
80%
60%
40%
20%
0%
82%
80%
67%
44%
84%
81%
I find that using sustainable means of transport instead of the private car is useful.
I find that using sustainable means of transport instead of the private car is pleasant.
I find that using sustainable means of transport instead of the private car is right.
WORKERS
STUDENTS


Perceived behavioural control
100%
80%
60%
40%
20%
0%
40%
60%
42%
71%
33%
15%
It would be easy for me to use sustainable means of transport.
I am sure that in the next week I can use sustainable means of transport.
For me using sustainable means of transport is impossible.
WORKERS
STUDENTS


Frequency of walking for trips different from work
60%
50%
40%
30%
20%
10%
0%
12%
9%
8%
5%
17%
13%
27%
29%
36%
44%
Never
A few times a year
Several times a month
Several times a week
Every day
WORKERS
STUDENTS


Frequency of bicycle use for trips different from work
80%
60%
40%
20%
0%
60%
72%
19%
17%
10%
6%
7%
3%
4%
2%
Never
A few times a year
Several times a month
Several times a week
Every day
WORKERS
STUDENTS

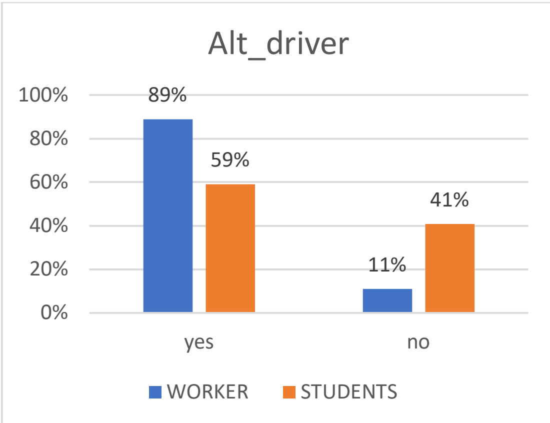

Frequency of public transport use for trips different from work
60%
50%
40%
30%
20%
10%
0%
18%
7%
34%
12%
22%
14%
12%
24%
14%
44%
Never
A few times a year
Several times a month
Several times a week
Every day
WORKERS
STUDENTS

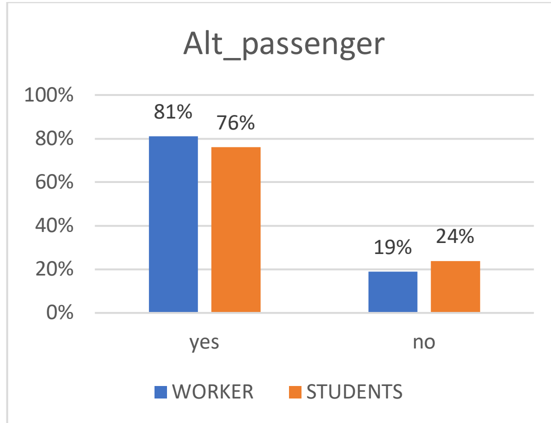

Frequency of car use for trips different from work
60%
50%
40%
30%
20%
10%
0%
4%
14%
5%
12%
15%
22%
28%
28%
48%
24%
Never
A few times a year
Several times a month
Several times a week
Every day
WORKERS
STUDENTS

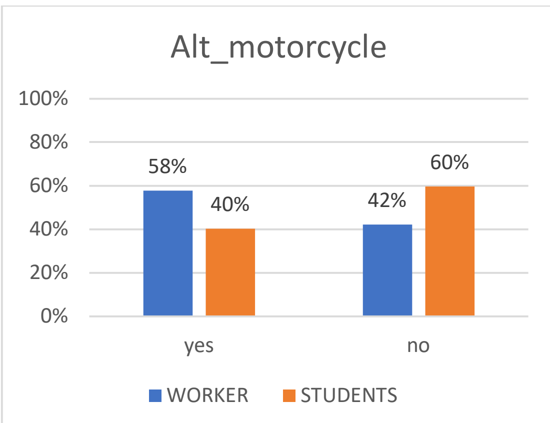
		Average Workers	Average Students	Difference	Z* stat	
CH1	My choice to use sustainable transport is consciously and intentionally motivated by a specific desire to do good for the environment.	1.36	2.75	-1.39	-15.98	*
CH2	My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).	1.46	2.87	-1.41	-15.61	*
CH3	My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.	1.35	2.35	-1.00	-11.85	*
CH4	My choice to use sustainable transport is obliged by the fact that I have no alternative	0.78	2.35	-1.57	-22.37	*
NS1	Most of the people I know think I should use sustainable means of transport instead of the car.	2.51	2.65	-0.13	-3.51	*
NS2	Most of the people I know use sustainable means of transport instead of the car.	2.01	2.78	-0.77	-20.33	*
NM1	I feel morally obligated to use sustainable means of transport regardless of what others are doing.	3.56	3.47	0.09	2.24	*
EM1	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	2.46	2.62	-0.16	-4.18	*
EM2	If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	3.56	3.41	0.15	3.84	*
EM3	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	2.78	2.99	-0.22	-5.62	*
RESP 1	I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	3.47	3.52	-0.05	-1.32	
RESP 2	I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.	3.04	2.57	0.46	10.93	*
AWA1	I am aware that the use of private car has negative impacts on the environment and people's health.	4.38	4.55	-0.17	-7.38	*
AWA2	I am aware that I can personally contribute (by using the car less) to reducing pollution.	4.30	4.49	-0.19	-7.51	*
LOC1	This city is part of my identity and therefore I respect it.	4.50	4.30	0.21	8.28	*
LOC2	I feel at home in this city.	4.36	3.98	0.38	11.98	*
LOC3	I feel I belong to this city and therefore I must contribute to make it a better place.	4.36	4.02	0.34	11.52	*
HABIT_W	Frequency of walking for trips different from work	3.68	3.92	-0.24	-6.00	*
HABIT_B	Frequency of bicycle use for trips different from work	1.76	1.45	0.31	9.99	*
HABIT_PT	Frequency of public transport use for trips different from work	2.70	3.87	-1.17	-29.02	*
HABIT_CAR	Frequency of car use for trips different from work	4.12	3.36	0.77	19.61	*
INT1	During the next two weeks, I intend to use sustainable means of transport instead of the car	3.09	3.77	-0.68	-15.97	*
INT2	During the next two weeks, I intend to use the car.	3.61	2.76	0.85	19.44	*
INT3	In the next two weeks, I do not have any interest in using sustainable means of transport.	2.09	1.84	0.25	7.09	*
ATT1	I find that using sustainable means of transport instead of the private car is useful.	4.18	4.13	0.05	1.46	*
ATT2	I find that using sustainable means of transport instead of the private car is pleasant.	3.79	3.15	0.64	16.20	*
ATT3	I find that using sustainable means of transport instead of the private car is right.	4.29	4.20	0.09	3.08	*
PCB1	It would be easy for me to use sustainable means of transport.	2.84	3.52	-0.68	-15.15	*
PCB2	I am sure that in the next week I can use sustainable means of transport.	2.94	3.89	-0.95	-20.87	*
PCB3	For me using sustainable means of transport is impossible.	2.57	1.86	0.71	16.71	*

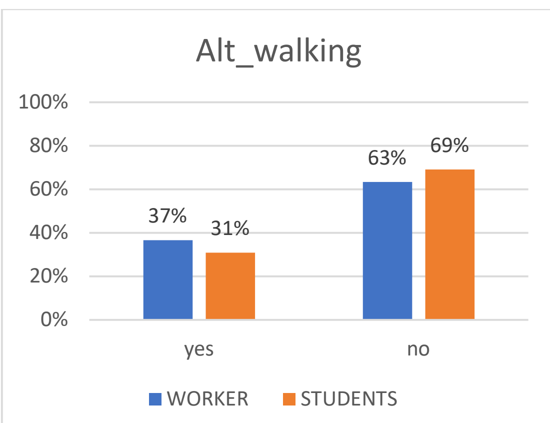
* *Significant at 95% confidence level*

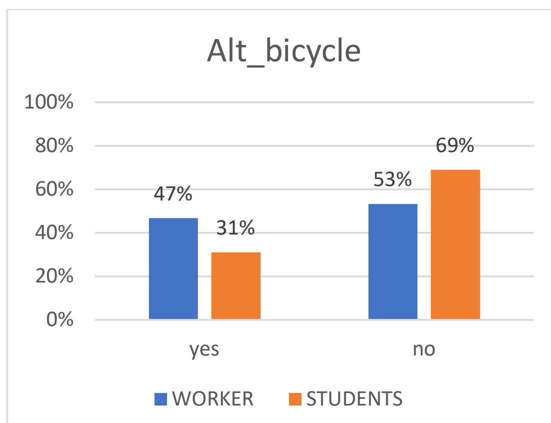
A.1.4 Alternative means of transport

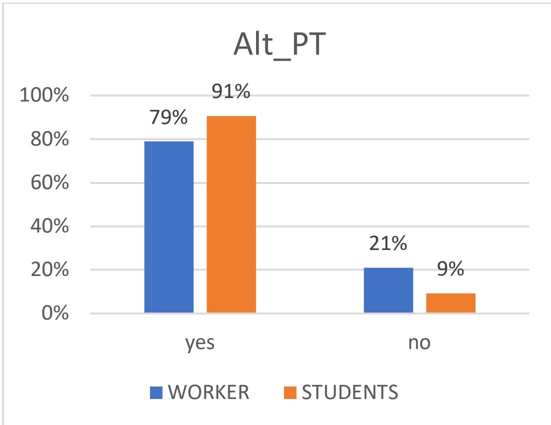


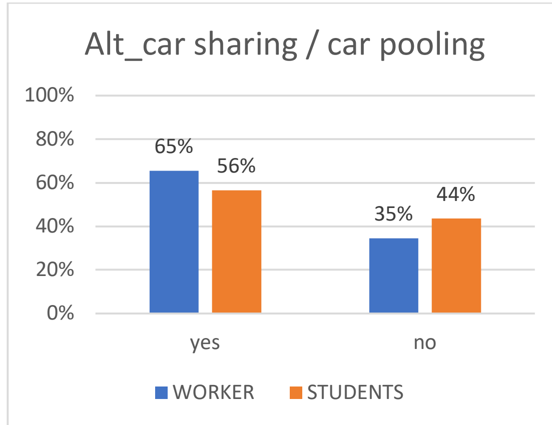










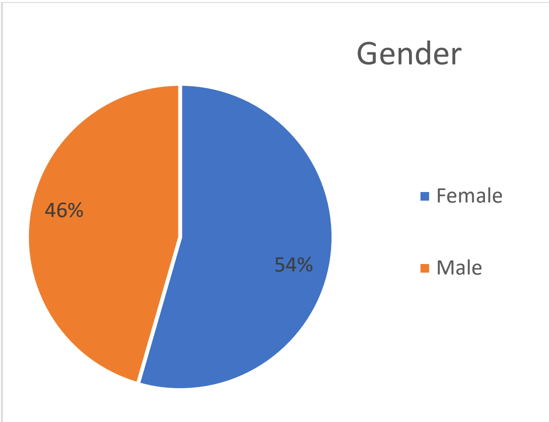


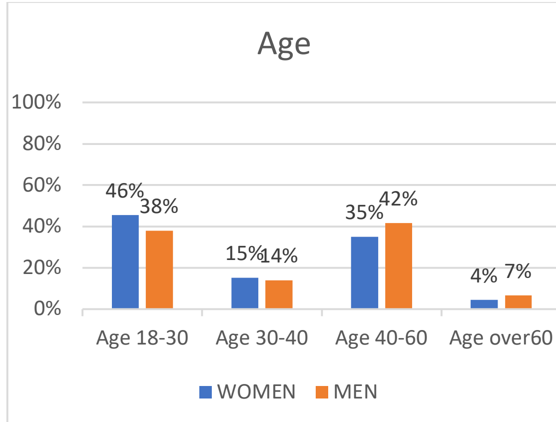
	Workers	Students	Difference	Z* stat	
Alt_driver	89%	59%	30%	22.49	*
Alt_passenger	81%	76%	5%	3.89	*
Alt_motorcycle	58%	40%	17%	11.12	*
Alt_walking	37%	31%	6%	3.86	*
Alt_bicycle	47%	31%	16%	10.13	*
Alt_PT	79%	91%	-12%	-10.11	*
Alt_carsharing_pooling	65%	56%	9%	5.86	*

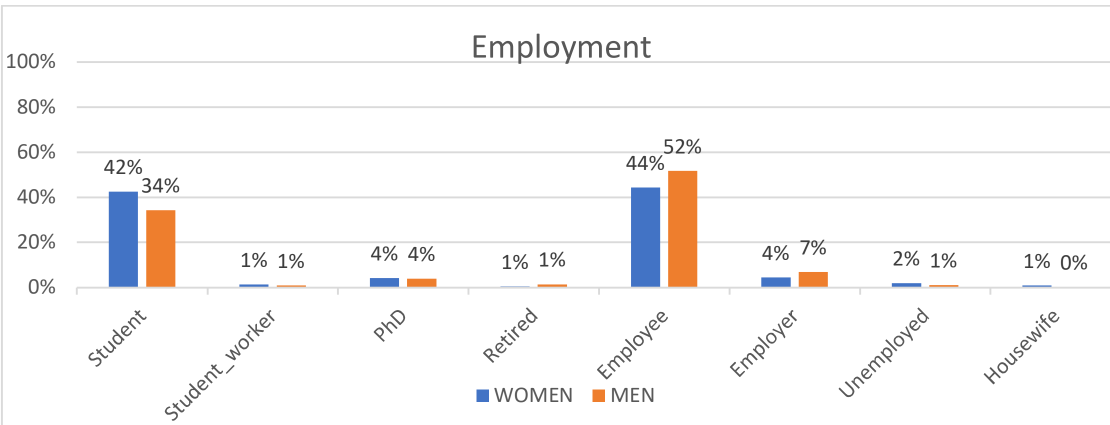
** Significant at 95% confidence level*

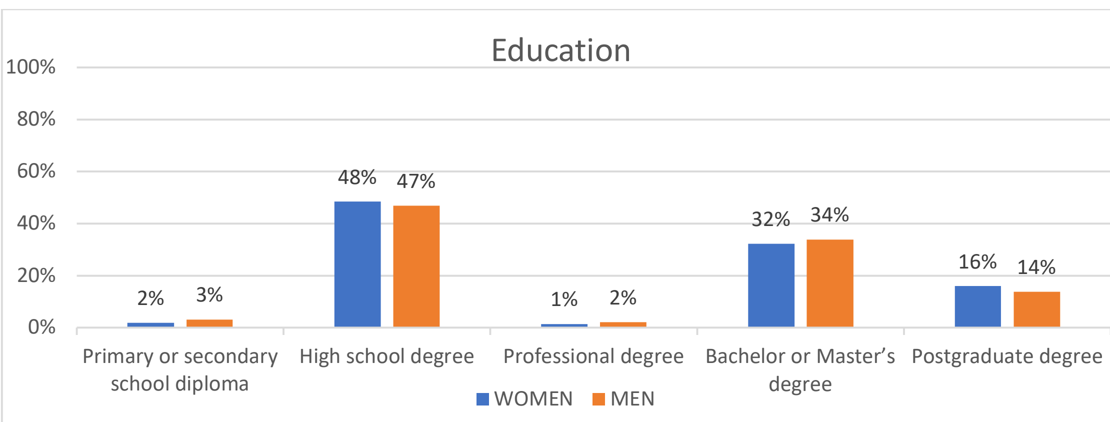
A.2 WOMEN vs MEN

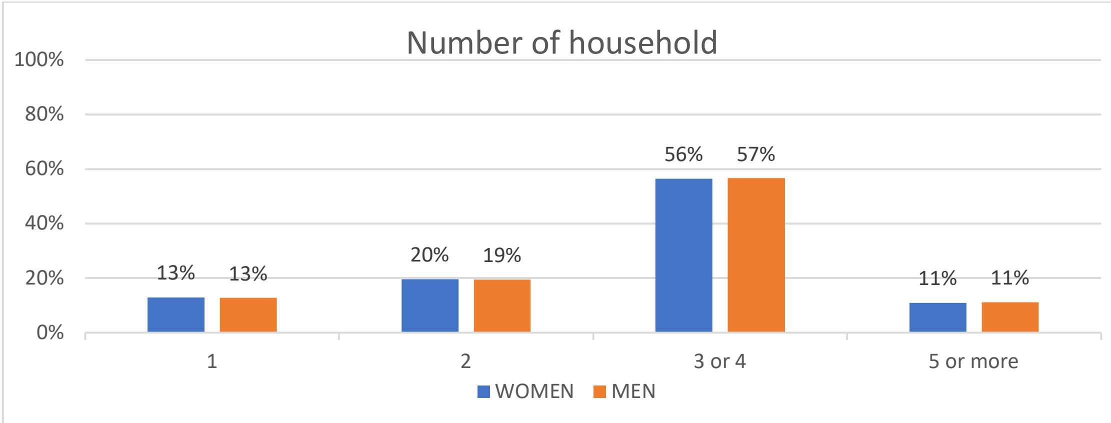
A.2.1 Socioeconomic characteristics

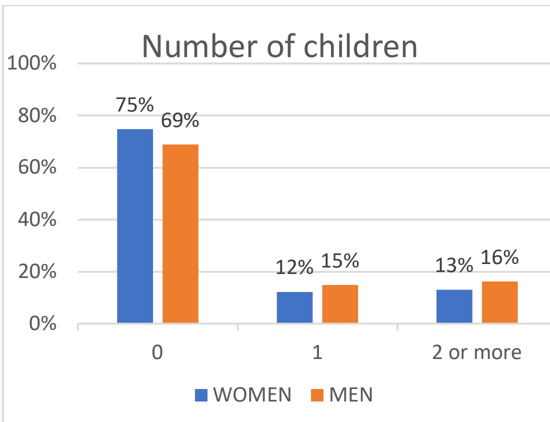


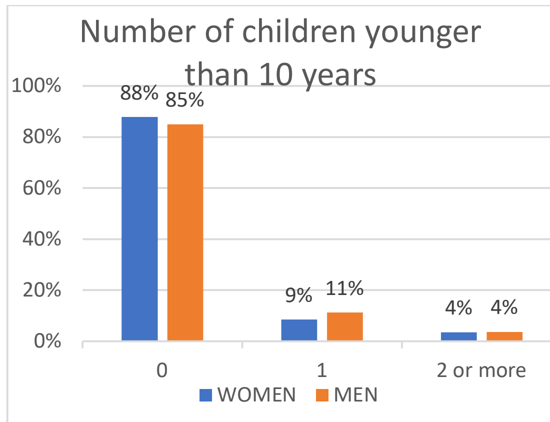


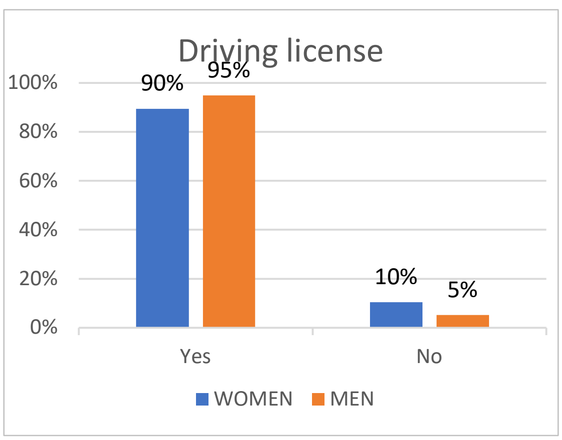


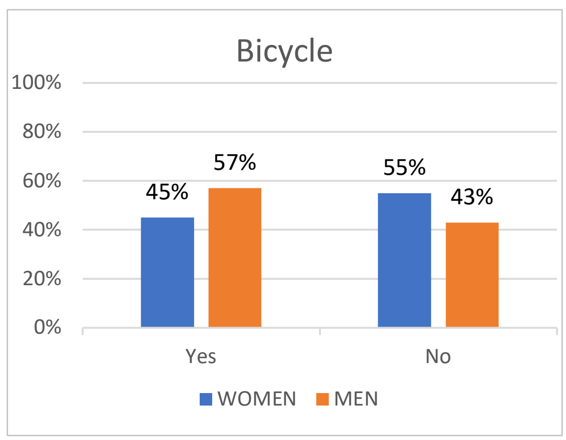


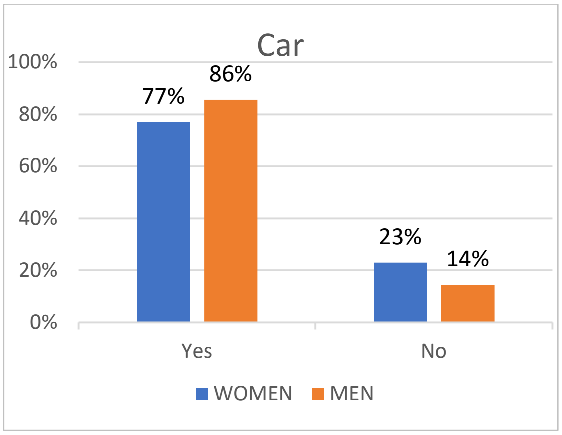

Number of household
100%
80%
60%
40%
20%
0%
13% 13%
20% 19%
56% 57%
11% 11%
1
2
3 or 4
5 or more
WOMEN MEN

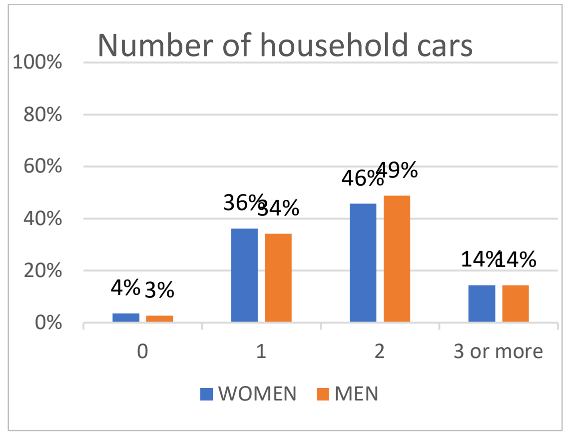

Number of children
100%
80%
60%
40%
20%
0%
75% 69%
12% 15%
13% 16%
0
1
2 or more
WOMEN MEN

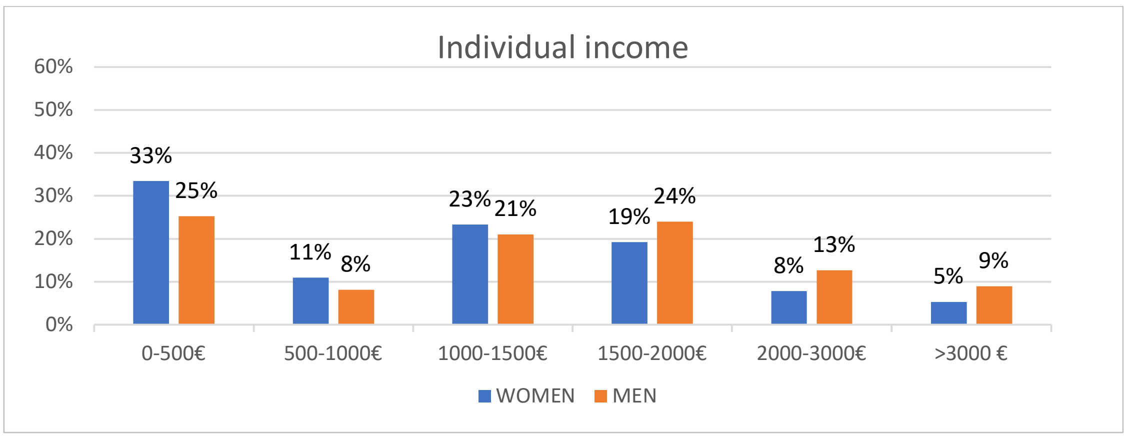

Number of children younger than 10 years
100%
80%
60%
40%
20%
0%
88% 85%
9% 11%
4% 4%
0
1
2 or more
WOMEN MEN


Driving license
100%
80%
60%
40%
20%
0%
90% 95%
10% 5%
Yes
No
WOMEN MEN


Bicycle
100%
80%
60%
40%
20%
0%
45% 57%
55% 43%
Yes
No
WOMEN MEN



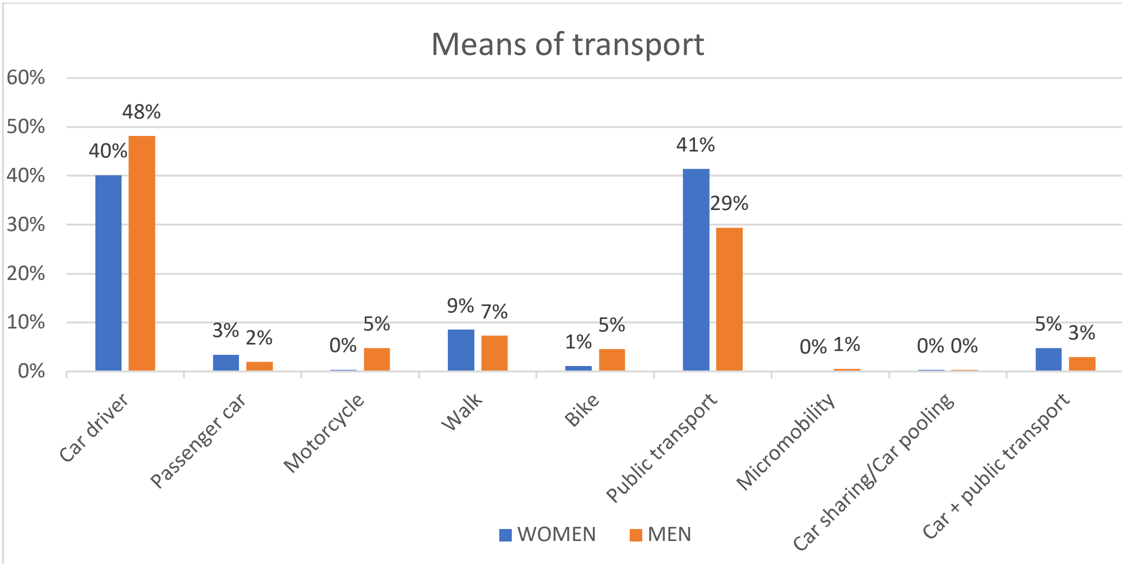


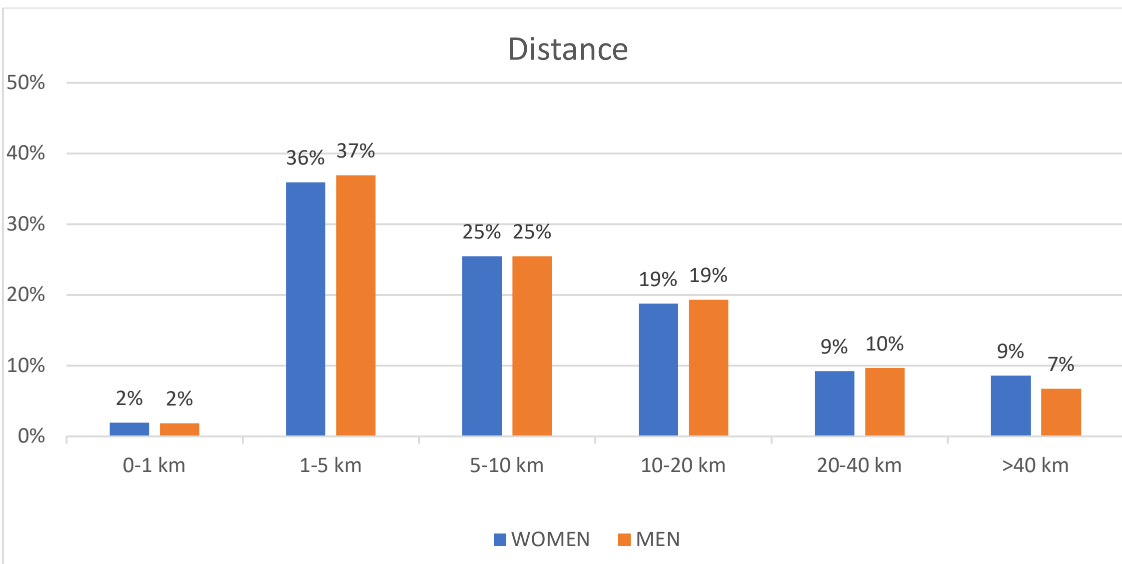


	Average Women	Average Men	Difference	Z* stat	
Age	36.1	38.8	-2.7	-6.26	*
N_household	3.1	3.1	0.0	0.02	
N_children	0.4	0.5	-0.1	-4.15	*
N_children10	0.2	0.2	0.0	-2.23	*
N_car	1.7	1.8	0.0	-1.72	
Income	2.7	3.2	-0.4	-9.29	*

** Significant at 95% confidence level*

A.2.2 Trip characteristics

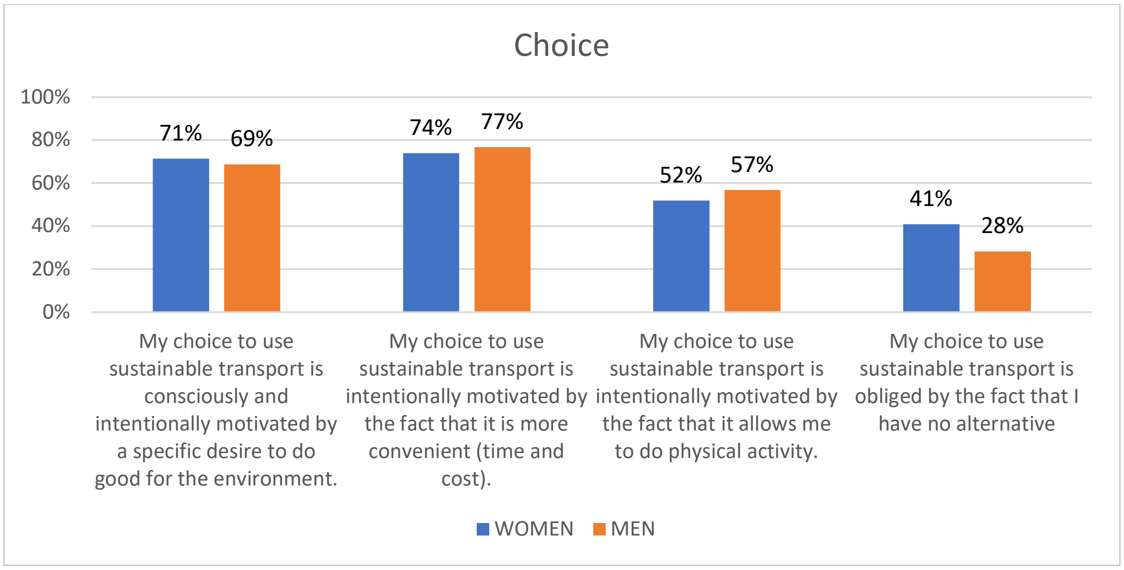


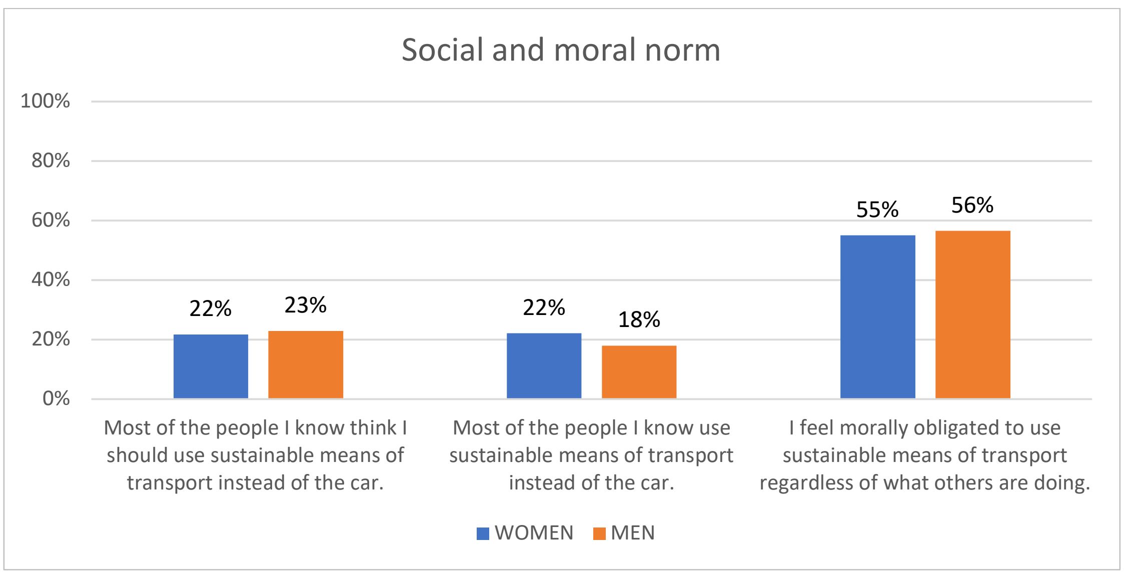


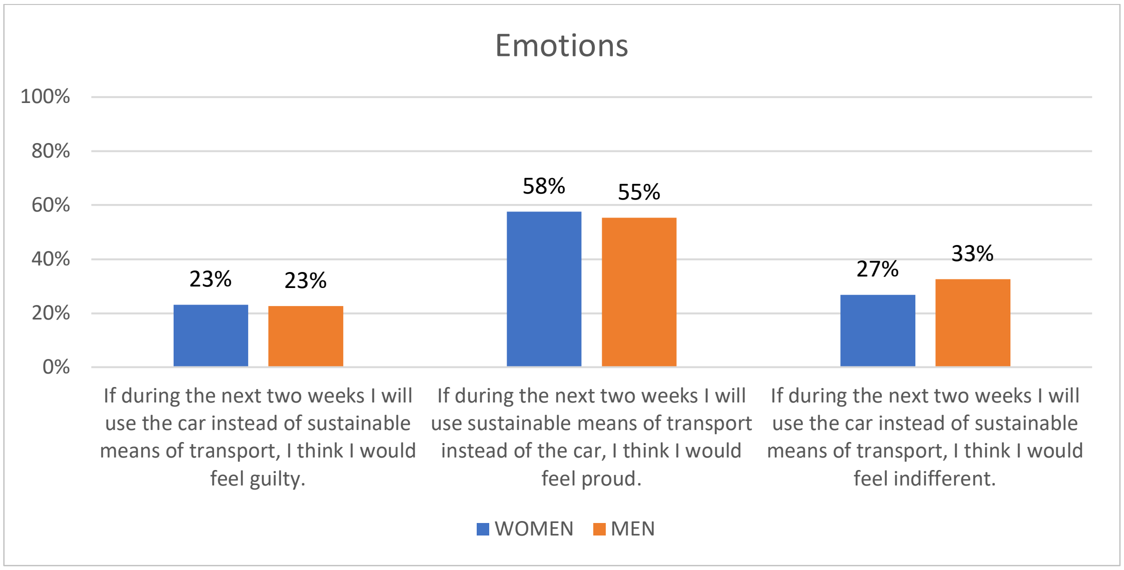
ORIGIN/DESTINATION WOMEN	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	136	5.8%	540	23.0%	0	0.0%	0	0.0%	676
CAGLIARI	293	12.5%	987	42.0%	1	0.0%	9	0.4%	1290
NUORO	0	0.0%	1	0.0%	0	0.0%	0	0.0%	1
ORISTANO	4	0.2%	23	1.0%	0	0.0%	0	0.0%	27
SUD SARDEGNA	60	2.6%	294	12.5%	0	0.0%	0	0.0%	354
Total	493	21.0%	1845	78.6%	1	0.0%	9	0.4%	2348

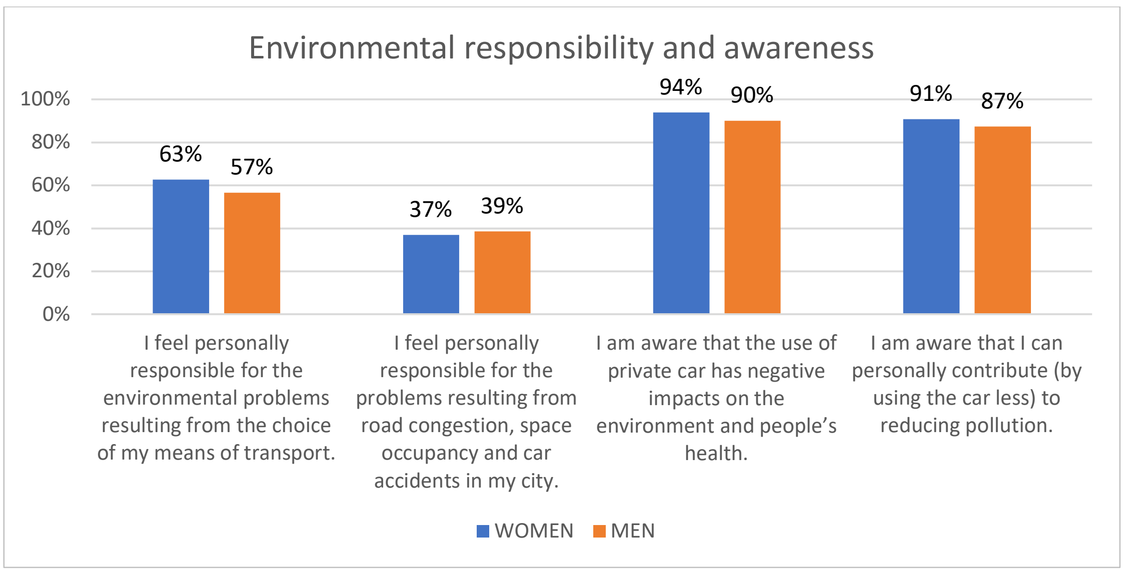
ORIGIN/DESTINATION MEN	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	68	3.5%	499	25.4%	0	0.0%	0	0.0%	567
CAGLIARI	184	9.4%	922	47.0%	2	0.1%	14	0.7%	1122
ORISTANO	2	0.1%	13	0.7%	0	0.0%	0	0.0%	15
SUD SARDEGNA	29	1.5%	230	11.7%	0	0.0%	0	0.0%	259
Total	283	14.4%	1664	84.8%	2	0.1%	14	0.7%	1963

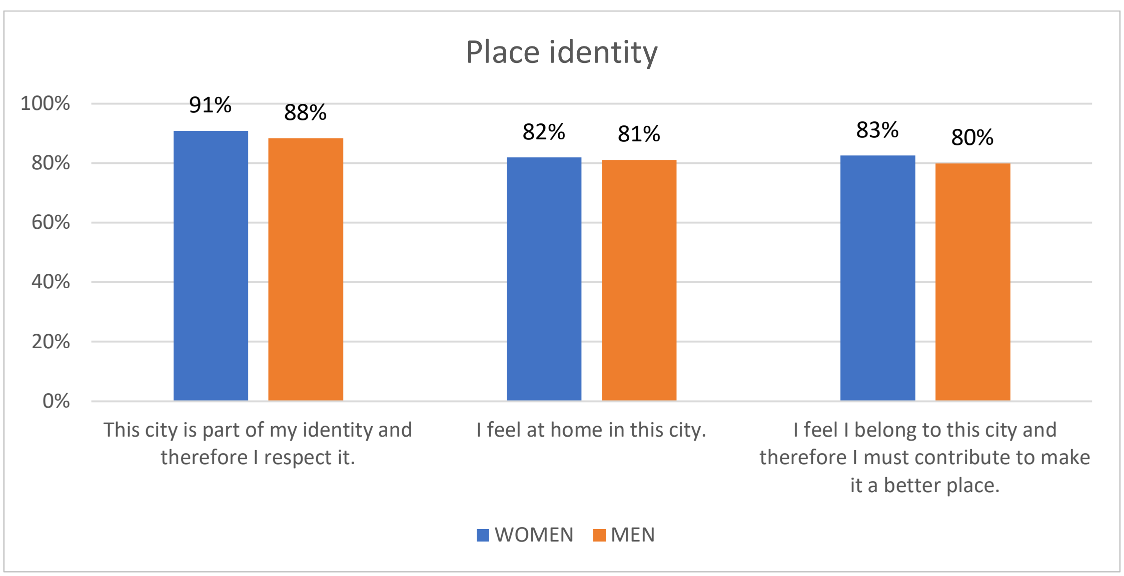
A.2.3 Psychosocial characteristics

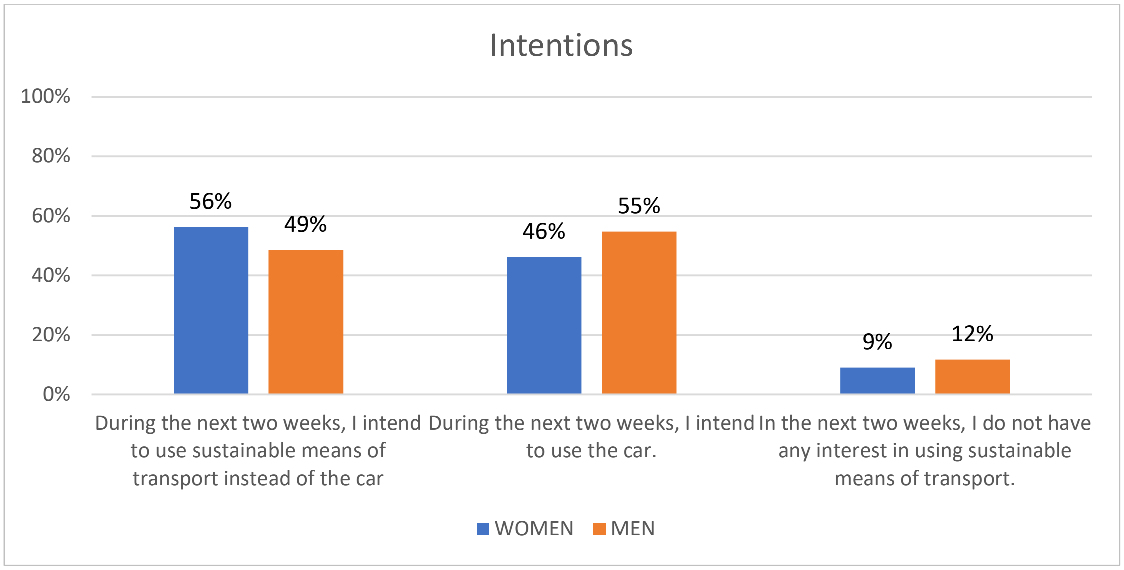


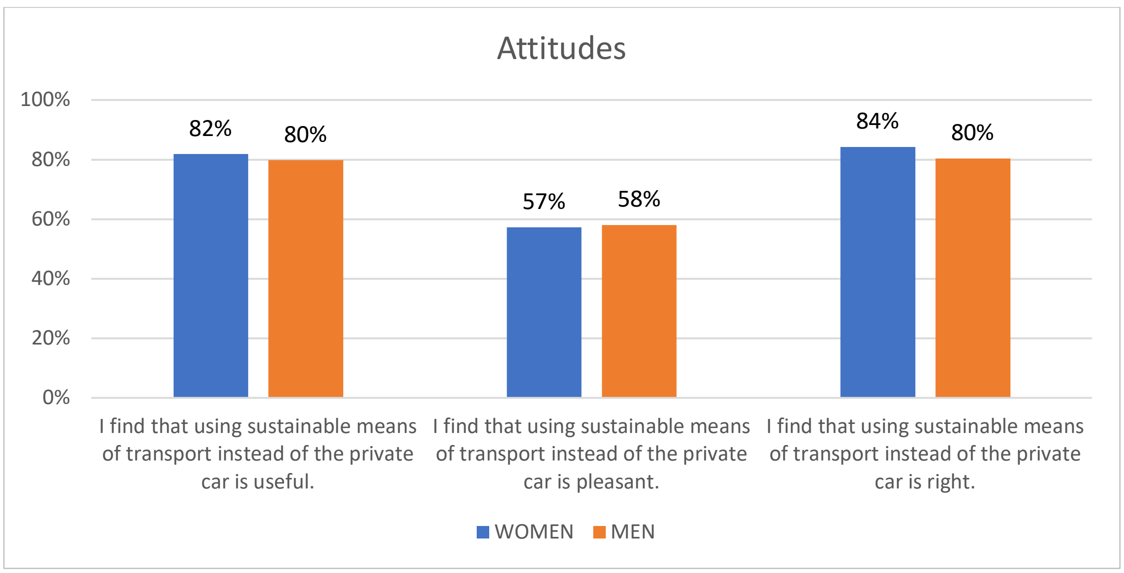


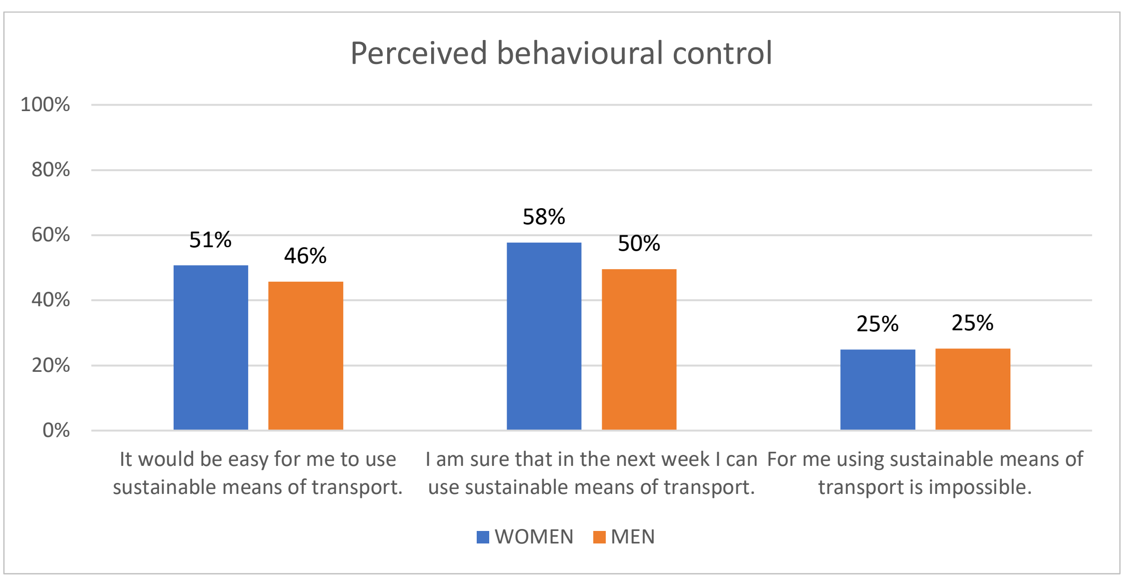

Emotions
100%
80%
60%
40%
20%
0%
23%
23%
58%
55%
27%
33%
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.
If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.
WOMEN
MEN

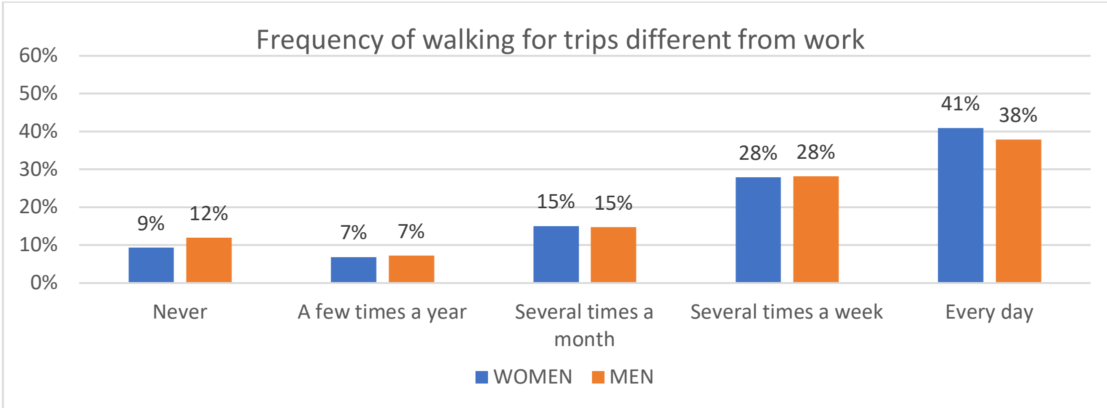

Environmental responsibility and awareness
100%
80%
60%
40%
20%
0%
63%
57%
37%
39%
94%
90%
91%
87%
I feel personally responsible for the environmental problems resulting from the choice of my means of transport.
I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.
I am aware that the use of private car has negative impacts on the environment and people's health.
I am aware that I can personally contribute (by using the car less) to reducing pollution.
WOMEN
MEN

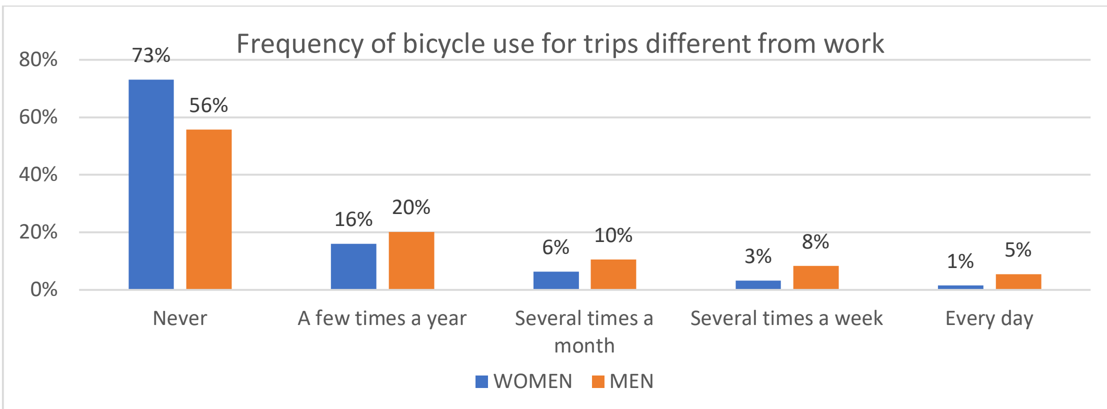

Place identity
100%
80%
60%
40%
20%
0%
91%
88%
82%
81%
83%
80%
This city is part of my identity and therefore I respect it.
I feel at home in this city.
I feel I belong to this city and therefore I must contribute to make it a better place.
WOMEN
MEN

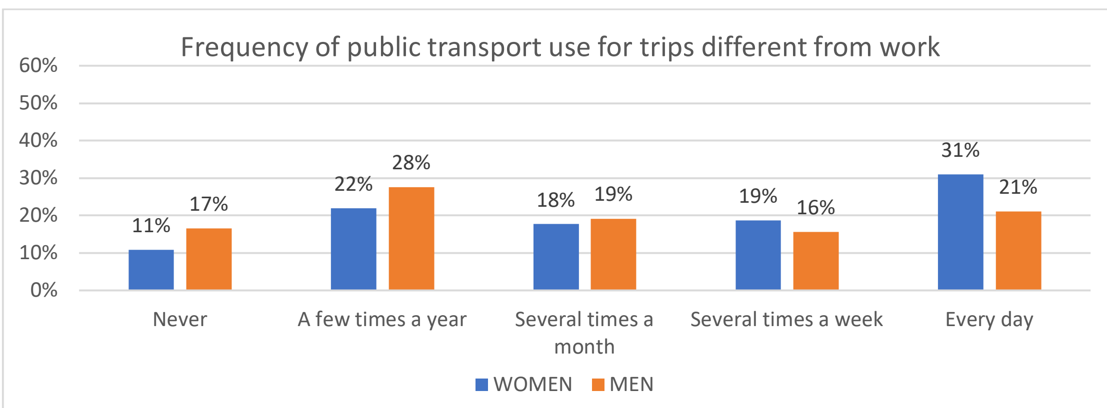

Intentions
100%
80%
60%
40%
20%
0%
56%
49%
46%
55%
9%
12%
During the next two weeks, I intend to use sustainable means of transport instead of the car
During the next two weeks, I intend to use the car.
In the next two weeks, I do not have any interest in using sustainable means of transport.
WOMEN
MEN

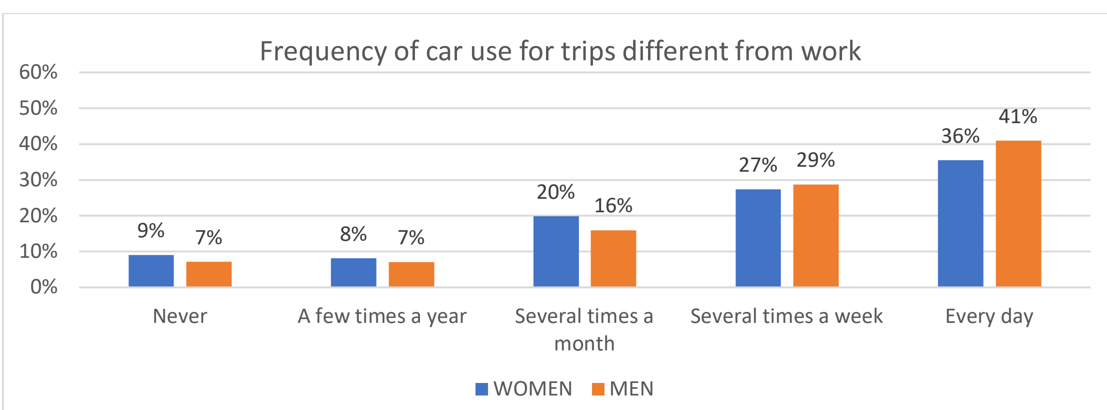

Attitudes
100%
80%
60%
40%
20%
0%
82%
80%
57%
58%
84%
80%
I find that using sustainable means of transport instead of the private car is useful.
I find that using sustainable means of transport instead of the private car is pleasant.
I find that using sustainable means of transport instead of the private car is right.
WOMEN
MEN


Perceived behavioural control
100%
80%
60%
40%
20%
0%
51%
46%
58%
50%
25%
25%
It would be easy for me to use sustainable means of transport.
I am sure that in the next week I can use sustainable means of transport.
For me using sustainable means of transport is impossible.
WOMEN
MEN


Frequency of walking for trips different from work
60%
50%
40%
30%
20%
10%
0%
9%
12%
7%
7%
15%
15%
28%
28%
41%
38%
Never
A few times a year
Several times a month
Several times a week
Every day
WOMEN
MEN


Frequency of bicycle use for trips different from work
80%
60%
40%
20%
0%
73%
56%
16%
20%
6%
10%
3%
8%
1%
5%
Never
A few times a year
Several times a month
Several times a week
Every day
WOMEN
MEN

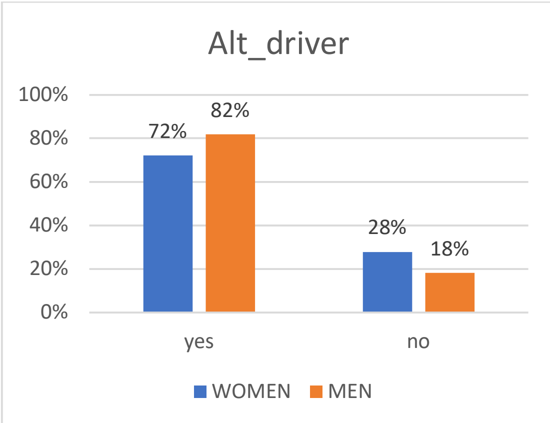

Frequency of public transport use for trips different from work
60%
50%
40%
30%
20%
10%
0%
11%
17%
22%
28%
18%
19%
19%
16%
31%
21%
Never
A few times a year
Several times a month
Several times a week
Every day
WOMEN
MEN

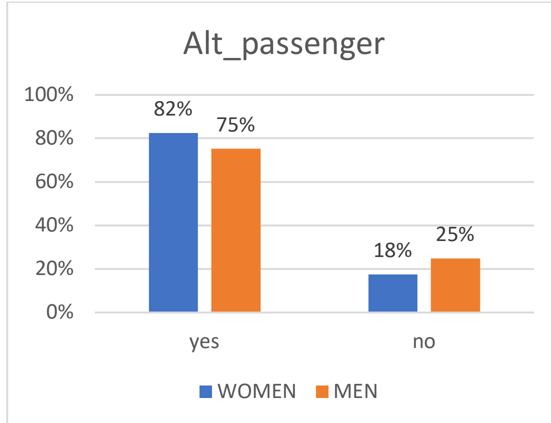

Frequency of car use for trips different from work
60%
50%
40%
30%
20%
10%
0%
9%
7%
8%
7%
20%
16%
27%
29%
36%
41%
Never
A few times a year
Several times a month
Several times a week
Every day
WOMEN
MEN

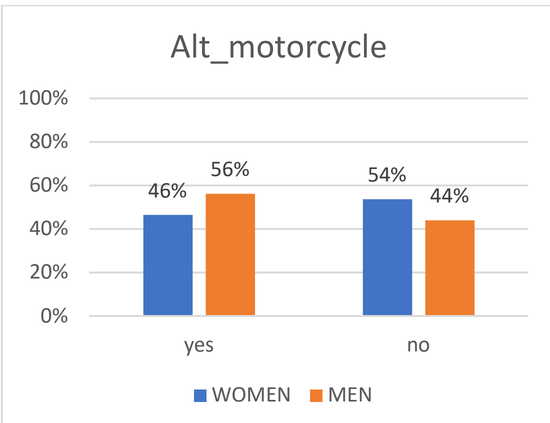
		Average Women	Average Men	Difference	Z* stat	
CH1	My choice to use sustainable transport is consciously and intentionally motivated by a specific desire to do good for the environment.	2.15	1.70	0.45	5.03	*
CH2	My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).	2.24	1.85	0.39	4.18	*
CH3	My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.	1.95	1.59	0.36	4.26	*
CH4	My choice to use sustainable transport is obliged by the fact that I have no alternative	1.67	1.16	0.51	6.83	*
NS1	Most of the people I know think I should use sustainable means of transport instead of the car.	2.55	2.61	-0.06	-1.69	
NS2	Most of the people I know use sustainable means of transport instead of the car.	2.36	2.30	0.07	1.76	
NM1	I feel morally obligated to use sustainable means of transport regardless of what others are doing.	3.54	3.52	0.02	0.56	
EM1	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	2.57	2.49	0.08	2.20	*
EM2	If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	3.55	3.44	0.12	3.06	*
EM3	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	2.78	2.96	-0.18	-4.81	*
RESP1	I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	3.60	3.38	0.22	6.06	*
RESP2	I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.	2.85	2.86	0.00	-0.06	
AWA1	I am aware that the use of private car has negative impacts on the environment and people’s health.	4.51	4.37	0.14	5.80	*
AWA2	I am aware that I can personally contribute (by using the car less) to reducing pollution.	4.44	4.30	0.14	5.37	*
LOC1	This city is part of my identity and therefore I respect it.	4.44	4.39	0.05	2.17	*
LOC2	I feel at home in this city.	4.23	4.18	0.05	1.74	
LOC3	I feel I belong to this city and therefore I must contribute to make it a better place.	4.26	4.19	0.07	2.40	*
HABIT_W	Frequency of walking for trips different from work	3.84	3.73	0.11	2.83	*
HABIT_B	Frequency of bicycle use for trips different from work	1.44	1.88	-0.44	-13.38	*
HABIT_PT	Frequency of public transport use for trips different from work	3.37	2.97	0.40	9.41	*
HABIT_CAR	Frequency of car use for trips different from work	3.72	3.89	-0.17	-4.52	*
INT1	During the next two weeks, I intend to use sustainable means of transport instead of the car	3.48	3.27	0.21	4.84	*
INT2	During the next two weeks, I intend to use the car.	3.13	3.41	-0.28	-6.45	*
INT3	In the next two weeks, I do not have any interest in using sustainable means of transport.	1.92	2.08	-0.16	-4.44	*
ATT1	I find that using sustainable means of transport instead of the private car is useful.	4.19	4.12	0.07	2.33	*
ATT2	I find that using sustainable means of transport instead of the private car is pleasant.	3.51	3.57	-0.06	-1.59	
ATT3	I find that using sustainable means of transport instead of the private car is right.	4.30	4.19	0.10	3.76	*
PCB1	It would be easy for me to use sustainable means of transport.	3.18	3.07	0.12	2.57	*
PCB2	I am sure that in the next week I can use sustainable means of transport.	3.45	3.21	0.24	4.99	*
PCB3	For me using sustainable means of transport is impossible.	2.24	2.32	-0.08	-1.89	

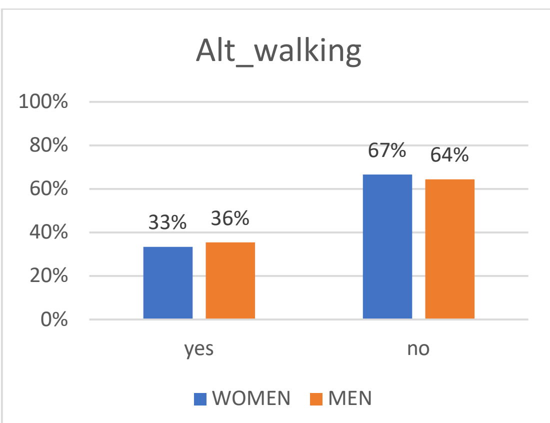
** Significant at 95% confidence level*

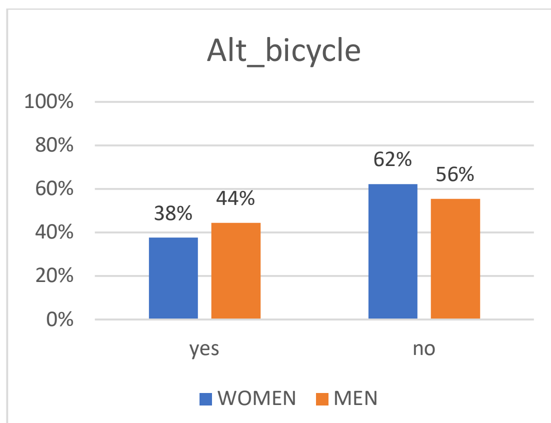
A.2.4 Alternative means of transport

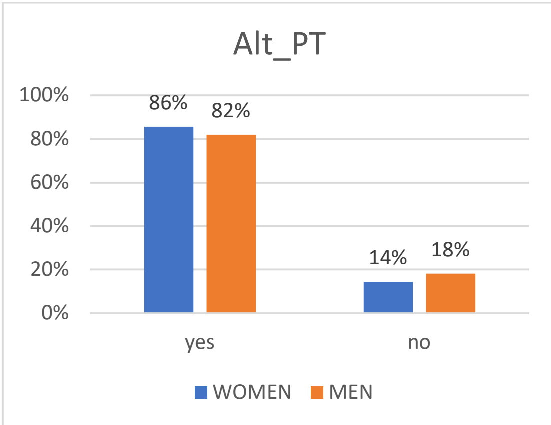


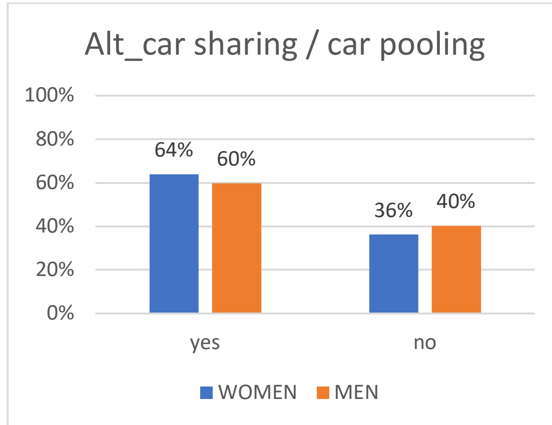










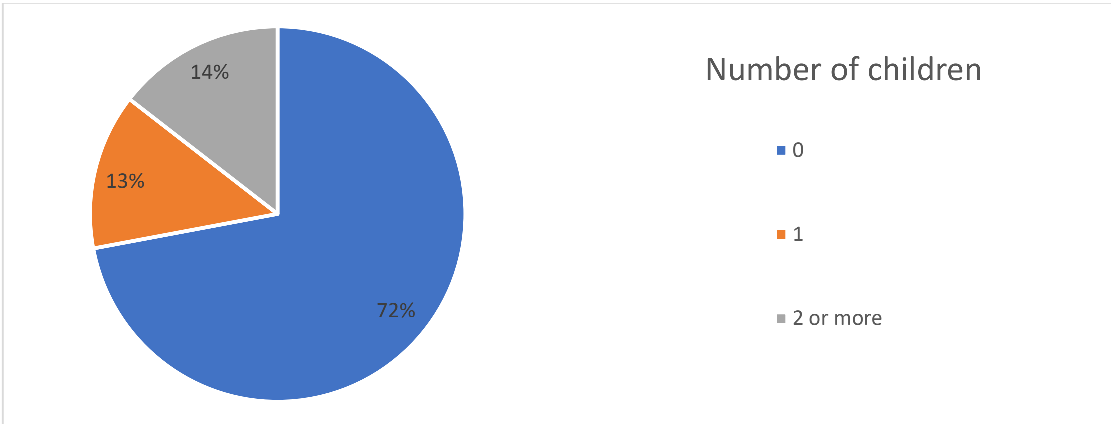


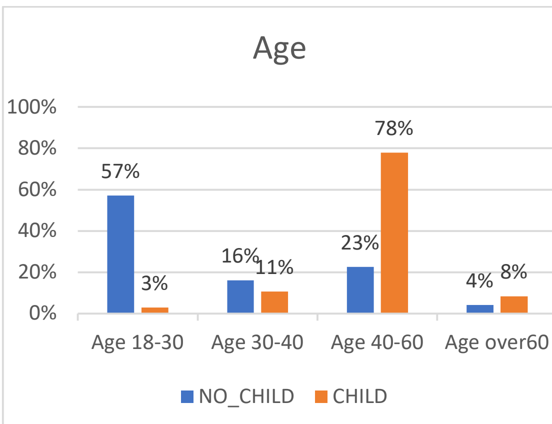
	Women	Men	Difference	Z* stat	
Alt_driver	72%	82%	-10%	-7.45	*
Alt_passenger	82%	75%	7%	5.92	*
Alt_motorcycle	46%	56%	-10%	-6.35	*
Alt_walking	33%	36%	-2%	-1.40	
Alt_bicycle	38%	44%	-7%	-4.51	*
Alt_PT	86%	82%	4%	3.32	*
Alt_carsharing_pooling	64%	60%	4%	2.75	*

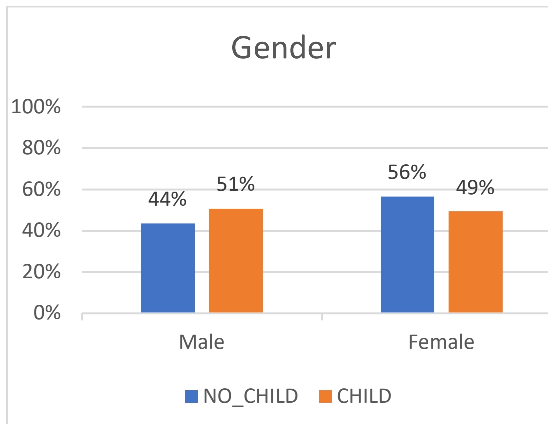
** Significant at 95% confidence level*

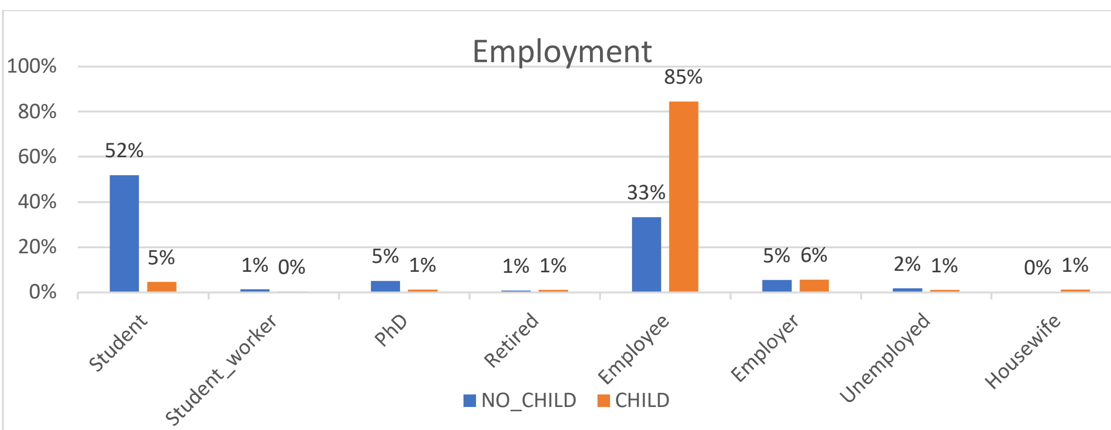
A.3 NO CHILDREN vs WITH CHILDREN

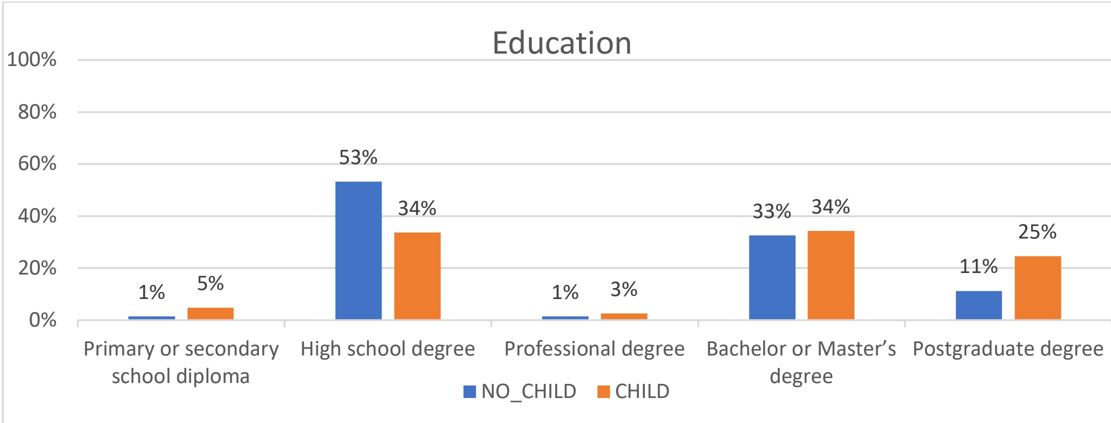
A.3.1 Socioeconomic characteristics

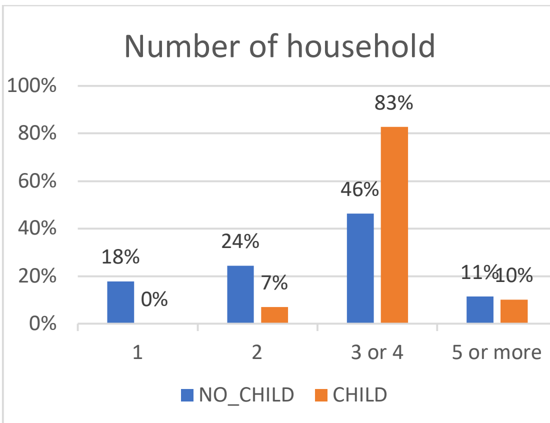


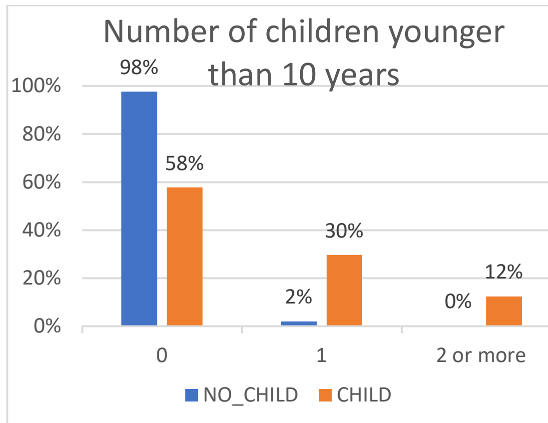


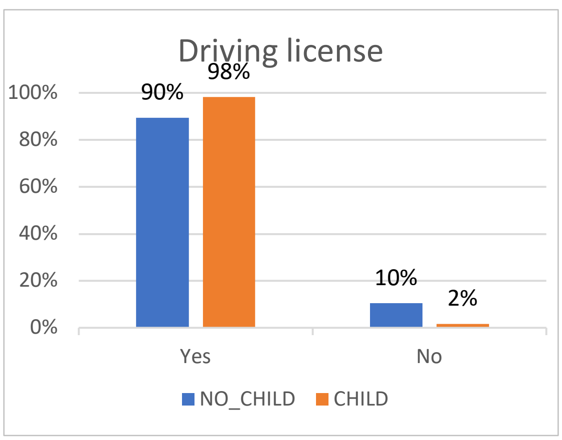


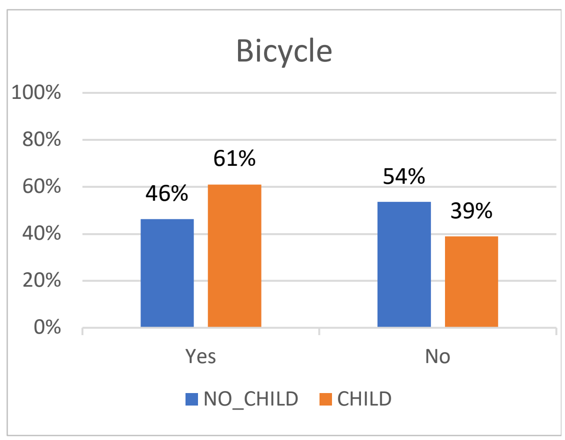


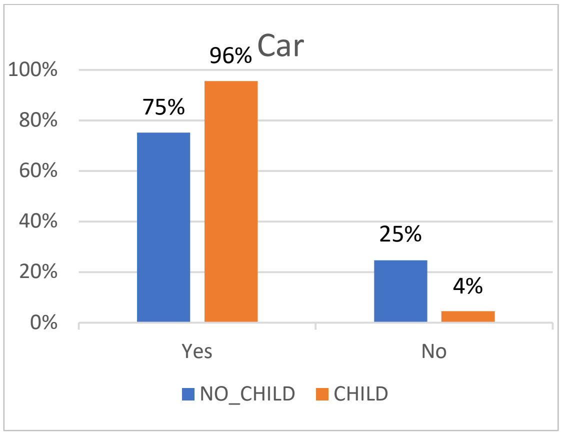

Education
100%
80%
60%
40%
20%
0%
1%
5%
53%
34%
1%
3%
33%
34%
11%
25%
Primary or secondary school diploma
High school degree
Professional degree
Bachelor or Master's degree
Postgraduate degree
NO_CHILD
CHILD

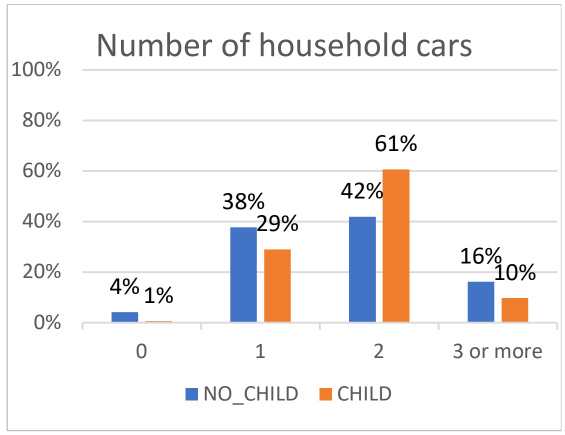

Number of household
100%
80%
60%
40%
20%
0%
18%
0%
24%
7%
46%
83%
11%
10%
1
2
3 or 4
5 or more
NO_CHILD
CHILD

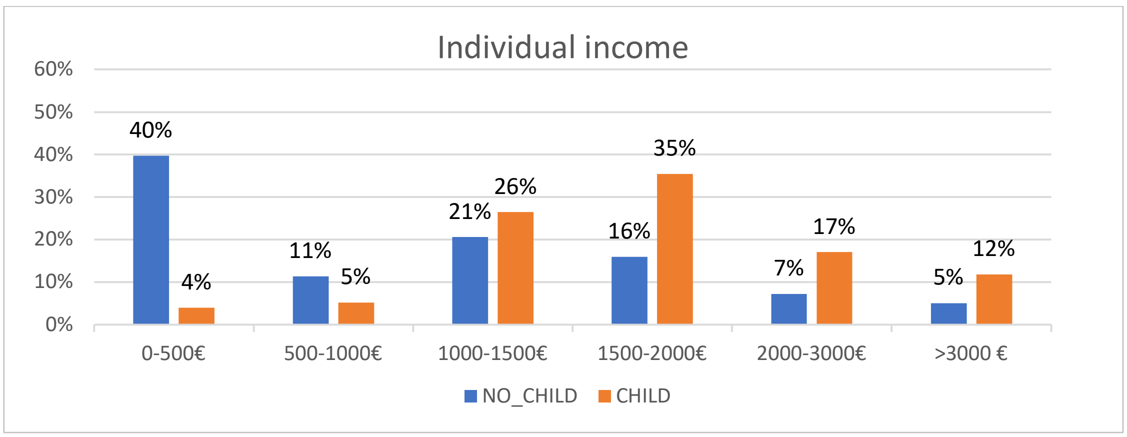

Number of children younger than 10 years
100%
80%
60%
40%
20%
0%
98%
58%
2%
30%
0%
12%
0
1
2 or more
NO_CHILD
CHILD


Driving license
100%
80%
60%
40%
20%
0%
90%
98%
10%
2%
Yes
No
NO_CHILD
CHILD


Bicycle
100%
80%
60%
40%
20%
0%
46%
61%
54%
39%
Yes
No
NO_CHILD
CHILD



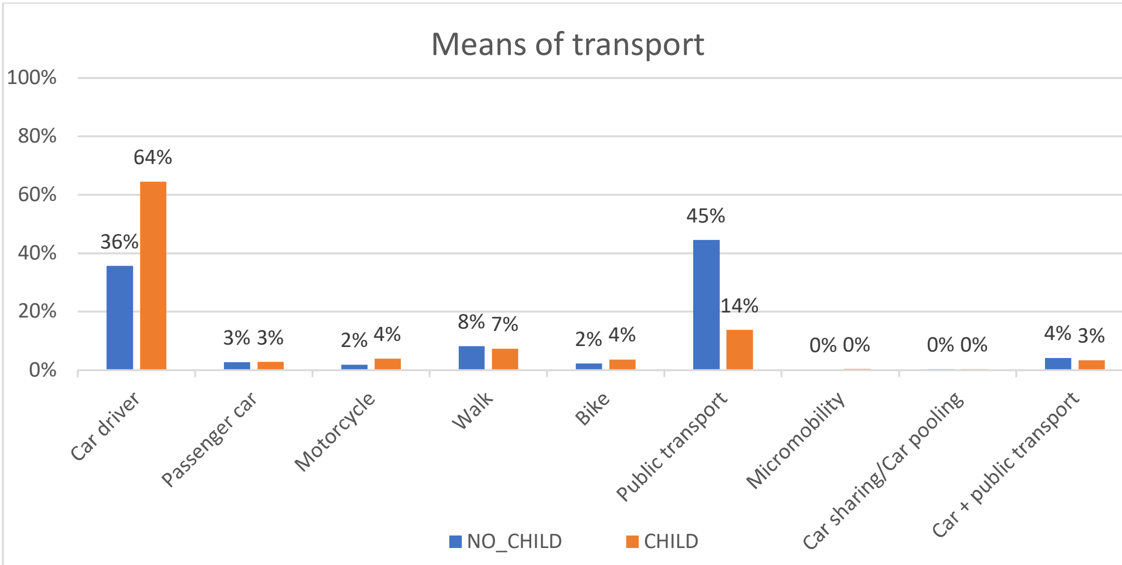


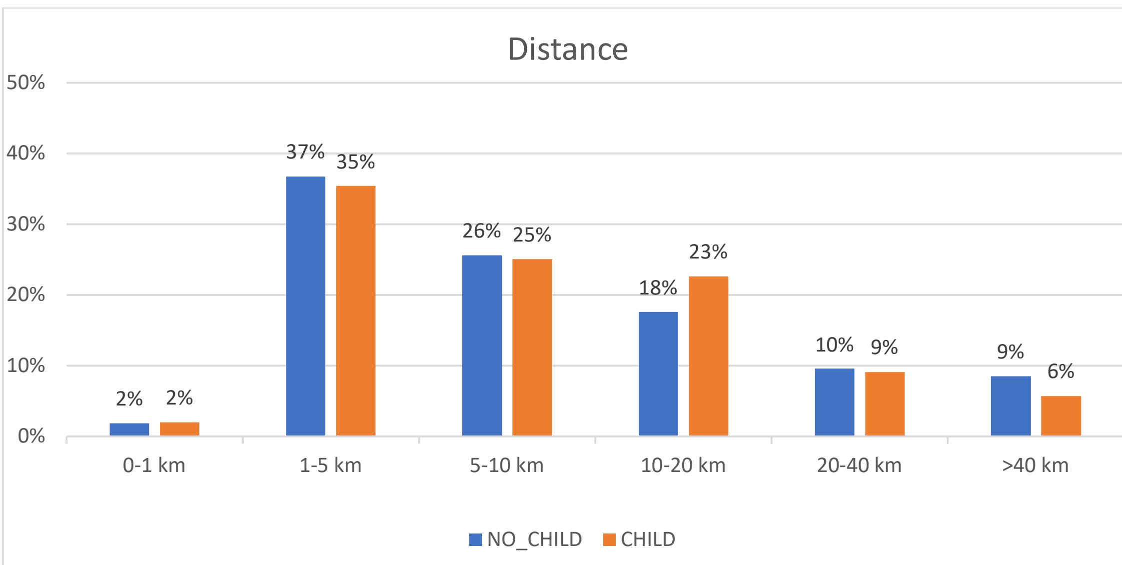


	Average NoChild	Average Child	Difference	Z* stat	
Age	32.8	49.1	-16.3	-47.16	*
N_household	2.9	3.6	-0.6	-18.49	*
N_children	0.0	1.6	-1.6	-77.34	*
N_children10	0.0	0.6	-0.5	-24.94	*
N_car	1.7	1.8	-0.1	-2.71	*
Income	2.5	3.9	-1.4	-30.64	*

** Significant at 95% confidence level*

A.3.2 Trip characteristics

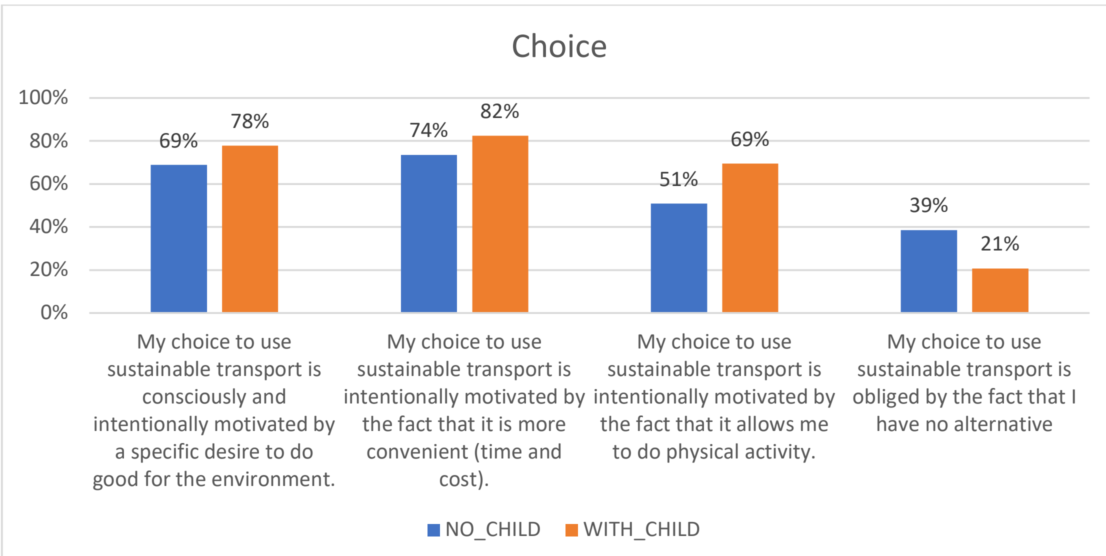


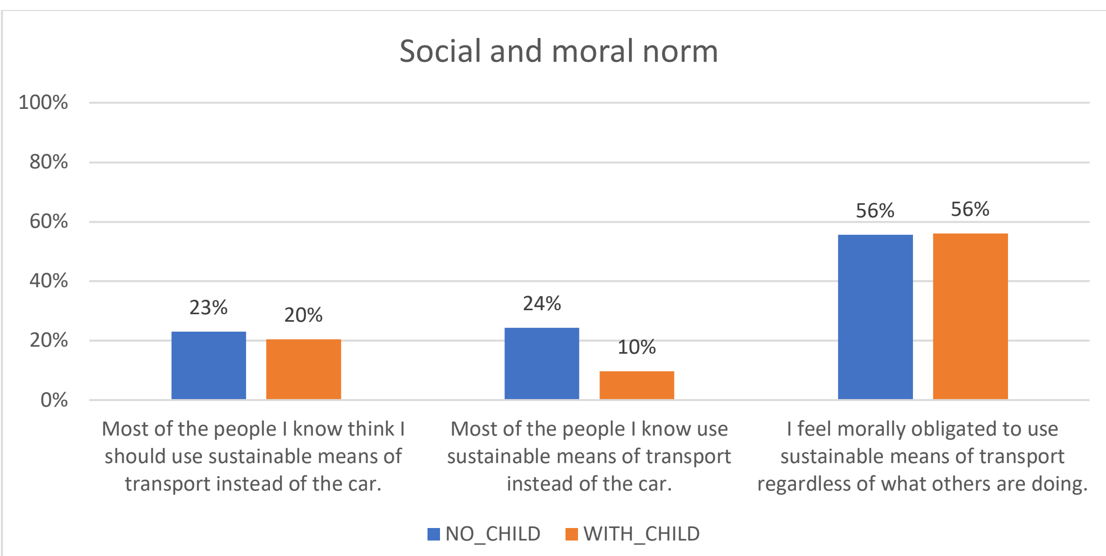


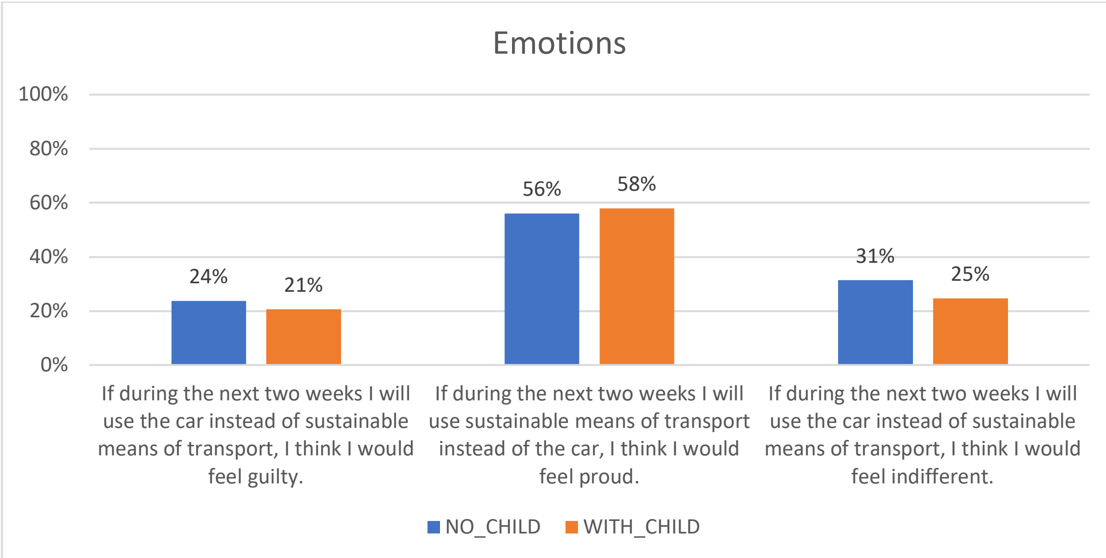
ORIGIN/DESTINATION NO_CHILD	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	163	5.2%	700	22.5%	0	0.0%	0	0.0%	863
CAGLIARI	387	12.5%	1343	43.2%	3	0.1%	14	0.5%	1747
NUORO	0	0.0%	1	0.0%	0	0.0%	0	0.0%	1
ORISTANO	6	0.2%	28	0.9%	0	0.0%	0	0.0%	34
SUD SARDEGNA	72	2.3%	389	12.5%	0	0.0%	0	0.0%	461
Total	628	20.2%	2461	79.2%	3	0.1%	14	0.5%	3106

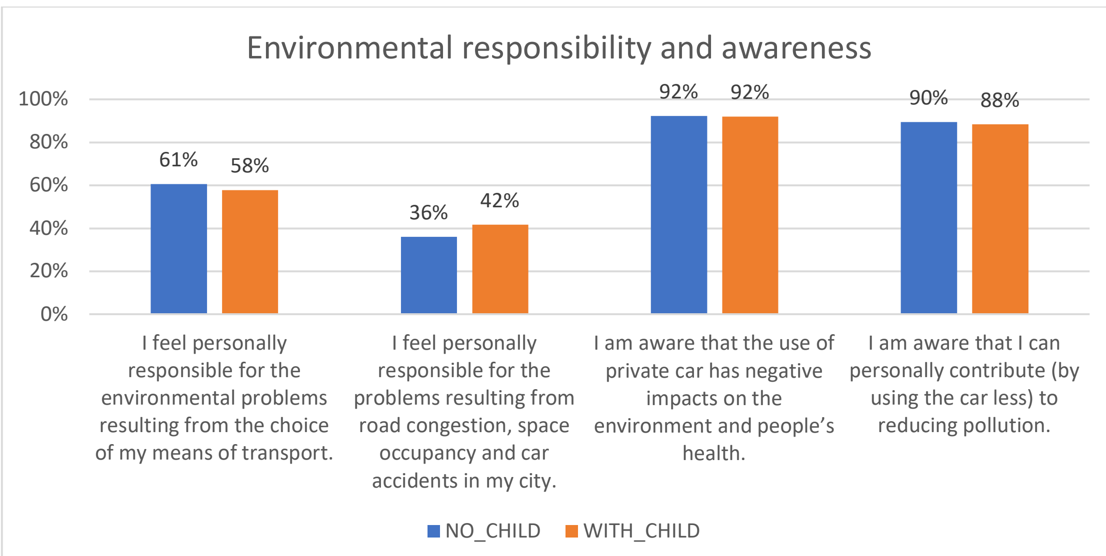
ORIGIN/DESTINATION WITH_CHILD	AREA METROPOLITANA CAGLIARI		CAGLIARI		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	41	3.4%	339	28.1%	0	0.0%	380
CAGLIARI	90	7.5%	566	47.0%	9	0.7%	665
ORISTANO	0	0.0%	8	0.7%	0	0.0%	8
SUD SARDEGNA	17	1.4%	135	11.2%	0	0.0%	152
Total	148	12.3%	1048	87.0%	9	0.7%	1205

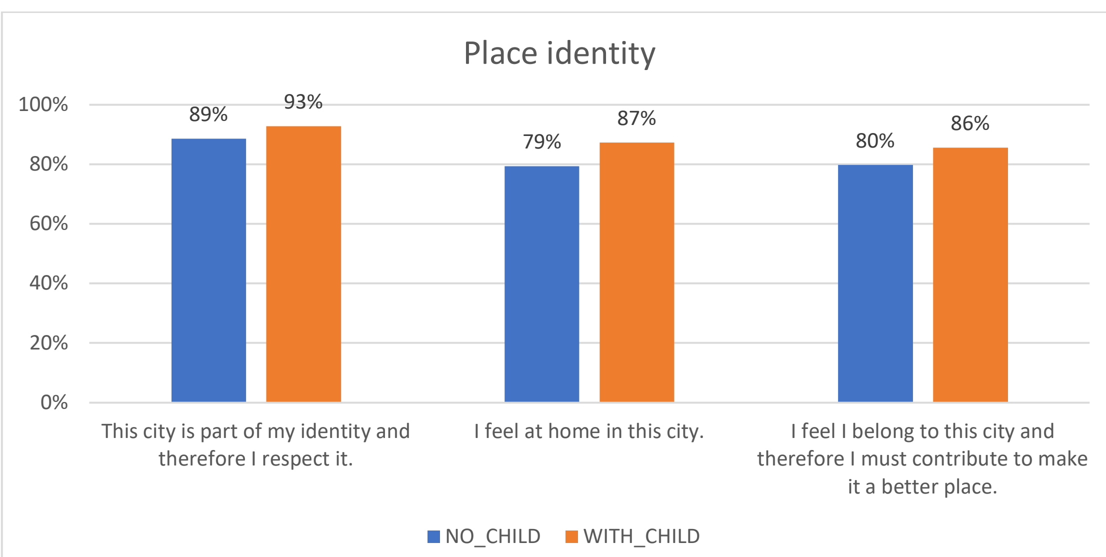
A.3.3 Psychosocial characteristics

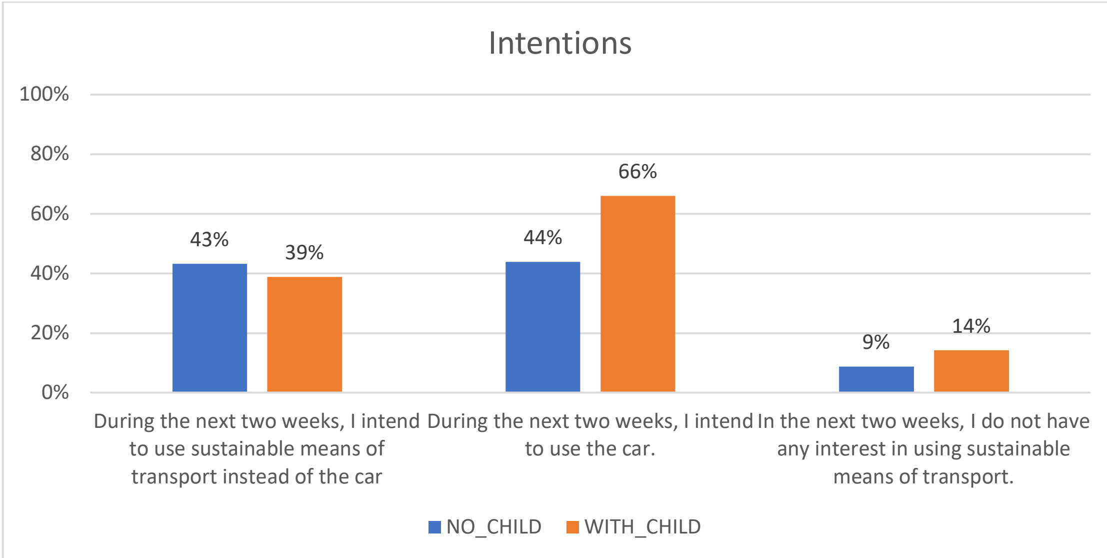


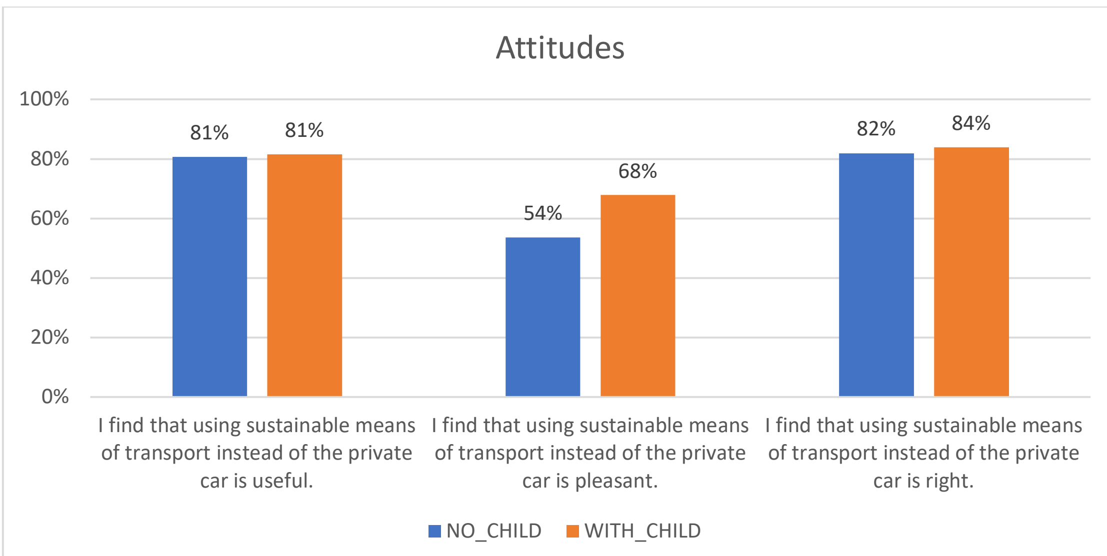


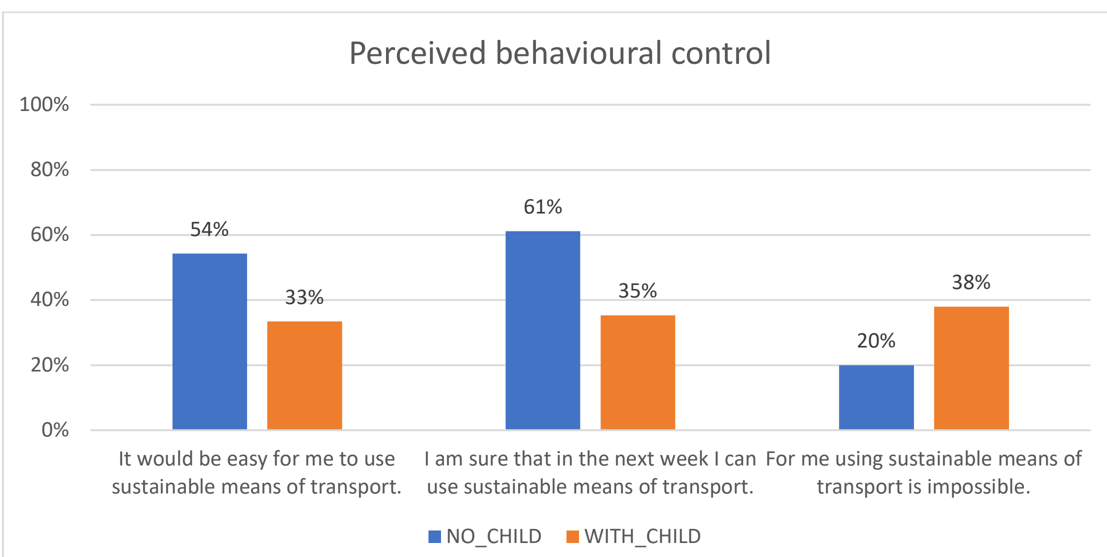

Emotions
100%
80%
60%
40%
20%
0%
24%
21%
56%
58%
31%
25%
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.
If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.
NO_CHILD
WITH_CHILD

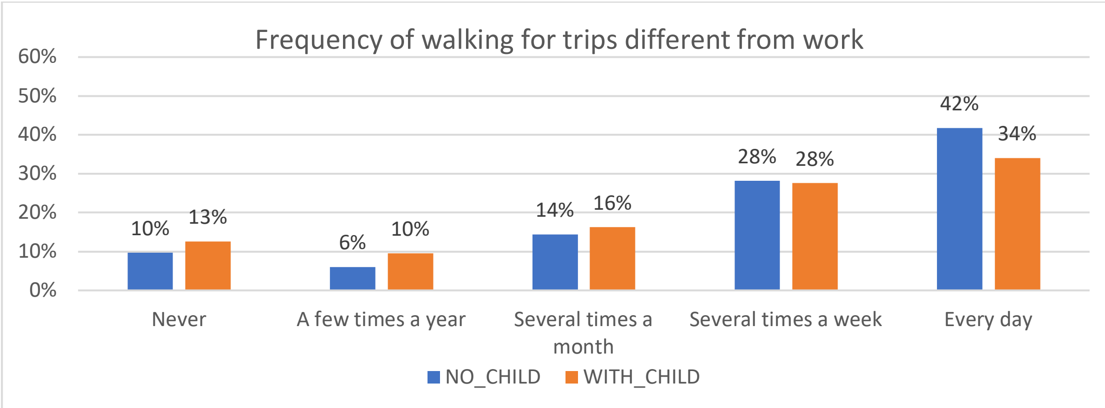

Environmental responsibility and awareness
100%
80%
60%
40%
20%
0%
61%
58%
36%
42%
92%
92%
90%
88%
I feel personally responsible for the environmental problems resulting from the choice of my means of transport.
I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.
I am aware that the use of private car has negative impacts on the environment and people’s health.
I am aware that I can personally contribute (by using the car less) to reducing pollution.
NO_CHILD
WITH_CHILD

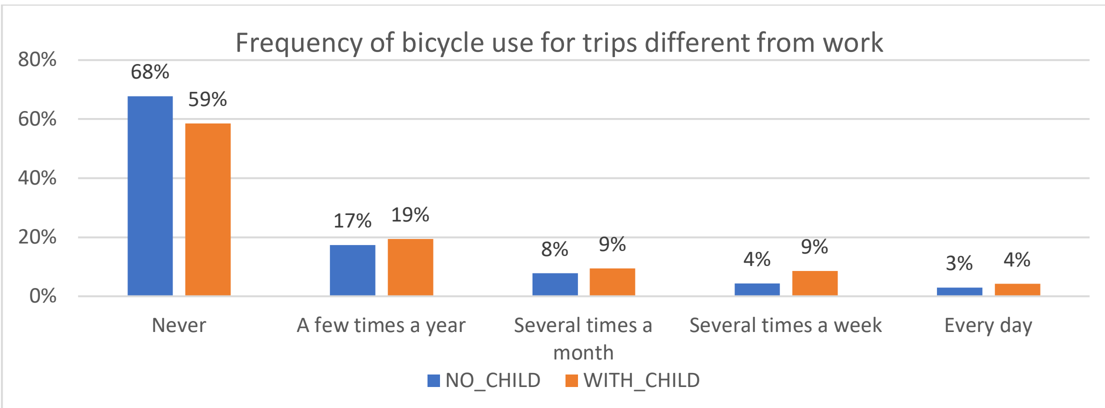

Place identity
100%
80%
60%
40%
20%
0%
89%
93%
79%
87%
80%
86%
This city is part of my identity and therefore I respect it.
I feel at home in this city.
I feel I belong to this city and therefore I must contribute to make it a better place.
NO_CHILD
WITH_CHILD

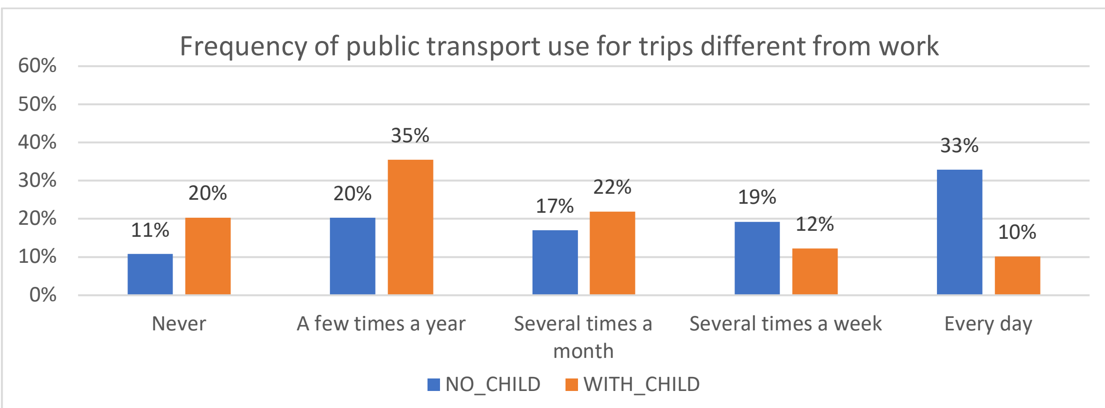

Intentions
100%
80%
60%
40%
20%
0%
43%
39%
44%
66%
9%
14%
During the next two weeks, I intend to use sustainable means of transport instead of the car
During the next two weeks, I intend to use the car.
In the next two weeks, I do not have any interest in using sustainable means of transport.
NO_CHILD
WITH_CHILD

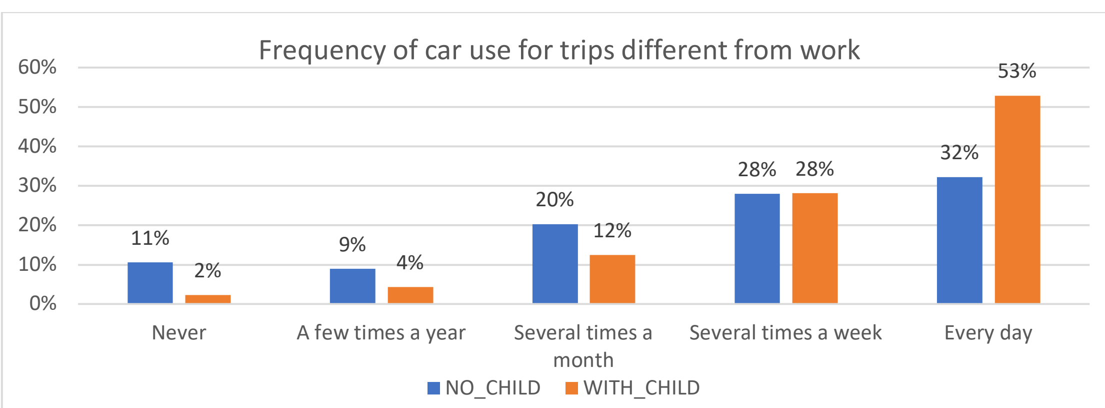

Attitudes
100%
80%
60%
40%
20%
0%
81%
81%
54%
68%
82%
84%
I find that using sustainable means of transport instead of the private car is useful.
I find that using sustainable means of transport instead of the private car is pleasant.
I find that using sustainable means of transport instead of the private car is right.
NO_CHILD
WITH_CHILD


Perceived behavioural control
100%
80%
60%
40%
20%
0%
54%
33%
61%
35%
20%
38%
It would be easy for me to use sustainable means of transport.
I am sure that in the next week I can use sustainable means of transport.
For me using sustainable means of transport is impossible.
NO_CHILD
WITH_CHILD


Frequency of walking for trips different from work
60%
50%
40%
30%
20%
10%
0%
10%
13%
6%
10%
14%
16%
28%
28%
42%
34%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CHILD
WITH_CHILD


Frequency of bicycle use for trips different from work
80%
60%
40%
20%
0%
68%
59%
17%
19%
8%
9%
4%
9%
3%
4%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CHILD
WITH_CHILD

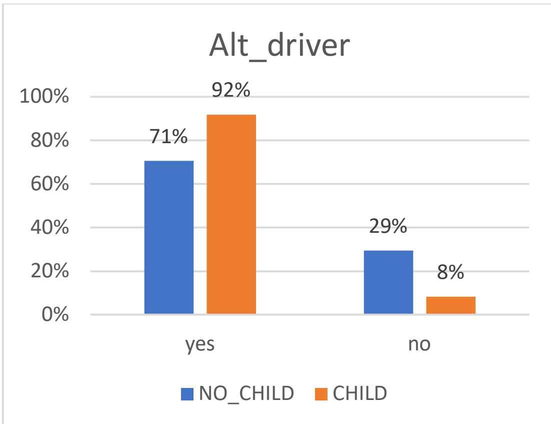

Frequency of public transport use for trips different from work
60%
50%
40%
30%
20%
10%
0%
11%
20%
20%
35%
17%
22%
19%
12%
33%
10%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CHILD
WITH_CHILD

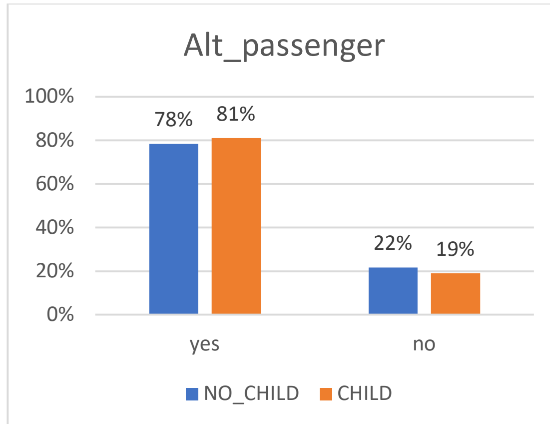

Frequency of car use for trips different from work
60%
50%
40%
30%
20%
10%
0%
11%
2%
9%
4%
20%
12%
28%
28%
32%
53%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CHILD
WITH_CHILD

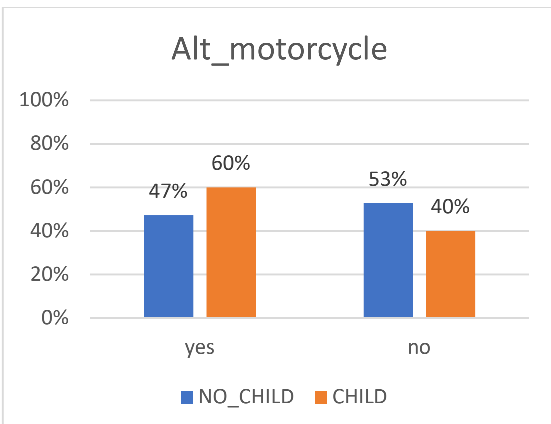
		Average NoChild	Average Child	Difference	Z* stat	
CH1	My choice to use sustainable transport is consciously and intentionally motivated by a specific desire to do good for the environment.	2.260	1.140	1.120	9.91	*
CH2	My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).	2.388	1.217	1.172	9.99	*
CH3	My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.	2.037	1.136	0.901	8.08	*
CH4	My choice to use sustainable transport is obliged by the fact that I have no alternative	1.742	0.651	1.091	13.52	*
NS1	Most of the people I know think I should use sustainable means of transport instead of the car.	2.596	2.538	0.058	1.42	
NS2	Most of the people I know use sustainable means of transport instead of the car.	2.465	1.995	0.470	12.49	*
NM1	I feel morally obligated to use sustainable means of transport regardless of what others are doing.	3.533	3.525	0.007	0.17	
EM1	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	2.583	2.410	0.173	4.14	*
EM2	If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	3.489	3.537	-0.048	-1.16	
EM3	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	2.896	2.777	0.119	2.92	*
RESP 1	I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	3.537	3.396	0.141	3.48	*
RESP 2	I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.	2.796	3.007	-0.210	-4.66	*
AWA 1	I am aware that the use of private car has negative impacts on the environment and people’s health.	4.471	4.380	0.091	3.47	*
AWA 2	I am aware that I can personally contribute (by using the car less) to reducing pollution.	4.413	4.276	0.137	4.65	*
LOC1	This city is part of my identity and therefore I respect it.	4.392	4.490	-0.097	-3.88	*
LOC2	I feel at home in this city.	4.147	4.360	-0.213	-6.96	*
LOC3	I feel I belong to this city and therefore I must contribute to make it a better place.	4.180	4.352	-0.172	-5.88	*
HABIT_W	Frequency of walking for trips different from work	3.862	3.608	0.254	5.56	*
HABIT_B	Frequency of bicycle use for trips different from work	1.573	1.804	-0.231	-6.06	*
HABIT_PT	Frequency of public transport use for trips different from work	3.431	2.563	0.868	20.02	*
HABIT_CAR	Frequency of car use for trips different from work	3.624	4.251	-0.627	-17.09	*
INT1	During the next two weeks, I intend to use sustainable means of transport instead of the car	3.560	2.927	0.633	12.75	*
INT2	During the next two weeks, I intend to use the car.	3.064	3.749	-0.686	-15.39	*
INT3	In the next two weeks, I do not have any interest in using sustainable means of transport.	1.905	2.205	-0.300	-7.28	*
ATT1	I find that using sustainable means of transport instead of the private car is useful.	4.164	4.152	0.012	0.34	
ATT2	I find that using sustainable means of transport instead of the private car is pleasant.	3.433	3.816	-0.383	-9.43	*
ATT3	I find that using sustainable means of transport instead of the private car is right.	4.239	4.281	-0.042	-1.39	
PCB1	It would be easy for me to use sustainable means of transport.	3.325	2.632	0.693	14.01	*
PCB2	I am sure that in the next week I can use sustainable means of transport.	3.578	2.737	0.841	16.24	*
PCB3	For me using sustainable means of transport is impossible.	2.086	2.764	-0.678	-13.50	*

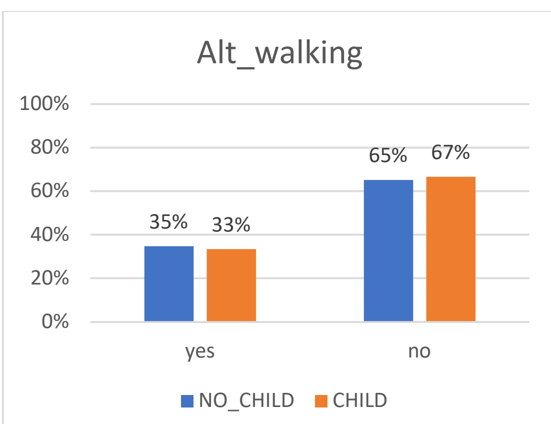
* *Significant at 95% confidence level*

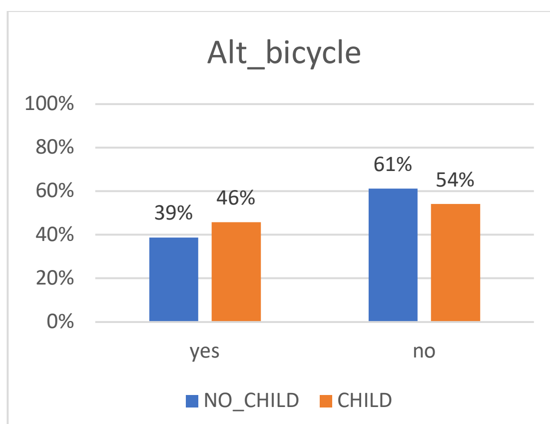
A.3.4 Alternative means of transport

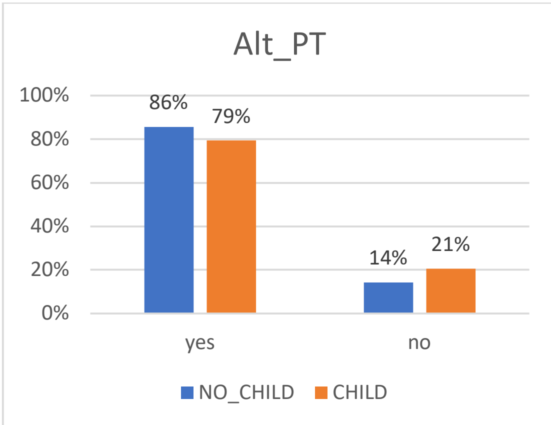


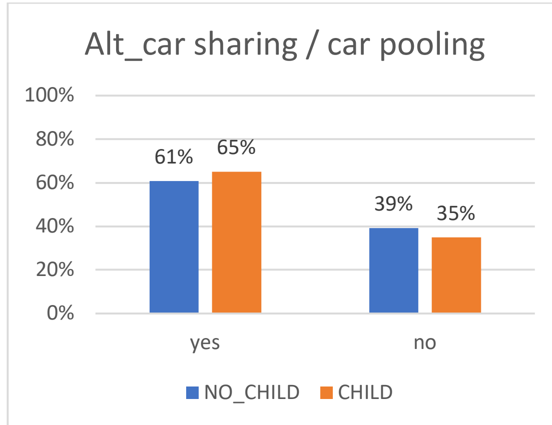










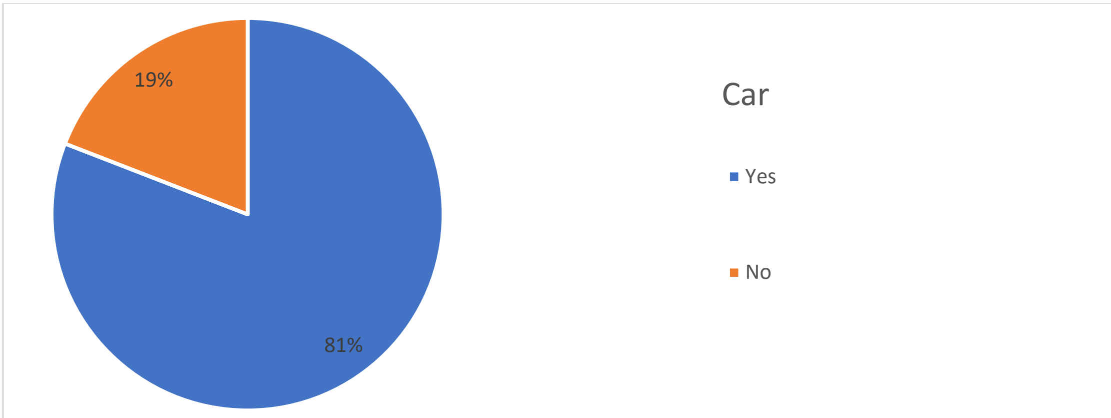


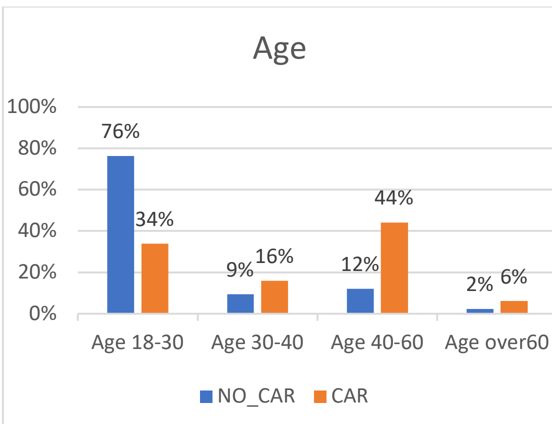
	No_Child	Child	Difference	Z* stat	
Alt_driver	71%	92%	-21%	-14.74	*
Alt_passenger	78%	81%	-3%	-1.86	
Alt_motorcycle	86%	79%	6%	5.05	*
Alt_walking	35%	33%	1%	0.89	
Alt_bicycle	39%	46%	-7%	-4.25	*
Alt_PT	47%	60%	-13%	-7.53	*
Alt_carsharing_pooling	61%	65%	-4%	-2.60	*

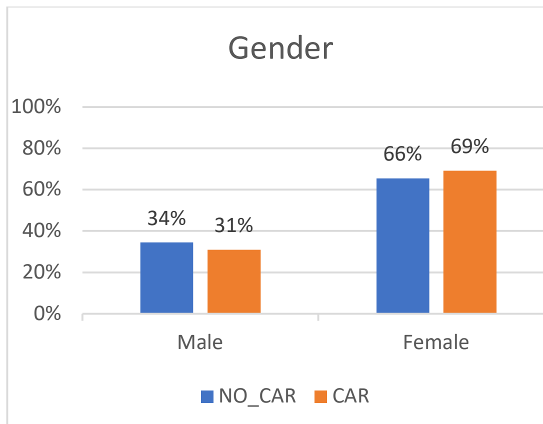
** Significant at 95% confidence level*

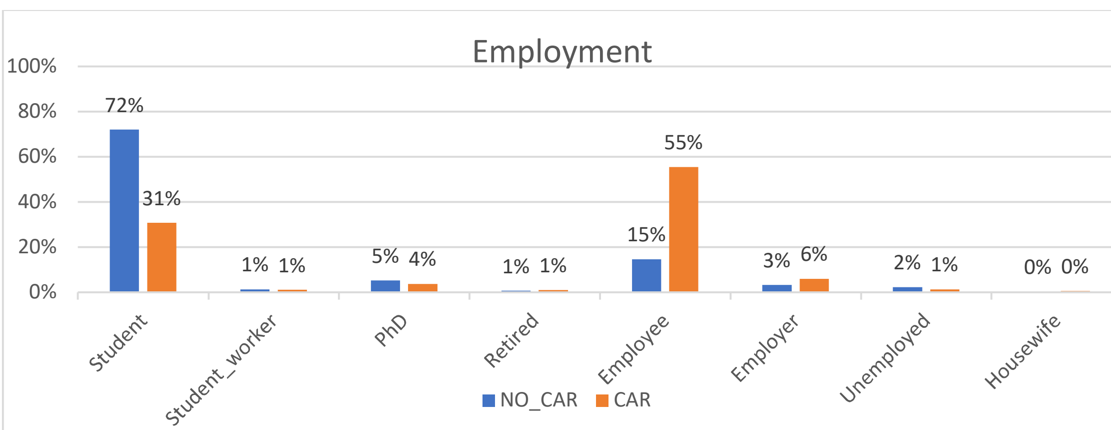
A.4 CAR OWNERSHIP vs NO CAR OWNERSHIP

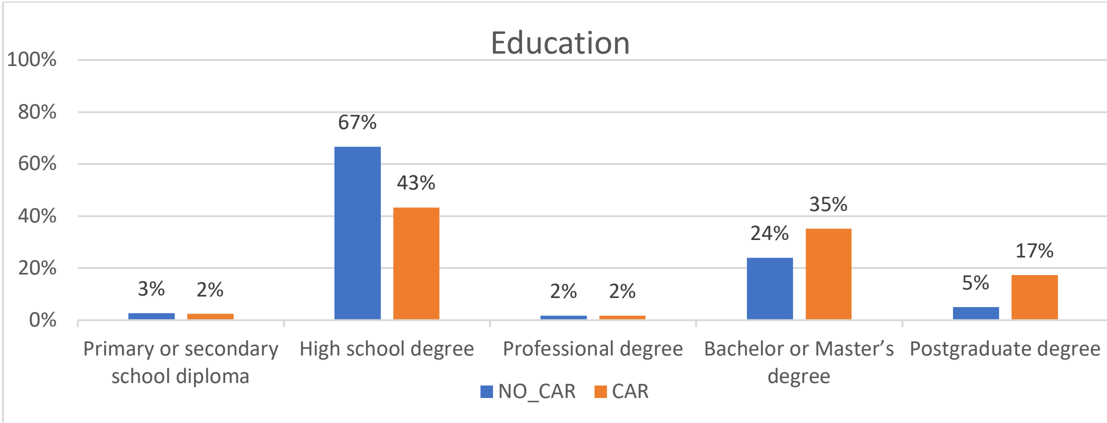
A.4.1 Socioeconomic characteristics



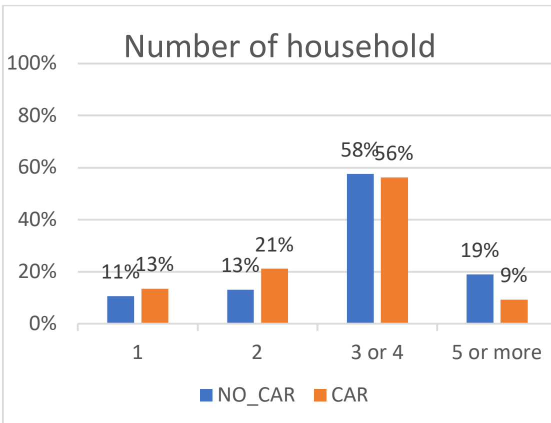




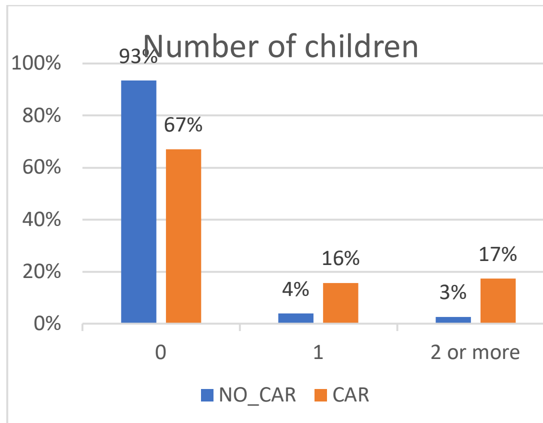




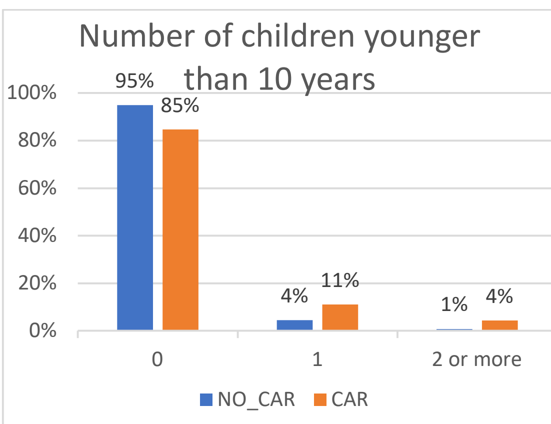
Education
100%
80%
60%
40%
20%
0%
67%
43%
3%
2%
2%
2%
24%
35%
5%
17%
Primary or secondary school diploma
High school degree
Professional degree
Bachelor or Master's degree
Postgraduate degree
NO_CAR
CAR



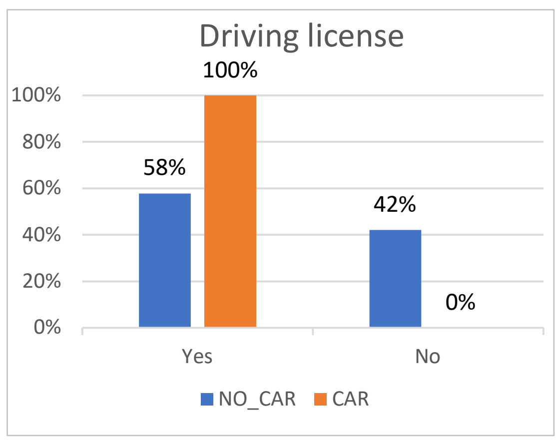
Number of household
100%
80%
60%
40%
20%
0%
11%
13%
13%
21%
58%
56%
19%
9%
1
2
3 or 4
5 or more
NO_CAR
CAR



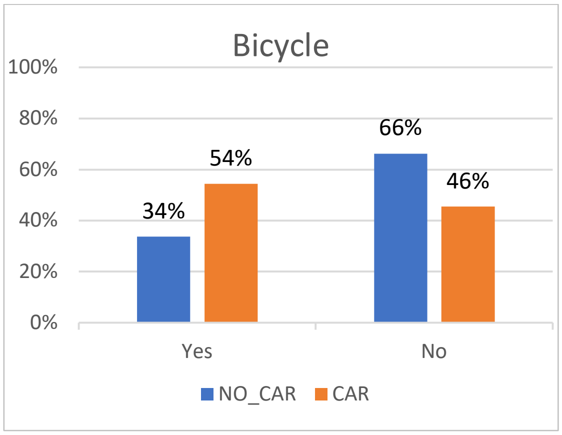
Number of children
100%
80%
60%
40%
20%
0%
93%
67%
4%
16%
3%
17%
0
1
2 or more
NO_CAR
CAR

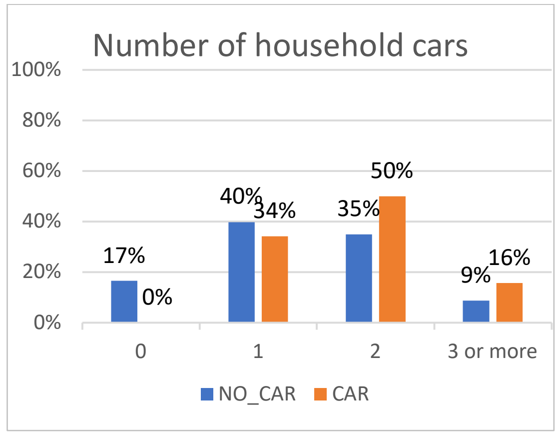


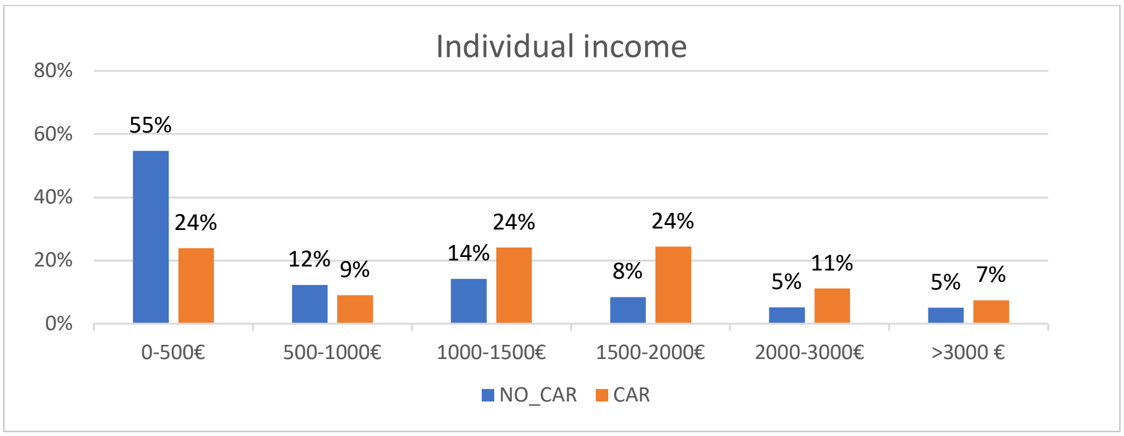
Number of children younger than 10 years
100%
80%
60%
40%
20%
0%
95%
85%
4%
11%
1%
4%
0
1
2 or more
NO_CAR
CAR



Driving license
100%
80%
60%
40%
20%
0%
58%
100%
42%
0%
Yes
No
NO_CAR
CAR



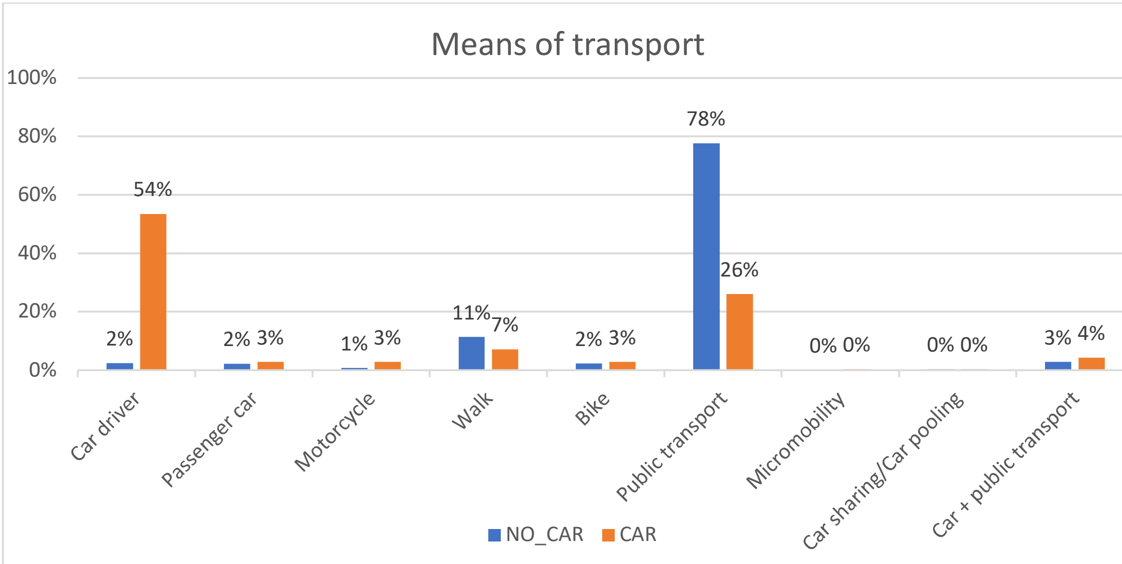


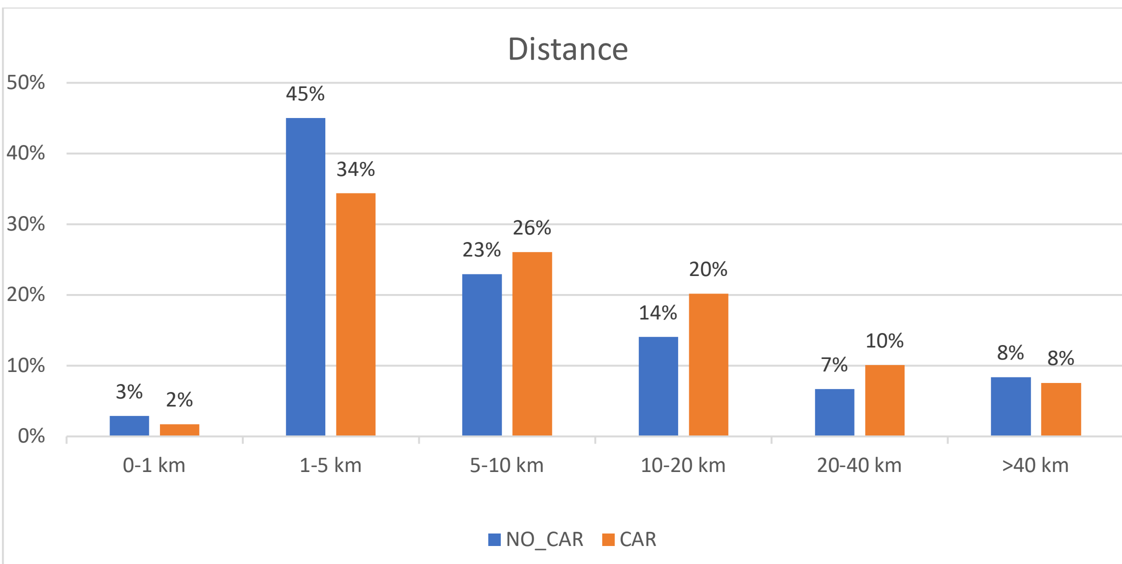


	Average NoCar	Average Car	Difference	Z* stat	
Age	27.9	39.6	-11.6	-25.29	*
N_household	3.4	3.0	0.4	8.24	*
N_children	0.1	0.5	-0.4	-21.45	*
N_children10	0.1	0.2	-0.1	-11.29	*
N_car	1.4	1.9	-0.5	-13.69	*
Income	2.1	3.1	-1.0	-16.92	*

** Significant at 95% confidence level*

A.4.2 Trip characteristics

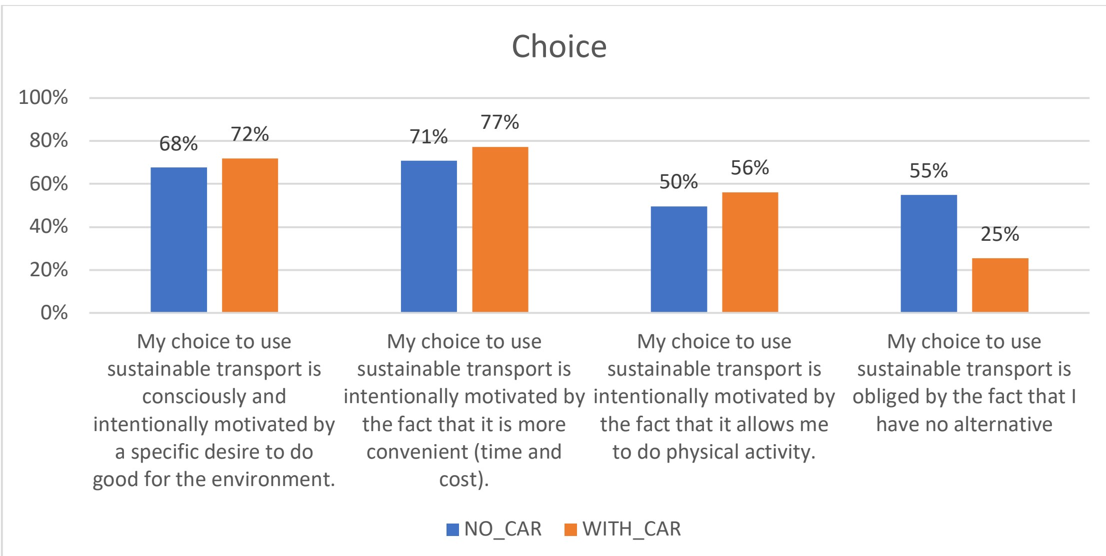


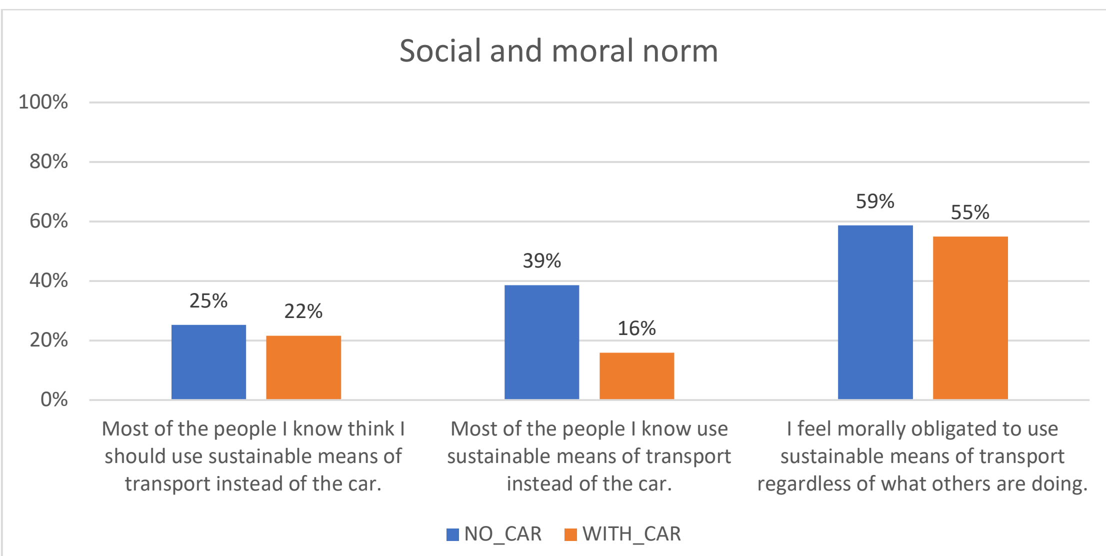


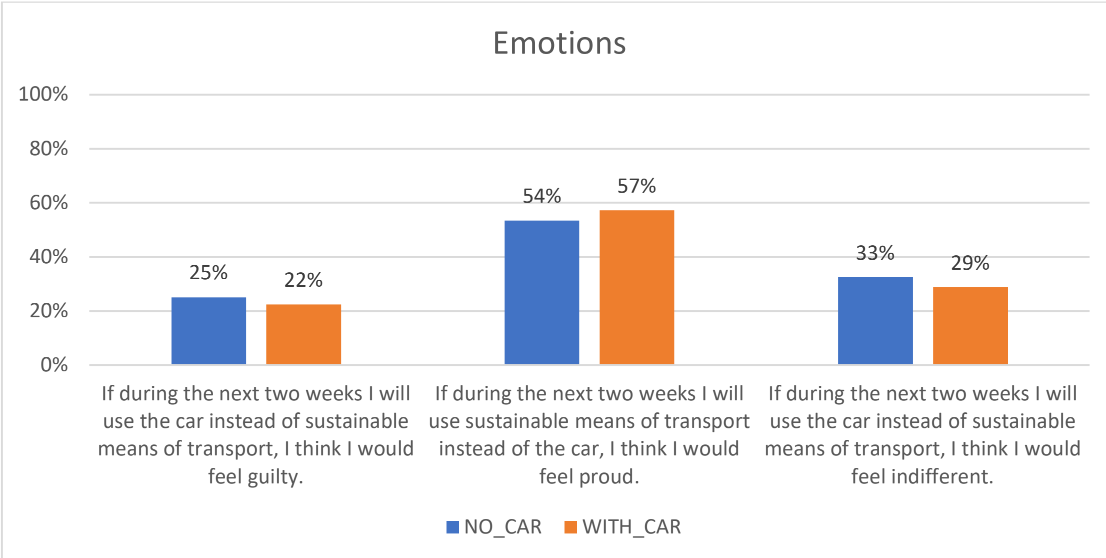
ORIGIN/DESTINATION CAR	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	158	4.5%	895	25.7%	0	0.0%	0	0.0%	1053
CAGLIARI	361	10.4%	1500	43.0%	3	0.1%	21	0.6%	1885
NUORO	0	0.0%	1	0.0%	0	0.0%	0	0.0%	1
ORISTANO	5	0.1%	29	0.8%	0	0.0%	0	0.0%	34
SUD SARDEGNA	76	2.2%	438	12.6%	0	0.0%	0	0.0%	514
Total	600	17.2%	2863	82.1%	3	0.1%	21	0.6%	3487

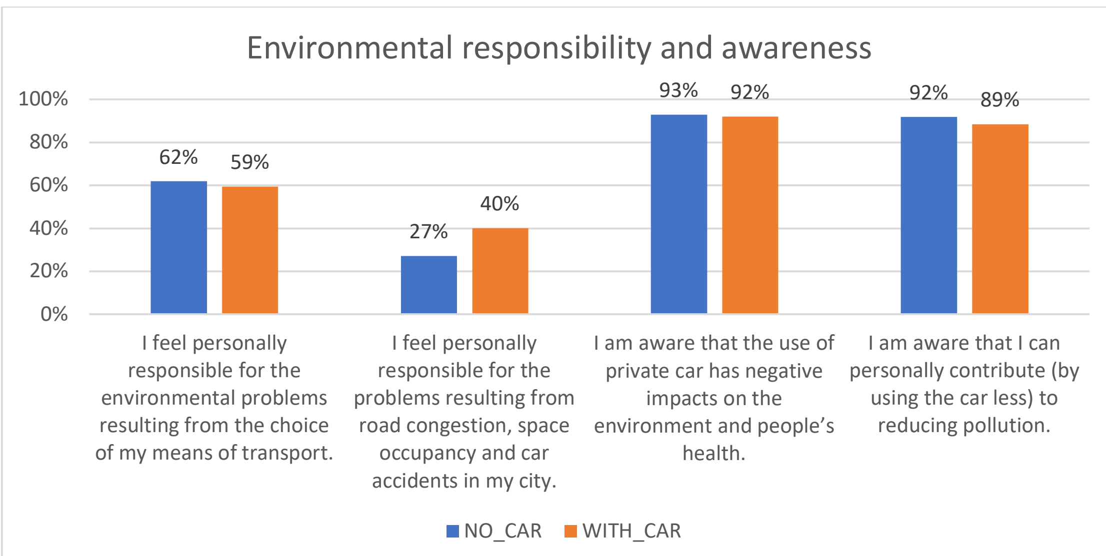
ORIGIN/DESTINATION NO_CAR	AREA METROPOLITANA CAGLIARI		CAGLIARI		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	46	5.6%	144	17.5%	0	0.0%	190
CAGLIARI	116	14.1%	409	49.6%	2	0.2%	527
ORISTANO	1	0.1%	7	0.8%	0	0.0%	8
SUD SARDEGNA	13	1.6%	86	10.4%	0	0.0%	99
Total	176	21.4%	646	78.4%	2	0.2%	824

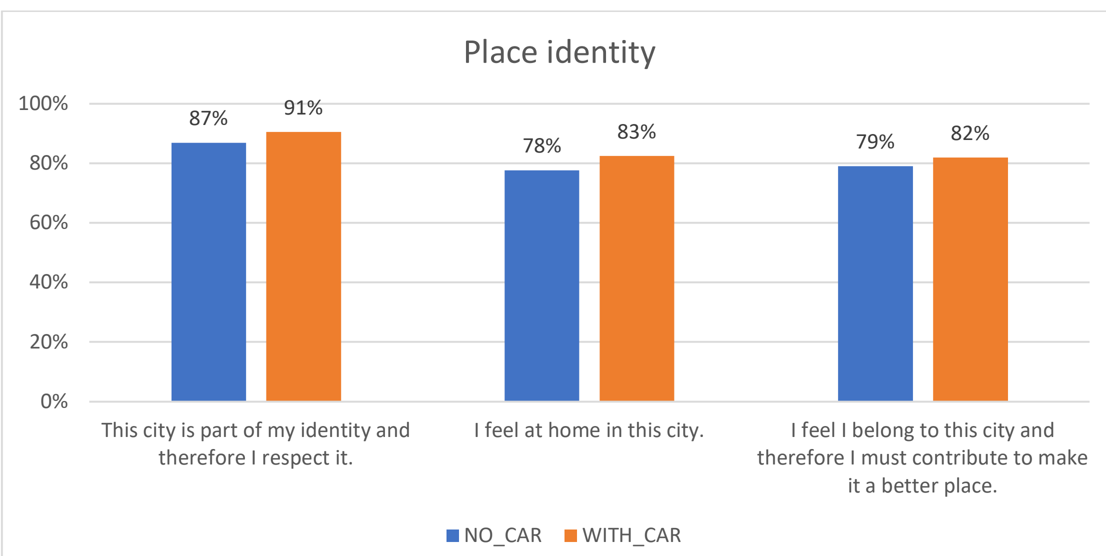
A.4.3 Psychosocial characteristics

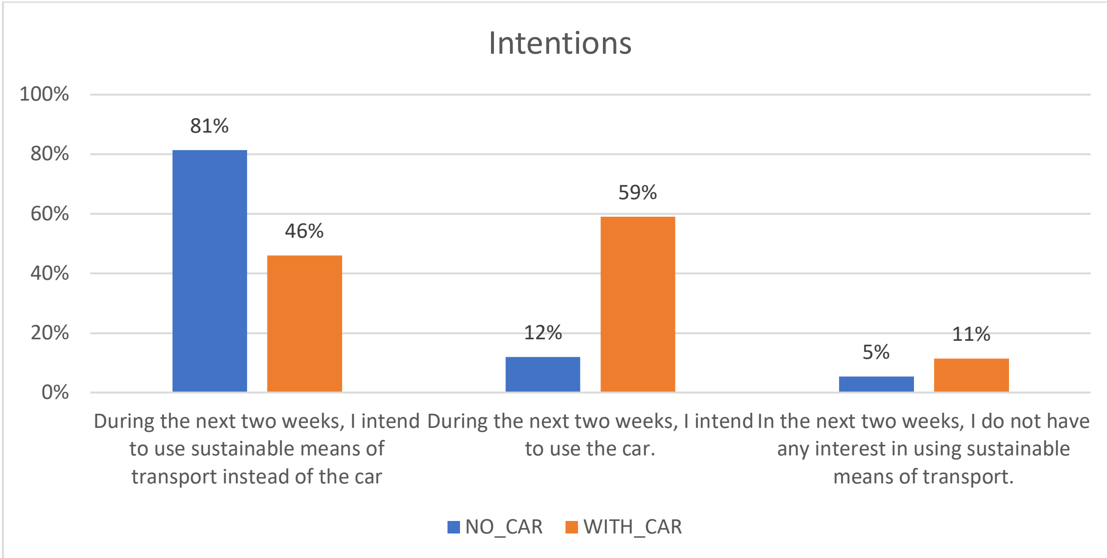


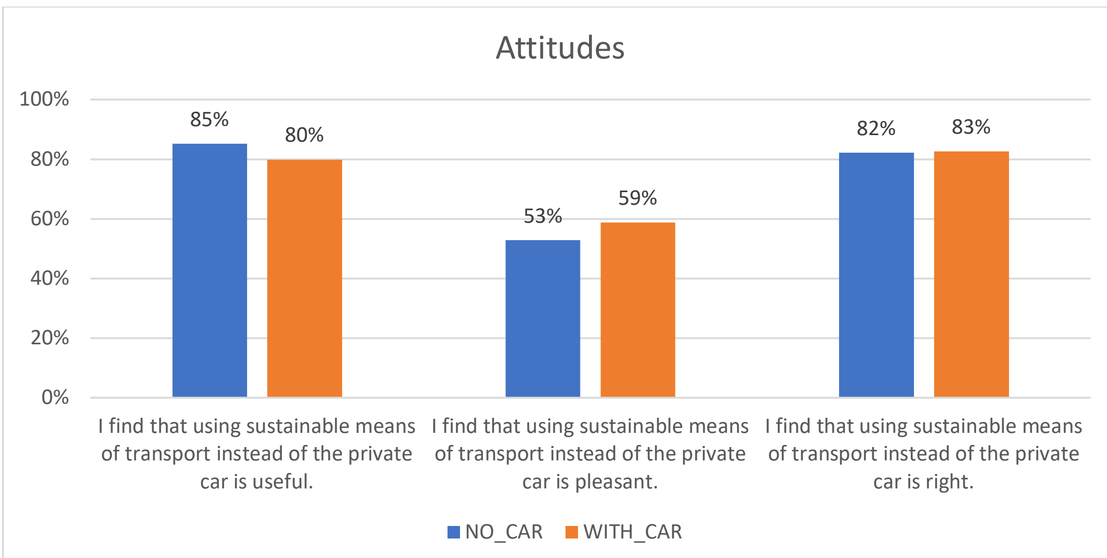


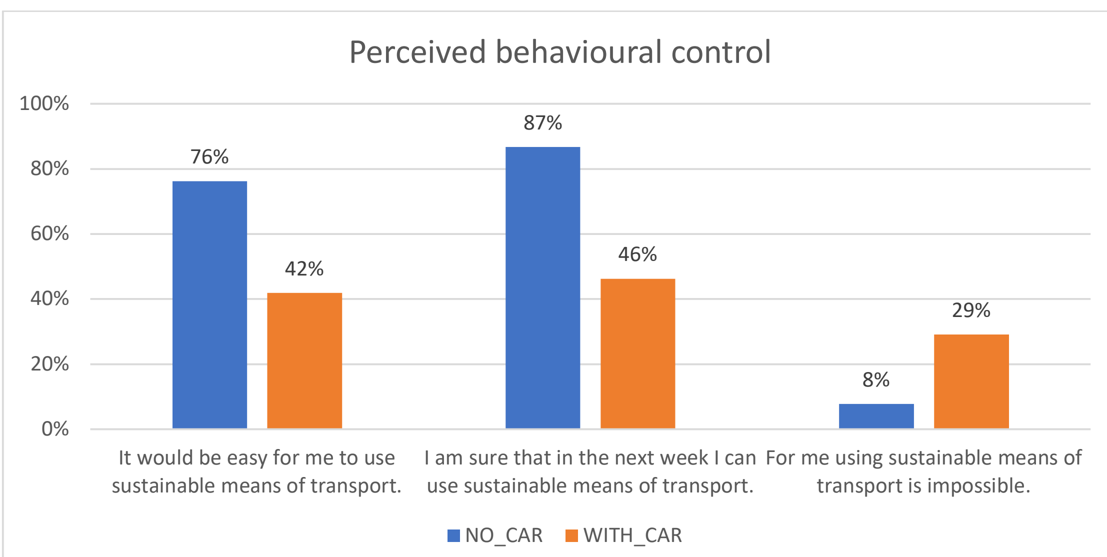

Emotions
100%
80%
60%
40%
20%
0%
25%
22%
54%
57%
33%
29%
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.
If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.
If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.
NO_CAR
WITH_CAR

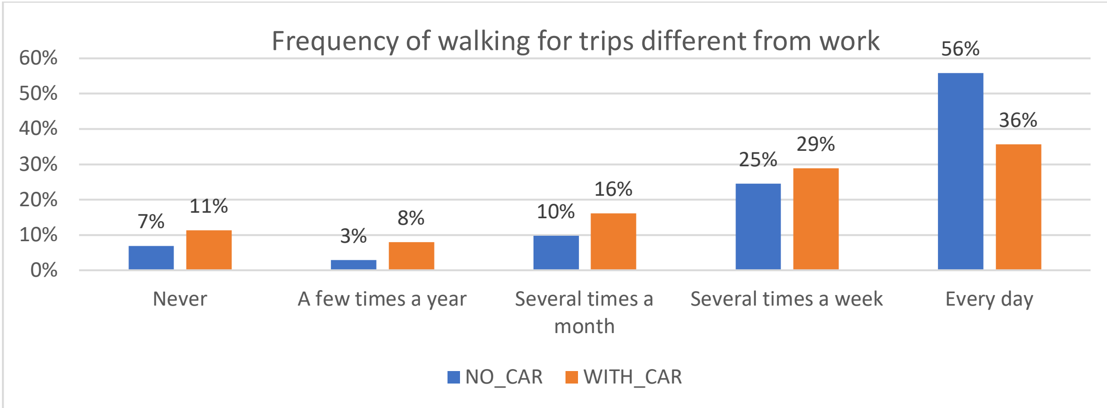

Environmental responsibility and awareness
100%
80%
60%
40%
20%
0%
62%
59%
27%
40%
93%
92%
92%
89%
I feel personally responsible for the environmental problems resulting from the choice of my means of transport.
I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.
I am aware that the use of private car has negative impacts on the environment and people's health.
I am aware that I can personally contribute (by using the car less) to reducing pollution.
NO_CAR
WITH_CAR

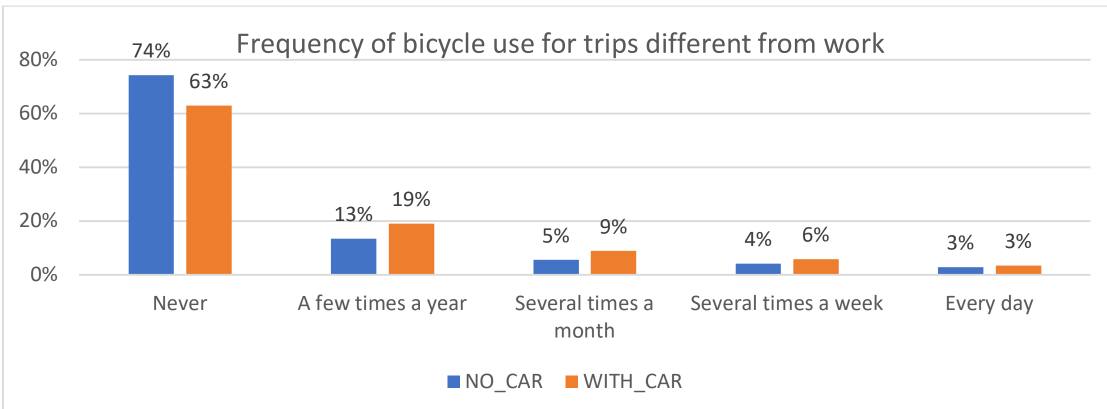

Place identity
100%
80%
60%
40%
20%
0%
87%
91%
78%
83%
79%
82%
This city is part of my identity and therefore I respect it.
I feel at home in this city.
I feel I belong to this city and therefore I must contribute to make it a better place.
NO_CAR
WITH_CAR

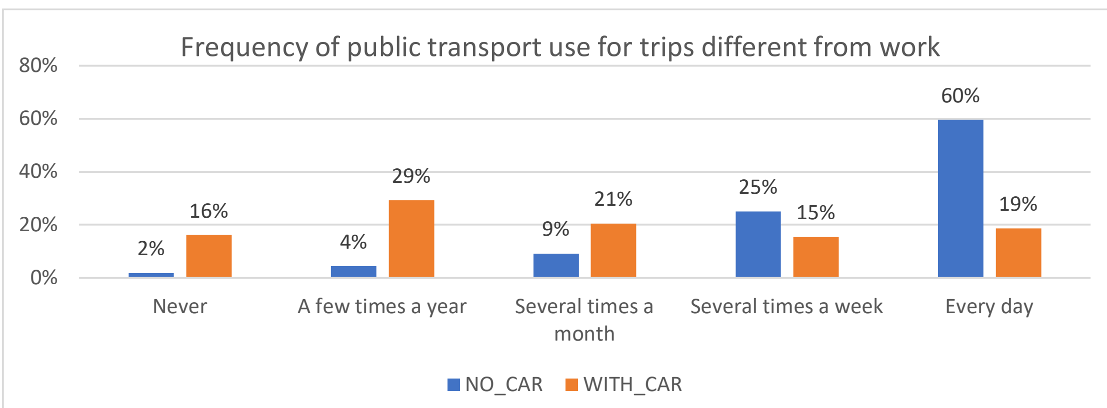

Intentions
100%
80%
60%
40%
20%
0%
81%
46%
12%
59%
5%
11%
During the next two weeks, I intend to use sustainable means of transport instead of the car
During the next two weeks, I intend to use the car.
In the next two weeks, I do not have any interest in using sustainable means of transport.
NO_CAR
WITH_CAR

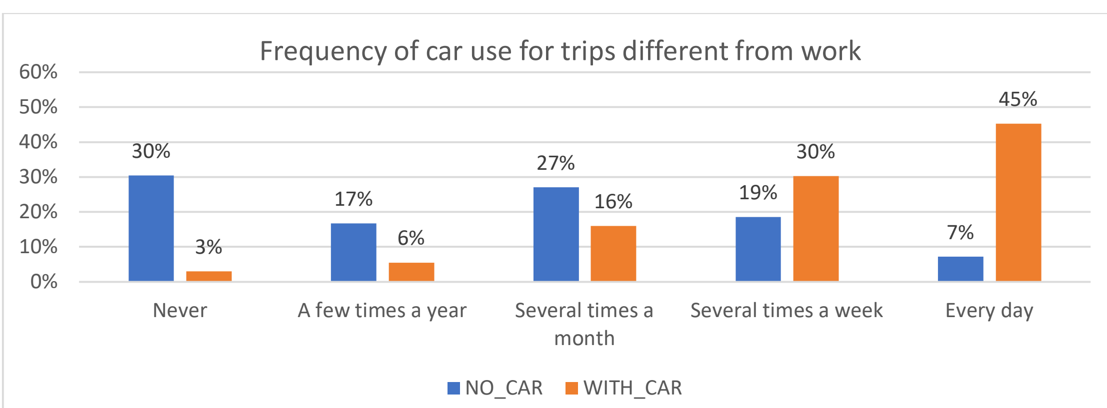

Attitudes
100%
80%
60%
40%
20%
0%
85%
80%
53%
59%
82%
83%
I find that using sustainable means of transport instead of the private car is useful.
I find that using sustainable means of transport instead of the private car is pleasant.
I find that using sustainable means of transport instead of the private car is right.
NO_CAR
WITH_CAR


Perceived behavioural control
100%
80%
60%
40%
20%
0%
76%
42%
87%
46%
8%
29%
It would be easy for me to use sustainable means of transport.
I am sure that in the next week I can use sustainable means of transport.
For me using sustainable means of transport is impossible.
NO_CAR
WITH_CAR


Frequency of walking for trips different from work
60%
50%
40%
30%
20%
10%
0%
7%
11%
3%
8%
10%
16%
25%
29%
56%
36%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CAR
WITH_CAR


Frequency of bicycle use for trips different from work
80%
60%
40%
20%
0%
74%
63%
13%
19%
5%
9%
4%
6%
3%
3%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CAR
WITH_CAR

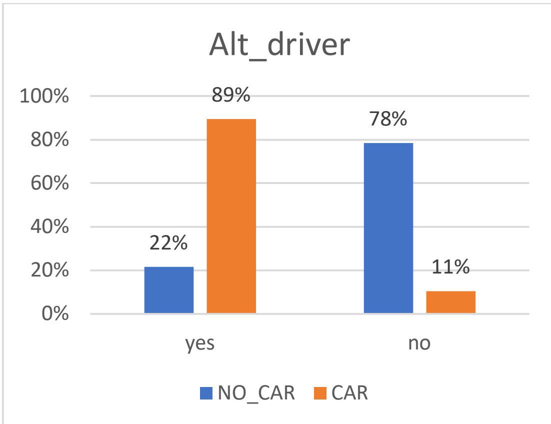

Frequency of public transport use for trips different from work
80%
60%
40%
20%
0%
2%
16%
4%
29%
9%
21%
25%
15%
60%
19%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CAR
WITH_CAR

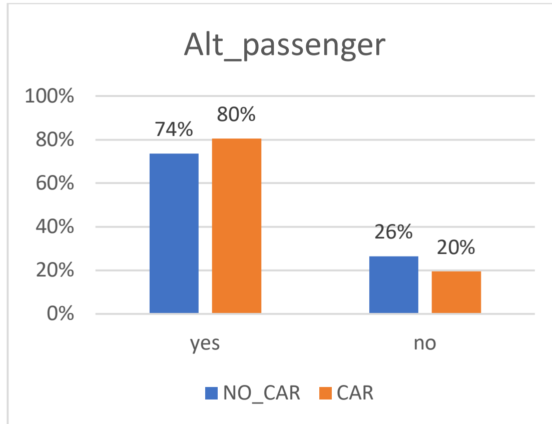

Frequency of car use for trips different from work
60%
50%
40%
30%
20%
10%
0%
30%
3%
17%
6%
27%
16%
19%
30%
7%
45%
Never
A few times a year
Several times a month
Several times a week
Every day
NO_CAR
WITH_CAR

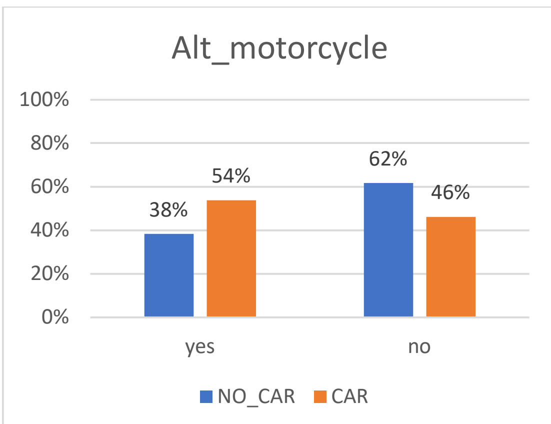
		Average NoCar	Average Car	Differe nce	Z* stat	
CH1	My choice to use sustainable transport is consciously and intentionally motivated by a specific desire to do good for the environment.	3.540	1.571	1.969	26.36	*
CH2	My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).	3.705	1.672	2.033	26.90	*
CH3	My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.	3.212	1.448	1.764	24.36	*
CH4	My choice to use sustainable transport is obliged by the fact that I have no alternative	3.324	0.991	2.333	33.77	*
NS1	Most of the people I know think I should use sustainable means of transport instead of the car.	2.693	2.553	0.140	2.92	*
NS2	Most of the people I know use sustainable means of transport instead of the car.	2.887	2.202	0.685	13.19	*
NM1	I feel morally obligated to use sustainable means of transport regardless of what others are doing.	3.665	3.499	0.166	3.61	*
EM1	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.	2.701	2.495	0.206	4.46	*
EM2	If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.	3.434	3.518	-0.084	-1.75	
EM3	If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent.	2.876	2.859	0.017	0.35	
RESP 1	I feel personally responsible for the environmental problems resulting from the choice of my means of transport.	3.563	3.482	0.081	1.76	
RESP 2	I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.	2.500	2.939	-0.439	-8.07	*
AWA1	I am aware that the use of private car has negative impacts on the environment and people's health.	4.540	4.423	0.117	4.10	*
AWA2	I am aware that I can personally contribute (by using the car less) to reducing pollution.	4.515	4.342	0.172	5.64	*
LOC1	This city is part of my identity and therefore I respect it.	4.369	4.431	-0.062	-2.02	*
LOC2	I feel at home in this city.	4.085	4.235	-0.150	-3.73	*
LOC3	I feel I belong to this city and therefore I must contribute to make it a better place.	4.163	4.243	-0.081	-2.23	*
HABI T_W	Frequency of walking for trips different from work	4.194	3.696	0.498	10.73	*
HABI T_B	Frequency of bicycle use for trips different from work	1.478	1.676	-0.197	-5.15	*
HABI T_PT	Frequency of public transport use for trips different from work	4.362	2.911	1.450	36.10	*
HABI T_CA R	Frequency of car use for trips different from work	2.552	4.093	-1.541	-31.95	*
INT1	During the next two weeks, I intend to use sustainable means of transport instead of the car	4.295	3.167	1.127	26.99	*
INT2	During the next two weeks, I intend to use the car.	1.933	3.568	-1.635	-35.36	*
INT3	In the next two weeks, I do not have any interest in using sustainable means of transport.	1.647	2.070	-0.423	-10.43	*
ATT1	I find that using sustainable means of transport instead of the private car is useful.	4.331	4.120	0.211	5.66	*
ATT2	I find that using sustainable means of transport instead of the private car is pleasant.	3.445	3.562	-0.117	-2.43	*
ATT3	I find that using sustainable means of transport instead of the private car is right.	4.274	4.245	0.029	0.85	
PCB1	It would be easy for me to use sustainable means of transport.	4.008	2.923	1.085	23.30	*
PCB2	I am sure that in the next week I can use sustainable means of transport.	4.419	3.089	1.330	30.31	*
PCB3	For me using sustainable means of transport is impossible.	1.533	2.451	-0.918	-20.84	*

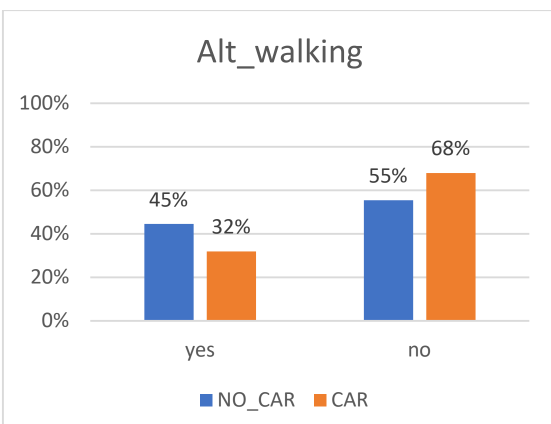
* *Significant at 95% confidence level*

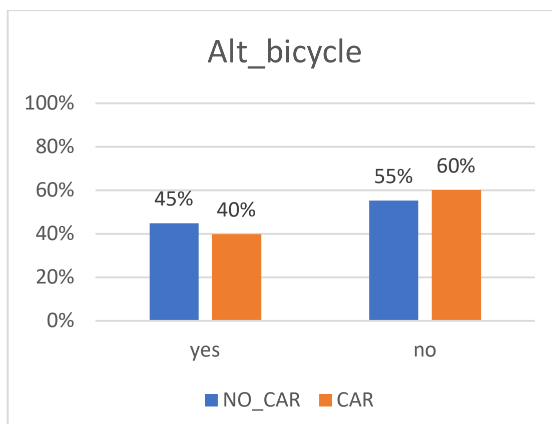
A.4.4 Alternative means of transport

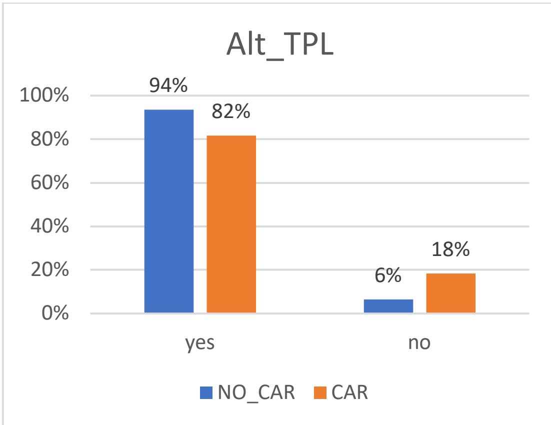


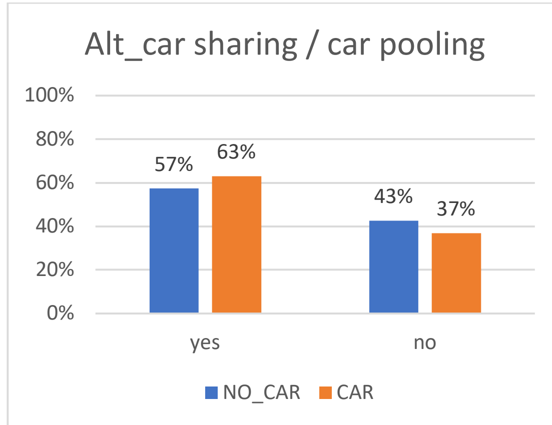










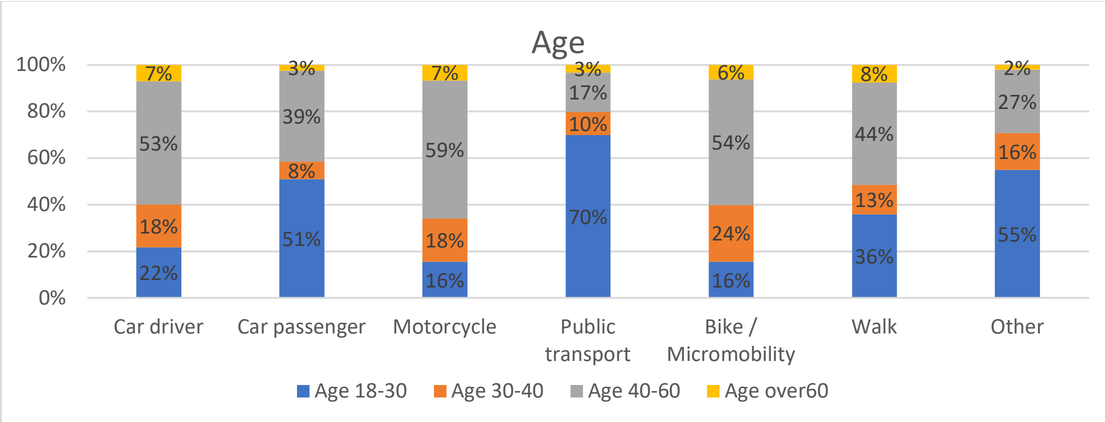


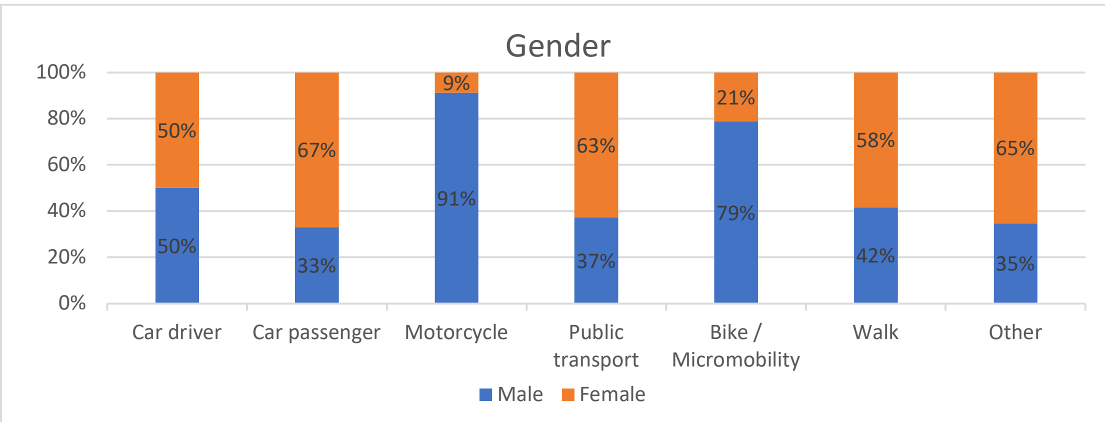
	NoCar	Car	Difference	Z* stat	
Alt_driver	21.60%	89.48%	-67.87%	-41.33	*
Alt_passenger	73.54%	80.47%	-6.93%	-4.40	*
Alt_motorcycle	38.35%	53.74%	-15.39%	-7.95	*
Alt_walking	44.54%	32.00%	12.53%	6.81	*
Alt_bicycle	44.78%	39.83%	4.95%	2.60	*
Alt_PT	93.57%	81.67%	11.89%	8.36	*
Alt_carsharing_pooling	57.40%	63.06%	-5.66%	-3.01	*

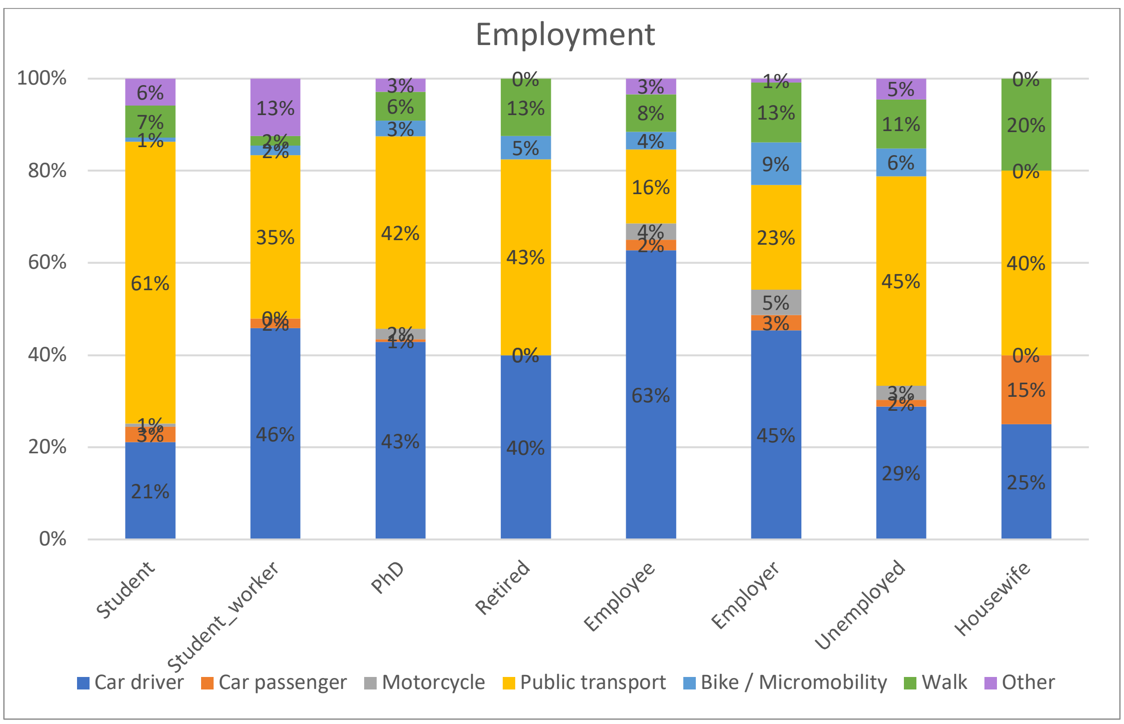
** Significant at 95% confidence level*

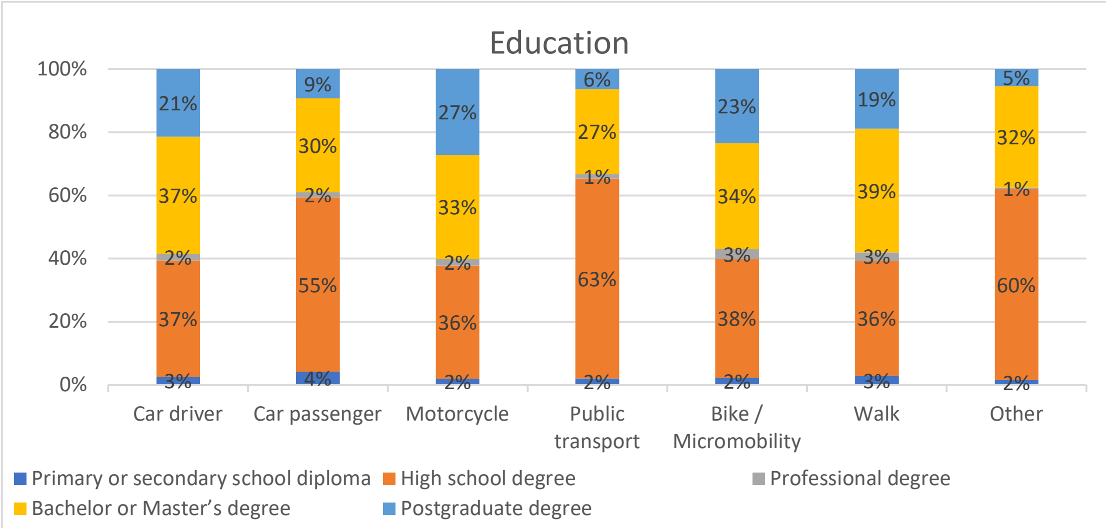
A.5 MEANS OF TRANSPORT

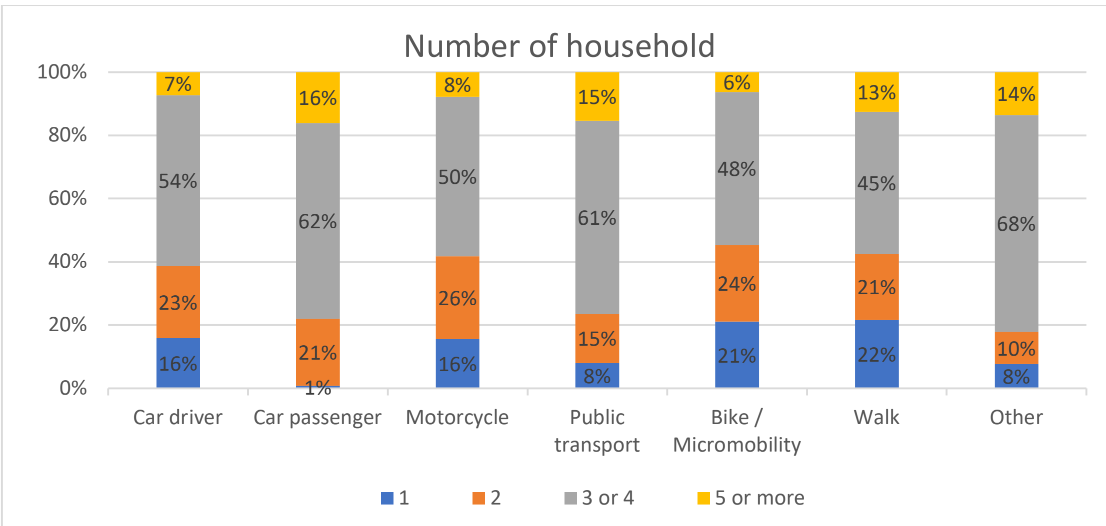
A.5.1 Socioeconomic characteristics

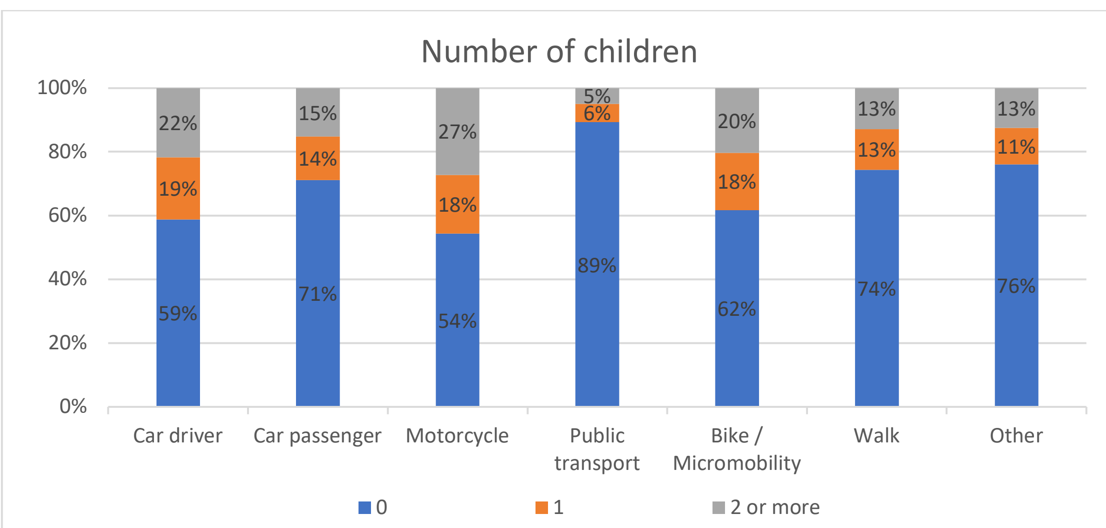


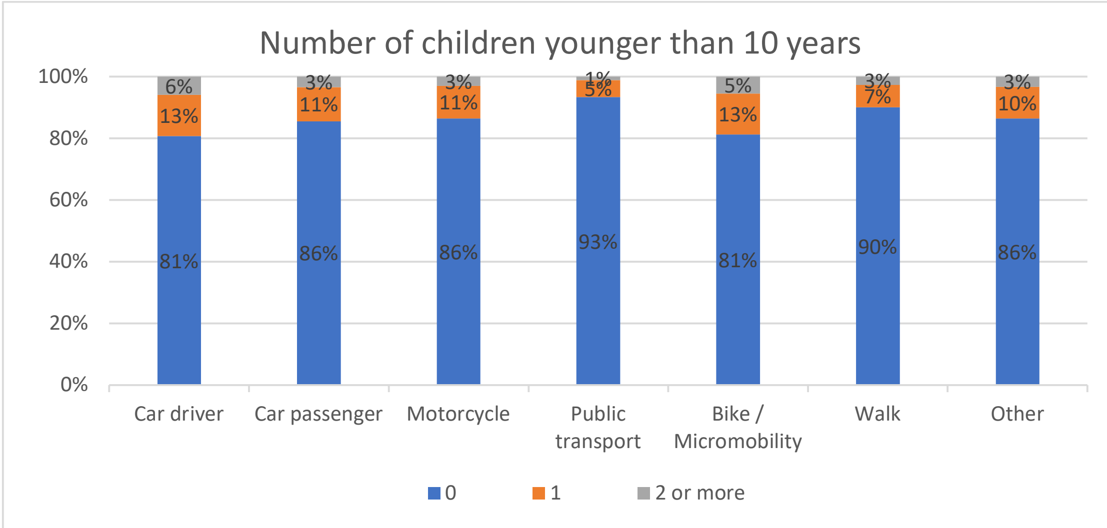


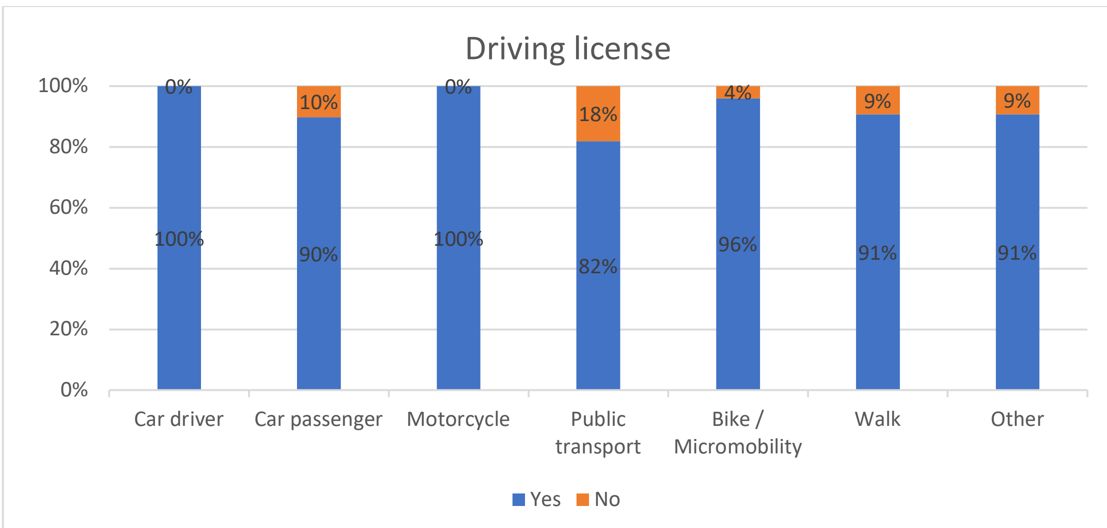


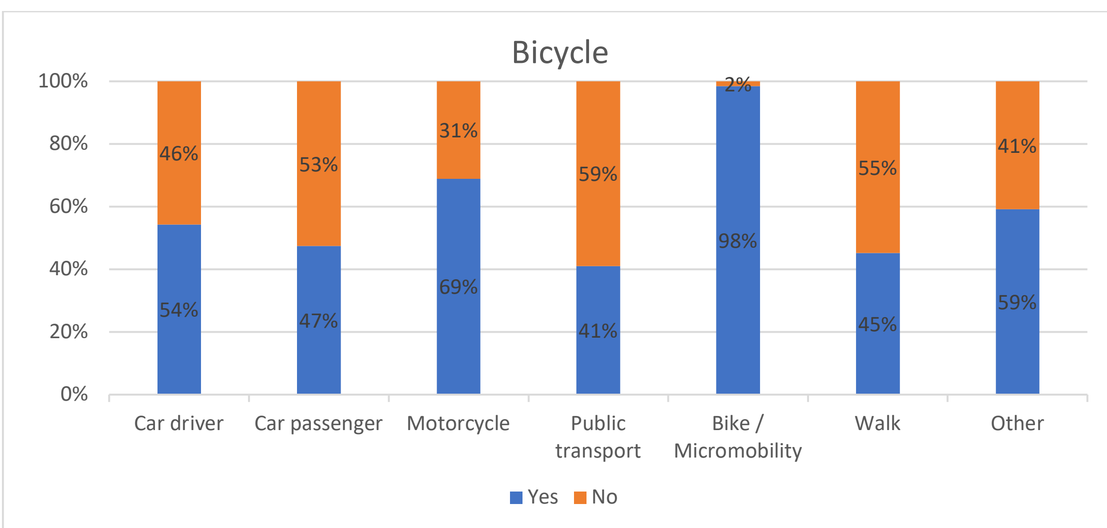

Education
100%
80%
60%
40%
20%
0%
21%
37%
2%
37%
3%
9%
30%
2%
55%
4%
27%
33%
2%
36%
2%
6%
27%
1%
63%
2%
23%
34%
3%
38%
2%
19%
39%
3%
36%
3%
5%
32%
1%
60%
2%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Primary or secondary school diploma
High school degree
Professional degree
Bachelor or Master's degree
Postgraduate degree

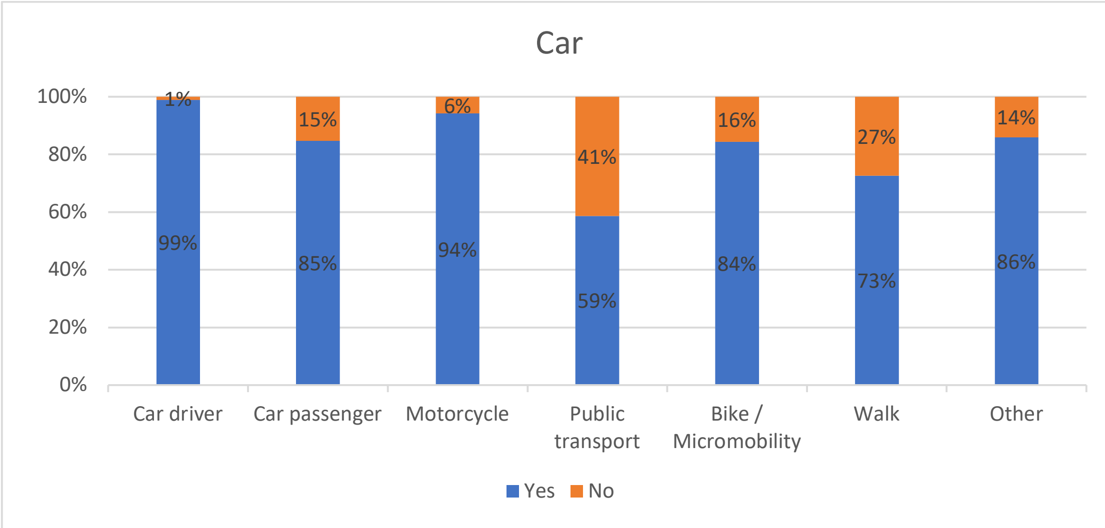

Number of household
100%
80%
60%
40%
20%
0%
7%
54%
23%
16%
16%
62%
21%
1%
8%
50%
26%
16%
15%
61%
15%
8%
6%
48%
24%
21%
13%
45%
21%
22%
14%
68%
10%
8%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
1
2
3 or 4
5 or more

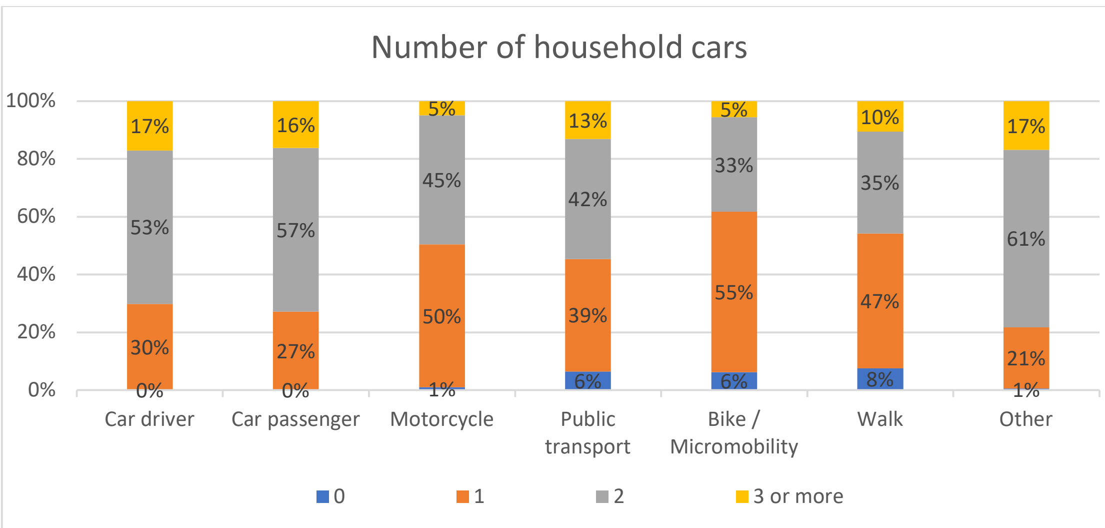

Number of children
100%
80%
60%
40%
20%
0%
22%
19%
59%
15%
14%
71%
27%
18%
54%
5%
6%
89%
20%
18%
62%
13%
13%
74%
13%
11%
76%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
0
1
2 or more

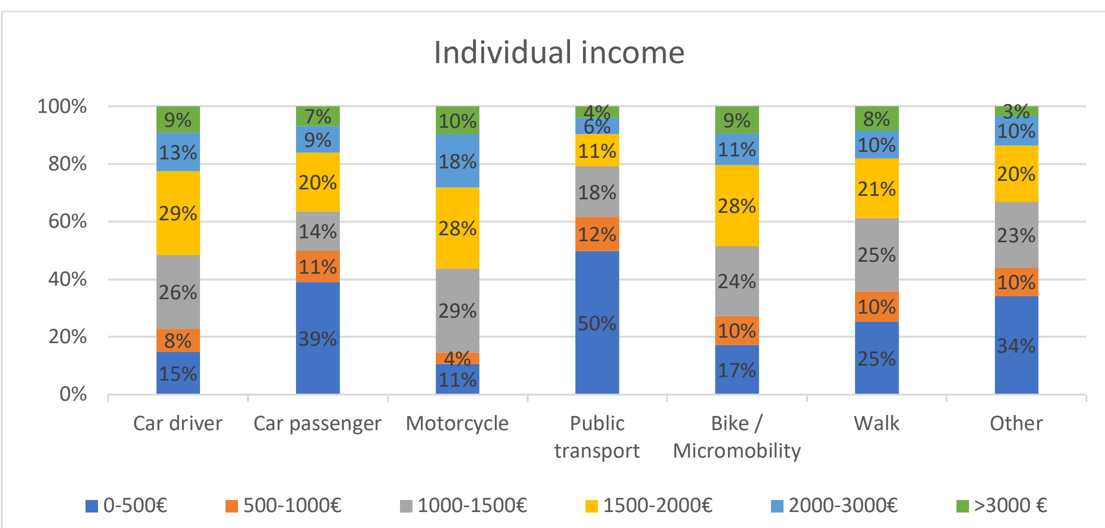

Number of children younger than 10 years
100%
80%
60%
40%
20%
0%
6%
13%
81%
3%
11%
86%
3%
11%
86%
1%
5%
93%
5%
13%
81%
3%
7%
90%
3%
10%
86%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
0
1
2 or more


Driving license
100%
80%
60%
40%
20%
0%
0%
100%
10%
90%
0%
100%
18%
82%
4%
96%
9%
91%
9%
91%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Yes
No


Bicycle
100%
80%
60%
40%
20%
0%
46%
54%
53%
47%
31%
69%
59%
41%
2%
98%
55%
45%
41%
59%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Yes
No

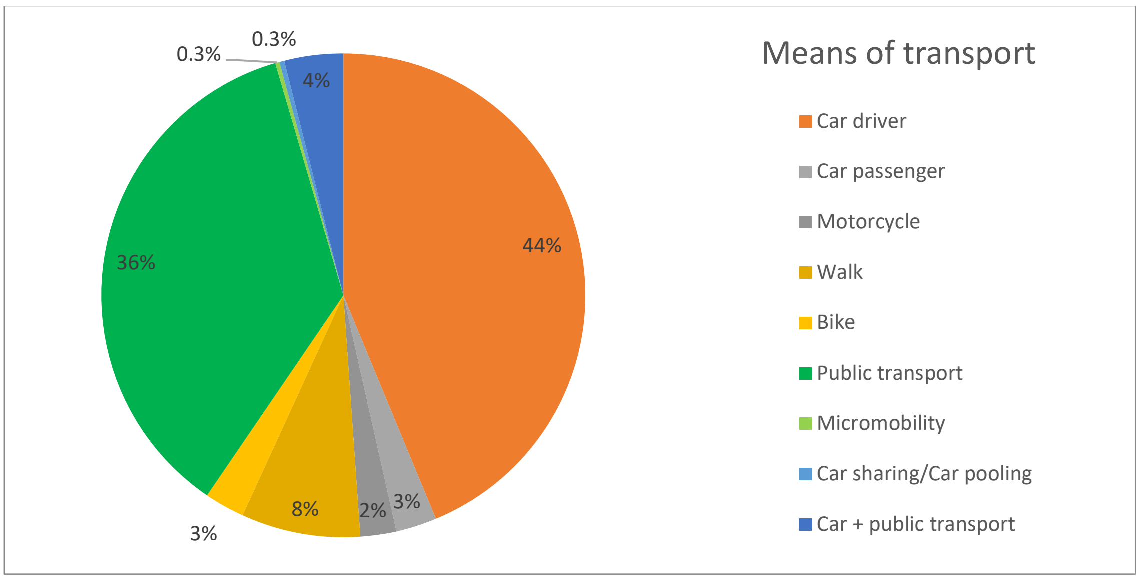

Car
100%
80%
60%
40%
20%
0%
1%
99%
15%
85%
6%
94%
41%
59%
16%
84%
27%
73%
14%
86%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Yes
No

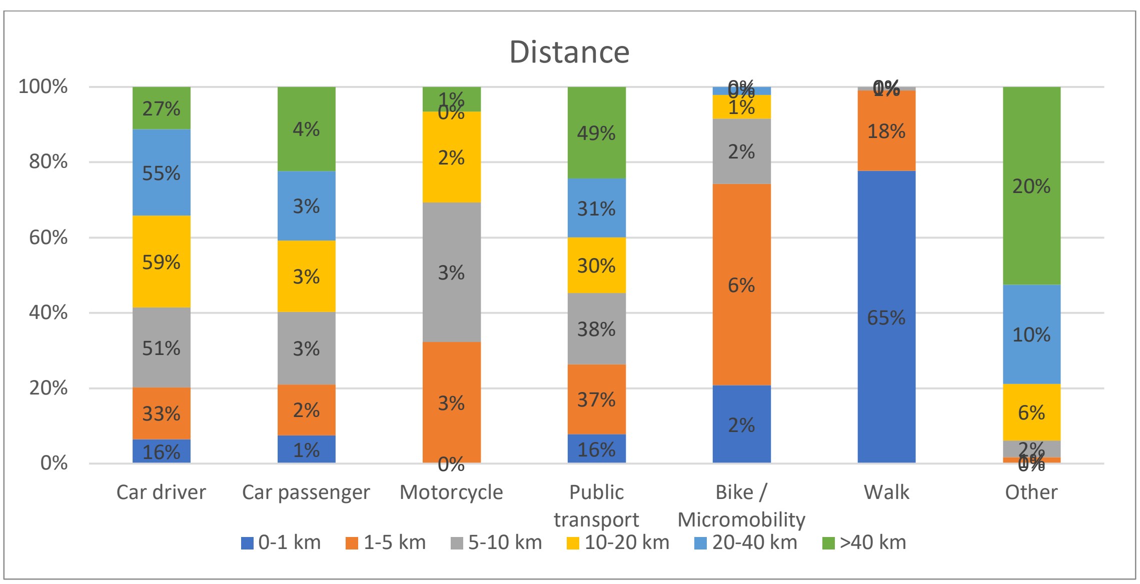

Number of household cars
100%
80%
60%
40%
20%
0%
17%
53%
30%
0%
16%
57%
27%
0%
5%
45%
50%
1%
13%
42%
39%
6%
5%
33%
55%
6%
10%
35%
47%
8%
17%
61%
21%
1%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
0
1
2
3 or more

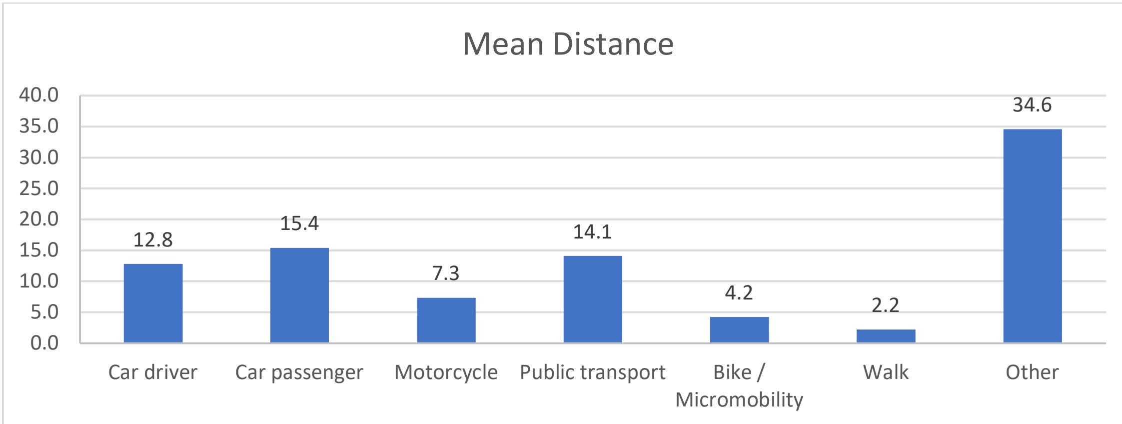

Individual income
100%
80%
60%
40%
20%
0%
9%
13%
29%
26%
8%
15%
7%
9%
20%
14%
11%
39%
10%
18%
28%
29%
4%
11%
4%
6%
11%
18%
12%
50%
9%
11%
28%
24%
10%
17%
8%
10%
21%
25%
10%
25%
3%
10%
20%
23%
10%
34%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
0-500€
500-1000€
1000-1500€
1500-2000€
2000-3000€
>3000 €

	Average Car driver	Average Car passenger	Average Motorcycle	Average Public transport	Bike / Micromobility	Walk	Other
Age	42.8	35.6	45.5	29.8	43.0	39.9	32.6
N_household	2.9	3.4	2.9	3.4	2.7	2.6	3.4
N_children	0.7	0.5	0.8	0.2	0.6	0.4	0.4
N_children10	0.3	0.2	0.2	0.1	0.3	0.1	0.2
N_car	1.9	1.9	1.6	1.6	1.4	1.5	2.0
Income	3.5	2.7	3.7	2.2	3.3	3.0	2.7

A.5.2 Trip characteristics







ORIGIN/DESTINATION Car driver	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	97	5.1%	574	30.4%	0	0.0%	0	0.0%	671
CAGLIARI	208	11.0%	706	37.4%	1	0.1%	13	0.7%	928
NUORO	0	0.0%	1	0.1%	0	0.0%	0	0.0%	1
ORISTANO	1	0.1%	6	0.3%	0	0.0%	0	0.0%	7
SUD SARDEGNA	45	2.4%	234	12.4%	0	0.0%	0	0.0%	279
Total	351	18.6%	1521	80.6%	1	0.1%	13	0.7%	1886

ORIGIN/DESTINATION Car passenger	AREA METROPOLITANA CAGLIARI		CAGLIARI		Total
AREA METROPOLITANA CAGLIARI	4	3.4%	38	32.2%	42
CAGLIARI	11	9.3%	45	38.1%	56
ORISTANO	0	0.0%	2	1.7%	2
SUD SARDEGNA	0	0.0%	18	15.3%	18
Total	15	12.7%	103	87.3%	118

ORIGIN/DESTINATION Motorcycle	AREA METROPOLITANA CAGLIARI		CAGLIARI		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	3	2.9%	34	33.0%	0	0.0%	37
CAGLIARI	7	6.8%	57	55.3%	1	1.0%	65
SUD SARDEGNA	0	0.0%	1	1.0%	0	0.0%	1
Total	10	9.7%	92	89.3%	1	1.0%	103

ORIGIN/DESTINATION Public transport	AREA METROPOLITANA CAGLIARI		CAGLIARI		ORISTANO		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	86	5.6%	326	21.0%	0	0.0%	0	0.0%	412
CAGLIARI	242	15.6%	636	41.1%	2	0.1%	6	0.4%	886
ORISTANO	3	0.2%	17	1.1%	0	0.0%	0	0.0%	20
SUD SARDEGNA	33	2.1%	198	12.8%	0	0.0%	0	0.0%	231

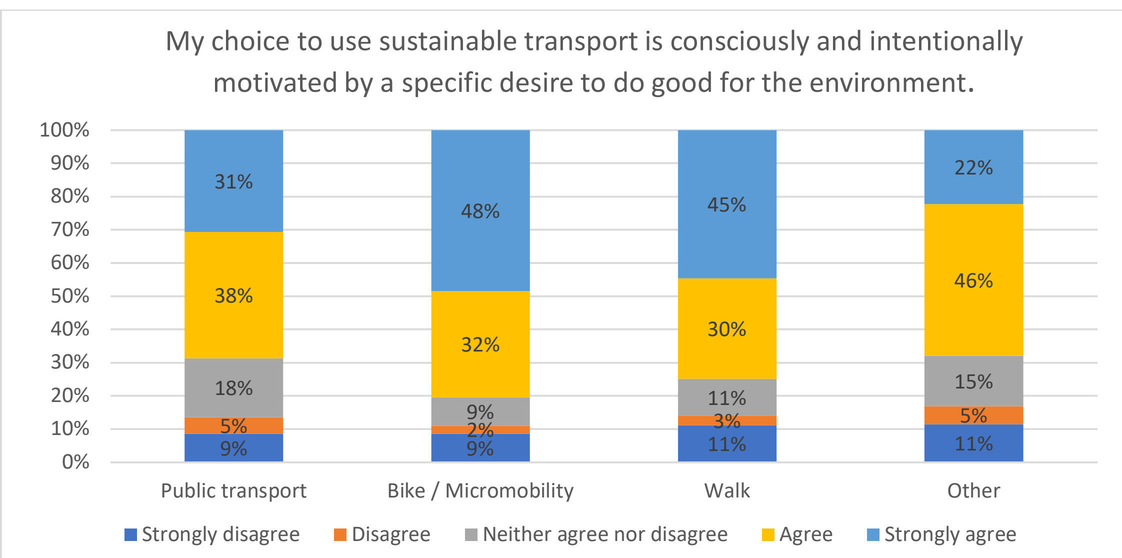
Total	364	23.5%	1177	76.0%	2	0.1%	6	0.4%	1549

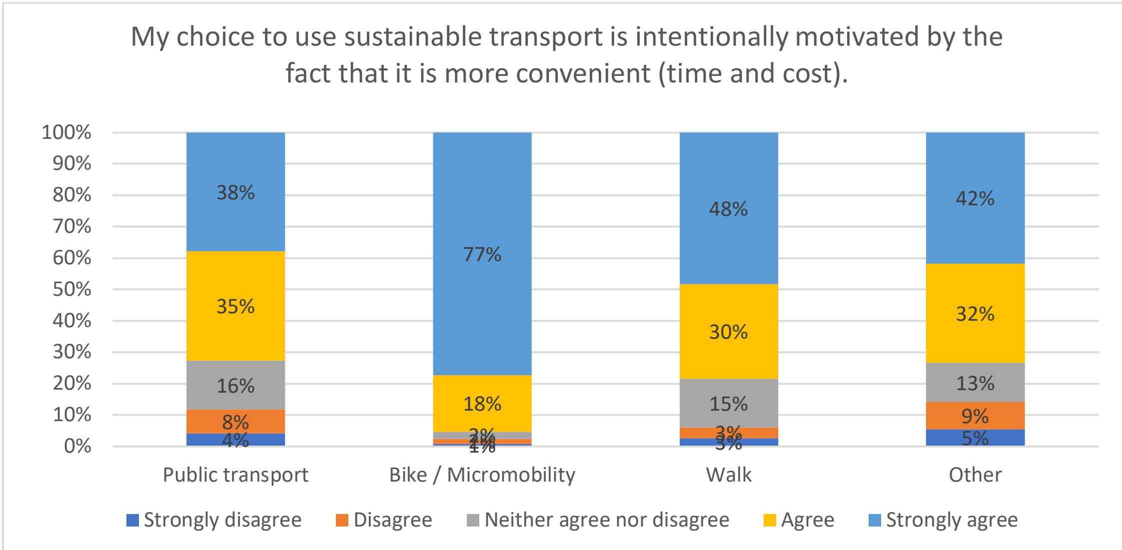
ORIGIN/DESTINATION Bike - Micromobility	AREA METROPOLITANA CAGLIARI		CAGLIARI		Total
AREA METROPOLITANA CAGLIARI	0	0.0%	13	10.2%	13
CAGLIARI	2	1.6%	111	86.7%	113
SUD SARDEGNA	1	0.8%	1	0.8%	2
Total	3	2.3%	125	97.7%	128

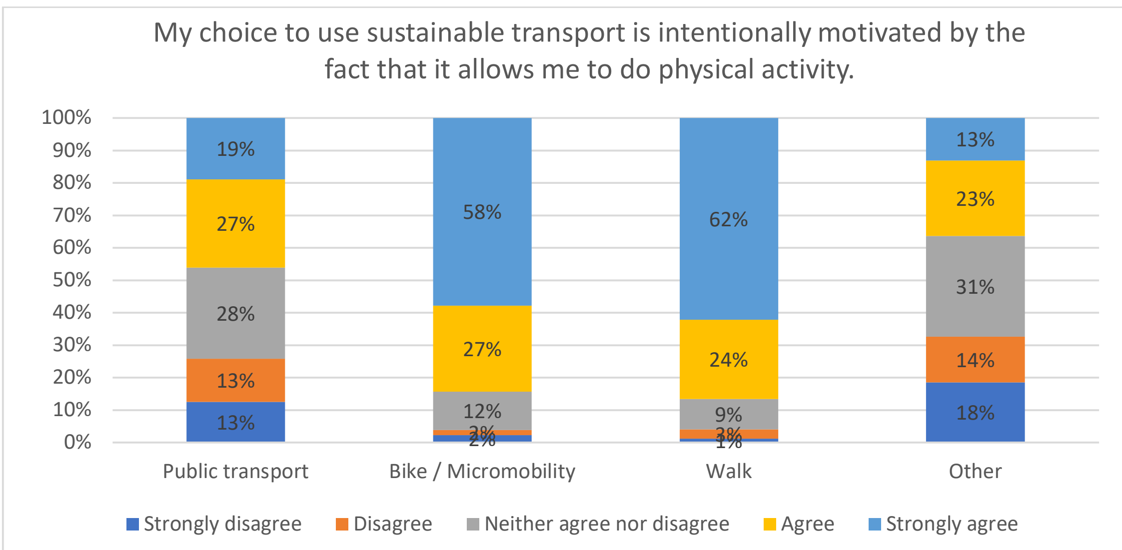
ORIGIN/DESTINATION Walk	AREA METROPOLITANA CAGLIARI		CAGLIARI		Total
AREA METROPOLITANA CAGLIARI	2	0.6%	0	0.0%	2
CAGLIARI	0	0.0%	341	99.4%	341
Total	2	0.6%	341	99.4%	343

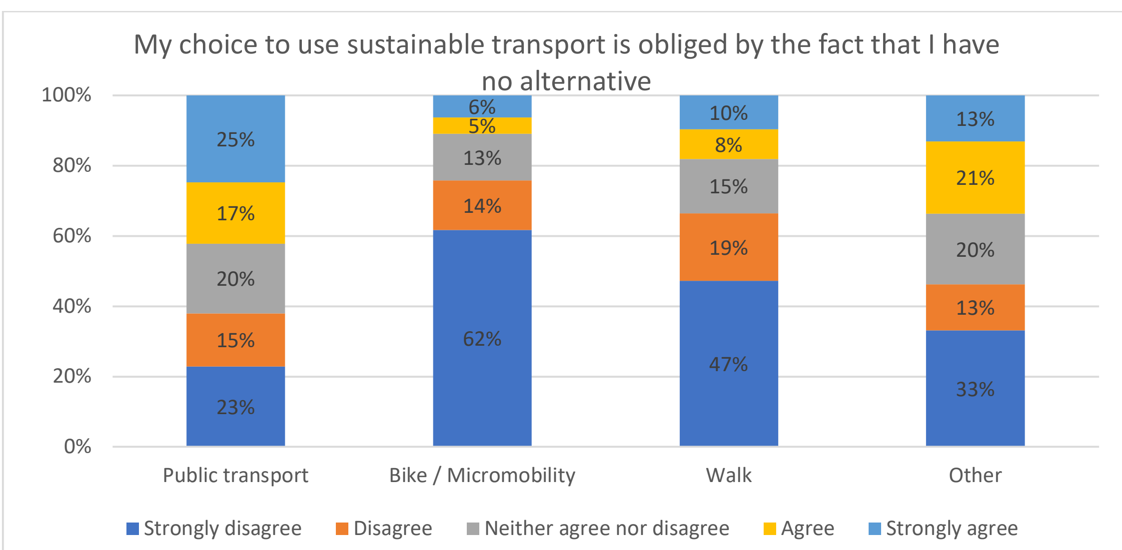
ORIGIN/DESTINATION Other	AREA METROPOLITANA CAGLIARI		CAGLIARI		SUD SARDEGNA		Total
AREA METROPOLITANA CAGLIARI	12	6.5%	54	29.3%	0	0.0%	66
CAGLIARI	7	3.8%	13	7.1%	3	1.6%	23
ORISTANO	2	1.1%	11	6.0%	0	0.0%	13
SUD SARDEGNA	10	5.4%	72	39.1%	0	0.0%	82
Total	31	16.8%	150	81.5%	3	1.6%	184

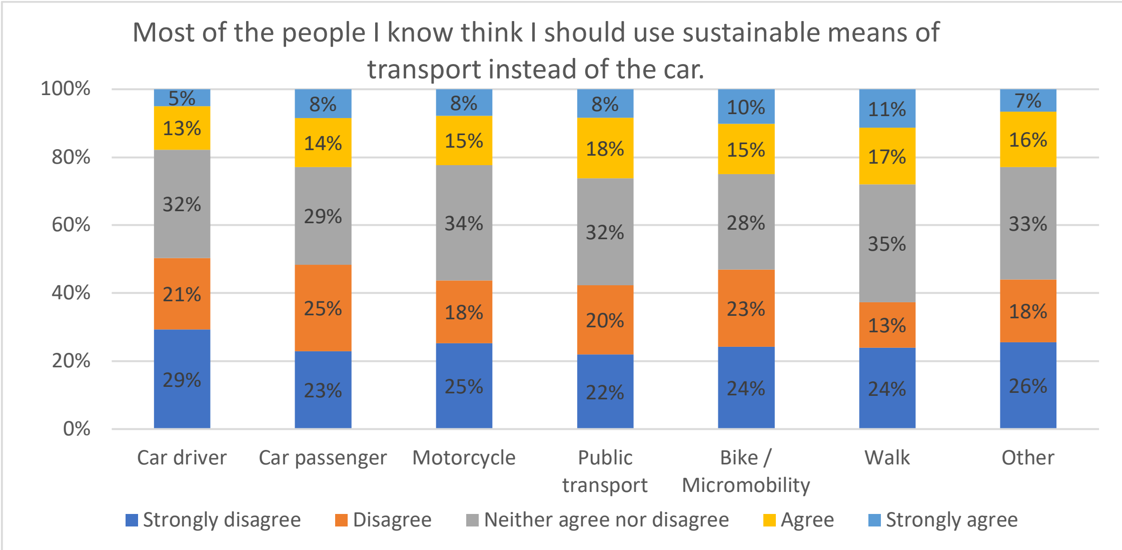
A.5.3 Psychosocial characteristics

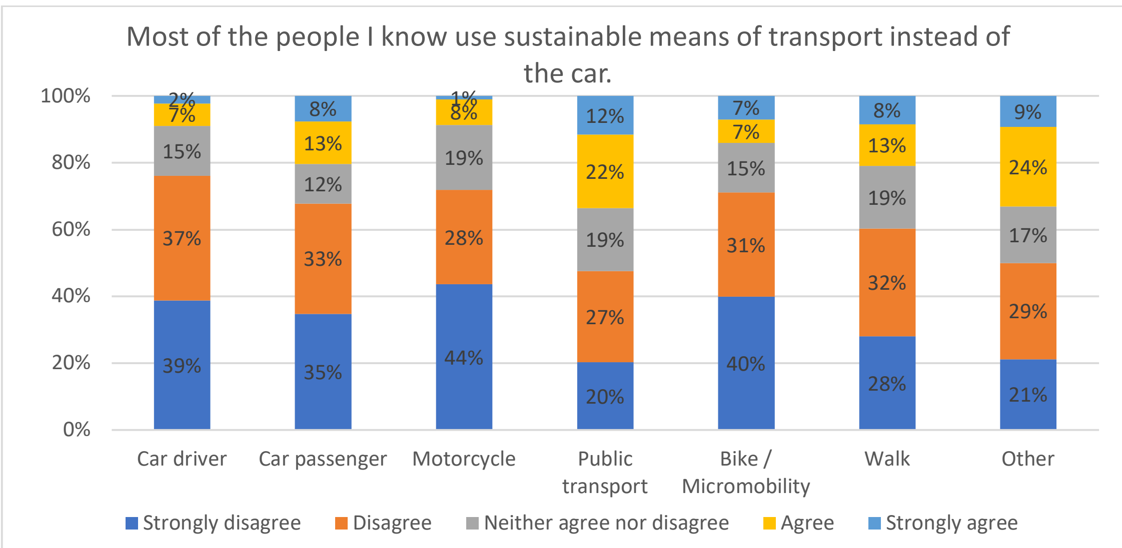


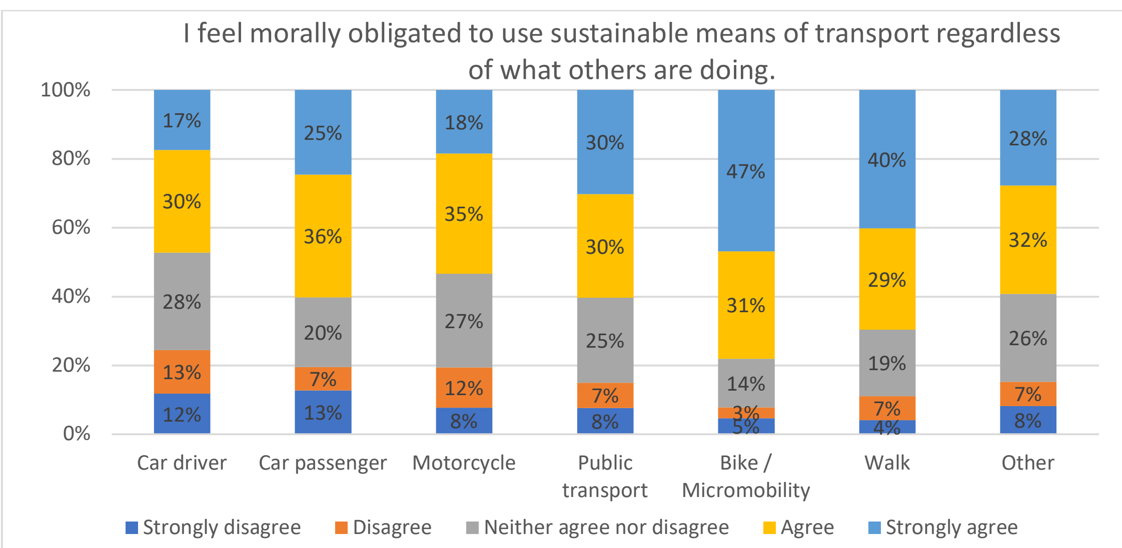

My choice to use sustainable transport is intentionally motivated by the fact that it is more convenient (time and cost).
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
38%
35%
16%
8%
4%
77%
18%
48%
30%
15%
3%
42%
32%
13%
9%
5%
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

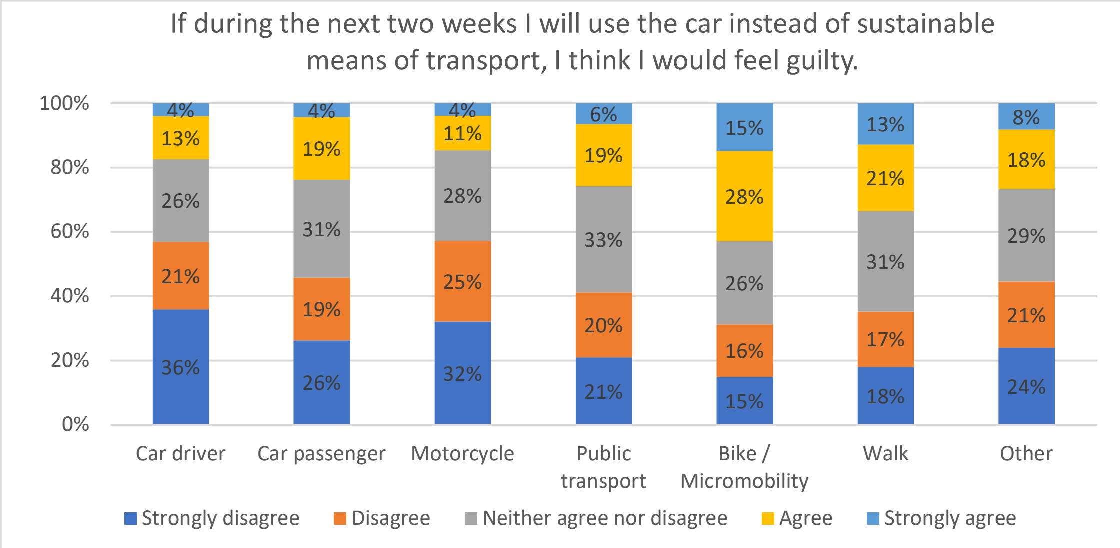

My choice to use sustainable transport is intentionally motivated by the fact that it allows me to do physical activity.
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
19%
27%
28%
13%
13%
58%
27%
12%
2%
62%
24%
9%
1%
13%
23%
31%
14%
18%
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

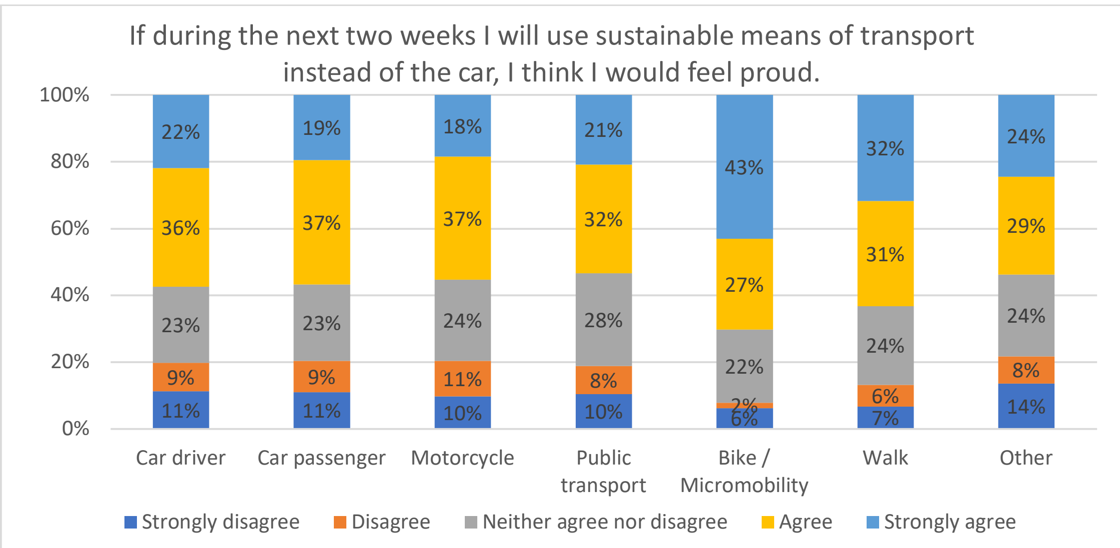

My choice to use sustainable transport is obliged by the fact that I have no alternative
100%
80%
60%
40%
20%
0%
25%
17%
20%
15%
23%
6%
5%
13%
14%
62%
10%
8%
15%
19%
47%
13%
21%
20%
13%
33%
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

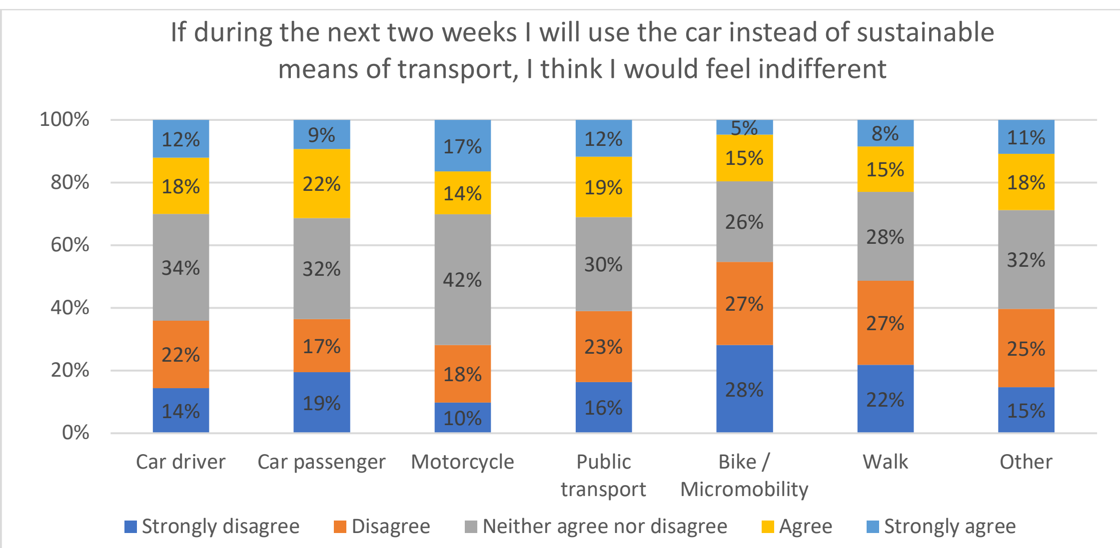

Most of the people I know think I should use sustainable means of transport instead of the car.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

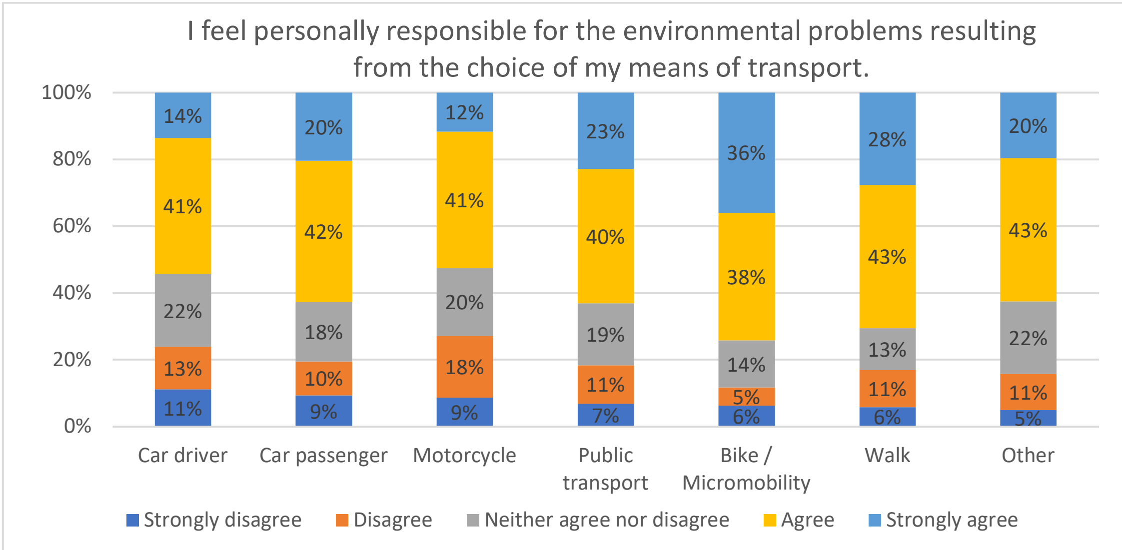

Most of the people I know use sustainable means of transport instead of the car.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

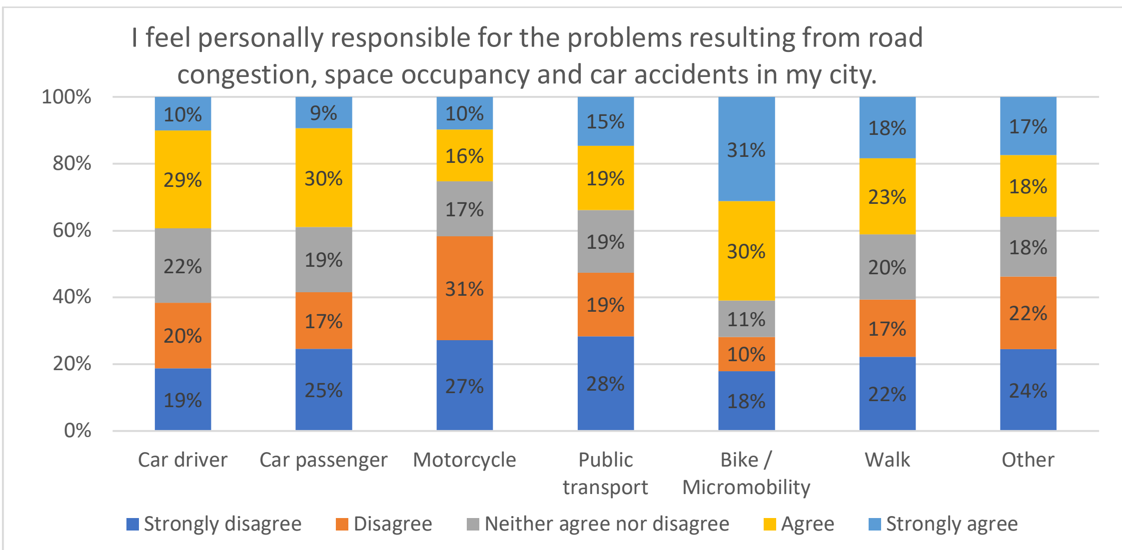

I feel morally obligated to use sustainable means of transport regardless of what others are doing.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

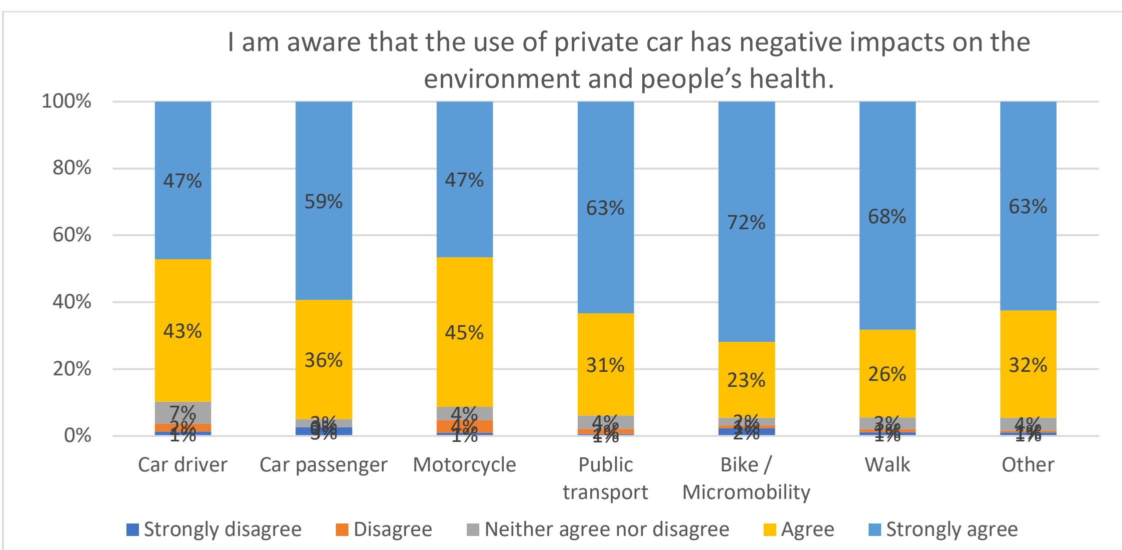

If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel guilty.
100%
80%
60%
40%
20%
0%
4%
13%
26%
21%
36%
4%
19%
31%
19%
26%
4%
11%
28%
25%
32%
6%
19%
33%
20%
21%
15%
28%
26%
16%
15%
13%
21%
31%
17%
18%
8%
18%
29%
21%
24%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

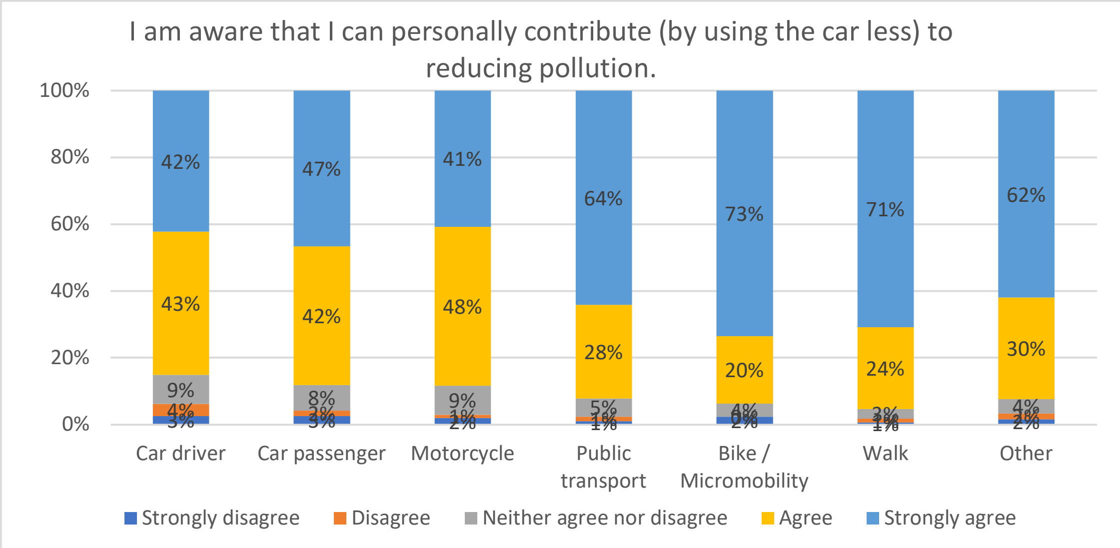

If during the next two weeks I will use sustainable means of transport instead of the car, I think I would feel proud.
100%
80%
60%
40%
20%
0%
22%
36%
23%
9%
11%
19%
37%
23%
9%
11%
18%
37%
24%
11%
10%
21%
32%
28%
8%
10%
43%
27%
22%
2%
6%
32%
31%
24%
6%
7%
24%
29%
24%
8%
14%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

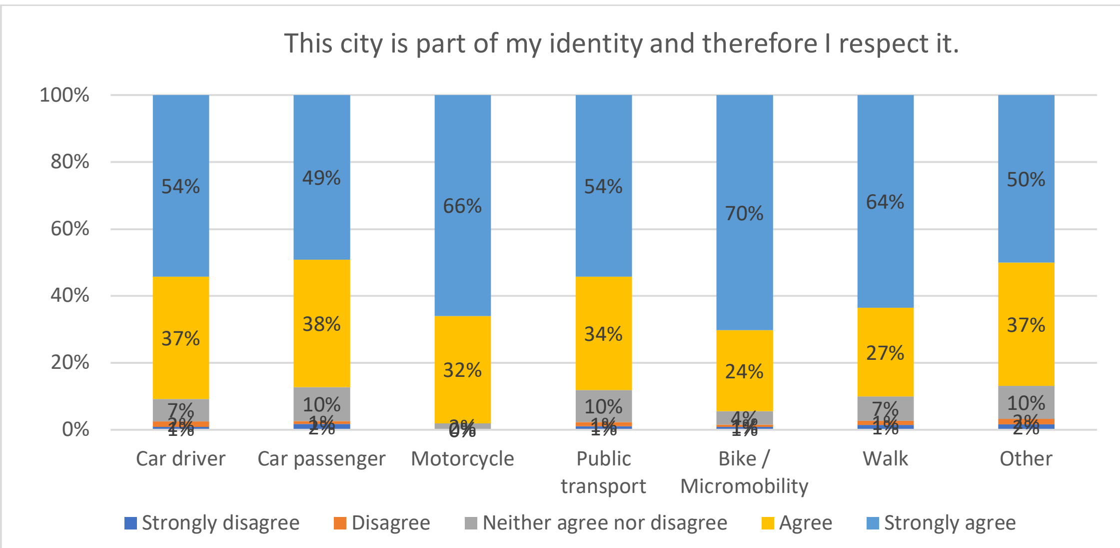

If during the next two weeks I will use the car instead of sustainable means of transport, I think I would feel indifferent
100%
80%
60%
40%
20%
0%
12%
18%
34%
22%
14%
9%
22%
32%
17%
19%
17%
14%
42%
18%
10%
12%
19%
30%
23%
16%
5%
15%
26%
27%
28%
8%
15%
28%
27%
22%
11%
18%
32%
25%
15%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

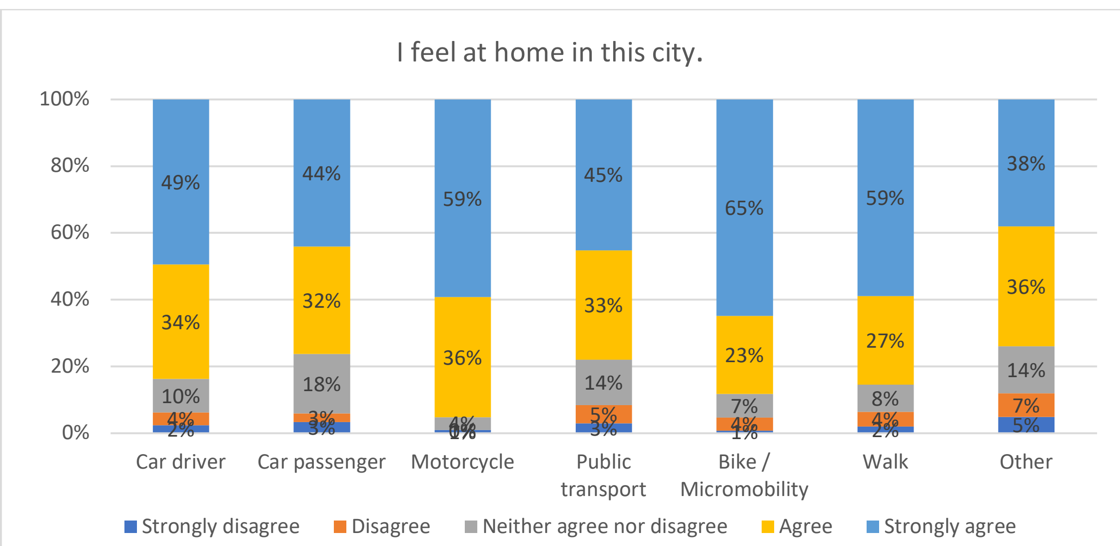

I feel personally responsible for the environmental problems resulting from the choice of my means of transport.
100%
80%
60%
40%
20%
0%
14% 41% 22% 13% 11%
20% 42% 18% 10% 9%
12% 41% 20% 18% 9%
23% 40% 19% 11% 7%
36% 38% 14% 5% 6%
28% 43% 13% 11% 6%
20% 43% 22% 11% 5%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

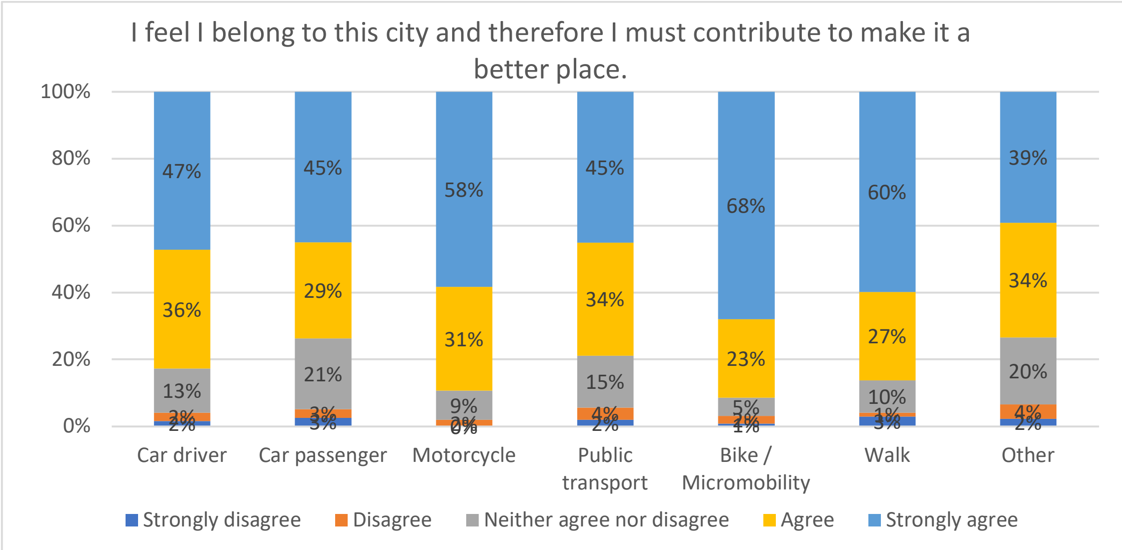

I feel personally responsible for the problems resulting from road congestion, space occupancy and car accidents in my city.
100%
80%
60%
40%
20%
0%
10% 29% 22% 20% 19%
9% 30% 19% 17% 25%
10% 16% 17% 31% 27%
15% 19% 19% 19% 28%
31% 30% 11% 10% 18%
18% 23% 20% 17% 22%
17% 18% 18% 22% 24%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

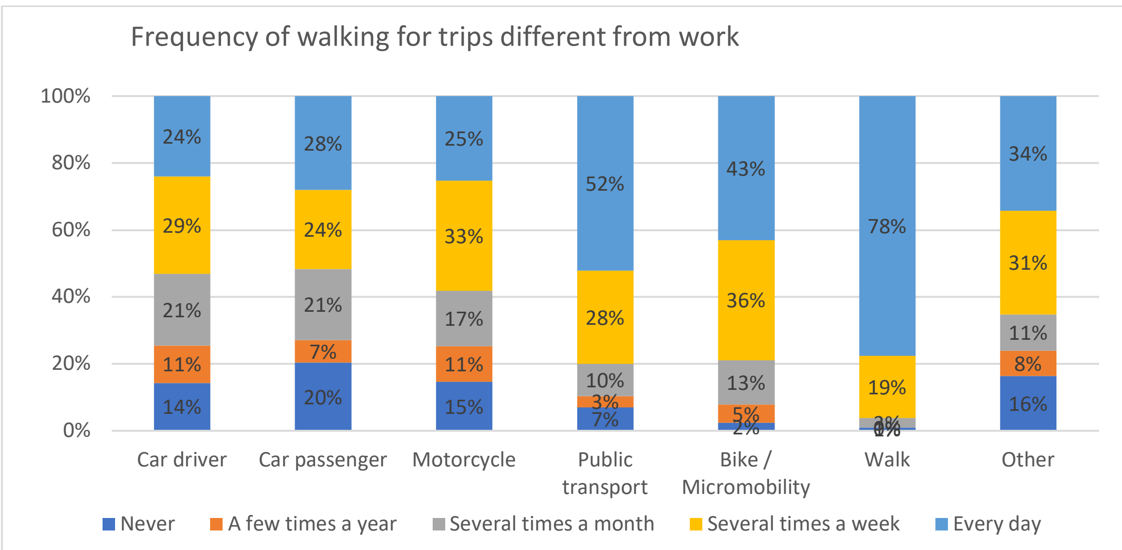

I am aware that the use of private car has negative impacts on the environment and people's health.
100%
80%
60%
40%
20%
0%
47% 43% 7%
59% 36%
47% 45% 4%
63% 31% 4%
72% 23%
68% 26%
63% 32% 4%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

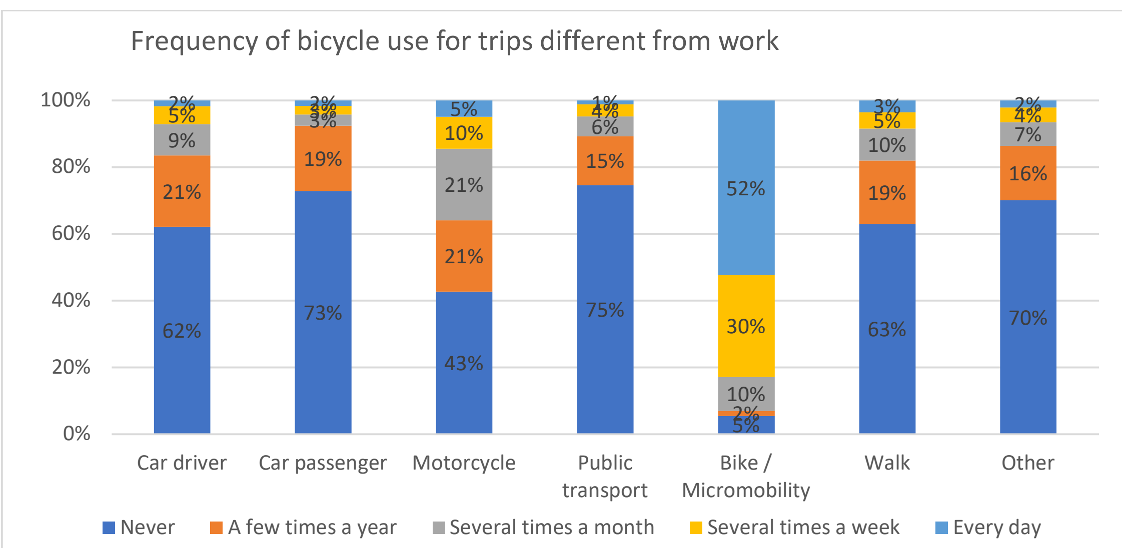

I am aware that I can personally contribute (by using the car less) to reducing pollution.
100%
80%
60%
40%
20%
0%
42%
43%
9%
47%
42%
8%
41%
48%
9%
64%
28%
5%
73%
20%
71%
24%
62%
30%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

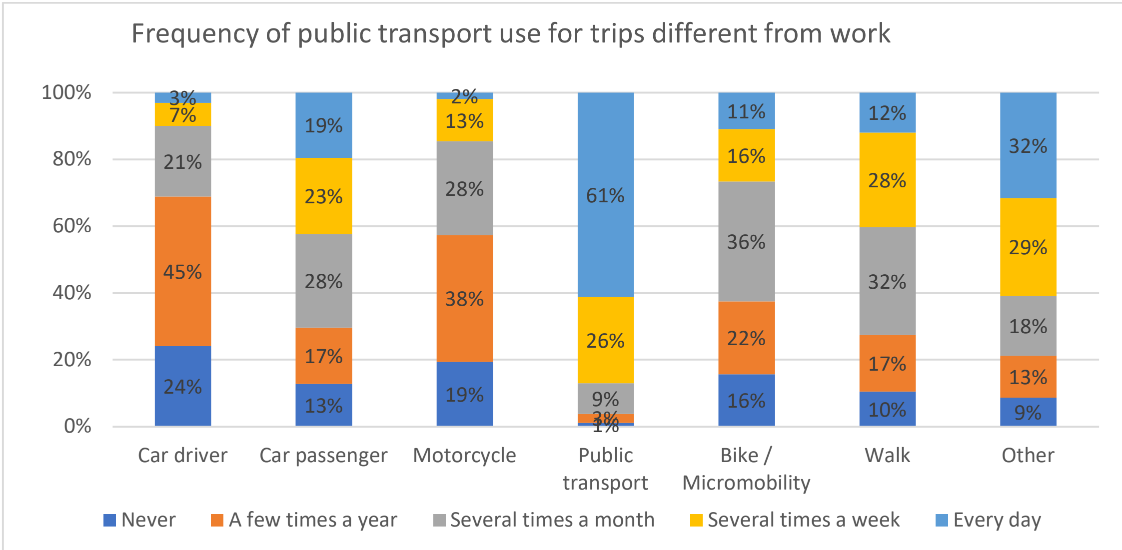

This city is part of my identity and therefore I respect it.
100%
80%
60%
40%
20%
0%
54%
37%
7%
49%
38%
10%
66%
32%
54%
34%
10%
70%
24%
4%
64%
27%
7%
50%
37%
10%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

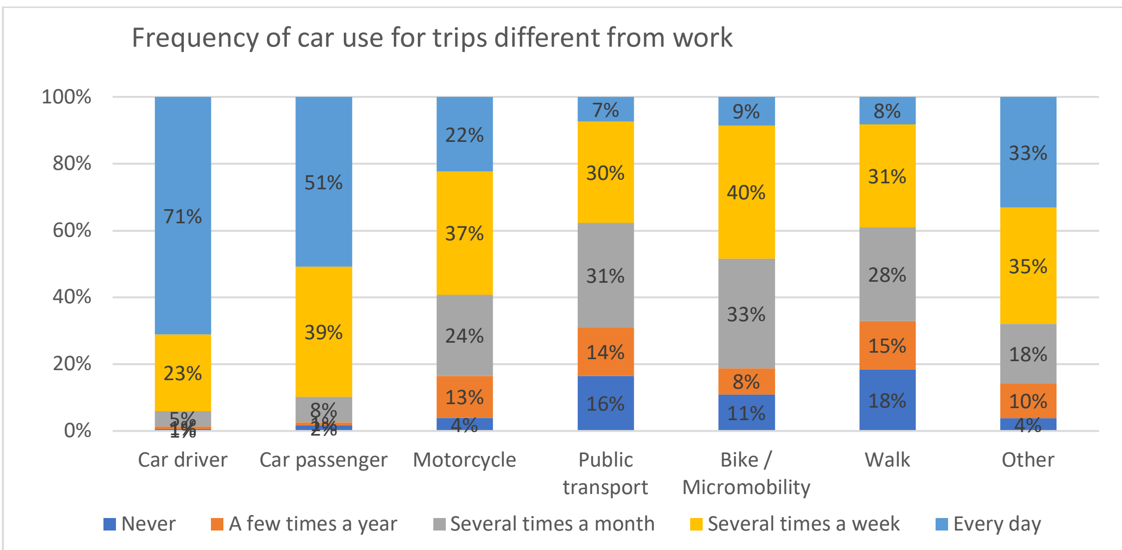

I feel at home in this city.
100%
80%
60%
40%
20%
0%
49%
34%
10%
4%
2%
44%
32%
18%
3%
59%
36%
4%
45%
33%
14%
5%
3%
65%
23%
7%
4%
1%
59%
27%
8%
4%
2%
38%
36%
14%
7%
5%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

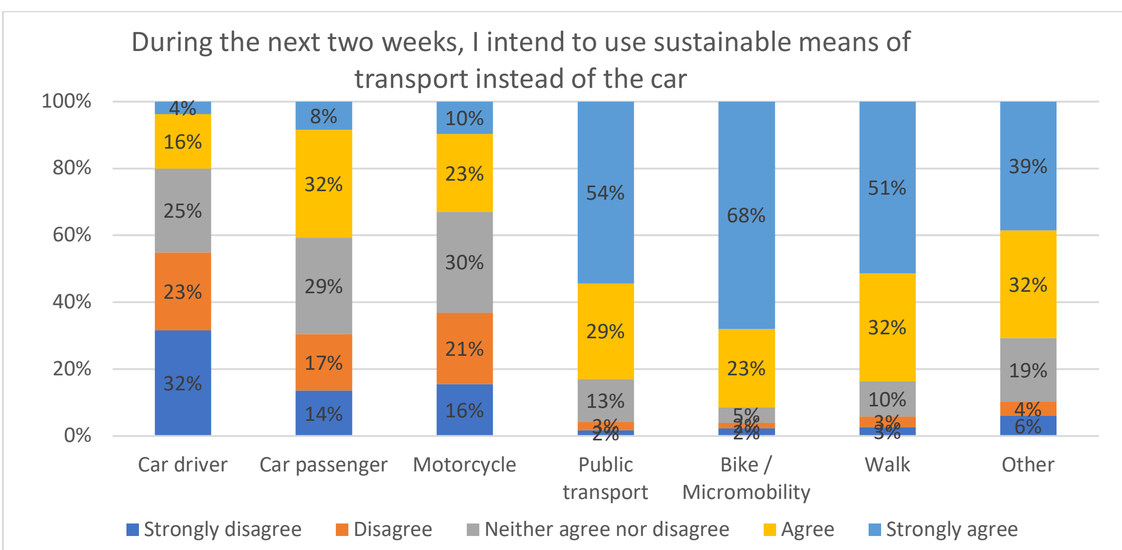

I feel I belong to this city and therefore I must contribute to make it a better place.
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

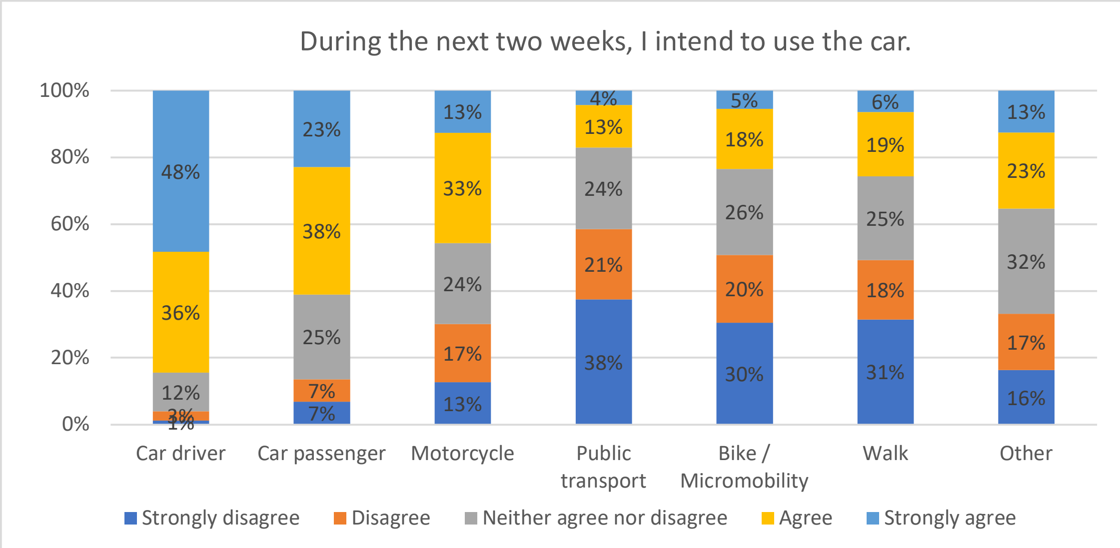

Frequency of walking for trips different from work
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Never
A few times a year
Several times a month
Several times a week
Every day

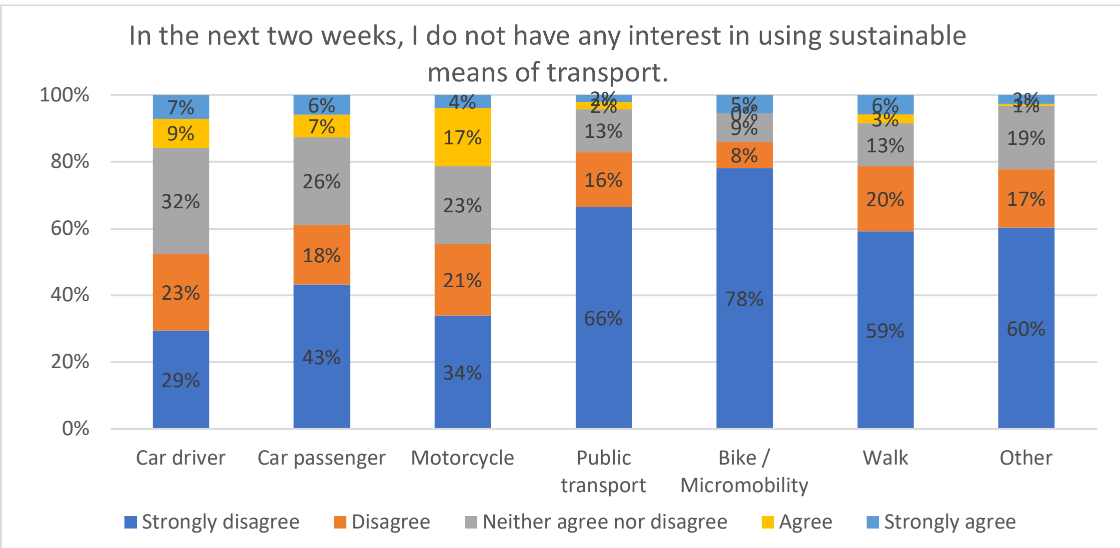

Frequency of bicycle use for trips different from work
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Never
A few times a year
Several times a month
Several times a week
Every day

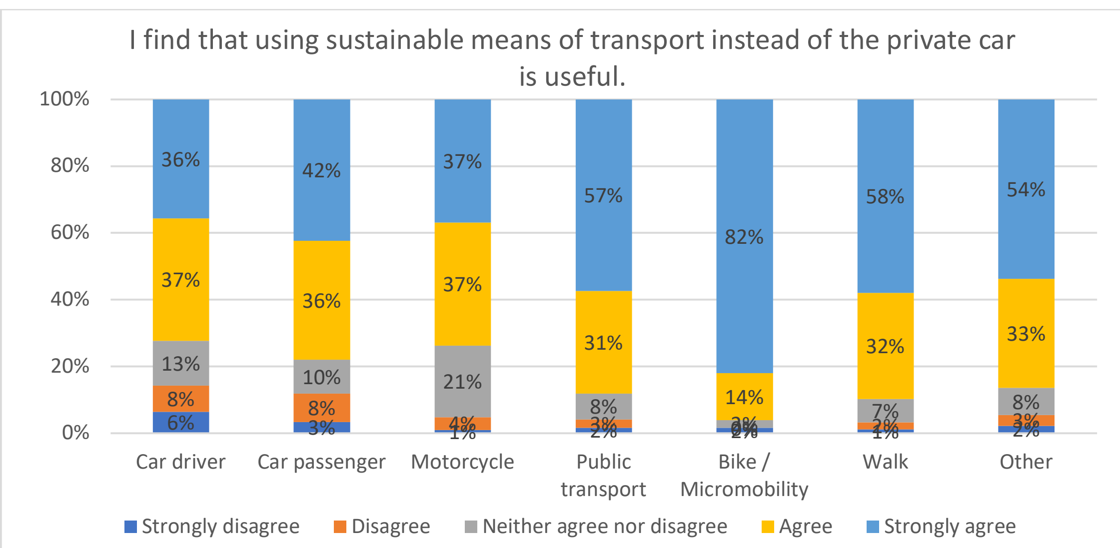

Frequency of public transport use for trips different from work
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Never
A few times a year
Several times a month
Several times a week
Every day

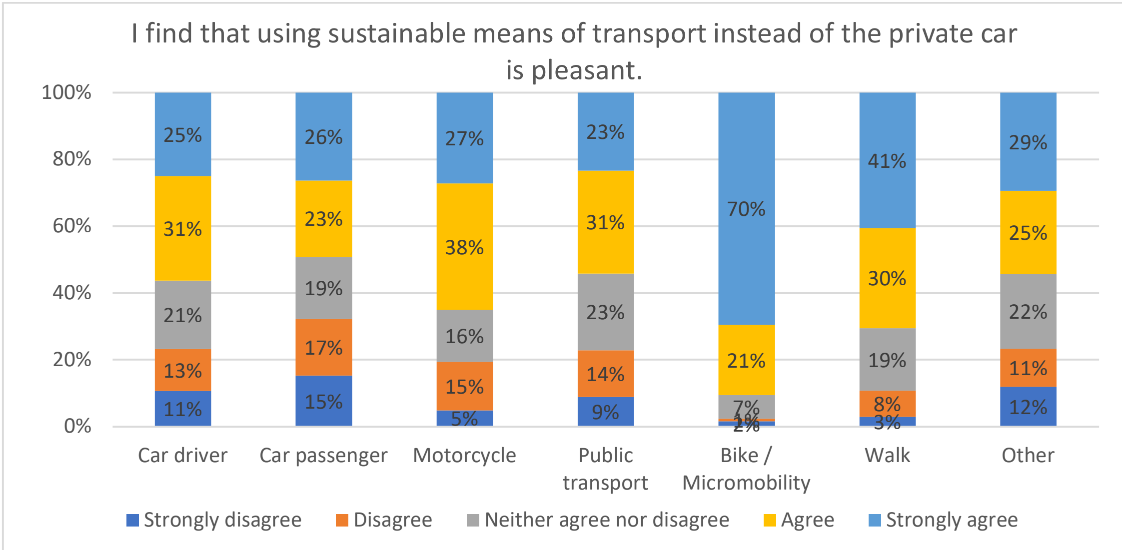

Frequency of car use for trips different from work
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Never
A few times a year
Several times a month
Several times a week
Every day

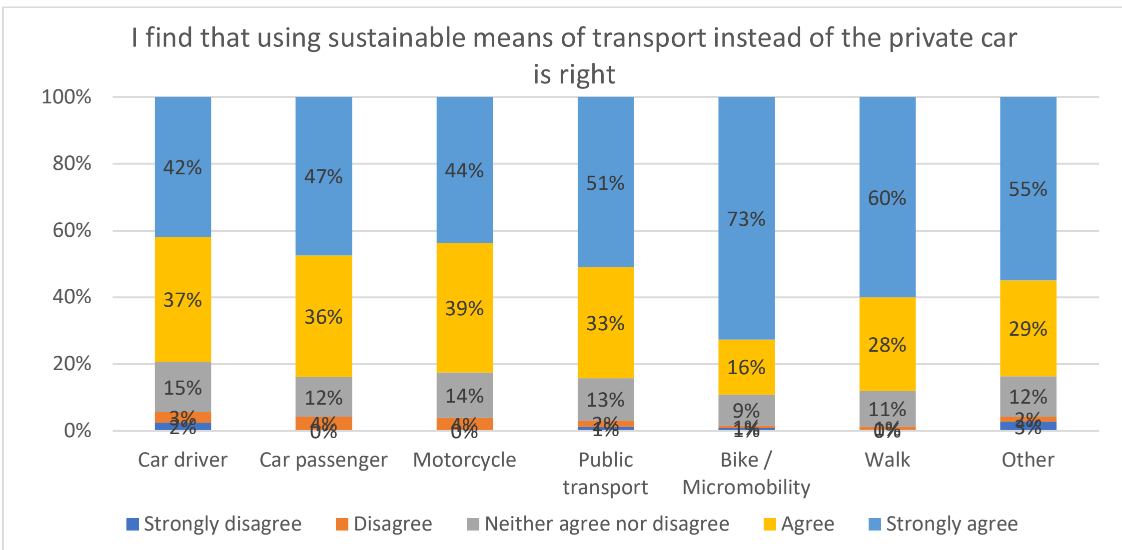

During the next two weeks, I intend to use sustainable means of transport instead of the car
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

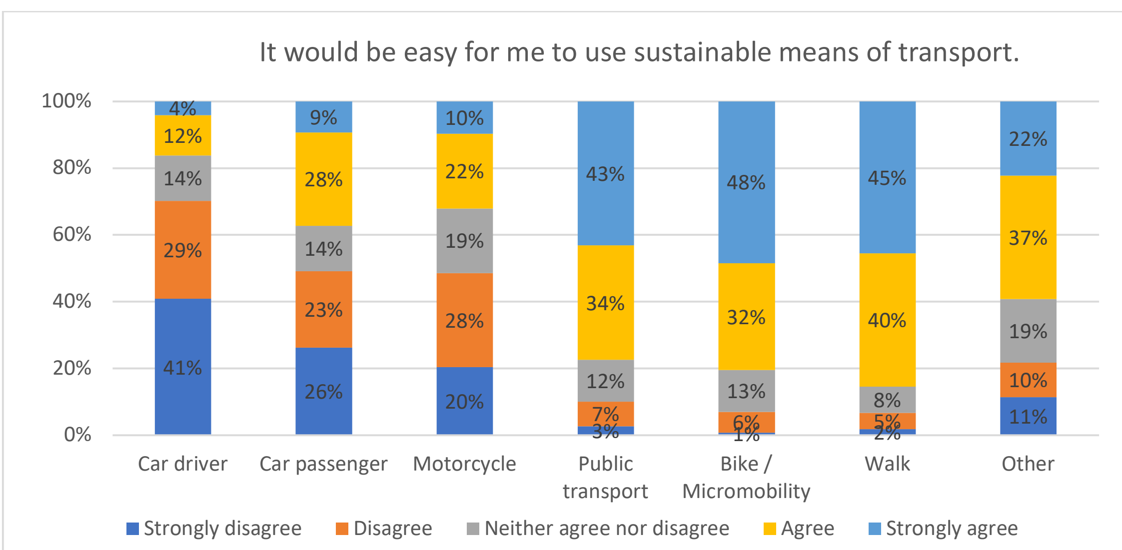

During the next two weeks, I intend to use the car.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

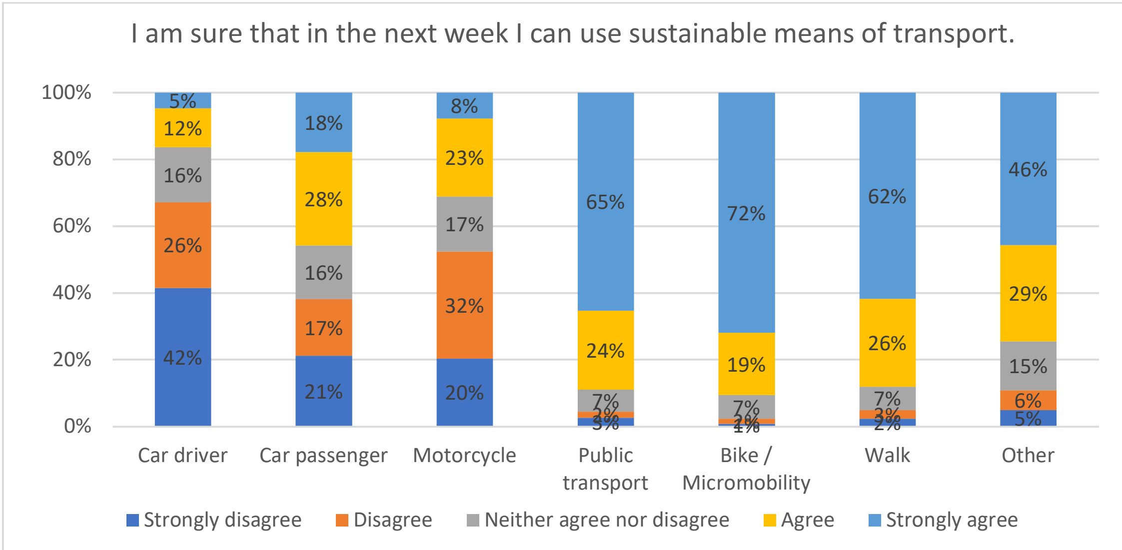

In the next two weeks, I do not have any interest in using sustainable means of transport.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

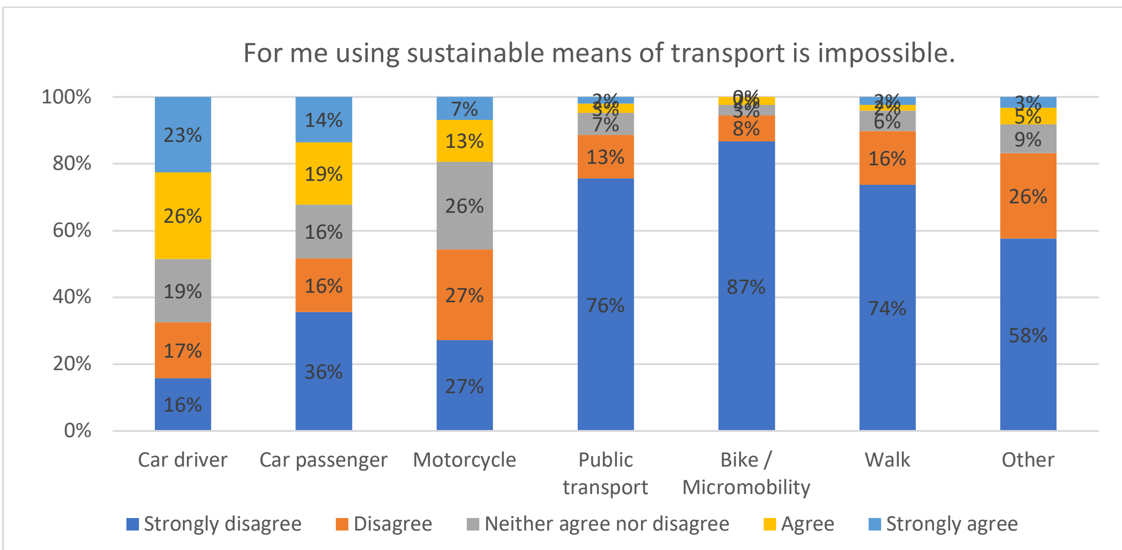

I find that using sustainable means of transport instead of the private car is useful.
100%
80%
60%
40%
20%
0%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree


I find that using sustainable means of transport instead of the private car is pleasant.
100%
80%
60%
40%
20%
0%
25%
31%
21%
13%
11%
26%
23%
19%
17%
15%
27%
38%
16%
15%
5%
23%
31%
23%
14%
9%
70%
21%
7%
2%
41%
30%
19%
8%
3%
29%
25%
22%
11%
12%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

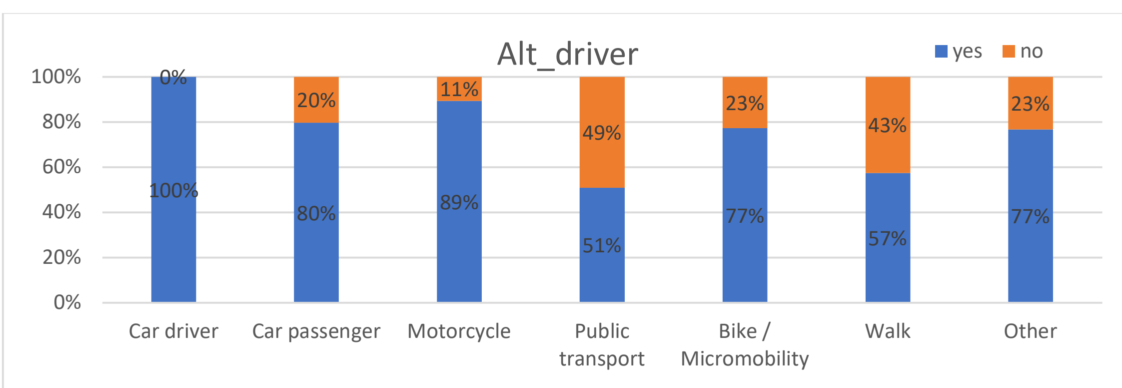

I find that using sustainable means of transport instead of the private car is right
100%
80%
60%
40%
20%
0%
42%
37%
15%
3%
2%
47%
36%
12%
4%
0%
44%
39%
14%
4%
0%
51%
33%
13%
2%
1%
73%
16%
9%
1%
60%
28%
11%
0%
55%
29%
12%
2%
3%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

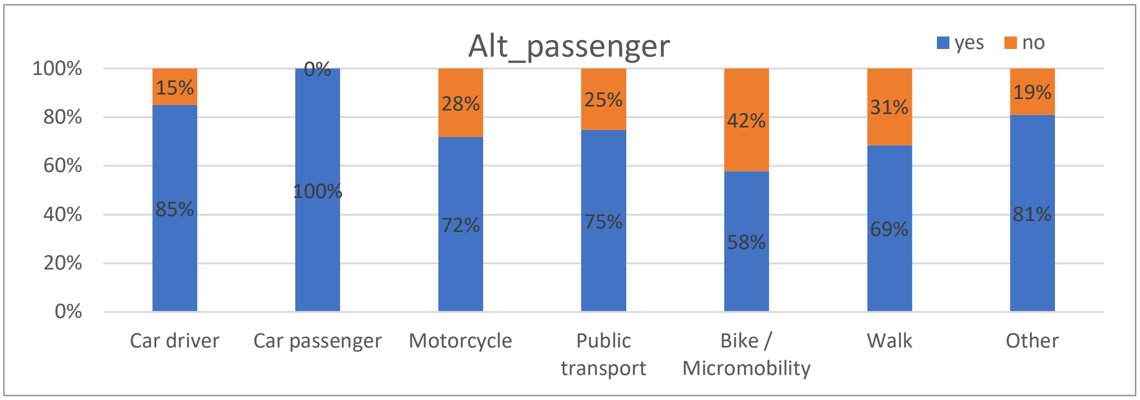

It would be easy for me to use sustainable means of transport.
100%
80%
60%
40%
20%
0%
4%
12%
14%
29%
41%
9%
28%
14%
23%
26%
10%
22%
19%
28%
20%
43%
34%
12%
7%
3%
48%
32%
13%
6%
1%
45%
40%
8%
5%
2%
22%
37%
19%
10%
11%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree

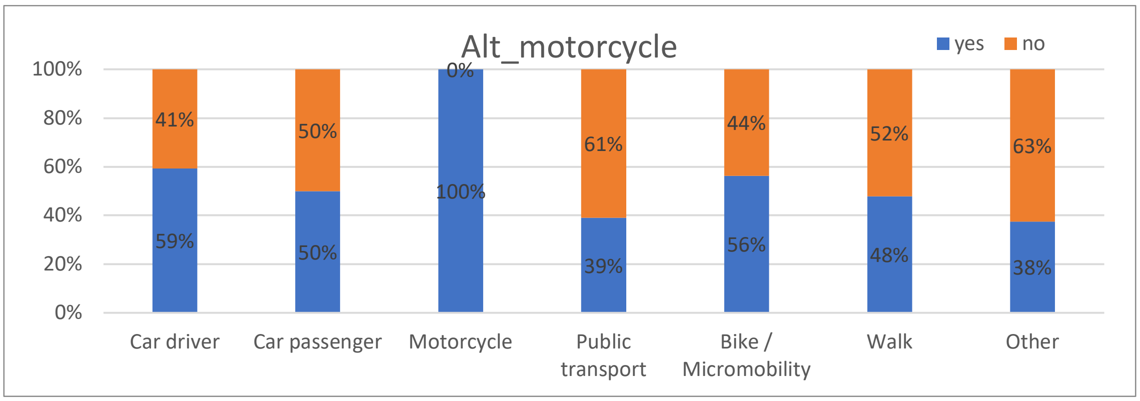


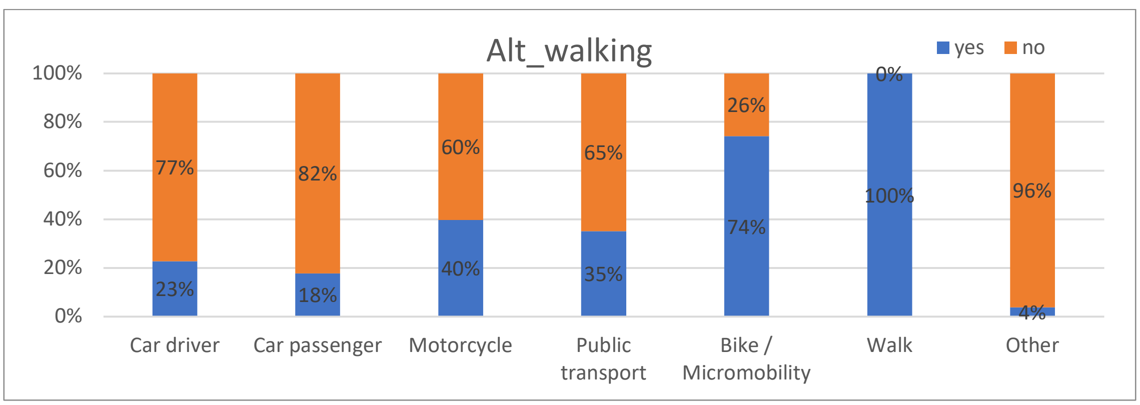


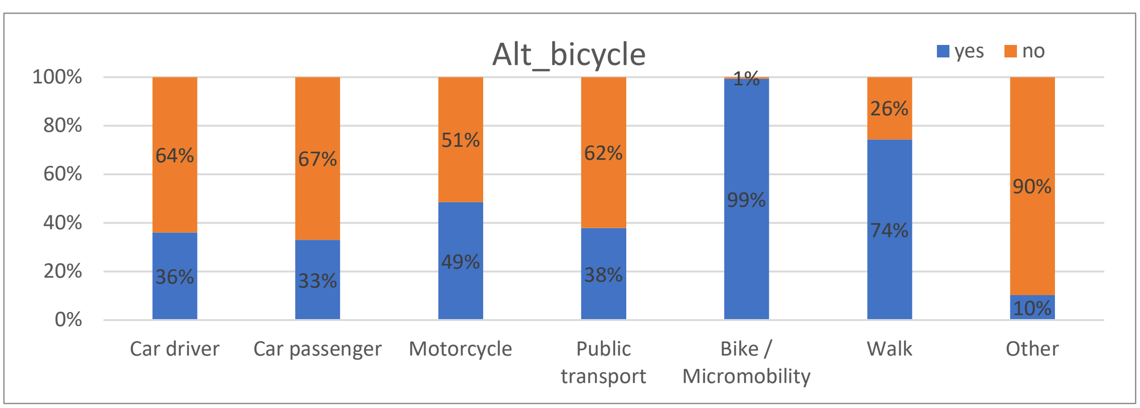
A.5.4 Alternative means of transport

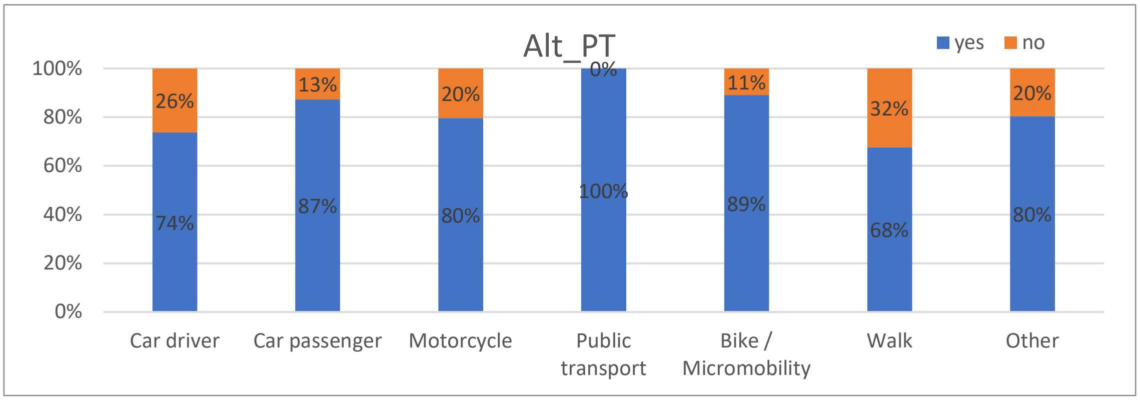


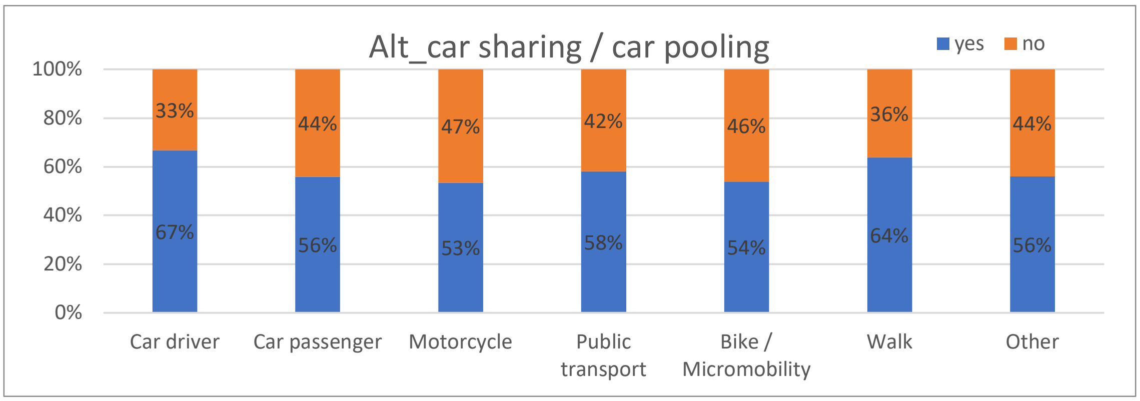

Alt_passenger
yes
no
100%
80%
60%
40%
20%
0%
15%
85%
0%
100%
28%
72%
25%
75%
42%
58%
31%
69%
19%
81%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other


Alt_motorcycle
yes
no
100%
80%
60%
40%
20%
0%
41%
59%
50%
50%
0%
100%
61%
39%
44%
56%
52%
48%
63%
38%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other


Alt_walking
yes
no
100%
80%
60%
40%
20%
0%
77%
23%
82%
18%
60%
40%
65%
35%
26%
74%
0%
100%
96%
4%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other


Alt_bicycle
yes
no
100%
80%
60%
40%
20%
0%
64%
36%
67%
33%
51%
49%
62%
38%
1%
99%
26%
74%
90%
10%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other


Alt_PT
yes
no
100%
80%
60%
40%
20%
0%
26%
13%
20%
0%
11%
32%
20%
74%
87%
80%
100%
89%
68%
80%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other


Alt_car sharing / car pooling
yes
no
100%
80%
60%
40%
20%
0%
33%
44%
47%
42%
46%
36%
44%
67%
56%
53%
58%
54%
64%
56%
Car driver
Car passenger
Motorcycle
Public transport
Bike / Micromobility
Walk
Other

APPENDIX B: R script to estimate models

- Probit model 1 - R code:

```r
setwd("C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test")

#install.packages("spatialprobit")

library(spatialprobit) #Import spatialprobit library

Mydata <- read.csv(file = "C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test/dataset_svolta.csv")

Mydata$Distance <- log(Mydata$Distance)
Mydata$Age <- log(Mydata$Age)

fitP <- glm(Choice ~ Age + Bicycle + Driving_license + Employment + Gender + Graduate + Income0_1000 + Income1000_2000 + number_car
            + N_children + N_household + Own_car + Distance + Peakhour + N_transit_300m_dest + N_transit_300m_or,
            family = binomial(link = "probit"), data=Mydata)

summary(fitP)
logLik(fitP)

```

- Probit model 2 - R code

```r
setwd("C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test")

#install.packages("spatialprobit")

library(spatialprobit) #Import spatialprobit library

Mydata <- read.csv(file = "C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test/dataset_svolta.csv")

Mydata$Distance <- log(Mydata$Distance)
Mydata$Age <- log(Mydata$Age)

fitP <- glm(Choice ~ Age + Driving_license + Employment + Gender + Income0_2000 + number_car + N_children + N_household
            + Own_car + Distance + Peakhour + N_transit_300m_dest + N_transit_300m_or + INT + PCB,
            family = binomial(link = "probit"), data=Mydata)

summary(fitP)
logLik(fitP)

```

- Independent probit and spatial probit models (origin) R code

```r
setwd("C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test")

#install.packages("spatialprobit")
#install.packages("lmtest")

library(spatialprobit) #Import spatialprobit library
library(lmtest) #Import lmtest library

Mydata <- read.csv(file = "C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test/dataset_svolta.csv")

Mydata$Distance <- log(Mydata$Distance)
Mydata$Age <- log(Mydata$Age)

nb <- knn2nb(knearneigh(cbind(Mydata$Lat_origine, Mydata$Long_origine), k=80))
listw <- nb2listw(nb, style="W")
W1 <- as(as_dgRMatrix_listw(listw), "CsparseMatrix")
fitS <- sarprobit(Choice ~ Age + Distance + Driving_license + Employment + Gender + Income0_2000 + N_household + number_car +
                  N_children + Own_car + Peakhour + INT + PCB + N_transit_300m_dest + N_transit_300m_or,
                  W=W1, data=Mydata, ndraw=600, burn.in = 100, showProgress=TRUE)

fitP <- glm(Choice ~ Age + Distance + Driving_license + Employment + Gender + Income0_2000 + N_household + number_car +
            N_children + Own_car + Peakhour + INT + PCB +  N_transit_300m_dest + N_transit_300m_or,
            family = binomial(link = "probit"), data=Mydata)

lrtest(fitP,fitS)
summary(fitP)
summary(fitS)
logLik(fitS)
impacts(fitS)
```

- Independent probit and spatial probit models (destination) R code

```r
setwd("C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test")

#install.packages("spatialprobit")
#("lmtest")

library(spatialprobit) #Import spatialprobit library
library(lmtest)

Mydata <- read.csv(file = "C:/Users/Elena/Dropbox (Politecnico Di Torino Studenti)/Elena_Vaccargiu/5.Spatial_model_test/dataset_svolta.csv")

Mydata$Distance <- log(Mydata$Distance)
Mydata$Age <- log(Mydata$Age)

nb <- knn2nb(knearneigh(cbind(Mydata$Lat_destinazione, Mydata$Long_destinazione), k=80))
listw <- nb2listw(nb, style="W")
W1 <- as(as_dgRMatrix_listw(listw), "CsparseMatrix")
fitS <- sarprobit(Choice ~ Age + Distance + Driving_license + Employment + Gender + Income0_2000 + N_household + number_car +
                  N_children + Own_car + Peakhour + INT + PCB + N_transit_300m_dest + N_transit_300m_or,
                  W=W1, data=Mydata, ndraw=600, burn.in = 100, showProgress=TRUE)

fitP <- glm(Choice ~ Age + Distance + Driving_license + Employment + Gender + Income0_2000 + N_household + number_car +
            N_children + Own_car + Peakhour + INT + PCB +  N_transit_300m_dest + N_transit_300m_or,
            family = binomial(link = "probit"), data=Mydata)

lrtest(fitP,fitS)
summary(fitP)
summary(fitS)
logLik(fitS)
impacts(fitS)
```