Car Dependency and Alternative Travel Behavior at the ASU Campus

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Abstract

American metropolitan university campuses have been identified as major trip generators that create many negative externalities such as emissions, nuisance, and congestion as these trips are mostly made by car due to their embeddedness in the American culture. Therefore, a modal shift towards more sustainable modes is encouraged to counter these negativities. This paper aims to gain insight into the level of car dependency and the intention to make use of alternative transport modes among students, faculty, and staff who travel to the Arizona State University's Tempe campus. To research the travel behavior and geographical patterns of these campus attendees, the main research question is as follows: *'What is the role of proximity to campus and public transport and the effect of individual characteristics on car dependency and alternative transport mode use intentions for student, faculty, and staff travel to the Arizona State University's Tempe campus in the Phoenix Metropolitan Area?'*

In doing so, an extensive dataset of the university's Parking & Transit Services includes whether an individual has purchased a campus parking permit or public transportation pass, or has registered a bike combined with their address.

Through QGIS mapping of all campus respondents, the results show that those possessing a parking permit are widespread across the Phoenix metropolitan area while individuals that have a bike registration are clustered around the center points of downtown Tempe or campus and downtown Phoenix. The importance of the geographic location of individuals, as well as their proximities and distances from campus and public transport stops, appear to be useful predictors of whether people have a parking permit, bike registration, and/or public transportation pass and opt to have monomodal or multimodal travel intention and behavior towards the ASU campus. Individuals with a public transport pass appear to be located in the downtown areas and along the Phoenix-Mesa railway with no visible clustering around bus stops. Besides, logistic regressions analyses were utilized to identify that the university groups of higher educated, males, those living near a train station, and individuals within half an hour distance driving tend to be less dependent on the car and pursue other forms of transportation. The same conclusions apply to multimodal users who are also for the majority located close to campus.

To stimulate changes to the current travel behavior of university affiliates, new policies and infrastructural investments are needed to switch from car-dependent commute to alternative transport that is more sustainable in the long-term while targeting the entire Phoenix Metropolitan Area and those groups that tend to use the car more as opposed to others.

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1. Introduction

1.1 Background motivation

As a student who has been studying most of the time in the Netherlands, in particular at the University of Groningen in the North of the country, most of my travel behavior has been based around public transport (e.g. train and bus), biking, and walking. When traveling from my parental home, it takes up to one hour by train to get to the station in Groningen, followed by a twenty-minute bus ride towards campus, equal to the same journey by car. After moving to Groningen, the personal journey consisted either of a five-minute walk to the bus stop and a fifteen-minute ride to arrive at the university campus or a bike ride of approximately twenty minutes to get there. Since students in the Netherlands usually do not have a full-time job with modal income and most of them make use of a student loan to cover monthly rents and expenditures that result in study debts, buying and owning a car is out of the ordinary due to the high maintenance and gas costs. Therefore, most students decide, on the one hand, to utilize the convenience of the available (multimodal) public transport that is well-connected throughout cities and in the entire country or, on the other hand, through walking and cycling which are very practical due to the short to medium distances, car-free inner cities, and well-maintained and safely integrated biking paths.

As a result, an entire transport culture revolves around the bike that exists in the Netherlands, especially in university cities that house many students who do not have the financial means to afford a car. Country context, city infrastructural design, and personal preferences form important predictors of transportation mode intention and also car ownership levels. In the Netherlands, there is an established cycling 'mobility culture' where, in particular, cities such as Amsterdam and Groningen are known for the numerous bikes that can be detected everywhere and used by everyone (Jones et al., 2016). Biking culture in the Netherlands stems from the proximity to important day-to-day locations within cities and the sophisticated biking network in and around cities all over the Netherlands and Northwestern Europe. Furthermore, the Netherlands has a long tradition of good public transport with good train and bus connections that reach most cities, villages, and areas in the country. The tradition to utilize other modes of transport different from the car originates from a spatial context which causes a mobility culture surrounding other transport modes, however, it can also be the other way around where a certain travel behavior shapes the spatial context, where this causality differs per country. The design of Dutch and European cities is shaped for bike usage through proper and safe bike lanes due to its spatial infrastructural policy. (Pelzer, 2010).

According to Martens (2004), European citizens are more likely to opt for a multimodal travel approach like public transport or bike as a more sustainable alternative to the car, referred to as bike-and-ride. In European countries such as the Netherlands, Germany, and the United Kingdom the bike-and-ride principle is actively used in daily commutes. Martens (2004) also state that even though the biking cultures in these countries differ, there are strong similarities in the modal choice due to travel preferences of the people in these countries, access to biking infrastructure, and the maximum commuting distances of these people. Mostly, the strong relationship between biking and public transport is dependent on the fast and high quality of these public transport modes, where trains and intercity busses attract significantly more bike-and-ride users than slower and lower quality types of public transport such as local buses and trams. The feeling of safety due to enhanced bicycle infrastructure and network is for cyclists one of the most important features to travel by bike which is incorporated in European cities (Hull & O'Holleran, 2014).

1.2 The United States and Phoenix context

America's transportation system has been designed, built, and centered around the automobile which causes public health and environmental problems due to high CO2 emissions and other exhaust gases. Traffic-related air pollution costs many citizens' lives and leads to numerous illnesses ranging from asthma to cancer, heart disease, and dementia. Besides, thousands of people are killed and injured in accidents through excessive driving. In many areas of the United States, there is no viable public transit to reduce or replace the exacerbating car use (Horrox, 2021). Tayal et al. (2001) indicated that the Phoenix Metropolitan Area, consisting of Phoenix, Mesa, Glendale, Scottsdale, Tempe, Chandler, Peoria, and Gilbert, in the state of Arizona used to belong to one of the most automobile-dependent cities in the world. The research also claims that the cities with the most car use, total road length or road density, and lowest settlement densities have the highest road expenditure, least transit cost recovery (fraction of operating expenses met by the total fare revenue), spent most on commuting, highest external costs from road deaths and emissions, and the largest proportion of city wealth going into transportation (income % spent on public transport). Since the landscape in the western regions of the United States, specifically Arizona, consists of large open spaces, mountainous areas, and high temperatures, it can be difficult to get around in large urban areas. Moreover, public transport in the Phoenix Metropolitan Area lacks a well-integrated network due to problems in the consistency and frequency of buses and the shortage of metro lines. Also, the bike is a less straightforward alternative due to the vast distances, badly maintained bicycle paths, and sweaty exhaustive temperatures for most of the year in Phoenix.

Since universities are large employers, educational institutions, and community leaders, they are also large trip generators, therefore they can contribute to the transition towards a less car-dependent environment and provide leadership in the field of sustainable transportation (Balsas, 2003). Currently, cleaner technologies and infrastructural changes have become available with zero-emission electric automobiles that do not lower car dependency but do decrease the negative externalities associated with the regular car that drives on gas. This is a viable alternative wherein a rapid increase in ownership can be observed everywhere in the United States. Furthermore, cities and school districts in the United States and Arizona have added electric busses to their transport network that are more sustainable and cheaper. Other developments are the improved and expanded bicycle network with more bike lanes, bike-sharing, e-bikes, and e-scooters which are increasingly more common in American cities (Horrox, 2021). The Arizona State University (ASU) is also gradually implementing these solutions to the transportation network in Phoenix and Tempe to reduce the car dependency in the inner city, campus area, and surrounding neighborhoods to decrease the carbon footprint and become more sustainable.

According to a report called the Transportation Demand Management Playbook by the Parking & Transportation Services (PTS) of ASU (2020), there are already some measures taken to decrease the car dependency around Campus and to promote other modes of transport. Measures that were tested and considered for usage are introducing permit restrictions or increasing the price for parking. In terms of new modes of travel to the university, in collaboration with the city and its adjacent neighborhoods, the university contributed to setting up Orbit buses and constructed the Metro Valley Line, while also having started the construction of the extension of the rail line in the form of Tempe Streetcar. However, due to COVID-related issues, the project has been delayed and is expected to be running later than planned, aiming for 2022 (Thompson, 2021). Besides, ASU is exploring the possibilities for new (micro)mobility hubs with bike- and scooter-sharing. Furthermore, not only the use of a single alternative travel mode can be considered to decrease car dependency but also the use of several different travel modes in a commute, referred to as multimodality or multimodal transport, can be applied to lower car usage (Nobis, 2007). The transition from a single to multiple travel modes is emerging in contemporary and future travel behavior to ensure a more sustainable urban mobility (Kent, 2014). However, it needs to be noted that the level of multimodality is very dependent on the composition and availability of several transport modes such as public transport networks and bicycle lanes infrastructure, which would be able to encourage the bike-and-ride principle as mentioned before by Martens (2004). However, to enhance the transfer from bike to public transport, the speed and interconnections of public transport need to improve. Consequently, these improvements can strengthen the possible advantages of multimodality in American cities and infrastructural contexts (Klinger, 2017).

Given these recent attempts to decrease car dependency in a highly car-dependent environment such as Phoenix, Arizona, it is relevant to explore current intentions towards more sustainable transport modes among students, faculty, and staff at ASU. These are the main three groups in the university dataset with the main difference between the latter two is that faculty consists of educators at the university (e.g. professors, lecturers, researchers, teachers, etc.) while staff consists of other employees of the university or any organization (e.g. administrators, counselors, assistants, cleaners, etc.) (Surbhi, 2017). As the theoretical framework points out, most of the travel intentions towards the Arizona State University campus are guided by the situational factors that mainly constitute the access to the road, bike, and public transport network that influences the modal choice of individuals to commute to campus. The distance and access to public transport differ for everybody, based on where they live. Therefore, these spatial proximities to campus and public transport are considered. Besides, not every individual thinks according to the same rationale and has different preferences. Deviations among individual sociodemographic groups are also considered to see whether there are groups that tend to use different travel modes that contribute to explaining the differences in transport mode intentions and the role that these situational and individual factors have. As a result, generalized outcomes from these situational factors will be affected by the individual characteristics of sociodemographic university groups that cause deviations in these transport mode intentions.

2. Research questions

To contribute to the existing literature and analyze the described problem statement concerning the theoretical framework, the main research question belonging to the academic article is as follows:
'What is the role of proximity to campus and public transport and the effect of individual characteristics on car dependency and alternative transport mode use intentions for student, faculty, and staff travel to the Arizona State University's Tempe campus in the Phoenix Metropolitan Area?'

To understand, analyze and explain the research problem, the main question is divided into the sub-questions below that support and structure the remainder of the paper:

- What are the main shares of travel modes and geographical patterns in traveling to and from the ASU Campus in Tempe?
- How does proximity to public transport affect the travel behavior of students, faculty, and staff to the ASU Tempe campus?
- Which sociodemographic university groups tend to use alternative or multimodal travel modes?

2.1 Societal and scientific relevance

Since universities tend to be a major trip generator within cities across the globe, specifically in the United States, it is important to understand the travel patterns and behavior of those that commute to these destinations daily. In the societal context, it is very convenient for the university and the metropolitan area of Phoenix to have insights into the different types of transport used to travel to the campus of the Arizona State University, the level of ridership, and which routes are being used and more importantly the ones that are underused and subject for improvement and enhancement. Furthermore, it provides an overview of the modal shares and if there are new developments in multimodality or new sorts of transport mobility. However, currently, the travel patterns of students, staff, faculty, and other attendees have not been mapped or highlighted which makes this thesis a starting point for the university and possibly the city and metropolitan area of Phoenix to update the information, data, and campus travel patterns yearly based on new data that is gathered by the PTS to gain a better understanding in the evolving transport mobility towards campus. The outcomes can subsequently be converted to new policies and measures to promote alternative and more sustainable travel modes in a highly car-dominated locations such as Phoenix and Tempe, where the university is based. Other societal benefits will be aligned with the effects of a more sustainable transition towards alternative transport options that can be explored further through the outcome of the study. This can be the development of a better integrated public transport network that would reduce car dependency and consequently increase health benefits through more active transportation and the reduction of greenhouse gasses while also creating employment for those working in the public transport sector or construction.

In the scientific context, many articles have been written on car dependency in the United States and around the world, as stated in the theoretical framework. However, the concept of multimodality is still relatively new and becoming more prevalent in contemporary transport literature. In particular in combination with student and university travel, not much is written about multimodal transport towards American university campuses while it could be a great opportunity to study and identify these patterns, how to improve them and what policies work to decrease car dependency and increase cleaner options of mono- and multimodal transport to counter the ongoing problems in climate change, sustainability and congestion.

The research problem is concerning the high share of car dependency in large cities in the United States, mainly due to the design of these cities which are highly influenced by the development of the automobile and, therefore, have a lot of urban sprawl with big distances between neighborhoods, facilities and service areas. At the same time, there are not many greener and more sustainable alternatives to cope with the negative externalities of the car such as pollution, nuisance, and congestion. Therefore, it is advantageous to take a closer look into these alternatives for a population that has not been researched thoroughly enough but creates a substantial flow of traffic towards one area: university students and other attendees.

The current literature does focus on travel patterns, demand, and behavior of students toward campus, but merely focuses on the distinction between on-campus and off-campus students and analyses the differences between these two (Wang et al., 2012; Limanond et al., 2011; Ma, 2015). Furthermore, other literature also identifies the mode of travel correlated to the distance toward campus (Shannon et al., 2006; Crotti, 2022) or the impact of policies modal choice (Danaf, 2014; Tezcan, 2013), while others focus on how infrastructural changes or transit-oriented development affect travel behavior (Shen et al., 2016; Tsai, 2009). However, the contemporary literature lacks analysis of individuals attending a university that intend to use or switch towards transport patterns that include alternative modes to the car or by using multimodal trips that either involve the car partly of their journey or could explain the first-and-last mile of these trips that could alter and diminish the car dependency in favor of more sustainable alternatives in the form of public transport, either mono- or multimodal. Contrarily, this paper fills that gap by studying and analyzing the university and student groups that form an upper bound of the general population where this kind of transition can be detected first. Besides, it provides specific insights into primary signals that these kinds of phenomena in travel behavior or intention are occurring as they are happening rather than post sustainable transition by measuring these intentions instead of waiting for years to be able to measure these behavioral impacts.

Lastly, current research does not highlight the spatial distribution nor combine the effect of distance to campus and proximity to public transport stops that alter the intention of transit to the Arizona State University and other locations in the Phoenix Metropolitan Area. Therefore, the research contributes and adds to the scientific relevance in the way that it incorporates the spatial distribution and proximities during such a transition while also taking into consideration the differences in individual characteristics that affect the travel behavior of these university groups.

3. Structure of the paper

The first section of the paper consists of the theoretical framework that first describes car dependency in the United States. In the second part, it links the main factors and concepts that are relevant in explaining the level of car dependency, intention to use alternative transport modes, and multimodality that affect travel behavior of students, faculty, and staff at the Arizona State University. The main factors that influence these travel mode intentions are situational factors that include proximity to campus and public transport stops while also policies around car use and other costs are relevant. Also, differences in individuals' characteristics form an important predictor for travel mode intentions while psychological factors are acknowledged but not actively studied in this research. The theoretical framework is eventually concluded by the expectations of the study that is summarized in the hypotheses section.

The next section is about the methodology and empirical approach that describes how the article tries to answer the research questions. The section consists of multiple chapters of which the study context and data collection are the first two chapters, providing more detail about where and how the data is collected and handled. The other chapters are about the statistical and spatial approach that provides more in-depth information about the taken approaches and processes to get to the results in the software applications Stata, SPSS, and QGIS. Moreover, some of the descriptive data is discussed to create a better image of the data that was on hand that allowed the research to be executed in the manner it has been done. The third section presents and describes the results. These are connected to the previous sections in the way that they followed the lines of the theoretical framework and methodology. Consequently, the results are followed up by the discussion section that reflects on the research in terms of execution and general implications for theory, policy, and society. Moreover, in the discussion section, there is a comprehensive reflection on the shortcomings and possible improvements or additional topics for further research. Finally, the last section provides a conclusion to the research questions stated in the introduction. These conclusions answer the sub-questions one by one in a generic sense without stating extra information or coming up with new data that should contribute to an overarching conclusion on the main research question that has been stated in the introductory stages of the academic paper.

4. Theoretical framework

The literature on university campus travel behavior and patterns focuses on several aspects that contribute to explaining the modal intention of students and non-students in their mobility towards campus and the many factors that influence these travel mode considerations. The growing interest from scholars and policy-makers on how to address sustainable mobility issues at universities needs more adequate research on commute mode choices to urban campuses. These sites display specific transportation features such as many parking spaces and concessive parking permits while having a relatively deficient public transportation supply (Vale et al., 2018). To understand the factors contributing to the intention to use a certain travel mode, it is important to first discuss the existing literature on car dependency in the United States. After the context of car dependency in the United States has been outlined, the two main factors will be discussed. Firstly, the situational factors focus on factors such as cost, time, and access that contribute to individuals' commuter choices. Secondly, the impact of individual characteristics causes deviations in the situational factors outcomes and shows differences among sociodemographic university groups.

4.1 Car dependency in the United States

When comparing the Dutch and American 'mobility culture', it is acknowledged that the United States tend to be more car-dependent in their mobility behavior. American cities have been developed around the car as the main transport mode due to the emergence of the car simultaneously with city growth in the United States that resulted in lower settlement densities and the lack of other transport mode infrastructure (McIntosh et al, 2014; OBF, 2021). The car culture trend has been visible throughout the history of developed countries. In particular, 'new world' countries have seen a rapid increase in motorization in the 20th century that has gone hand-in-hand with significant changes in land-use patterns that have created low-density car-dependent settlement patterns that are referred to as urban sprawl that reached extremes in the United States (Mattioli et al., 2020). An analysis by Saeidizand et al. (2021) found that car dependency in cities worldwide is influenced by multiple factors of which settlement density, public transport supply, fuel price, and level of congestion are important predictors of car use.

According to Santos et al. (2011), nearly 90% of personally traveled miles in the United States have been done by private cars in 2009, which emphasizes that driving had become the most dominant transportation mode. According to Buehler et al. (2017), the private car has taken a prominent role as the primary choice in travel patterns almost everywhere in the developed world. In the United States, around 86% of all trips are made by private car which is among the highest rates across the globe. The UITP (2015) monitored that, on average, 44% of daily trips in their sample are made by car. No other mode of transport can compete with these numbers. However, Richter (2022) also indicates that there is a declining trend in car dependency since this percentage has decreased over time to 76% which is still relatively large compared to Germany (65%) and the Netherlands (56%). There is potential to grow the share of daily trips per bike since around 48% of commutes in American cities are shorter than three miles while at the same time more commutes are increasingly done by bike (Pucher et al., 1999). However, due to the lack of a cycling tradition, low costs of car use, and the less-developed biking infrastructure for cyclists in infrastructure and transport systems in

North America, these countries will remain far below the standards of the European countries (Pucher et al., 1999). However, there is a wide variety between the percentages of car use for daily trips per car. In cities such as Vienna, Prague, and Casablanca it is relatively low with respectively 27%, 25%, and 15%, whereas in Chicago (81%), Sydney (73%) and Abu Dhabi (72%) the rate of car use compared to other transport modes is significantly high. When comparing these groups of cities it becomes clear that there are large differences between urban form, socioeconomic characteristics, and public transport availability that influences the levels of car use.

A comparative study conducted by English (2018) between public transport networks in Canadian and American cities highlights and emphasizes the significant differences in intention and importance of these networks. While in Toronto it is fairly fast and easy to travel from suburb to downtown and suburb to suburb, this is very difficult and time-consuming in American transit systems that were laid out in cities that mainly serve the downtown areas. The inaccessibility of transit in American cities and suburbs has become a crisis over time. According to English (2018), service drives demand. So, to encourage the population to switch from automobile to public transport, it is required to improve local transit services that will attract more riders. According to Cullinane (2001), public transport can never re-emerge as the dominant mode of transport in the developed world due to the link between rising GDP and car ownership. However, in the case of Hong Kong, it shows that whenever there is an adequate, abundant, and cheap public transport network available while car ownership is extremely low, it could deter the level of car ownership in a city or location. In general, when public transport is perceived as cheap and good, it can suppress the desire to own a car (Cullinane, 2001). On the contrary, when the quality of public transport is poor, it has an insignificant impact on the mode choice of individuals. De Witte et al. (2006) found that 'free' or cheaper public transport among two similar groups increases 'free' bus ridership in the travel behavior of the benefiting group, however, the non-benefiting group did outnumber the benefiting group while also having a higher trip frequency. Contrarily, the train requiring a fee is used more by the benefitting group that could ride buses for free. Due to the counterintuitive result, the author concluded that other factors such as the residential location of students are crucial in understanding different travel behaviors and modal choices.

In the face of climate change, there is a contemporary and permanent necessity to develop and utilize more sustainable ways of transport in these typical American cities. Even though these cities have many dissimilarities to European cities, there are still many aspects that can be learned from the spatial infrastructural policies and design that are adopted in these densely urban populated cities across the Atlantic Ocean. The main priority is to reduce the carbon footprint and CO_2 emissions by lowering the current high level of car use and dependency that is embedded in the younger generation of Americans that attend universities. In studies about the sustainable commute in car-dependent cities, Zhou (2012), finds different factors affecting alternative travel mode choices among university students in Los Angeles. Although the city is infamous due to its car-dominated traffic, the study finds that being embedded in this environment does not make university students more car-dependent compared to peers in other cities. Multimodality and a discounted transit pass increase utility of alternative transit modes such as walking, biking, carpooling, and telecommuting while holding a parking permit reduces the utility of alternative modes to

UCLA. By identifying the location of alternative transport modes, areas that have the highest levels of car dependency, and the population groups that tend the use the car most, policies can be created to reduce automobile dominance in favor of less polluting transport modes while also handling other negative externalities such as congestion and nuisances.

4.2 Situational factors

The first situational perspective aims at the assets of individual mobility behavior which is referred to by Kaufmann (2002) as an individual's 'motility' or the travel potential of an individual, which is assessed by access, skills, and experience. The first factor access is linked to the availability of different travel modes which is subsequently related to location and accessibility to transportation networks (Flamm, 2003). Besides, income and time also play a significant role in the access factor where people are constrained to finances, in particular persons with lower income like students are concerned by public transport prices and modify their transport behavior accordingly (Hine and Scott, 2000). The value of time is also a limiting factor for access that negatively influences to choice of public transport in favor of the car (van Wee & Annema, 2014). The second factor of skills is mainly related to acquired skills or knowledge of what kind of travel modes are available at what time and for what price (Kaufmann, 2000). The third factor of experience is developed by an individual's perception, habits, and values that are linked to certain ways of transport that consequently affect their access and skills towards these travel modes. In this sense, representation of several transport modes in quality and quantity is important to modify one's perception of public transport as opposed to the car. Hine & Scott (2000) states that the former is profoundly more sensitive to changes in service quality, especially when it involves a reduction of speed or frequency of services. Although these three factors construct the 'motility' concept, only the first factor of accessibility is measured throughout the paper while the subjective elements are not explicitly measured.

Secondly, studies that take proximity into account as a significant factor for modal choice mention that there is a difference between those that live on-campus compared to those off-campus who live further from the destination. Wang et al. (2012) found that on-campus and off-campus students show different travel behaviors due to the unique context of these living areas in terms of land-use mix, sidewalks, bicycle paths, and bicycle parking facilities. When comparing three different categories based on their proximity to campus (on-campus, near-campus, farther-from campus), it became evident that on-campus students generally took more daily trips to campus with a high percentage by foot or bicycle. In contrast, farther-from-campus students had fewer daily trips with a higher percentage of trips by car which gradually increased when the distance became larger. This was the other way around for walk and bike trips. Besides, Limanond et al. (2011) investigated the travel patterns of on-campus students in more rural areas. Although vehicle ownership does strongly influence the choice of transport mode, it does not much affect trip generation or travel distance regardless of gender and car ownership. The reason is that there is a high social interdependency where those that do not own a private vehicle are either a passenger on a friend's vehicle, drive a friend's vehicle, or take the bus since that is the only form of public transport on-campus. Ma (2015) also acknowledges that the travel patterns of university students are unique compared to the general population. It reinstates that there is a significant difference in the number of trips whether a university student lives on- or off-campus and is, therefore, the most important factor. On-campus students choose to walk for most of their trips while off-campus students travel more than half of their trips alone by car. More than half of the trips generated by students that have a parking permit are also by driving alone. Shannon et al. (2006), describe commuting patterns, the potential for change and barriers, and motivators affecting transport decisions in a University population that is divided into three different zones existing of concentric rings 1 and 8 kilometers from the university. The results suggest that students, staff, and faculty are willing to switch to an 'active' transit when barriers are reduced in using these kinds of 'active' transport modes, in particular by reducing actual and perceived travel time by bus and bicycle that would have the greatest impact on commuting patterns. Policy applications such as the implementation of a subsidized public transport pass, increased student housing on or near campus, increased cost of parking, and improved bus services and cycling networks appear to hold particular promise in reducing car dependency and altering transport demand patterns.

It becomes apparent that the proximity to campus or the destination is an important factor that should be incorporated in modal choice models. Thirdly, proximity to public transport stops and hubs are also influential aspects that need to be taken into consideration for using public transport since it reduces these previously mentioned barriers as indicated by Shannon et al. (2006). In large cities, rail-transit-supported suburbs with proximity to a metro stop have a significant positive association with the choice of rail transit as the primary commuting mode, decreasing car ownership (Shen et al., 2016). Besides, longer commuting distance is strongly related to higher probabilities of riding the metro rather than driving to work. However, when the distance to a metro stop grows larger, the metro ridership decreases to a large extent (Shen et al., 2016). Therefore transit-oriented development (TOD), which increases density, turns out to be an encouraging policy strategy (Tsai, 2009). In addition, Crotti et al. (2022) find that in a less dense public transport network area, students and staff tend to be more car-dependent but differ regarding trip frequency, on the one hand, where daily campus commutes increase the intention to leave the car at home and opt for local buses and trains. On the other hand, distance to campus and proximity to public transportation affects commuting behavior where short- to medium-haul commuters tend to drive alone by car instead of using local buses while long-haul commuters tend to utilize the train which shows that proximity to rail is a striking factor in reducing car-dependency.

Fourth and finally, Whalen et al. (2013) confirm that modal choices are influenced by costs, individual attitudes, and environmental factors such as street and sidewalk density. Key findings are that higher street density results in increases in motorized vehicles, while higher sidewalk density decreases the use of motorized vehicles. Besides, the utilities of motorized and unmotorized vehicles are positively affected by travel time, although at a decreasing rate when travel time increases. In terms of policies that should drive university students towards more sustainable travel modes like public transport as opposed to cars, increasing parking fees and decreasing bus travel times by provision of shuttle services or shared taxis could be promising strategies for mode switching from car to public transport or non-motorized travel modes (Danaf, 2014). Moreover, Tezcan (2013) explores responses from different parking pricing scenarios and a conducted willingness-to-pay analysis shows that significant switches to public transit can be sustained if these parking fees are introduced. These responses have been analyzed in a different report at the University of Berkeley, where the introduction of parking pricing and transit fare subsidies influenced the overall mode share of campus affiliates. Factors found that significantly altered the mode choice were travel times, costs, gender, student status, age older than 70, and home location topography. To spur a mode shift away from the drive-alone car dependency, it would be recommended to, on the one hand, disincentivize car use by increasing costs through parking pricing. On the other hand, combine it with incentives to use alternative modes by making it relatively cheaper or by lifting barriers that make riding public transport more convenient (Proulx et al., 2014).

4.3 Impact of individual characteristics

Although the situational factors such as costs, time, and access already cover a great extent of the literature in terms of travel behavior and modal choice, there are still deviations among individuals that interact with these situational factors. However, these can also be captured by psychological differences and personal characteristics like age, academic level, gender, income, etcetera.

The strand of literature that focuses on psychology, aims to improve the understanding of car dependency and mobility behavior. Therefore, despite it is not actively measured in this research, it is useful to know the psychological motivations behind car use and how this affects the intention of individuals. People, including university students, usually decide on a more comfortable mode of travel toward campus which is often the car. The bicycle is neglected due to the pressure of time, the discomfort of weather conditions, and the inconvenience of not having a car for other activities that need transport (Kaplan, 2015). Bamberg & Schmidt (2003) seek to explain and predict students' car use for university routes by investigating the behavioral motivations for car ownership and usage. Accordingly, the decision to commute by car is based on personal norms and feelings of moral obligations towards the environment and other people that influence individuals' travel behavior and modal choice. Furthermore, an individual makes decisions based on their social beliefs, intentions, and subjective norms towards the automobile and alternative transport options. Moreover, once a mode of commute has been established, an individual is unlikely to change their decision due to emotions and habits that have locked in a specific transport mode for university campus commutes.

Throughout the literature, there are multiple views regarding the importance of several descriptive statistics and characteristics described above. Zhou (2012) finds that for UCLA students who are located in a highly car-dominant environment, a wide array of individual characteristics such as gender, status, and age are significantly correlated to biking, walking, or public transport usage. Significant results highlight that, firstly, being female increases the utility of walking and biking. Secondly, undergraduates are more likely to walk or bike than graduates. Thirdly, older campus affiliates tend to use public transit less than younger aged students. Akar and Clifton (2009), in their research specifically aimed at bicycle commute, added that people tend to be more sensitive towards nonmotorized vehicles and women are less likely to ride a bicycle which is in line with the previous study. Nguyen-Phuoc (2018) found that in developing countries individual factors such as gender, year of student, living status, and family income influence the travel mode choice made by students. First-year students were more inclined to use public transport compared to more advanced students, female students near university tend to cycle more, and those from a family with medium to high income are more likely to use motorized vehicles to commute. Contrary to previous findings, Zhan et al. (2016) reveal that males are more likely to use the bike to campus while females tend to ride public transit more. Besides, the choice for nonmotorized commute decreased with distance whereas it increases for public transport with the increase of distance. Family income does not have a significant effect on student mode choice but rather on increased student travel frequency due to the costs.

Several studies also research the effect of individual characteristics on those that tend to be more multimodal. Although the research field is still relatively young, there have been significant developments going on lately in most Western countries. Especially young adults in urban areas contribute to the rise of multimodal behavior that is emphasized in national data from the United States (Buehler & Hamre, 2015). Kuhnimhof et al. (2012) address that even though motorization and car use for young adults in Germany increased in the 1990s across all age groups, car dependency decreased steadily among young adults between 18 and 29 as a result of two underlying trends. Firstly, an increasing share of young drivers started to use alternative transport modes that indicate a rise in multimodal transport behavior. Secondly, gender differences have disappeared since young men, who drive more than women, reduced car ownership which affects the level of car usage and ownership among young adults. Heinen (2018) states that the use of multimodal transport as has happened in Germany leads to behavioral modal choice change over time. In particular, individuals who were more multimodal at the baseline have also a higher tendency to decrease car usage.

So the behavioral aspect is influenced by the psychological factors combined with the situational factors to use other transport options like public transport, biking, and walking. In their turn, these factors depend on factors such as proximity to the destination or transport towards their destination. Moreover, other factors that play a significant role are the costs of using alternative transport modes or an individual's characteristics such as age, gender, income, etcetera. Also, the effect of new policies that alter the circumstances for modal choice can be considered.

5. Conceptual framework

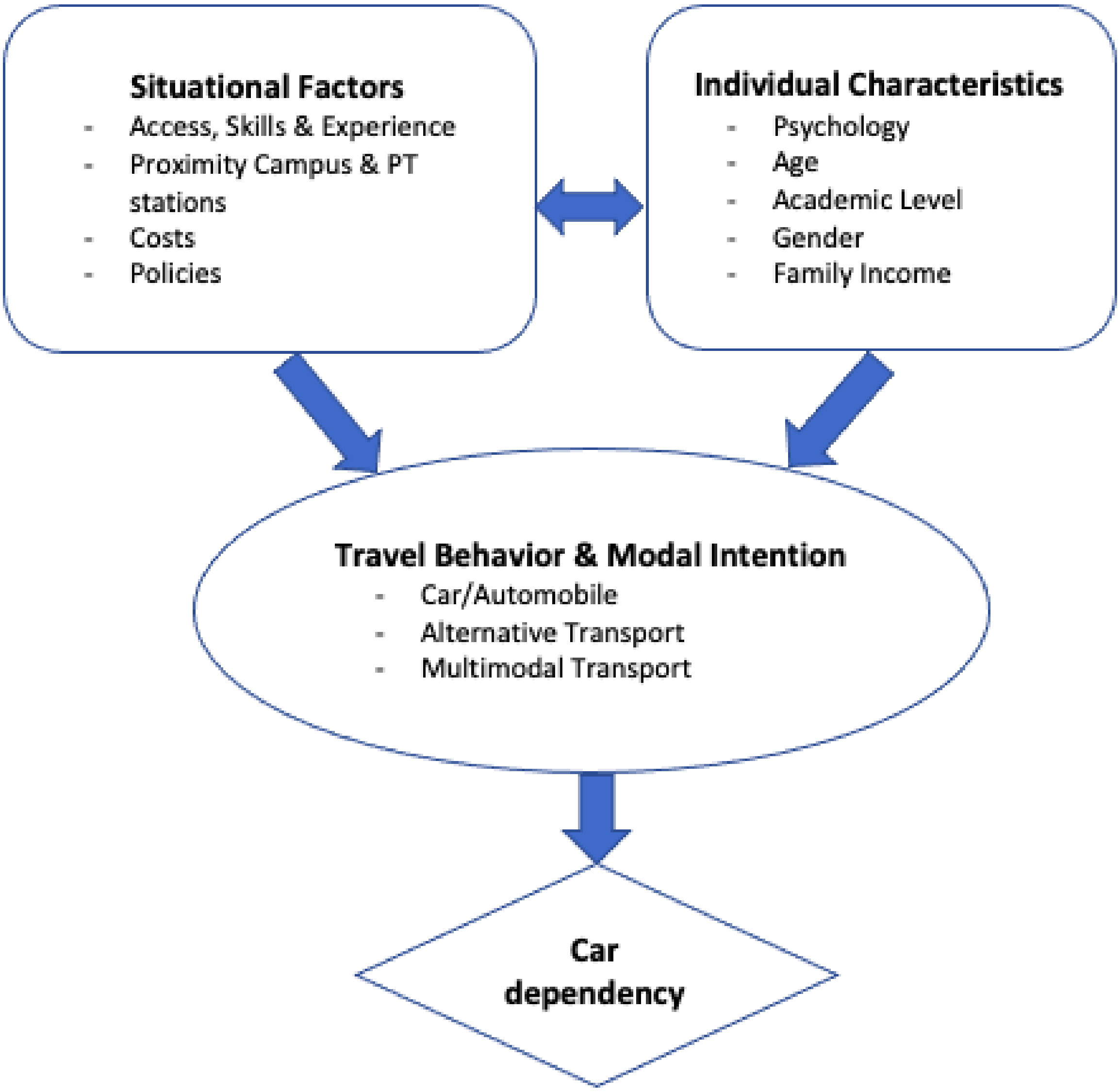

Figure 1: Conceptual model of Travel Behavior & Modal Intention

As derived from the theoretical framework, two major aspects determine the modal intention and choice of the university campus for students, faculty, and staff. These consist of multiple factors that are interconnected. Firstly, the situational factors that focus on the assets of access and proximity in terms of distance and travel time to the university campus or a public transport stop and line to the campus, costs connected to the journey of the travel mode choice, and the policies regarding these modes. Secondly, the impact of individual characteristics that comprise psychological characteristics that are not actively measured such as comfort, convenience, and habit as well as personal characteristics such as age, academic level, gender, family income, etcetera have a more prominent role in explaining the deviations among sociodemographic university groups. The interaction between these two factors is predominantly studied in the research to determine what transport mode is intended to be used to travel toward campus.

6. Hypotheses

Since the United States and especially the southwestern states have a history that has been relying heavily on the car with its long distances between cities, villages, and residential areas, as well as the vast amount of wasteland and mountains in between these populated places, the expectation is that the people living here are still majorly dependent on the car due to habit (Tayal et al., 2001; Mattioli et al., 2020; Saedizand et al., 2021). Despite that, the level of car dependency has been reduced through improved public transport services and infrastructural developments (Pucher, et al., 1999; Richter, 2022) the car will likely still be the most dominant mode of moving around. Therefore, the travel behavior and patterns of students, staff, and faculty towards the university campus will also remain a large share based on car commute. Walking, cycling and public transport can be beneficial and are used more for short distances up to around three miles that do not require a car, however, exceeding the closest three miles or so from campus, students and staff will tend to use the car due to the comfort and convenience that the car offers (Kaplan, 2015). For the same reasons, I do not expect that multimodality will be something common in the travel patterns of students, faculty, and staff attending ASU. Differences in alternative transport behavior between students, staff, and faculty are expected due to the lower financial savings of young students that are forced to either use public transport or bikes, as well as the physical ability of students to utilize non-motorized travel modes related to age. Besides, freshmen are often housed in the dormitories on campus which adds to the lesser need of owning a car on and around campus. Although faculty and staff might be more morally inclined to use greener travel modes than students, this does not change the lower degree of car ownership among students. Furthermore, I expect that those living near a train or bus stop are more inclined to take alternative travel modes rather than the car (Shannon et al., 2006; Shen et al., 2016; Crotti et al., 2022). As a result, the level of those possessing a parking permit will therefore be lower while more people in these areas along the metro valley rail line will own a public transportation pass. The same holds for those living close to campus that are more willing to travel by bike or public transport (Limanond et al., 2011; Wang et al., 2012; Ma, 2015). The outcome will be that the number of people with a parking permit will be lower as opposed to the areas further away from the ASU Tempe campus which are not accessible within thirty minutes by either bike or a public transport option.

7. Methodology

To understand and interpret the data correctly it is, at first, useful to gain insights into the study area where the data has been collected which is described in the next subchapter. Secondly, the data that had been collected is screened and edited to identify and clear out any data that could have hampered the accuracy of the results. Moreover, the descriptive data have accordingly been linked with other geographical data, such as proximity to campus and public transport and travel time per transport mode to campus, that matches the individual respondents. Thirdly, the first level of descriptive analysis has been conducted that summarizes variables and absolute numbers that can find patterns in the collected data. Finally, an inferential analysis has been run to show relationships between variables to generalize results and make predictions.

7.1 Study context

As stated in the introduction, the study context is the Phoenix Metropolitan Area with emphasis on the city of Tempe where the main ASU campus is located. Figure 2 shows greater Phoenix with its districts and main roads in dark lines and the more local roads in lighter lines. The focus here should be on Tempe since everybody who goes to university has this district as their destination point, hence that the research revolves around the distance

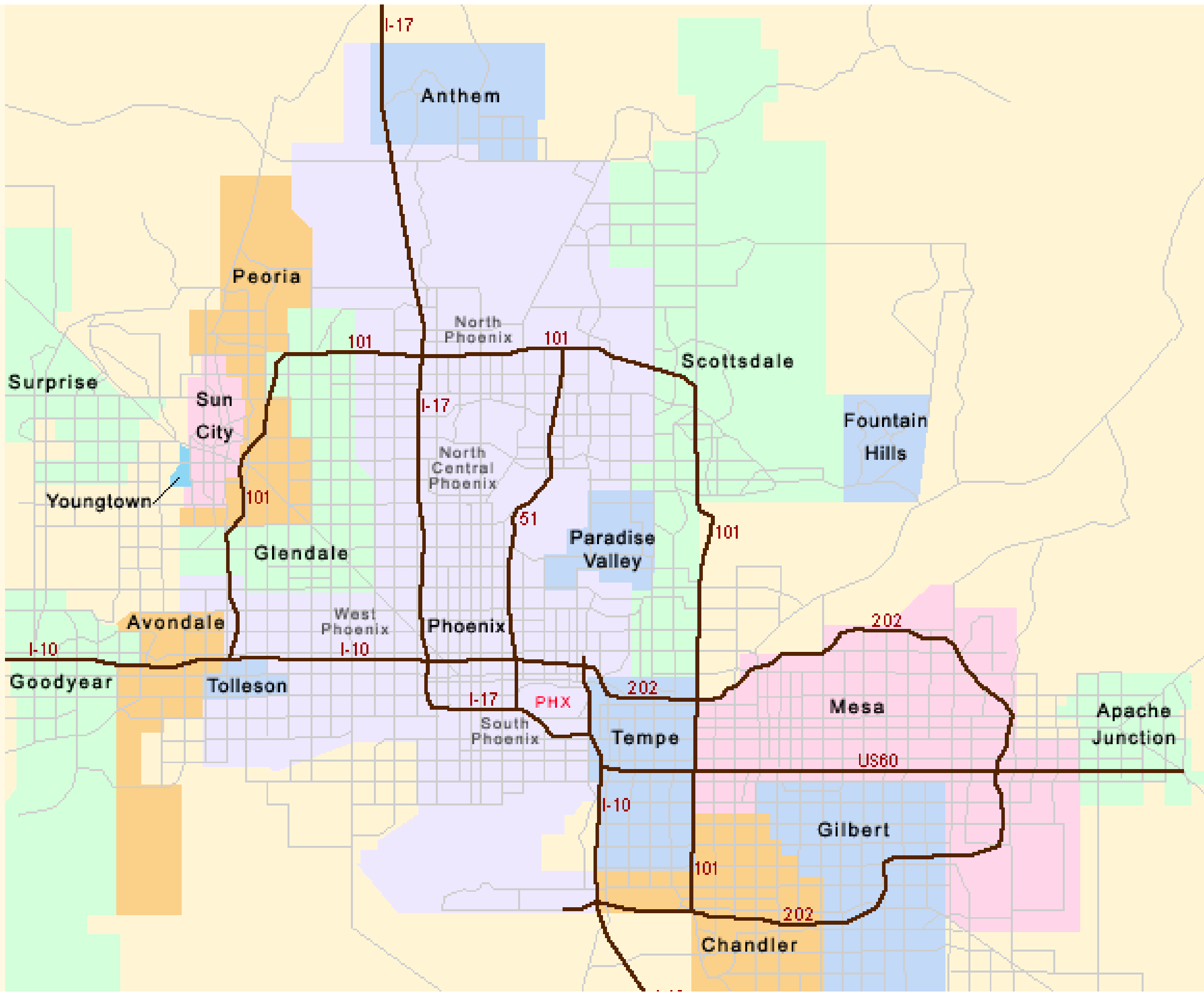

Figure 2: Greater Phoenix (American Southwest, 2022)

and travel time towards here. Moreover, other districts such as Phoenix downtown, Mesa, and Scottsdale are also mentioned throughout the paper.

The second map of the public transport provider Valley Metro (2021) in Figure 3 focuses on the public transportation network in the PMA while Figure 4 zooms into the downtown areas of Phoenix and Tempe. Since the proximity to public transport such as train stations and bus stops in the Phoenix Metropolitan Area is an important aspect of an individual's modal choice and travel intention, it is advantageous to understand the public transport network. On the one hand, there is a dense bus network, indicated in purple, circling every block of the greater Phoenix area. Twelve lines directly link an area to the campus, as shown

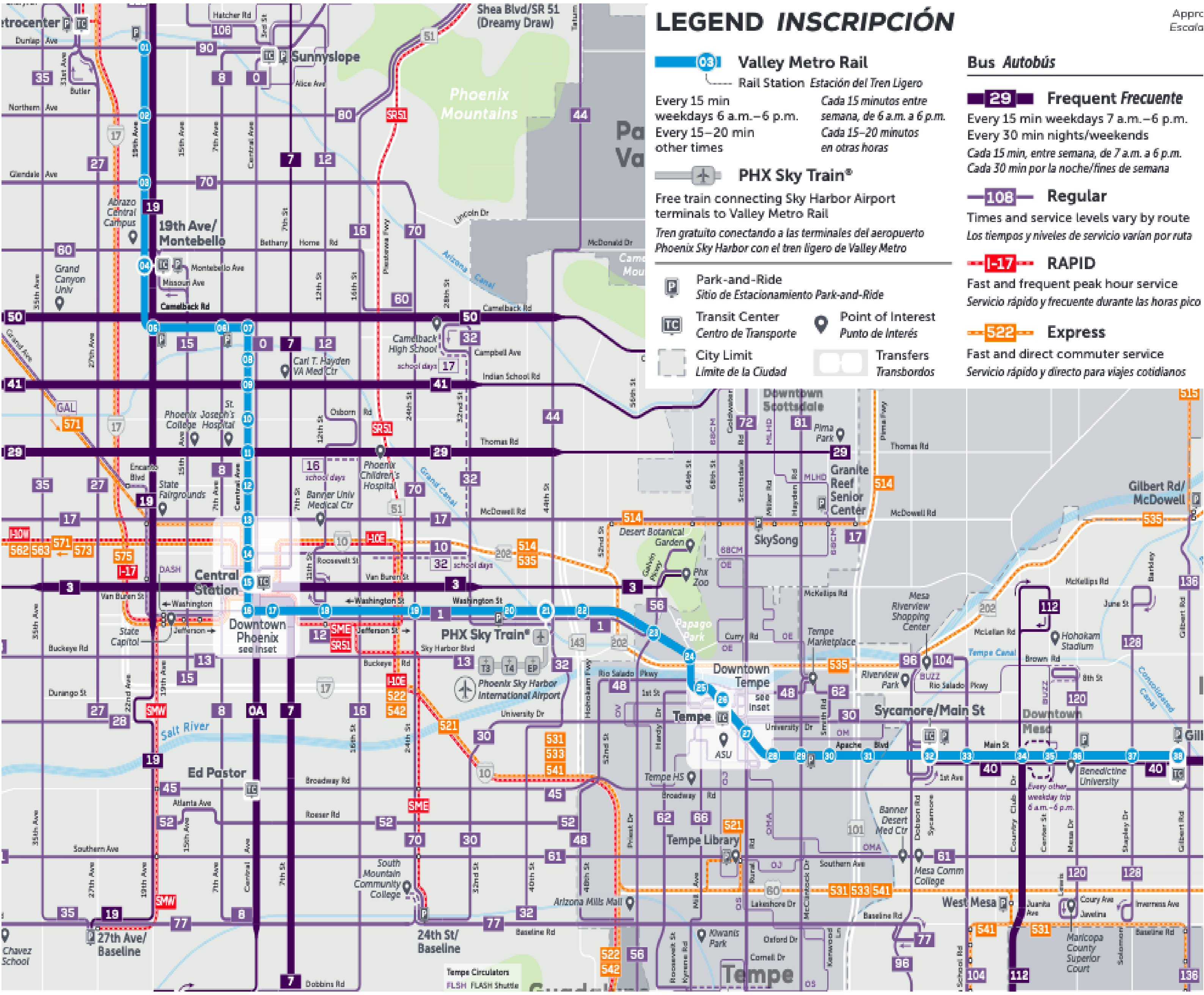

Figure 3: Public Transport Network PMA (Valley Metro, 2021)

Figure 4: Transport network downtown Tempe & Phoenix (Valley Metro, 2021)

in Figure 3. The twelve lines that drive towards Downtown Tempe and ASU campus according to the Metro Valley System Map (Valley Metro, 2021) are the circulator buses Flash, Orbit Earth, Orbit Jupiter, Orbit Mars, Orbit Mercury, Orbit Saturn, Orbit Venus, and local buses 30, 48, 62, 66, 72. On the other hand, there is only a single valley metro or train line highlighted in blue that crosses through the entire area from northwest of Phoenix, going through downtown Phoenix and downtown Tempe, and stops southeast in Mesa-Gilbert.

7.2 Data collection

The data that have been used to conduct the research was collected by the Arizona State University, providing detailed information about addresses/locations, whether someone possesses a parking permit and/or public transportation pass and whether they have a bike registered on campus. These separate datasets have been merged into one large dataset with the respondents matched on their unique ID numbers. Also, other useful variables linked to a person have been registered in the data file and can be seen in Table 1 below.

The main variables from the collected data of the respondents include a unique ID number, their classification (e.g. student, faculty, staff), student (0=no, 1=yes), academic level or year of study as an ordinal value (0=non-student, 1=freshman, 2=sophomore, 3=junior, 4=senior, 5=postbaccalaureate, 6=graduate, 7=law) that in the models is recoded into three distinctive categories to to make an easier distinction between lower and higher educated individuals. The first category is 'Low Academic Level', including freshman and sophomore, that summarizes the lower half of undergraduates. The second category 'Medium Academic

Level' consists of junior and senior that fits the upper half of undergraduates. The third category 'High Academic Level' includes those that finished their undergraduate: postbaccalaureate, law, and graduate. These three categories have been generated by creating dummy variables for each recoded dummy variable where for every individual that belongs to the 'Low Academic Level' variable and, therefore, is either classified as a freshman of sophomore student is specified in the data as 1, while others that are not categorized as such are specified in the data as 0. The same process is conducted for the other two academic level variables. The 'Academic Level' categories measure the differences among groups that are divided through the academic progress against the reference group of non-students. Since these non-students are either faculty or staff, the variable also refers to the relation between students, on the one hand, against faculty and staff on the other hand. This variable measures the differences in probabilities of the distinct student academic level progressions to purchase a parking permit, public transport pass or register a bike Since the reference for both variables slightly differ due to unaligned definitions in the dataset from the Arizona State University. For example, some individuals are referred to as 'graduate' in the academic level variable while classified as faculty in the class variable.

Furthermore, there are the variables of age, gender (0=male, 1=female), address (street, city, state, and zip code), car or parking permit, bike registration, public transport pass, and whether they live within a quarter-mile or between a quarter and half a mile of a bus stop or train station, and whether a respondent is multimodal. The last six variables are all binary variables where a 0 is equal to 'no' and a 1 to 'yes'.

ID	Class	Student	Acad. Level	Age	Gender	Address	Car	Bike	PT	1/4m Bus/Train	1/4to1/2m Bus/Train	Multimodal

Table 1: Collected data per respondent

7.3 Data management

To provide more in detail information about the dataset, every descriptive statistic is summarized in Table 2. Most of the variables consist of 23.114 observations except for some due to missing or unknown values. For the age and gender variables, it is due to the lack of data of some respondents in their date of birth or gender which leads to unknown or 'NULL' values. The distance was not measurable by the computer which also results in some missing values. Furthermore, Table 2 provides interesting information about the mean, minimum and maximum values associated with the variables. 69% of respondents are students. These students are split in three categories with 19,9% of the people that commute to campus is freshman or sophomore, 39,8% is junior or senior, and 16,0% is graduated or continued studying after their graduation. Since some faculty or staff belongs to the group of graduates, the academic level percentages surpass the 69% that are students. All respondents together are on average 29,7 years with the youngest respondent being 16 while the oldest is 90 years of age. Since most of the variables are binary variables, it is convenient to determine the number of students, females, transport permits and passes, the number of individuals living within a threshold of a public transport stop, distance or travel time buffer by simply using the mean number as a percentage of the total number of observations. This, for example, shows the gender divide is equal with half of the respondents being female. Other interesting mean numbers are that 86% have a parking permit while respectively 7,9% and 8,6% have registered a bike permit or public transport pass, 10,6% are located within a quarter-mile of a bus stop while almost 27% are housed between a quarter and half a mile of a bus stop. For the train stations, this is respectively 3,3% and 4,1% due to the few numbers of stations. The minimum and maximum values show the binary variables and indicate that there are eight different academic categories in the dataset. Furthermore, distance variables have been generated using the extension TravelTime (2021) that takes into account the existing road, bike and public transport network. The extension creates isochrones, or time maps, that highlight the area to a single point that is reachable within a timeframe by using a certain transport more. For the model three different isochrone categories have been generated for car, bike, and public transport. Accordingly, for the driving time maps, most people in the dataset (34,6%) live twenty to thirty minutes by car from campus, followed by ten to twenty minutes (27%), beyond thirty minutes (25,6%), and zero to ten minutes (12,8%). For the bike and public transport time maps these percentages of the shorter times are a lot lower compared to the car due to the smaller size of these areas due to the slower transport speed and thus distance covered within these timeframes. The implementation of these isochrones is further elaborated upon in the next section and results. Finally, the multimodal binary variable indicates that only 2,5% of all 23.114 respondents are multimodal.

Variable	**Observation**	**Mean**	**Std. Dev.**	**Min**	**Max**
Student	23.114	0,690	0,462	0	1
Low Acad. Level	23.113	0,199	0,399	0	1
Medium Acad. Level	23.113	0,398	0,489	0	1
High Acad. Level	23.113	0,160	0,367	0	1
Age	23.085	29,739	13,718	16	90
Female	23.008	0,505	0,500	0	1
Parking Permit	23.114	0,860	0,346	0	1
Bike Registration	23.114	0,078	0,269	0	1
PT Pass	23.114	0,086	0,281	0	1
¼ Mile Bus	23.114	0,106	0,308	0	1
¼ to ½ Mile Bus	23.114	0,269	0,444	0	1
¼ Mile Train	23.114	0,033	0,179	0	1
¼ to ½ Mile Train	23.114	0,041	0,198	0	1
10 Min. Drive	23.114	0,128	0,334	0	1
10-20 Min. Drive	23.114	0,270	0,444	0	1
20-30 Min. Drive	23.114	0,346	0,476	0	1
10 Min. Bike	23.114	0,068	0,252	0	1
10-20 Min. Bike	23.114	0,061	0,240	0	1
20-30 Min. Bike	23.114	0,049	0,215	0	1
10 Min. PT	23.114	0,021	0,144	0	1
10-20 Min. PT	23.114	0,067	0,249	0	1
20-30 Min. PT	23.114	0,049	0,217	0	1
Multimodal	23.114	0,025	0,157	0	1

Table 2: Summarized variables all campus respondents

7.4 Geographical Information Systems approach

To visualize the address data provided by the Parking & Transport Services of ASU, the application QGIS has been used as the software program to run a geographical information systems analysis. Kammruzaman et al. (2011) emphasize the importance of GIS to evaluate travel behavior to increase the understanding of accessibility and transport demand.

Since there are many addresses included in the dataset, it can be difficult to distinguish areas with many inhabitants that possess a specific document that allow them to park, store or use a particular transport mode that belongs to their travel behavior. To generate more comprehensive maps that identify these dense and thinly permit and pass populated areas that display those properly, there will be made use of census tracts of the Arizona state that allows seeing differences in densities and modal shares for commuter permits, bike registrations and public transport passes. Through the combined analyses of vector and raster data, insight will be presentable in a comprehensive manner. Another empirical problem of the analysis of different transport modes has been resolved by using multiple destination points and running travel time analysis using several 7-minute time intervals within a 30-minute time frame during peak hours from 8.45 to 9.15 am. Next, these various travel time buffers based on different destination points and day times have been unionized, forming the current travel time catchment areas. Currently, there are major differences in the distances that can be covered in a certain amount of time by the several transport modes that are shown by the isochrones produced by the TravelTime API (2021) that indicate the destinations and catchment areas that can be reached within a certain amount of time by using different modes of transport highlighted in Figure 6. The source of their data is country-specific and directly from local transport providers and other sources such as OpenStreetMap while not utilizing from other routing providers. Therefore, TravelTime generates reliable and user-friendly time maps that can be analyzed accordingly.

7.5 Statistical approach

With the collected data, described in the section above, some statistical modeling is used to see the effect of the independent variables academic level, age, gender, public transport stops/stations proximities, modal travel time, and distance on the dependent variable that varies based on the model. These dependent variables are whether someone has a parking permit, public transportation pass, bike registration, and whether a respondent is multimodal. As a result, binary and multinomial logistic regressions have been utilized to analyze to what extent these aforementioned independent variables have on the dependent variable. The binary logistic regression is a model where the dependent variable is binary and therefore has a dichotomous outcome, it can only take two values, 0 or 1 (King, 2008) For example, as will be highlighted, binary logistic regressions have been performed to find out what kind of campus attendees are more likely to have a parking permit as opposed to those that did not purchase one. To check the influence the multiple independent variables have on the travel behavior of an individual attending ASU, a simple logit model with a dependent variable of a parking permit (1) as opposed to those without a parking permit (0) which includes bike-only, PT-only, and bike-PT. Also, to find out which sociodemographic university groups intend to be more multimodal and have several documents (1) and who intends to be monomodal with one transport mode (0). These regressions have been run for single-use of alternative options but also for multimodal options where either the commuter permit or car, is included or for some individuals excluded.

In addition, multinomial logistic regressions have been executed as an extension of the binary logistic regression that allows for more than two categories of the dependent outcome variable (Starkweather & Moske, 2011). In this study, the multinomial logistic regression is used to find out what sociodemographic university groups have decided to register alternative transport options with the university, with a parking permit as the base outcome that shows the intention to alter the travel behavior more sustainably. For the multinomial logistic regression, the three transport modes together are organized as nominal variables where they have a value from one to three without having an order in the outcome that the parking or commuter permit (1) is better than a bike registration (2) or public transport pass (3).

8. Results

8.1 Travel modes and geographical patterns

Since Phoenix is a city with a relatively weak history of public transport use, developed around car usage, alternative forms of transport are miles behind as stated by the introduction and theoretical framework. However, some developments can contribute to the desired transition towards the use of more environmental-friendly and sustainable forms of transport such as the recurring enhancement and improvement of existing public transport lines and bike lanes, as well as the options at the Parking & Transportation Services department of the university to register a bike or purchase a public transport pass. At the same time, parking is becoming more expensive and less accessible at the university campus through implemented policies reported in the Transportation Demand Management Playbook by ASU (2020). Even though the effects of promoting alternative transport and multimodality ASU and Tempe are not very visible, the main shares of travel modes are listed in Table 3.

Transport Modes	**Frequency**	**Percent**	**Cumulative %**
Parking Permit	19.371	83,81	83,81
Bike Registration	1.321	5,72	89,52
PT Pass	1.835	7,94	97,46
Parking & Bike	423	1,83	99,29
Parking & PT	93	0,40	99,69
Bike & PT	68	0,29	99,99
Parking, Bike & PT	3	0,01	100,00

Table 3: Totals and shares of parking permits, bike registrations, and public transport passes

The statistic that immediately stands out is the humongous portion of people that solely possess a parking permit with car transportation as the intended mode to commute to campus. The enormous share of 19.371 people, which translates to nearly 84%, indicates the dominance of the car embedded in the American travel culture. Besides, the other monomodal travel options come second and third as the most prominent travel modes with 1.835 (7,94%) people have purchased a public transport pass and 1.321 (5,72%) persons that decided to only register a bicycle at the university. In terms of multimodality, there are 587 (2,54%) individuals that have more than one permit or pass for transport modes which classify these university affiliates as multimodal. The bulk of these multimodal individuals has a parking permit and bike registration that allows them to travel vast distances by car while they are also able to bike around to and on campus due to the possession of a bicycle. This group consists of 423 (1,83%) individuals. The remaining groups that combine a parking permit and public transport pass, bike registration and public transport pass, or all previously mentioned transport modes combined, consist respectively of 93 (0,40%), 68 (0,29%), and 3 (0,01%) of all respondents that purchased single or multiple documents. Considering these multimodal numbers it can be concluded that public transport is not much considered a multimodal transport mode. The car performs well due to the high rate of car ownership and the bike reasonably well due to the short distance flexibility compared to public transport on or around campus. The combination of these two can also be the cause that the multimodal combination of a parking permit and bike registration is relatively popular among the multimodal combinations.

In a spatial or geographical aspect, these maximum travel times of thirty minutes per travel mode are visualized in Figure 5. Noticeable is the enormous area that is covered in red, indicating a large catchment area for car transport and immediately suggests the recurring theme of the dominance and dependency of the car among people and students that go to campus daily. Particularly, those living further away from Tempe are heavily dependent on the car to be able to go to university in a time maximum of half an hour which is in line with the statement of Crotti (2022) that students and staff living in less dense public transport network tend to use the car for longer distance trips to campus. Walking, displayed in green, is no match for the car in long distances but would be a fair alternative for those living in the dorms or extremely close to campus. At the same time, the bike as an alternative transport mode has the most potential. Due to the flexibility of the bicycle compared to public transport for short-haul commutes, people can travel in every direction without being subject to restrictions in the public transportation network or timetables while no expensive infrastructural investments are necessary to create a denser road network. Therefore, the bike could be an interesting alternative mode of travel as opposed to the car for those that live relatively close or some distance away from campus. Contrarily, the distance reachable by public transport in thirty minutes is relatively short as it does not compete with the car or outperform the bicycle. Since there is only one metro line and several buses that circulate the campus entailing that they do not reach far into other neighborhoods of the Phoenix

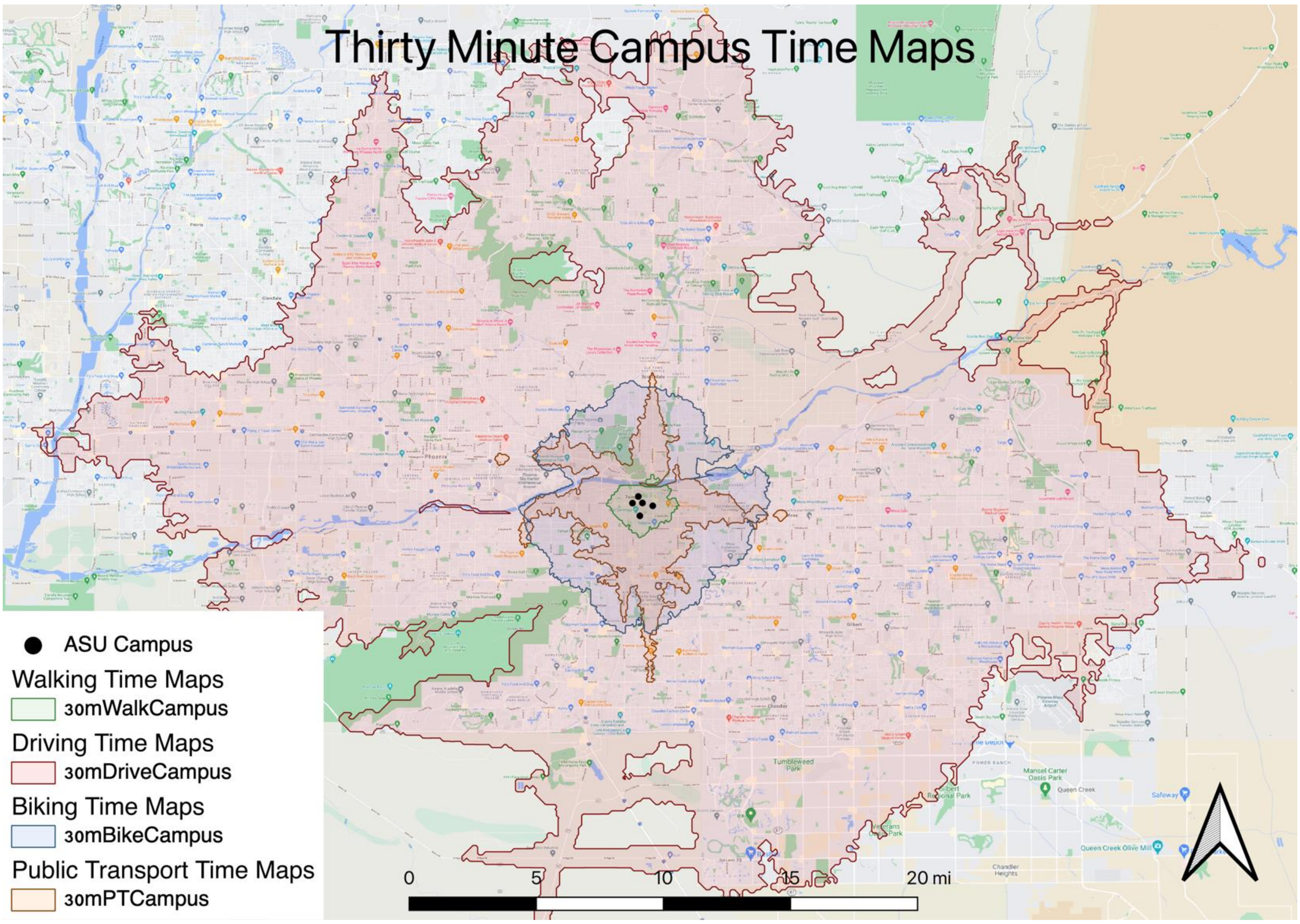

Figure 5: Time Isochrone per Transport Mode

Metropolitan Area, the public transport transit modes are bound to Tempe and some stops along the railway. However, there are changes in travel patterns and behavior that are expected to continue with infrastructural improvements and enhanced public transport services.

Furthermore, the same travel time buffers have been generated for all travel modes divided into 10-minute time intervals, as in Figure 5. This provides insight into the number of individuals that fall within or beyond a travel time interval. These distances and times are computed by using the road and public transport network that people take to go from home to campus and vice versa. Figure 6 depicts for all distance bands with 10-minute interval rings the number of addresses that intersect with these rings. The number allocated to the way of travel on the x-axis corresponds with the amount of time it takes for them to reach campus by that travel mode. For example, from all respondents, 1.126 people live within 20-30 minutes of biking to campus while respectively 1.142 and 7.995 live within 20-30 minutes by public transport or driving from campus. Since the car can bridge larger distances than a bike and public transport, the number of campus attendees within the red catchment areas or bands are substantially more than the alternative modes. Hence, the amount of campus attendees beyond 30 minutes is lower by car than the bike and public transport with their smaller 30-minute catchment areas. Interestingly, the number of people in the driving time bands grow when travel time, catchment area, and thus distance increases up to 30 minutes. When the travel time exceeds 30 minutes, there is a small decrease again. That concludes that most campus attendees live within a 30-minute drive of campus. Contrarily, for biking, there is a small decrease of campus attendees when the travel time increases to respectively 10-20 minutes and 20-30 minutes. The public transport travel time rings show that there is an increase from 0-10 minutes to 10-20 minutes that eventually decreases when travel time reaches the 20-30 minute interval ring. However, there is a sharp increase of campus attendees for both biking and public transport when it exceeds 30 minutes.

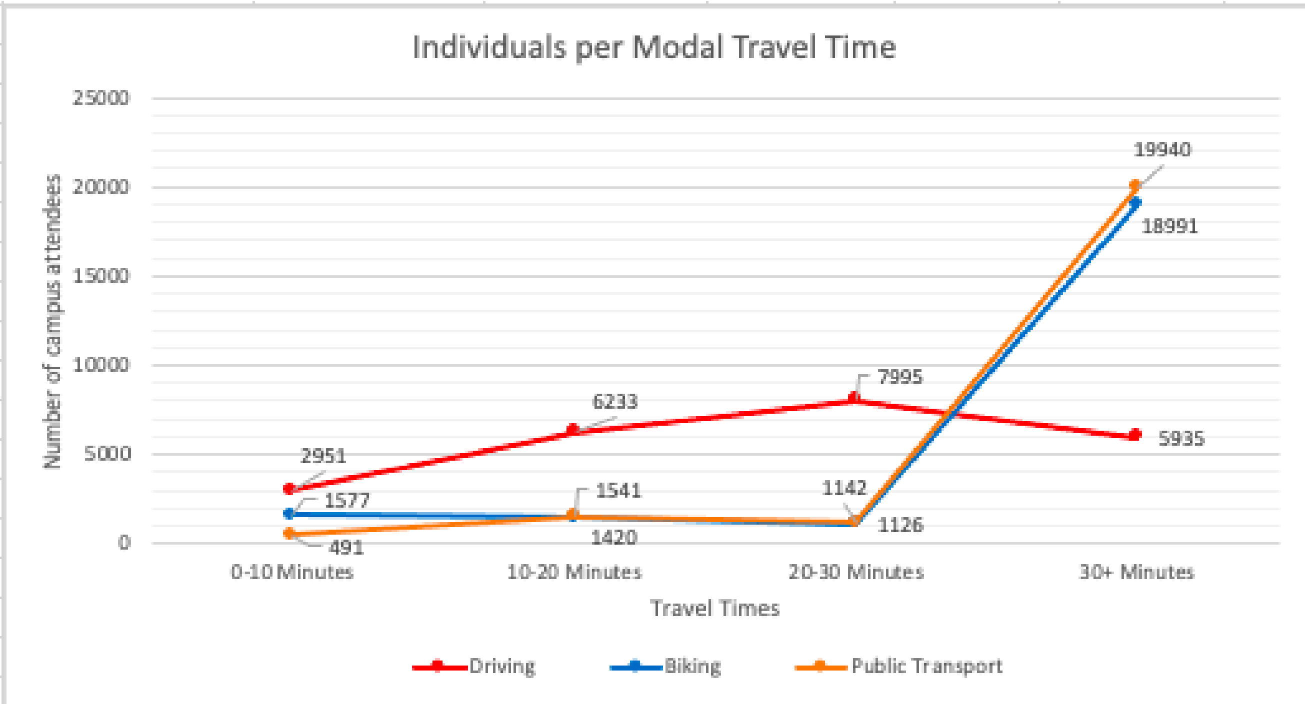

Figure 6: Individuals per Modal Travel Time

Linked to the maximum reachable distances per transport mode is the distribution of the permits, registrations, and passes within the region by people that attend Arizona State University. Figure 7 in Appendix A indicates that by far the majority of addresses are red, referring to parking permits. These permits are spread out across the entire Phoenix Metropolitan Area for which it does not matter if someone lives close to campus or further away. The bike registrations and public transport passes are equally distributed with most of the permits and passes owned by individuals that live in Tempe and along the Phoenix-Mesa railway. It can be deduced that a high percentage of the people in the PMA still intend to use the car, in particular further away from the campus.

The locations of individuals that have either one or multiple of the travel modes are also discussed in Figure 8abc which reveals the monomodal transport shares of individuals in the PMA census tracts that only possess a parking permit or public transport pass, or have a bike registered at the campus, which defines them as monomodal. Although census tracts do not

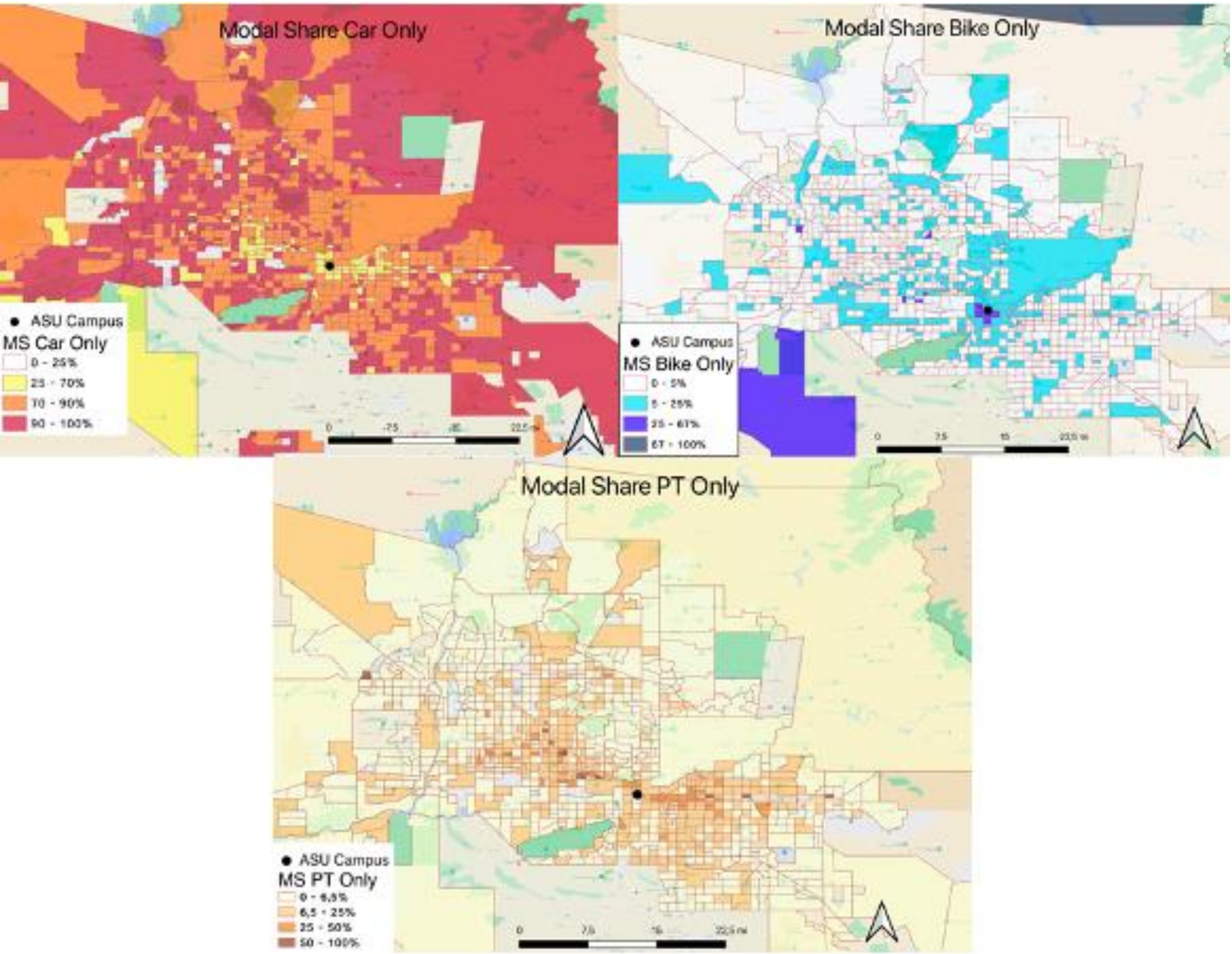

Figure 8abc: Monomodal Transport Shares (MS) encompass entire areas with information about the number of people living in it nor show details about actual behavior instead on who has what kind of permit, it is still insightful to show which areas people on average tend to have a lower share of parking permits and higher shares of alternative transportation registrations or passes.

These maps provide an overview of areas with a higher probability of alternative transportation usage, therefore the percentages of the numerous maps are not similar but computer-generated, based on natural breaks. The census tracts regarding the single-car use have many more areas with higher percentages from 70% or higher, especially further away from campus while the regions with a yellow shade are closely located to downtown Tempe as well as along the rail line that reaches west to Mesa and on the northeast side towards downtown Phoenix. These percentages of modal shares are correlated with the higher or darker shades in the single bike and public transport maps. The noticeable difference between these two maps is that the single bike use is more centered around downtown Tempe itself where campus attendees that live near campus are more likely to have their bike registered as opposed to those further away, accounting for 25-67% of all activity in these census tracts. Where the monomodal bike use aligns most of the lower degrees of car dependency around downtown Tempe, the single public transport use causes this for the census tracts adjacent to the metro valley rail line where the light orange tints are widespread through the Phoenix and Mesa city-neighborhoods and the darker orange and brown tints that represent 25-50% and 50-100% are mostly the census tracts where the rail line runs through. Therefore, it can be derived that individuals living closer to campus or public transport hubs are more tempted to opt for transport modes other than the car. Figure 8abc reinstates the dominance of the car in the context of the western states of America that has been widely discussed in the literature highlighted through other results where the number of individuals that purchased a parking permit for the car far exceeds the other mono- and multimodal options.

Figures 6 and 7 combined also demonstrate that many individuals have a bike registration or public transport pass that is far out of the 30-minute catchment areas of both transport modes. Therefore, it is unlikely that these permit and pass-holders travel toward campus by bike or take buses with multiple transfers that exceed half an hour. As a logical solution, these individuals might use multiple or a combination of transport modes. Possibly, people bring their bikes in the car and drop them off at the university where they can move freely due to the use of a bike on and around campus. The same holds for taking the bike in the metro or on a circulator bus where there is an opportunity to transport those to the university, park them and use the bike on and around campus. Another option is to have a parking permit and public transport pass to be able to drive long distances and commute with the metro and local buses to other areas without bringing the car and looking for parking space. Figure 9 in Appendix B highlights these multimodal individuals and where they are located in the PMA.

By analyzing the map with the addresses that have registered multiple permits or passes, it becomes evident that there are four different classifications. Firstly, there are the individuals that have a parking permit and bike registration showcased in red. These tend to be located randomly across the metropolitan area. However, there are some clusters visible with the biggest one located in Tempe around the university. This can be explained since it is the center of the city and hence that most people, including multimodal individuals, locate here. Moreover, there are some denser areas with people that have this combination but also some other combinations appear. However, the area around Scottsdale tends to be only multimodal with car and bike. An explanation for this pattern could be the lack of a direct train connection in the region that results in persons living here traveling solely by car and bike. Other places display several combinations of transport modes where some areas have multiple clusters and other places have singular multimodal individuals or outliers. Persons that possess a public transport pass and registered their bike are reasonably located mostly around campus and the valley metro rail line. However, there are also some outliers far away from campus without a direct public transport link to downtown Tempe. In terms of the car and public transport combination, the individuals are spread all over the PMA with a cluster around downtown Phoenix due to the metro line connection with downtown Tempe or ASU Campus. In three cases an individual has purchased all three permits and passes. Ideally, the three are perfectly lined up with the valley metro line and close to the university in a way that they fall within the 30-minute threshold for all transport modes.

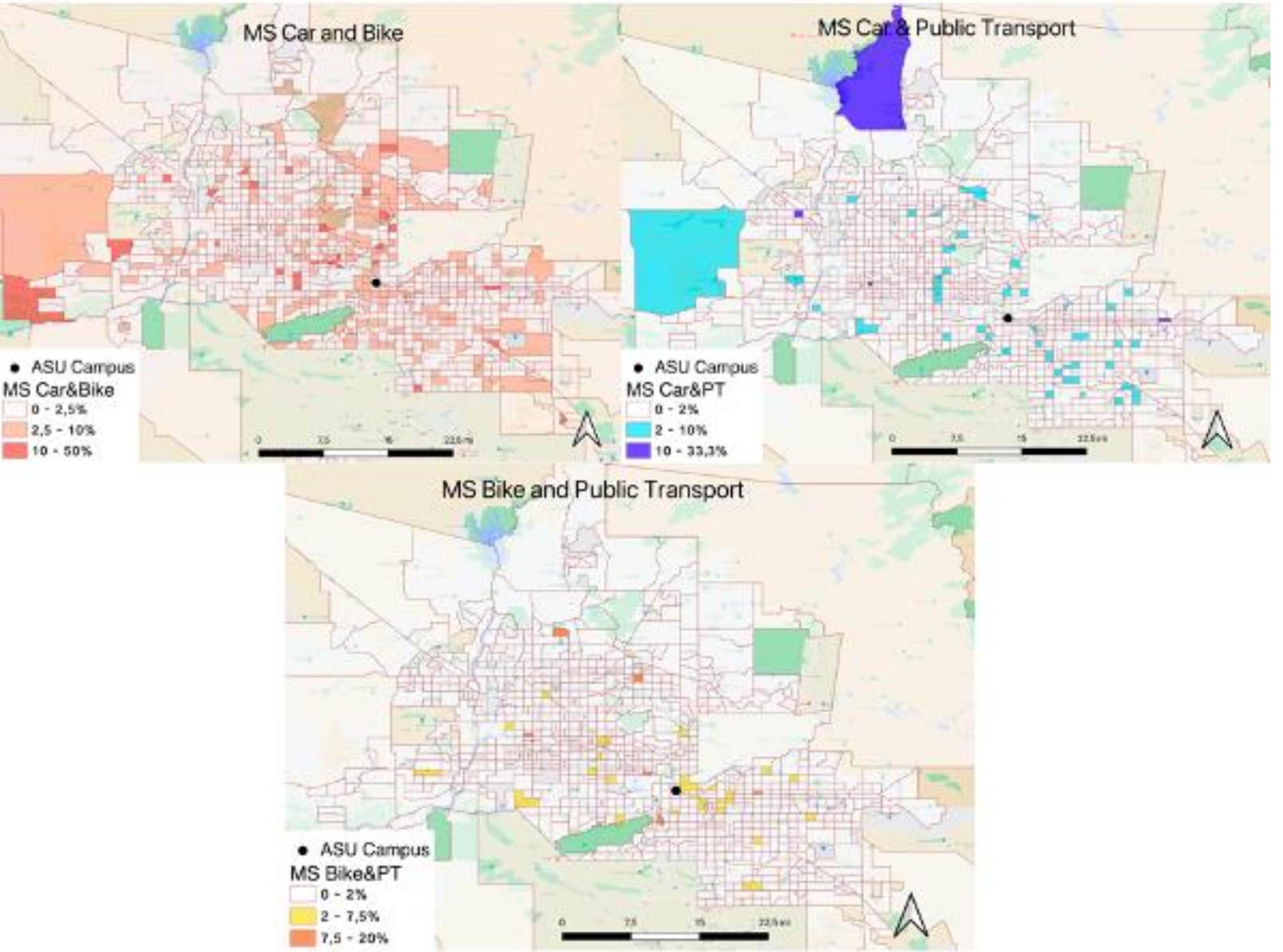

Figure 10abc: Multimodal Transport Shares (MS)

To provide better insights into the modal shares similar to the monomodal usages, the same modal transport share analysis has been conducted with multimodal individuals rather than monomodal people. Subsequently, a multimodal transport share analysis has been run, shown in Figure 10abc below. Although the modal shares are extremely low and appear to be random at certain times, some clusters can be identified. It stands out that the highest shares of multimodality involve a car combination which fits in with the previous observations regarding car dependency. Campus attendees try to combine the car with the bike and in fewer cases with the PT pass. These alternative transport modes might explain the first-and-last mile option where the costs of parking can be disregarded. For the parking and bike combination, the highest shares can be found around the Tempe campus and in the north and northeast direction, of up to 50%, where there is no fast public transport alternative, which makes the car and bike logical options. The car and PT combination seems more random due to the lack of clusters and the widespread pattern of light blue census tracts although somewhere in the vicinity of campus. The lowest share of multimodality excludes the car. There are no census tracts where the bike-public transport combination exceeds 20% of the modal share categories. However, there is a small cluster of yellow census tracts visible east of campus where individuals decided to have a bike registration and a public transport pass due to their proximity to campus as well as the metro valley rail line.

8.2 Characteristics of parking permit holders

To discover and inspect the characteristics of the campus attendees that possess a parking permit compared to those that do not own such a permit and can be described as a bike only, PT-only, or car-bike users, a simple logit model has been used, where the dependent variable of 1 = parking permit and 0 = no parking permit.

Binary Logistic Regression	Number of observations = 23.007
	LR chi^2 (18) = 2571,99
	Prob > chi^2 = 0,0000
Log Likelihood = -8029,223	Pseudo R^2 = 0,138
Significance levels	* < 0,1, ** < 0,05, *** <0,01

Parking Permit	**Coefficient**	**Std. Error**
Low Acad. Level	-0,263**	0,115
Medium Acad. Level	-0,760***	0,099
High Acad. Level	-1,340***	0,088
Age	0,015***	0,003
Female	0,265***	0,041
¼ Mile Bus	0,248**	0,096
¼ to ½ Mile Bus	0,137***	0,051
¼ Mile Train	-1,005***	0,096
¼ to ½ Mile Train	-0,905***	0,087
0-10 Min. Drive	-0,932***	0,191
10-20 Min. Drive	-0,764***	0,067
20-30 Min. Drive	-0,394***	0,064
0-10 Min. Bike	-0,456*	0,236
10-20 Min. Bike	-0,155	0,208
20-30 Min. Bike	-0,172*	0,103
0-10 Min. PT	-0,203	0,213
10-20 Min. PT	-0,692***	0,169
20-30 Min. PT	-0,152	0,135
Constant	2,675***	0,164

Table 4: Characteristics of parking permit holders

Interpreting the binary logistic regression in Table 4, it becomes clear that the portion of the output contains the results from a likelihood ratio chi-square test that indicates that the model containing the full set of predictors represents a significant improvement in fit relative to a null model where in this case LR Chi2(18) = 2571,99 with p<0.001. Therefore, it can be inferred that at least one population slope is not zero. According to Frost (2018), not all variables can be taken into account since there will be random noise, unexplainable interpersonal differences, or individual and psychological factors that are almost unmeasurable.

By observing the coefficients of the logit model there can be deducted that mainly depending on the positive or negative signs whether a certain group or proximity has a higher or lower tendency to purchase a parking permit or not. Therefore, it can be concluded that students (1) are less likely to possess a parking permit as opposed to non-students (0) since all academic categories have a negative sign. The academic level categories imply that when a student progresses during their studies from freshman to graduate, their probability of having a parking permit gradually reduces. Although low academic level has a weaker significancy, the negative value for the group indicates that freshmen and sophomore are less likely to have a parking permit as opposed to non-students. Due to the increasing coefficient from low to medium to high academic level, it appears that those students who have progressed through their academic program have a lower likelihood of purchasing a parking permit compared to faculty and staff. Over time it shows that students are less likely to have a parking permit. The age variable does not suggest that much changes in travel mode intentions regarding whether someone is more likely to purchases a parking permit when they are a year older with the coefficient being close to zero. In terms of gender differences, it appears that females (1) are more likely to have a parking permit compared to males (0) due to the positive coefficient correlated to the binary variable in favor of females. However, this outcome seem to be different throughout the literature in other countries, cities and regions. Other categorical variables such as the proximity of public transport appear to be positive for the bus stops while being negative for the train stations. Initially, that means that those living within either a quarter-mile or between a quarter to half a mile of a bus stop are more likely to have a parking permit than those living further than a half-mile away, which seems counterintuitive, possibly because bus stops are located all over the Phoenix metropolitan area. There are significantly fewer train stations which are located in closer proximity to the ASU Tempe campus and have a direct linkage. As a result, these train stations can have a higher impact on the decision-making process of students, faculty, and staff.

Moreover, this also suggests that the train is better able to attract people to use alternative transport than the bus. This relationship is confirmed by Crotti (2022) who claims that proximity to rail or metro stop is a striking factor in reducing car dependency and Shen et al. (2016) that find that the proximity to a metro stop has a significant positive association with the choice of rail-transit as primary commuting mode, decreasing car ownership. In terms of the different modal travel times and inherent distances toward campus, it seems that all variables are negative indicating that there is a higher probability that those within these travel time zones have a lower likelihood to purchase a parking permit as opposed to those living outside or beyond thirty minutes. However, there is a trend visible in driving, biking, and public transport times where the coefficients are decreasing for the rings that are related to longer travel distances which means that the intention to purchase a parking permit become larger when travel times and distances increase for alternative transport options. This observation holds for driving where the coefficients reduce gradually when travel time increases per ten minutes. For biking, this is also true since the coefficient for zero to ten minutes decreases from -0.453 to -0.176 for the twenty to thirty minute isochrone. For the public transport travel times, the relationship for zero ten minutes and twenty to thirty minutes is insignificant. Apparently, for public transport only medium travel times, between ten to twenty minutes, reduce the probability of having a parking permit. This means that for public transport, only travel times from ten to twenty minutes have a decreasing impact on the probability of someone purchasing a parking permit. Therefore, public transport only seem to be viable for the medium travel time distances.

8.3 Characteristics of alternative and multimodal transport users

When considering the multinomial logistic regression, visible in Table 5, it becomes clear that the portion of the output contains the results from a likelihood ratio chi-square test that indicates that the model containing the full set of predictors represents a significant improvement in fit relative to a null model where in this case LR Chi2(16) = 3077.10, p<0.001. Therefore, it can be inferred that at least one population slope is not zero.

Multinomial Logistic Regression	Number of observations = 22.420
	LR chi^2 (36) = 3493,06
	Prob > chi^2 = 0,000
Log Likelihood = -9500,038	Pseudo R^2 = 0,155
Significance levels	* < 0,1, ** < 0,05, *** <0,01

Single Mode	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Parking Permit	*Base outcome*			
Transport mode	**Bike Registration**		**PT Pass**	
Low Acad. Level	-1,614***	0,219	0,880***	0,153
Medium Acad. Level	0,412***	0,137	1,009***	0,137
High Acad. Level	1,403***	0,119	1,281***	0,125
Age	-0,010**	0,004	-0,020***	0,004
Female	-0,409***	0,063	-0,051***	0,051
¼ Mile Bus	-0,079	0,127	-0,367***	0,128
¼ to ½ Mile Bus	-0,163*	0,084	-0,106*	0,062
¼ Mile Train	-0,130	0,152	1,756***	0,112
¼ to ½ Mile Train	0,318***	0,122	1,351***	0,107
0-10 Min. Drive	0,793***	0,284	0,962***	0,243
10-20 Min. Drive	0,342***	0,106	1,031***	0,086
20-30 Min. Drive	-0,100	0,104	0,653***	0,082
0-10 Min. Bike	1,184***	0,344	-0,329	0,303
10-20 Min. Bike	0,188	0,313	0,092	0,263
20-30 Min. Bike	0,268*	0,159	0,081	0,132
0-10 Min. PT	0,566**	0,278	-0,052	0,298
10-20 Min. PT	0,570**	0,232	0,770***	0,230
20-30 Min. PT	0,218	0,191	0,119	0,178
Constant	-3,142***	0,226	-3,460***	0,229

Table 5: Multinomial logistic regression involving monomodal transport

Since the category 'Parking Permit' is assigned as the baseline outcome, there are no coefficients or tests related to that transport mode. However, the next section allows comparing the 'Bike Registration' and 'PT Pass' category with the 'Parking Permit' category which contributes in determining what independent variables significantly predict whether a person falls in the comparison groups as opposed to the baseline category. Starting with the category concerning the bike registration, the 'Low Academic Level' predictor is negative which infers that those that in the first two years of their education have a lower likelihood to have a bike registration than individuals classified as non-students while students that have progressed to more advanced levels of education and fall in the medium and high level categories show that they are more likely to have a bike registration relative to non-students. So, among the students, those individuals that have obtained a higher academic level prefer to use the bicycle over those that are less advanced in their education according to the ‘Low Academic Level’ variable being negative and significant while the ‘Medium Academic Level’ as well as the ‘High Academic Level’ categories are positive and significant with the latter having a larger coefficient. This implies that students who are in the early stages of their education tend to be more likely to have a parking permit than non-students as well as students that have progressed throughout their studies. The same trend holds for the likelihood to have a public transport pass. However, the main difference compared to the bike registration is that also the ‘Low Academic Level’ students have more intention to use public transport as opposed to faculty and staff. Since first years or freshmen are obliged to live on-campus, this outcome appears to be counterintuitive to the literature where those with on-campus housing tend to have more daily trips to campus by foot or bike (Wang et al., 2012; Limanond, 2011). Age is significant but has a coefficient close to zero that affects the intention for campus travel mode to a very low degree. Females have a negative and significant slope for both bike registration and public transport pass, although the latter is closer to zero and, as a result, more equal to males. The negative slope suggests that females have a greater probability of using the car, and a lower likelihood of traveling by bike or public transport, as compared to males in accordance to Zhan et al. (2016).

Lastly, proximities to public transport and campus affect the modal choice intention between car and bike as well as car and public transport. In terms of significant bus stop proximities, individuals that live within a quarter-mile and quarter to half a mile of a bus stop have a lower likelihood to have a public transport pass and appear to choose to commute by car. Those that live between a quarter to half a mile of a bus stop also tend to be less likely to have a bike registration and prefer to have a parking permit. The effect of living close to a train station appears to be positive for both the bike and public transport where individuals living within a quarter mile of a train station have more intention to utilize public transport while those within a quarter to half a mile are also more likely to have a bike registered beside owning a public transport pass relative to have a parking permit. The likelihood of having a public transport pass is larger than registering a bike considered the larger values of the two alternative transport options. Therefore, it seems that living nearby a bus stop does not have a positive effect on the use of alternative transportation to commute to campus while this effect is the other way around for living close to a train station that influences individuals to have their bike registered and possessing a public transport pass over the purchase of a parking permit and thus the intention to use alternative transport rather than being car-dependent.

The significant travel times buffers reveal that whenever someone lives in either the zero to ten and ten to twenty minute driving time intervals are more likely to have a bike registration or public transport pass than a parking permit while for the twenty to thirty minute driving interval this is only the case for the public transport pass compared to those that live beyond the thirty minute travel time isochrones. However, this has a decreasing coefficient when distance and time become larger. For the biking travel times to campus, only those that live within zero to ten and twenty to thirty minute are likely to register a bike over possessing a parking permit where coefficients are decreasing which shows that when someone lives closer to campus, individuals are more willing to use the bike. The public transport travel time zones indicate that for the zero to ten minute interval, individuals have more intention to have a bike registration but not a public transport pass, possibly due to the location very close to campus. The ten to twenty minute public transportation travel time to campus is significant for the bike registration and public transportation pass, disclosing that people living within this interval have a higher probability of a bike registration or owning a PT pass compared to the possession of a parking permit relative to those living outside these intervals.

To distinguish the people that are multimodal (1) from the monomodal (0) individuals, another logistic regression has been run to identify the main differences in characteristics between the two types of campus commuters. Through the use of a binary value for those that are classified as multimodal, or in possession of more than one permit or pass, the individuals that are using several transport modes to reach university are separated from those that only have one of the three included transport mode permits or passes.

Binary Logistic Regression	Number of observations = 23.007
	LR chi^2 (19) = 159,77
	Prob > chi^2 = 0,000
Log Likelihood = -2652,988	Pseudo R^2 = 0,292
Significance levels	* < 0,1, ** < 0,05, *** <0,01

Multimodal	**Coefficient**	**Std. Error**
Low Acad. Level	-0,747***	0,230
Medium Acad. Level	0,094	0,177
High Acad. Level	0,539***	0,158
Age	-0,004	0,005
Female	-0,302***	0,085
¼ Mile Bus	0,211	0,189
¼ to ½ Mile Bus	-0,019	0,102
¼ Mile Train	0,396*	0,214
¼ to ½ Mile Train	0,167	0,201
10 Min. Drive	-0,371	0,351
10-20 Min. Drive	0,389***	0,133
20-30 Min. Drive	0,167	0,127
10 Min. Bike	1,198***	0,453
10-20 Min. Bike	1,078***	0,371
20-30 Min. Bike	0,159	0,202
10 Min. PT	-0,987*	0,474
10-20 Min. PT	-0,358	0,340
20-30 Min. PT	-0,126	0,262
Constant	-3,718***	0,297

Table 6: Characteristics multimodal individuals

The binary logistic regression in Table 6 indicates that starting students are less likely while more advanced student are more likely to be multimodal compared to non-students. This outcome is contrary to the literature stating that young adults, in this case students, usually tend to be more multimodal (Buehler & Hamre, 2015). Faculty and staff in this dataset appears to be more multimodal. Moreover, the table addresses that, in line with use of alternative transportation, advanced students have more intention to be multimodal relative to their less advanced counterparts. Once again, the 'Low Academic Level' category is negative which indicates that students at the start of their education are less likely to be monomodal than the medium and high educated student. The gradual increase show that there is an upward trend in the level of multimodality among students. The gender differences state that females have a lower probability to use multiple transport modes in their campus commute than males in their journey. Proximities to public transport does not form an important factor in whether an individual is multimodal or not. Only when an individual lives within a quarter-mile of a train station their likelihood of being multimodal increases as opposed to those living beyond a quarter-mile. Furthermore, travel times have some significant values that relate to the multimodality phenomenon. It can be specified that those who have driving travel times between ten minutes to twenty minutes are more likely to be multimodal as opposed to individuals that have a longer driving time to campus. Individuals that are located within ten minutes or ten to twenty minutes biking from campus have a higher probability to be multimodal compared to those further away. For the public transport travel time, only the maximum ten minute interval is weakly significant entailing that people within a short public transport travel time are less likely to be multimodal, possibly relating to the proximity to campus and therefore no need to purchase multiple documents or make use of several transport modes. So, proximity to campus forms a useful predictor for whether an individual has intention to be multimodal. In particular those that have a medium driving, low to medium biking or short public transport travel time to the university campus.

A similar statistical approach as the monomodal travel intentions are executed to discover the characteristics of those that use the different multimodal combinations of transport, the multinomial logistic regression in Table 7 of Appendix C shows that many insignificant values imply that the coefficients cannot be taken into regard for explaining the variance from the model. However, some values provide further information about the differences among multimodal combinations relative to monomodal car usage or possession of the parking permit. In comparison to the baseline scenario of parking permit only, the multimodal and significant variables are mainly based on descriptive statistics and sometimes relate to the proximities and travel times of certain variables.

9. Discussion

To interpret and discuss the results as listed above, it is useful to unroll the main results and explain their meanings. Firstly, the travel modes and geographical patterns in the Phoenix Metropolitan Area are focused on car usage since there is a very high road density to very low public transport and railway density (Tayal et al., 2001). The fact that the entire city agglomeration is served by only one metro valley rail line, that goes in both directions, means that most people are forced to use the road network, either by private car, car-sharing, or bus (Horrox, 2021). As a result of the contrast in the car and public transport network, people tend to use the car over public transport which is convincingly displayed by the very large share of around 84% of campus affiliates that only possess a parking permit while small shares of these individuals have only a public transport pass (7,94%) or bike registration (5,72%). Also, the multimodal shares are still minimal. Moreover, the car as a transport mode has advantages over the bike and public transport in terms of distance that can be covered in a certain amount of time. The 30-minute catchment area of the car to and from campus covers a large part of the PMA while the 30-minute catchment areas of the bike and public transportation do cover Tempe but not far beyond. Public transportation just reaches adjacent suburbs of Scottsdale, Mesa, and South Tempe near Chandler (Valley Metro, 2021). Travel behavior and intention appear to be very car-dependent among students, faculty, and staff. Possible explanations are the lack of a well-integrated extensive public transport network with fast and high-quality public transport options that would allow for a bike-and-ride principle of 'active' transit to emerge and develop that decreases car dependency in favor of more bike commute and higher public transport ridership (Martens, 2004; Shannon et al., 2006). Transit-Oriented Development (TOD) could be a way to achieve these kinds of effects and results (Tsai, 2009).

Although the high levels of car dependency among university campus attendees throughout the entire Phoenix Metropolitan Area, there are some geographical locations and proximities that allow individuals to be more sustainable and use alternative or multimodal transportation. Particularly the modal shares depict and contribute to explaining where people have more intentions to use alternative transport modes. Relatively, the single-car shares are the lowest around the university campus and along the metro valley rail line. The modal shares of the bike are highest around campus because of the short distance to campus and the convenience to bike around on-campus, the car is not necessary for these individuals that live near or on-campus which automatically decreases car ownership close to the university campus. The significant difference stems from the unique context of the living areas with more sidewalks, bicycle paths, and bicycle parking facilities (Wang et al., 2012) that allows those living near or on-campus to walk and bike more in comparison with others further away (Ma, 2015). However, when living slightly further away, the single-car modal shares increase while single-bike modal shares decrease. The exception to this pattern is along the rail line where the single public transport modal share increase and single car modal shares remain relatively low. From Downtown Phoenix, through Downtown Tempe, to Mesa in the East, these modal shares are quite high since people that live on medium distances from campus have access to semi-fast public transport. The importance of proximity to rail-transit stops in reducing car dependency has also been identified by Shen et al. (2016). To a much lesser extent, the same effects can be seen in the multimodal combination shares. The positive correlation between public transportation use and proximity to train stations is confirmed in the logistic regression, again due to the access and proximity, that allow individuals to use these modes that, consequently, do not require them to have a parking permit. For the bus stops, there does not seem to be such a positive effect like the proximity to train stations which can be explained by the large number of bus stops that cover the entire area, as well as the slow pace of buses, the poorly integrated bus network and inaccuracy of time schedules and therefore proximity to rail, is more of a prerequisite to use public transport than to proximity to a bus stop (Crotti et al., 2022).

The effects of individual characteristics on car dependency, alternative transport use intention, and multimodality can be traced back to the results. The most striking outcome is that females have lower intentions to use the bike, alternative transport, or multimodal combinations than males. Although these results differ within the existing literature where in the context of the UCLA campus women tend to walk and bike more than men (Zhou, 2012. However, in the ASU Tempe context, safety concerns and weather conditions are possible reasons that women opt for the safety and convenience of the private car than being out on the bike or in public transport (Hull & O'Holleran, 2014). Also, higher educated students, classified as medium or high academic level, tend to have more intention to be sustainable through the higher likelihood of having a bike registration or public transport and the fact that they tend to be more multimodal as opposed to non-students. Contrarily, those classified as 'Low Academic Level', are less likely to use the bike, and have fewer intentions to be multimodal while being more likely to have a public transport pass compared to faculty and staff. However, other studies find the opposite results where undergraduates are more likely than graduates to use the bike or public transport (Zhou, 2012; Nguyen-Phuoc, 2018). These outcomes verify that the impact of individual characteristics is likely to be context related.

Since the research mostly investigates and describes the level of car dependency and alternative travel behavior in the case of the Tempe MUC it adds to the literature on campus and student travel behavior in a car-dependent setting in terms of modal transport behavior with a focus on geographical proximities and individual characteristics based upon exact and unique locational data. Consequently, these new insights could result in policies that could be introduced to improve and promote the advantages of other transport modes over the automobile which are specified in the conclusion. Besides, it could be used to identify and enhance the current public transport network by concluding what areas lack a direct or fast connection to these central hubs. Although the data provided by the Parking & Transit Services allow for many possibilities and has the potential to follow up on this research and study the travel patterns and behavior of those attending the Arizona State University Campus, there are also some points of discussion that include shortcomings in terms of general implications and use of the data in statistical analyses and geographical information systems.

First of all, the research acts as a starting point in the way that the address dataset is handled, used, and analyzed. Future research can be built upon this paper, either on the topic of alternative travel behavior by using the PTS data. However, there are some limitations due to the experimental use of the data without any reference to previous work involving the transport data. Changes over time after certain infrastructural changes or policy interventions were not able to be detected but could be an interesting option to consider for future research with the same dataset for a different year or period for the university. Since the implications of the dataset and locations of those that have purchased a parking permit, public transport pass, or registered their bike has been made insightful through the use of mapping, it would be doable to do a similar study to see whether the developments over time have altered the car dependency and popularity of other alternative transport modes throughout the Phoenix metropolitan area. A different shortcoming is the number of non-respondents or those that park at the campus or use the bike or public transport for their commutes to campus but do not possess a pass nor have a bike registration. These campus attendees are not included in the dataset while being a substantial share of the travel patterns towards campus. Therefore, a large number of people are not included in the dataset which makes it incomplete and impossible to gain insight into all campus' travel behavior in the analyses for the research. However, since the total number of 23.114 respondents is significantly large, the research on university campus travel behavior provides plenty of information and data to establish relationships between covariates that have been linked with geographic factors such as distance and travel time.

As far as technicalities go, there were some considerations in the placement of destination points when running analyses in QGIS, in particular for public transport, where a slight change of destination point locations gave different results in catchment areas, travel times, and public transport lines involved. Since driving and biking are relatively more flexible compared to public transport, the exact location of the destination point does not matter that much. A slightly wrong-placed point adds a maximum of a minute, however, for public transport this is important to consider as some buses do not reach a particular point, street, or area which could risk leaving out some important public transport lines in the data that serves a catchment area in the metropolitan area. Nevertheless, there might still be room for improvement to demarcate and include the ASU campus sites beside downtown Tempe. Another shortcoming is the lack of explaining independent variables that could be incorporated through the enhancement of the model by adding extra independent variables such as income, race, political preference, and more. Other studies already have investigated the effects of several of these variables on car dependency. However, just like gender and academic level in this research, there is no clear line in the mentioned variables for example family income is significant in the study by Nguyen-Phuoc (2018), while insignificant for Zhan et al. (2016) which emphasizes that the effect of a variable can differ depending on the environment. Due to the lack of these other variables in the individual respondents' data, this was not possible but might be collected and used in follow-up studies at the Arizona State University or other (American) Metropolitan University Campuses.

10. Conclusion

To answer the main research question: 'What is the role of proximity to campus and public transport and the effect of individual characteristics on car dependency and alternative transport mode use intentions for student, faculty, and staff travel to the Arizona State University's Tempe campus in the Phoenix Metropolitan Area?', the results will be briefly discussed clearly and comprehensible. The level of car dependency is primarily reflected in the number of parking permits that are being purchased by individuals at ASU, either solo or in combination with other documents such as a bike registration or public transport pass. 19.371 (83,81%) of all campus respondents in the dataset only possess a parking permit, while 423 (1,83%) individuals have a parking permit in combination with a bike registration and 93 (0,40%) together with a public transport pass. Also, solely 3 (0,01%) persons acquired all three different documents that are registered in the PTS system. All these car or parking permit owners add up to a share of 19.887 out of 23.114 which translates to 86,04% of the total respondents, highlighting the car dependence that is firmly embedded in the American culture, mindset, and habits of the inhabitants in the Phoenix metropolitan area. Therefore, after extensive research using the dataset from the ASU Parking & Transit Services, it can be concluded that the car-dependency among campus attendees, including students and non-students, is high, likely due to the historical design of the city that has been constructed revolving around the car due to the lower settlement densities and vast distances, while there was less attention for the public transport network in the western states of America including Arizona and thus the Phoenix Metropolitan Area. In particular, the campus attendees that live further away have more intention to use the car. Individuals that live near or on-campus tend to use the bike more while those that live along the metro valley rail line or close to a train station have the intention to use public transport over the car. Most of the multimodal combinations remain influenced by car usage which is widespread throughout the city landscape due to the vast distances the car can drive.

Besides, those that are more likely to use alternative or multimodal modes of transport live often near a train stop or within twenty minutes of biking or using public transport. There are also groups of campus attendees with descriptive and locational characteristics that can be regarded as more sustainable commuters as opposed to others. In terms of whether someone has a parking permit or not, the regressions point out that differences in academic level explain variations between students and non-students, as well as among student progressions. More advanced students that belong to the 'Medium Academic Level' and 'High Academic Level' are less likely to have a parking permit as opposed to the non-student reference category while students in the 'Low Academic Level' category appear to be way more car dependent compared to the non-student group. In all regressions there is a distinct trend visible between students and non-students where relatively new students have more intentions to have a parking permit, hence being more car dependent than non-students. However, the intention to use the car gradually declines when students progress through their education with a gradually increasing trend in the coefficients from 'Low Academic Level' to 'Medium Academic Level' and eventually 'High Academic Level', stating that students become more multimodal and have more intention to use alternative transport than non-students throughout their education. Also, females have more intention to purchase a parking permit and use the car to commute to campus as opposed to males. Individuals within half a mile of a bus stop are more likely to purchase a parking permit. Next, individuals living within half a mile of a train station or living within 30-minute driving, biking, or public transport travel time off-campus tend to have no parking permit as opposed to those living further away.

For monomodal transport usage, some groups tend to only have a bike registered or possess a public transport pass without purchasing a parking permit, which appears to make them more sustainable through the use of alternative transportation options. The sociodemographic university groups that are more likely to only have a bike registration are non-students, highly educated, males, a quarter to half-mile proximity to train station, and those living within twenty-minute driving and public transport distance as well as in ten or twenty to thirty-minute bike ride to campus. Groups that are more likely to have a PT pass than a parking permit are students, higher educated, males, within half a mile train station, within thirty-minute driving distance, and within 10-20 minute public transport travel time. In terms of multimodality, individuals that have the bike-PT combination are specifically clustered in Tempe downtown and along the metro valley rail line. The sociodemographic and university groups that tend to be more multimodal are non-students, higher educated, males, and those living within a ten to thirty driving or twenty-minute biking distance.

The alternative or multimodal travel behavior is not significantly visible in contrast with the large numbers of parking permits. Therefore, behavioral and policy changes, infrastructural improvements, and time are needed in a region where the biking and public transport network is still at the roots as expected in the hypothesis. On many points, the predicted outcomes were verified. However, there were also some mentionable differences. For example, lower educated individuals tend to be more car-dependent compared to lower educated and also that non-students are less likely to have a parking permit as opposed to a student in general. Although there is potential for change through the construction and development of new alternative transport infrastructure and willingness to travel by other transport modes than monomodal car use, which can be deducted from the census tracts patterns for modal shares throughout the PMA.

The main problem in the Phoenix Metropolitan Area, however, is the lack of fast and easily accessible public transport options (Martens, 2004). Currently, there is an alternative transport network centered around slow and low-quality local buses and trams while fast and high-quality intercity buses and trains would attract more people and change the mindset of those that are car-dependent, switching to more active and sustainable modes of transport. The construction of the Tempe streetcar is another example of a low-impact infrastructure investment that does not serve the greater area but only some streets adjacent to campus which expectedly will not be used by a large extent of the people, instead a second metro valley rail line from north to south would have been a better investment, prioritizing those that need public transport options that would contribute in decreasing car dependency while increasing public transport ridership as well as multimodality through the bike-and-ride principle. Also, policies focusing on disincentives to use the car through parking pricing (Tezcan, 2013; Danaf, 2014) and incentives to use alternative transport through transit fare subsidies would be recommended policy strategies (Proulx et al., 2014) that start with well-thought and adequate transit-oriented development

(TOD) that targets the entire Phoenix Metropolitan Area, in particular, university commuters that live far away and beyond the 30-minute travel time (Tsai, 2009). This is particularly addressed in the overarching literature but could also increase the importance of local buses due to the extra costs of using the car as highlighted by Whalen et al. (2013). Moreover, higher quality and faster public transportation could encourage more females to consider public transport as a way to commute to and from campus which is at this moment in time the main group that tends to have a parking permit. At last, improving bike lanes in density, safety, and visibility can encourage people to use the bike more to and around campus as this is an incentive to switch to active travel behavior where enhanced cycling networks appear to hold the particular promise in reducing car dependency and altering transport demand patterns (Shannon et al., 2016). In the research, this is confirmed by those areas closer to campus with higher sidewalk and bicycle path density that have lower car-dependency levels.

All in all, from the research analysis point of view to my personal experiences, the travel behavior and patterns in the Phoenix Metropolitan Area and Tempe are incomparable to the European and Dutch contexts with the main differences in the campus travel mode of the car against the bike and public transport. However, many things can be learned and possibly adopted to create a better, safer, and more sustainable transport environment in the Phoenix Metropolitan Area. As an international without previous knowledge or a car who has lived at two different addresses within an hour walking distance from the university campus, it is hard to commute to campus but not impossible. However, if American campus commuters take the time and effort to understand the public transport network like I did at my first address. Or make a small investment for a bike, like I did at my second address with worse public transport, they already contribute to a more sustainable city on the road to become less car-dependent.

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12. Appendices

12.1 Appendix A: Location of individuals' parking permits, registrations, and passes

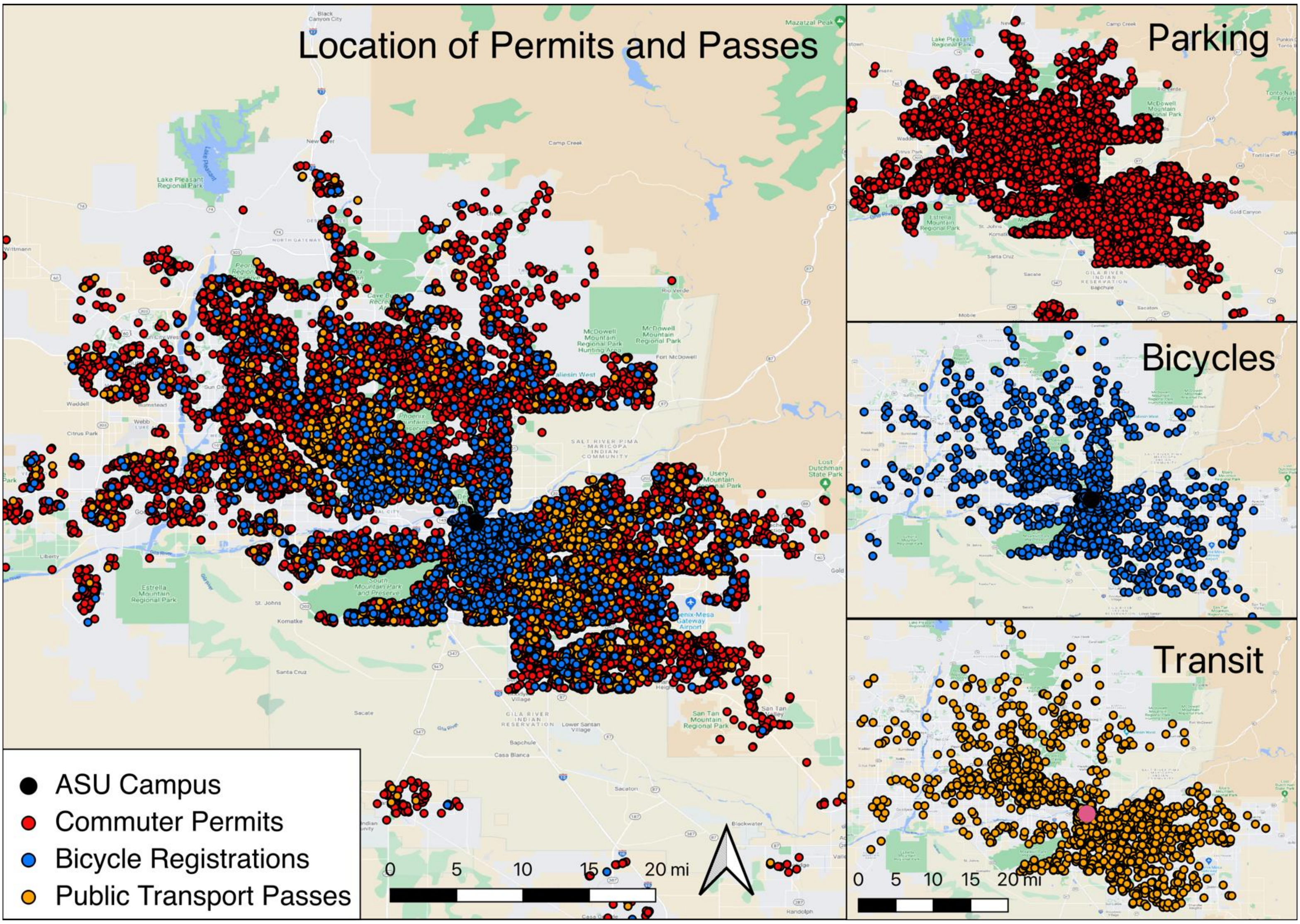

Figure 7: Location of Permits, Registrations & Passes

12.2 Appendix B: Location of Multimodal individuals

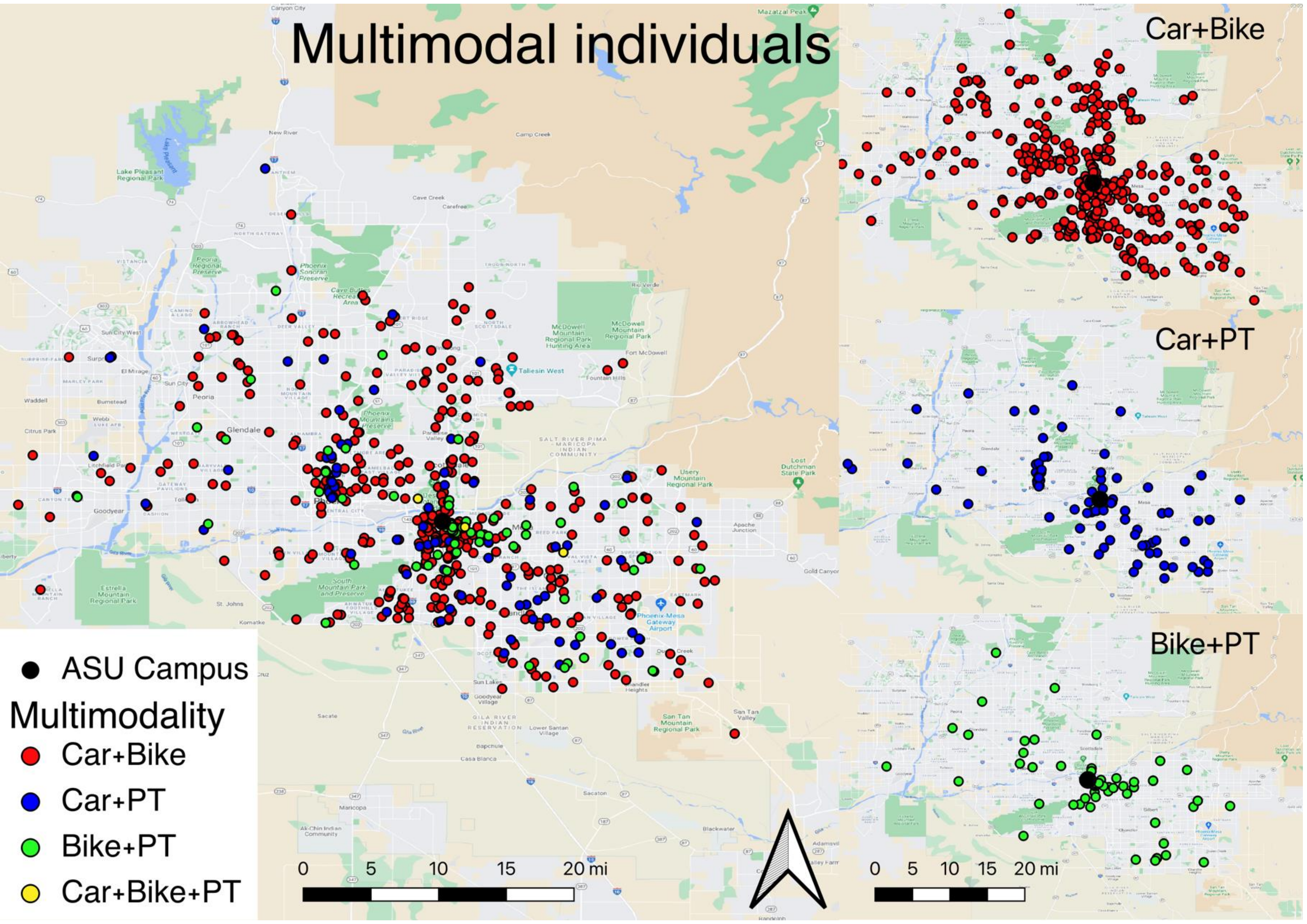

Figure 9: Location and Categorization of Multimodal Individuals

12.3 Appendix C: MLR Multimodal Categories

Multinomial Logistic Regression	Number of observations = 23.007
	LR chi2 (108) = 3803,80
	Prob > chi2 = 0,000
Log Likelihood = -12549,889	Pseudo R2 = 0,132
Significance levels	* < 0,1, ** < 0,05, *** <0,01

Multimodal	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**	**Coefficient**	**Std. Error**
Parking Permit	*Base outcome*							
Transport mode	**Parking & Bike**		**Parking & PT**		**Bike & PT**		**Parking, Bike & PT**	
Low Acad. Level	-1,453***	0,296	1,131*	0,516	-0,558	0,847	-18,809	3051,483
Medium Acad. Level	0,350	0,199	0,444	0,470	0,997	0,655	-3,130	1,928
High Acad. Level	0,645***	0,178	1,020*	0,411	1,655***	0,592	-1,695	1,665
Age	-0,009	0,006	0,016	0,013	-0,023	0,020	-0,168	0,126
Female	-0,336***	0,100	-0,240	0,210	-0,658**	0,255	-0,739	1,251
¼ Mile Bus	0,241	0,226	0,083	0,522	-0,188	0,514	-14,134	1599,163
¼ to ½ Mile Bus	0,055	0,118	-0,222	0,264	-0,450	0,335	1,324	1,401
¼ Mile Train	-0,109	0,340	2,316***	0,383	1,230**	0,515	1,224	3,200
¼ to ½ Mile Train	0,155	0,254	1,193**	0,468	1,251***	0,456	-13,426	3093,622
0-10 Min. Drive	-0,382	0,400	0,020	1,158	-0,693	1,053	34,002	35294,37
10-20 Min. Drive	0,467***	0,153	0,398	0,335	0,326	0,470	20,981	35268,99
20-30 Min. Drive	0,144	0,147	0,209	0,310	0,517	0,408	0,216	43481,10
0-10 Min. Bike	1,836***	0,539	-1,403	1,410	1,991*	1,165	-24,745	3783,095
10-20 Min. Bike	1,012**	0,431	-0,267	1,238	2,481**	1,000	-9,113	1338,435
20-30 Min. Bike	-0,160	0,257	0,462	0,491	1,635***	0,490	-23,135	1939,776
0-10 Min. PT	-1,369**	0,618	0,878	1,314	-0,245	1,117	-2,021	36723,93
10-20 Min. PT	-0,302	0,417	1,153	1,025	0,175	0,871	-1,801	3,473
20-30 Min. PT	0,155	0,315	-0,094	0,711	-1,373*	0,783	-16,641	1796,045
Constant	-3,706***	0,337	-6,692***	0,760	-6,173***	1,070	-22,757	35268,99

Table 7: Multinomial logit model all multimodal combinations