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Determinants of Transport Mode Choice in the Austrian Province of Vorarlberg

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1 ABSTRACT

Almost all countries have policies to reduce the usage of private car and to raise the usage of public transport by reducing the distance of travel, increasing density, increasing the access to public transport and so on. All of these developments are effective strategies for reducing car dependency. The factors which determine travel behavior of people are relatively broad. Besides the factors such as urban form and transport infrastructure, one important factor is the personal attribute which has a strong effect on the modal choice. By better understanding of this fact, the settlement development and transport planning can be integrated in a more sustainable way. This paper addresses the influence of socio-demographic and geographic factors on the selection of mode choice in the Austrian province of Vorarlberg. We used the mobility survey "Österreich unterwegs" from 2014 and applied bivariate and multinomial logit model in order to quantify the influence of factors on mode selection. Result show that the household size, age, gender, income and motivation of travel have a significant effect on the modal choice.

Keywords: Sociodemography, Transport policy, Logit model, Alpine space, Modal choice

2 INTRODUCTION

Urban structure and mobility appear to be inextricably linked (Hickman, et al., 2009). Urban transport is more complex than other transport sectors; it should integrate different transport systems with spatial development. The interrelation between urban structure and travel is complex and sustainable cities create balance between physical dimension, urban form and transport, social dimensions, people and their requirements (Banister, 2011).

The province of Vorarlberg is situated in Austria's alpine west and borders Switzerland, Liechtenstein and Germany. It is an economically vibrant region with a steadily growing population. Most of the homes and work places are concentrated in the Alpine Rhine Valley. In the last 50 years, this part of the region has gone through an intense urbanization process, and is now characterized in many parts by urban sprawl (Zech & Gassner, 2006), and clear spatial boundaries of the build-up areas are missing (Hoffmann-Bohner, 2013). This leads to a car-dependent lifestyle and high transport-related carbon emissions and one of the most important issues in this region is the link of settlement and transport planning. A better understanding of the factors influencing mode choice in the region is needed to develop strategies for a more sustainable regional mobility.

The aim of this article is to evaluate the role of spatial indicators such as population density, accessibility to public transport, type of area as well as gender, age and employment on the transportation modal choice. This research mainly focuses on the relation between urban structure and travel mode choice. We want to highlight to what extend spatial indicators can change and touch the travel behavior. The first research question relates to explore the factors which affect the modal choice in this region. We consider three main transportation modes including car (PKW), public transport (PT) and bike or walk (W-B). The second research question concerns in the magnitude of the impact of these factors on modal choice.

According on the utility theory, we assumed that individual travelers prefer to choose modes of transport that has higher utility for them e.g. residences prefer to choose car in long distance travel to reduce travel time. If each factor considered by the individual are known to the analyst for every alternative, modal choice could be developed to predict with certainty every choice (Mcfadden, 1974)

We first summarize the literature on modal choice in section 2. In section 3, we apply a descriptive statistical analysis and multinomial logit model to describe and estimate the effect of different factors on modal share. The results are discussed in section 4 which is followed by conclusion.

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2.1 Literature Review

This section briefly summarizes some main features of modal choice from different decades. The most extensive cited review on determinant of modal choice is done by (De Witte, et al., 2013). He distinguished three major approaches in determining of modal choice which are a rationalist approach, a socio-geographical approach and a socio-psychological approach (De Witte, et al., 2013). In the rationalist approach travelers take decision based on the utility maximization and individual will selects rational from the alternatives base on his preferences. As mentioned above this theory published by Mcfadden and after that is used by many authors e.g. Shen 2009, Buehler 2011 and Arbués 2015.

The socio-geographical approach describes two set of indicators; socio-demographic indicators and spatial indicators. The socio-demographic indicators describe the personal attributes of the travelers as well as their social communications. These factors are age, gender, education, employment, income, household size, car ownership and driver license (De Witte, et al., 2013). Internationally, income and automobile ownership are good predictors for mode choice. In industrialized countries where most households have a car, also demographic variables such as age, gender and life style are highly relevant for mode choice (De Witte, et al., 2013).

According to (Axhausen & Simma, 2003) elderly people prefer to use more public transport and young generation does not have resources to own car. But (Schwanen, et al., 2001) reported that age is not much influence factor on modal choice, rather than car ownership is more significant on the selection of mode and he also studied that men are more likely to use car while women are more dependent on public transport.

Income highly relates to the social status and higher educated people are more likely to have higher income levels and as the result they are more prone to use the car to go to work (De Witte, et al., 2013). In contrast, (Schwanen, et al., 2001) states that higher educated people use public transport more frequently than the car.

The spatial factor indicates the geographical characters of travel in which the trip and modal choice takes place such as density, type of area, access to public transport and distance to achieve destinations (De Witte, et al., 2013).

A famous and frequently quoted study on the impact of density on travel demand is that by Newman and Kenworthy (Newman & Kenworthy, 1989) on energy use by cars in 32 large cities in Europe, the US, Australia, Asia and Canada. He and Laube reported in 1996 that the balance between public transport use and private transport use is strongly related to urban density and high densities area may be expected to reduce the need to travel long distances for all modes and expands the usage of public transport and walking and cycling (Kenworthy & Laube, 1996). Furthermore, distance impacts the modal choice by increasing the preference to faster travel.

According to Axhausen & Simma income and automobile ownership are internationally good predictors for mode choice, but in industrialized countries where most households have a car, also demographic variables such as age, gender and life style are highly relevant for mode choice (Axhausen & Simma, 2003).

The distance of residential area from city center and job location has strong influence on modal split as well as living close to jobs will reduce the vehicle miles traveled (Gordon & Richardson, 1989) and increase the potential of bike and walking modes. In the other way if residence areas are in far distance from cities, increase the priority to use rapid modes of transport to reduce travel time, thus these residents often use individual motorized transport modes as the best variable transport.

In the line with previous research, we expect that modal choice is influenced by combination of socio-demographic characteristics and geographical factors. Our result provide evidence that the socio-demographic factors such as gender, gender, income, car ownership and reason of travel have a stronger effect on modal choice than the geographical factors.

3 ANALYSIS

3.1 Data sources and variables

3.1.1 Data description

Data for this study are derived from mobility survey questionnaire of "Österreich unterwegs" in 2014. The survey includes questions on four main parts which are household demographics, personal information of travelers, vehicle information and traveling attributes such as mode choice, duration, and distance.

For preparing the data, appropriate answers for each variable are selected and irrelevant answers are skipped from data set. For instance, observations within the category of no answer are deleted. After skipping the irrelevant answers, the analyzed dataset includes 6214 trip observations.

The analyzed survey consists of three separated SPSS files which all have the same column codes. For running the bivariate and multinomial model these tables are joined together based on each specific trip to have overview about all characters of each trip.

3.1.2 Descriptive statistics

Table 1 provides a detailed description of the characteristics of participants in the questionnaire. Interviewers that participate in the survey cover 21% of all households in the Vorarlberg. A comparison of age profiles which is illustrated in Table 1 shows that majority of participants are between 44 to 64 years old by 44%.

Table 1 shows the cumulative percent of households that majority of the families contain two or four persons. Among all participants, almost 75% of them have anytime access to car and almost 19% of them have opportunity to use car as transportation mode.

In figure 1, we conduct a descriptive cross tabulation of car ownership by different household sizes. Results show a dominant reliance on car for all households regardless of the household size. Besides, an increase in household size results in lower number of households without cars decreases and higher number of car ownership.

The cross tabulation of gender and modal choice is shown in figure 2. Results show that males are more dependent on car mode, while women prefer to use more bike and walking modes.

The travel motive is an important factor that highly effects on the mode choice. In this paper four types of travel reasons including business, education, shopping and entertainment are considered. Table 1 shows that the majority of travels belong to pleasure purpose by 47.1%, whereas just 4% of travels are made for education reason and 34% of travels for work reason. Besides, 65% of business travels are done by men and 35% by women, while 53% of education travels are done by women and 47% by men.

As shown in figure 3 the trips by education reason rely heavily on public transport while business trips as well as pleasure and shopping travels are done mostly by car. One assumption for high usage of public transport for education travel can be that the education travels are done by young age category, which most of them do not possess a valid driving license and may not own a car compared to those in the higher age groups. The usage of public transport in other types of travel reasons is very low, considering the fact in this region urban structure and transport planning are not successfully interlink to each other.

Figure 4 presents the percentage of modal share for shopping and pleasure travels in different age categories. As mentioned, 62 % of travels have pleasure and shopping reasons. More than 60% of these trips rely on car at the all age categories. Young and old participants, both are more interested to use PT and Walk or Bike as transportation mode than middle ages. One assumption for this can be that the students have less access to car ownership and senior prefer to choose less stressful transport modes such as walking or bike. For instance, the usage of public transport for young participants is more than other age categories by 16%. However, increases in the age results decreasing the usage of public transport.

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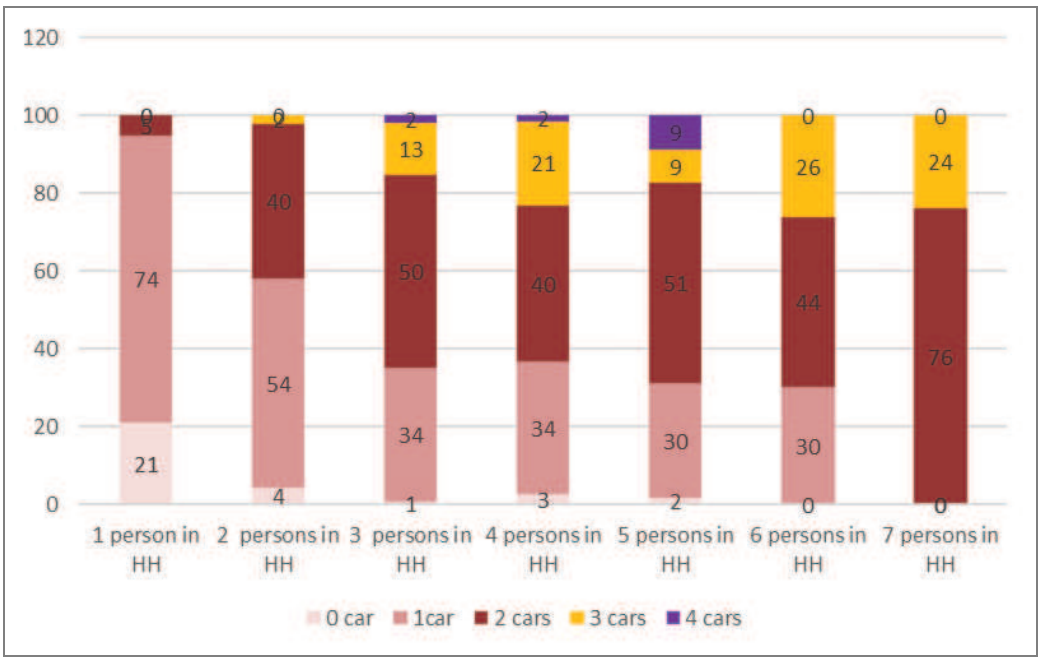

Fig 1: Percentage of number of car ownership by Household

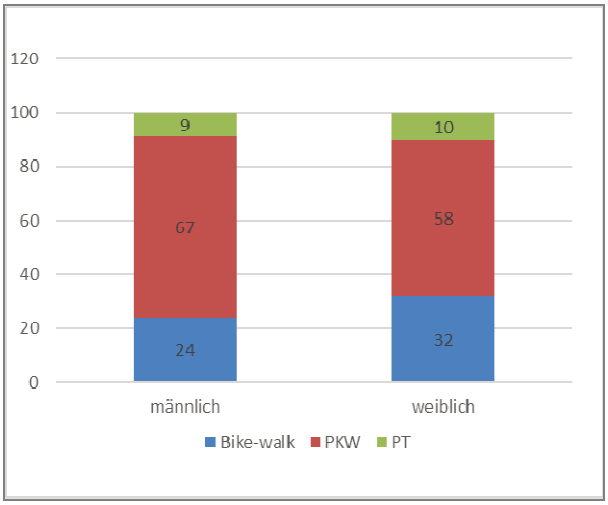

Fig. 2: percentage of modal share by gender

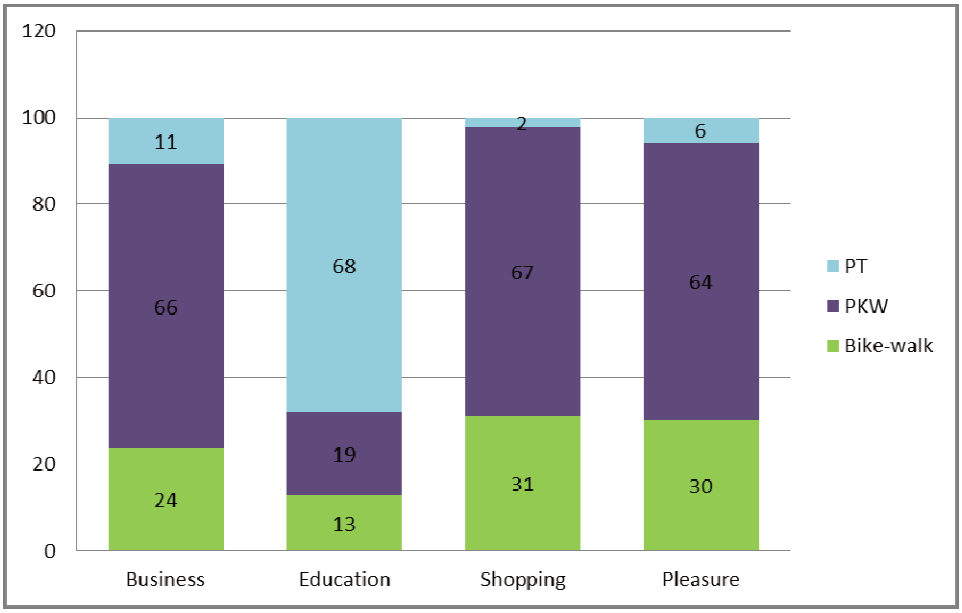

Fig 3: Percentage of modal share by reasons of travels

Income has a positive correlation with car ownership and higher income leads to an increase the probability of car usage. In this study five level of income including very low “less than 750 euro”, low “between 751 to 1250 euro”, middle “between 1250 to 1750 euro” and high income “1751 to 2250 euro” and very high incomes which is up than 2251 euro per month are considered. As shown in table 1 the level of income for 49% of participants is high, while 35% of participants have middle income and just 3% have low and very low income. Figure 5 shows that an increase in the level of income leads to a decrease the usage of public transport. For example, participants with very low income use public transport by 22%, however travelers with very high level of income prefer to choose public transport just by 7%. Besides, an increase in level of incomes results in a higher preference to choose biking or walking as transportation modes.

Another important factor in modal choice is the travel distance. Table 1 shows that 19% of travels were shorter than 1 km, 35% of travels between 1 to 5 km, 32% among 5 to 20 km, 12% among 20 to 50 km and only 2% longer than 50 km. Indeed, longer trips constitute a higher share of car choice. One reason for using more cars can be the long average trip distance and not suitable access to public transport. Figure 6 illustrates that 73% of short trips are made by walk or Bike and an increase in distance of travels results in an escalation in usage of faster travel modes e.g. car and public transport and less usage of bike or walking.

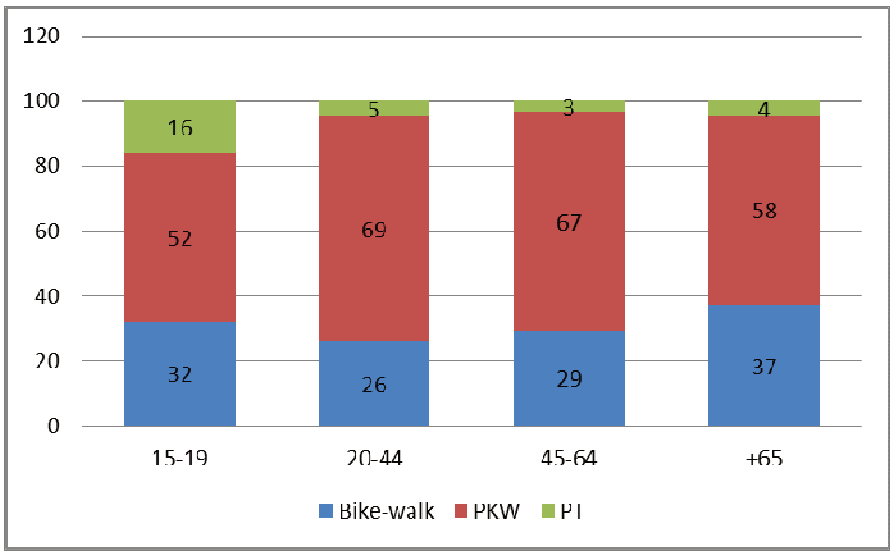

Fig 4: Percentage of modal share for Pleasure and Shopping reasons by age category

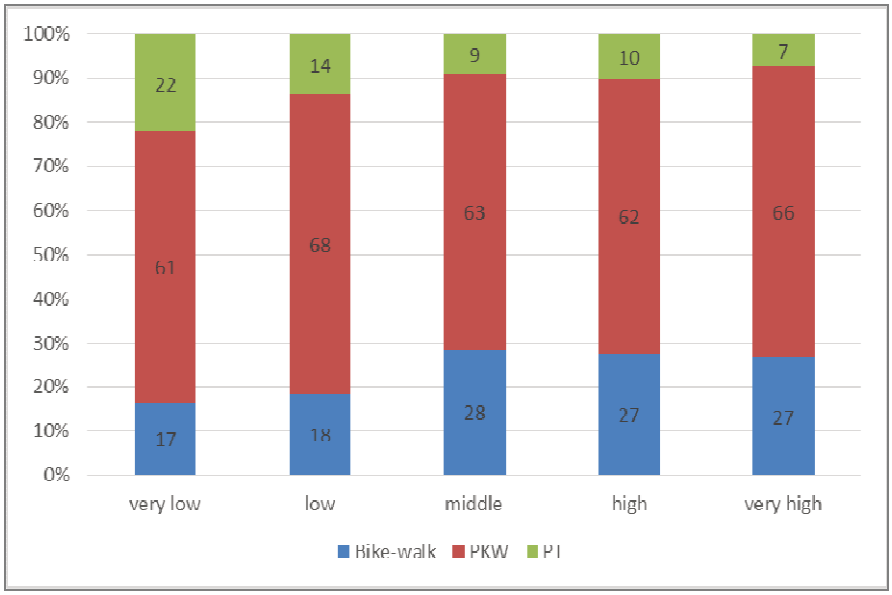

Fig 5: Percentage of modal share by level of incomes

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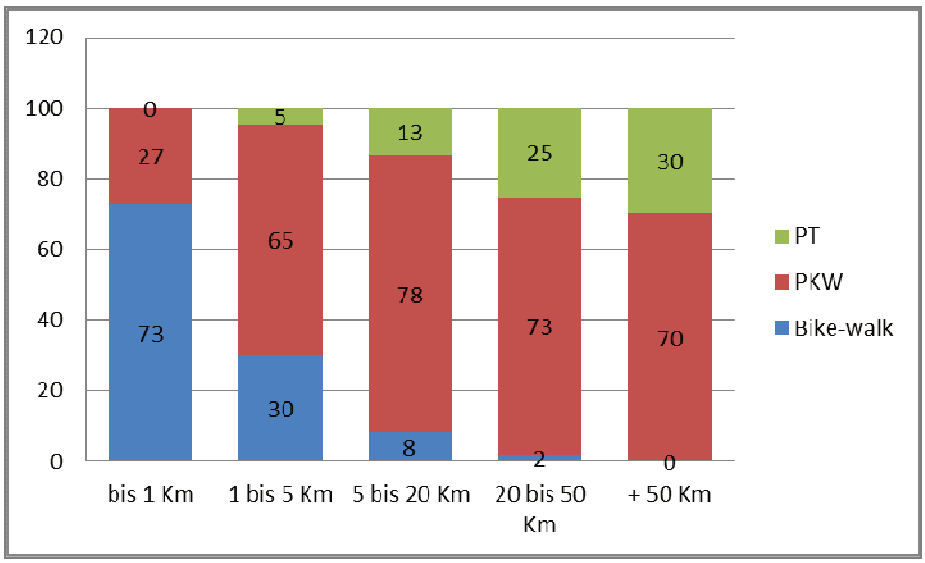

Fig 6: Percentage of modal share by distance of travels

According to (Kenworthy & Laube, 1996) usually high population densities are related to less car use and more walking or Bike and public transport use. Table 1 shows that 50% of participants live in the relatively dense areas which are more than 300 people per km2. As illustrated in figure 7 the share of car mode declines by increasing the population density might be interrelated to the raised usage of Bike or Walk in Vorarlberg by 37%.

Figure 8 shows that travelers from rural area are more likely to select faster modes such as car and public transport to reach central areas, while travels originated from center to rural areas are highly dependent on car mode by 72% and the main reason for these travels is pleasure. This means pleasure facilities are more likely to reach by car modes rather than public transport, walking or biking. Also, many leisure activities like hiking and skiing take place in the mountains, which are also easier to reach by car than by any other transport mode.

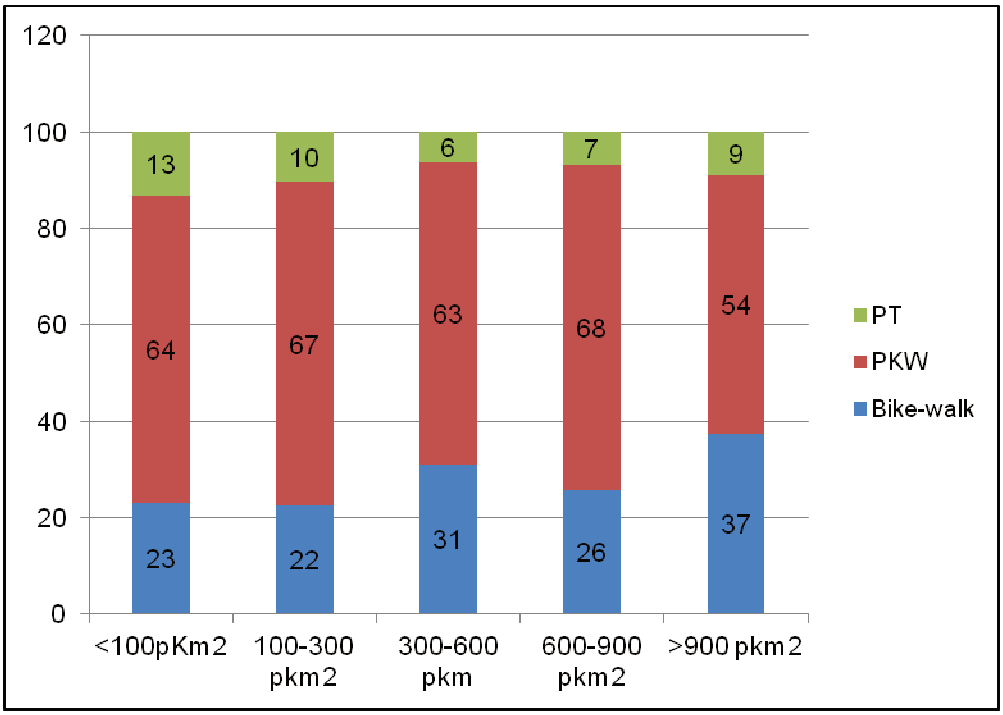

Fig 7: Percentage of modal share by population density

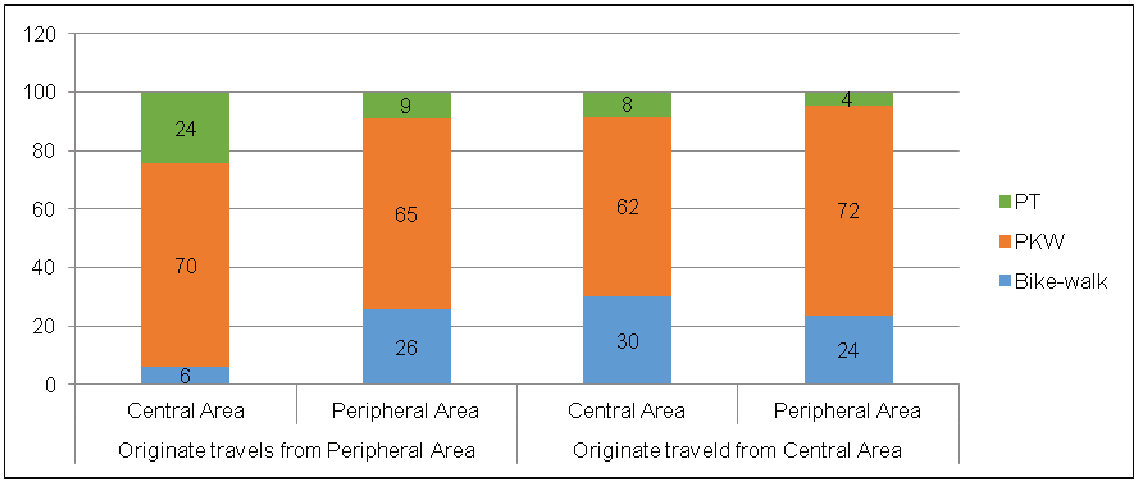

Figure 8: Percentage of modal share by destinations in central and peripheral areas

Explored variables	Frequency	Percentage	Cumulative Percentage
Number of people in a household			
1	584	9	9
2	2083	34	43
3	1406	23	66
4	1564	25	91
5	483	8	99
6	73	1	100
7	21	0	100
Car availability			
Jederzeit	4303	75	75
Gelegenheit	1109	19	94
Nie	342	6	100
Age category			
15-25	985	16	16
25-44	1569	25	41
45-64	2722	44	85
65	938	15	100
Reason of travel			
Business	2118	34	34
Education	256	4	38
Shopping	912	15	53
Pleasure	2928	47	100
Level of Income			
very low	18	0.3	0.3
low	174	2.8	3.1
middle	2150	34.6	37.7
high	3026	48.7	86.4
very high	846	13.6	100
Distance of Trips			
bis 1 Km	1195	19	19
1 bis 5 Km	2154	35	35
5 bis 20 Km	1996	32	32
20 bis 50 Km	732	12	12
+ 50 Km	137	2	2
Duration to PT			
5 Min	4567	74	74
6-15 Min	1470	24	97
16-30 Min	150	2	100
31-60 Min	18	0	100
61-120 Min	5	0	100
Population Density			
<100 km2	1736	27.9	27.9
100-300 km2	1379	22.2	50.1
300-600 km2	1771	28.5	78.6
600-900 km2	474	7.6	86.3
+900	854	13.7	100.0

Table 1: Frequency of explored variable

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3.2 Utility theory and Multinomial Logit Model

Theory of random utility is the most common theory for analyzing travel behavior particularly in the field of travel demand. Daniel McFadden received the Nobel Prize in 2000 for this theory which is used for analysis of discrete choices such as travel mode choice.

Based on the utility theory we assumed that when individual want to make a choice from set of discrete alternatives, he always selects the best option which has the highest utility for him. If every factor considered by the individual were known to the analyst for every alternative, discrete choice model could be developed to predict with certainty every choice (Mcfadden, 1974). The utility of alternatives is not known with certainty and part of it is random (Mcfadden, 1974), therefore, the utility function for each alternative is supposed to be the sum of two components which are shown in equation (1)

(1) $U_i = V_i + \varepsilon_i$

Where Ui is the utility function of individual i, Vi is the systematic and deterministic component of utility which is a linear combination of the observed variables, and εi is the random component of utility function which is unobserved part of utility function. It is important to note that the utility function is purely deterministic from decision maker's perspective and it is random from the Researcher's point of view because some of the determinants of the utility function are unobserved. Therefore, the choice can only be analyzed in terms of probabilities (Mcfadden, 1974)

According to the definition of the utility function, alternative j will be chosen if and only if the condition given in equation (2) is satisfied. (Bhat, 1999)

(2) $\forall j \neq i: \; U_j > U_i$

The equation (2) can be rewritten as in equation (3) and equation (4). (Bhat, 1999)

(3) $\forall j \neq i: \; V_j + \varepsilon_j > V_i + \varepsilon_i$

(4) $(P_j|\varepsilon_j) = P(U_j > U_1, \ldots, U_j > U_{iJ})$

By considering these assumptions, the probability of choosing each alternative can be calculated in a closed from which corresponds to the logit transformation of the deterministic part of the utility function. The probability of choosing alternative j is given in equation (5) (Mcfadden, 1974)

(5) $$P_j = \frac{e^{V_j}}{\sum_{i=1}^{J} e^{V_j}}$$

3.2.1 Model Result

Table 2 present odd ratios for the explored variables in Multinomial logit model. We consider the car mode as baseline mode and compare the Public transport and biking and walking to this baseline. The result of significant testing of variables and pseudo-R^2 e.g. McFadden confirms that the model is appropriate and can explain the influence of variable on mode choice. The values of R^2 vary from 28% to 47%. This means the model can predict correctly the modal share in the case study by different assumptions.

As we expected, the influence of sociodemographic factors is significantly stronger than then influence of spatial factors. In the used model three covariates including population density, distance to closest public transport station and distance of trips are considered. The population density dose not vary much over the alternatives and odd ratio is almost zero. The coefficient value for the distance to closest public transport station is negative by -0.02 and -0.03. A negative coefficient means that if the population density increases the likelihood to choose public transport and biking or walking over car decreases by 2% and 3%. The coefficient for distance of trips by public transport is 0.01 which means by increasing the distance of trip the likelihood to choose public transport over car is almost similar and just slightly differ by 1%, while the likelihood of selecting bike or walk over car decreases by 26%. As we displayed, the density and distance to public transport are quite weakly related to different modes of transport which is in contrast to the Kenworthy's result. This can be studied in more detail for further work in order to find an efficient way for public transport.

According to the results of social factors, females are 1.3 times more likely compared to males to choose public transport over car and they choose walk or biking 1.4 times more than males. The odd ratio by age

categories shows that young generation at the age 15 to 19 use public transport over car 5 times more than seniors older than 65, whereas they choose bike or walk almost as same as old generation. In the case of the travelers between 20 to 44 years, their preference to choose public transport over car is 10% more than seniors, but the likelihood of choosing biking or walk over car by them is 15% less than seniors. For the age category between 45 to 64 years, the likelihood of selecting of biking and walking over car shrinks by 21% compared to the senior generation.

As we expected increasing the number of car owners in each household is highly correlated to decreasing the usage of public transport and biking or walking. For instance, households with one car use public transport and walking or biking two times more than households which own four cars. The odd ratio of household without car shows almost 16 times more likelihood to use of public transport and 9 times more likelihood to select walking or biking over car compared to households with 4 cars.

According to the regression results, trip reason has a strong correlation with mode choice. Travelers with business reason prefer to select public transport over car almost 2.3 times more than travelers with pleasure reason. Travels for education purposes are highly dependent to the mode choices other than car compared to the travels for pleasure purpose. For instance, travels by education reason are done 2.6 times more with bike or walking over car and also almost 19 times more with public transport in comparison to the travels by pleasure reasons.

Explored Variables	Odd ratios	Exp (B)	Odd ratios	Exp (B)
	Public Transport		Bike-Walk	
Constance	-1.74	-1.74	-17.28	-17.28
Geographical Factors				
Population Density	0.00	1.00	0.00	1.00
Distance to closest Public Transport Station	-0.02	0.98	-0.03	0.97
Distance of trip	0.01	1.01	-0.30	0.74
Wohnraum Type Zentrale Bezirk	-0.26	0.77	0.10	1.11
Social Factors				
Age category 15-19 20-44 45-64	 1.60 0.10 0.12	 4.96 1.11 1.13	 0.04 -0.17 -0.24	 1.04 0.85 0.79
Gender Women	0.27	1.30	0.32	1.38
Number of car owner Number of car owner-0 Number of car owner-1 Number of car owner-2 Number of car owner-3	 2.76 0.69 -0.37 -1.19	 15.75 1.99 0.69 0.30	 2.16 0.62 -0.21 -0.35	 8.69 1.85 0.81 0.70
Reason of Travel Business Education Shopping	 0.82 2.93 -0.79	 2.26 18.81 0.45	 0.07 0.97 -0.41	 1.07 2.63 0.67
Income Low Middle	 -0.04 -0.32	 0.96 0.73	 -0.99 -0.02	 0.37 0.98

Table 2: Result of Multinomial logit model of transport mode choice, PKW as reference

4 CONCLUSION

We have analyzed the influence of personal characteristics and the attributes of spatial variables on the mode choice. The results show that even though the usage of car is the dominant transport mode choice in Vorarlberg region, but socio-demographic variables including age, gender, population density, level of incomes and travel motive are highly correlated with the modal choice as well. Besides, percentage of modal share by densities illustrate that the high-density areas related to more usage of biking and walking.

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In the Vorarlberg region, many leisure activities are hiking and skiing which take place in the nearby mountains which are easier to reach by car. As the major purpose of travels in this region is for pleasure, thus the car is the dominant travel mode choice. For instance, 62 % of travels have pleasure and shopping reasons which more than 60% of these trips are done by car. This means future transport policy in this region should therefore pay specific attention to develop low carbon transportation infrastructure for travels with leisure purpose, and to exploit the cohort effect resulting from the presumed change in mode preferences.

Results show that an increase in household size results in more likelihood to own a car and increasing car ownership results in less usage of public transport, biking and walking. For instance, households with no car use almost 16 times more public transport over car and 9 times more walking or biking over car compare to households with 4 cars.

According to the results, women are less dependent on car than men and they prefer to choose public transport more than men. The majority of travels for education purpose are done by young generation and they have limited car ownership. Therefore, these travels are mainly done by public transport. For young people at the age between 15 to 19, the odds ratio of using public transport over car is 5 times more than older generation.

Income status shows that by increasing the level of income the usage of public transport decreases. In the Vorarlberg region, participants with a very low income use public transport by 22%, while travelers with a very high level of income use public transport just by 7%. Besides, an increase in the level of income leads to a slight increase in biking or walking modal choices.

This paper has clearly highlighted the positive correlation of personal attributes on the modal choice in Vorarlberg region. The results provide a better assessment to find out if there is a potential for improvement in public transport and change in mode preferences. The future strategies should address these potentials and make alternatives to the car more attractive.

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