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In Depth Analysis of Trip Chains and Tours Based on the National Travel Survey Database in Austria

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In Depth Analysis of Trip Chains and Tours Based on the National Travel Survey Database in Austria

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Abstract

The database of the Austrian national travel survey is accessible to the public and many detailed analyses were carried out meanwhile based on these data. What is missing, was the in depth analysis of trip chains and tours of the mobile persons in the database, i.e., linking the single trips to chains at first as putting together tours from leaving the place of residence until returning to it. All mobile persons in the database will have at least one excursion. In combination with other variables, this allows detailed analyses of interrelation and effects on these trip chains, such as length, number of trips or modes used. The paper will show the distribution and types of the trip chains, starting from 2 trips per excursion (i.e., going somewhere e.g., for work and going back home after work) to more complex trips with a combination of different modes and purposes at the different destinations. The influence of the different activities carried out during the excursion on the mode choice, even for the whole trip chain is analysed. Differences in trip chaining in dependence on social demographic variables such as gender, family size, the area type of the place of residence are shown. Another aspect is the influence of the trip length and number of trips towards the mode choice. Results show, the big majority with a share of ca. 75% of all excursions consists of two trips only. People tend to avoid a bigger number of more complex tours, when leaving their place of residence. Furthermore, the majority of peoples' excursions (88.3%) not more than one main transport mode within the excursion itself was combined (only in 10% of the excursions, two modes were combined and less than 1% of the excursions, more than 2 modes). However there are differences, e.g., between cities (higher degree of complexity of excursions) and the rural areas (lower degree of complexity of excursions). Most of the excursions are work related (20%), followed by leisure related and shopping. The excursion with the highest share consisting of more than two trips are trips with a combination of two leisure activities, but with a share of 1.27% of all tours only (followed by the combination of working and shopping). As an example, looking at differences between male and females: the share of more complex tours including more than two trips is higher within the female population, especially in combining three trips within one tour (females 14.4% of all tours, whereas males 11.9% of all tours). In parallel, the total trip length in km (m: 33.5km/f: 26.2km) and duration in minutes (m: 61.5min/f: 55.6min) is shorter within the group of females. This leads to the conclusion females more likely combine more but shorter trips. The paper gives an overview of the most interesting socio demographic interrelations and impacts on trip chains and mode choice within these trip chains.

Keywords: *mobility behavior, trip chains, intermodality, mobility demand*

Introduction

As part of the mobility survey "Österreich Unterwegs 2013/2014", data on many of the possible variables influencing mobility behavior were collected and analysed already (Sora Ogris and Hofinger, 2017; Tomschy et al., 2016). However, the aspect of trip chains has hardly been considered in the publications of this survey so far. In order to obtain a more detailed picture of the mobility behavior of the Austrian population, this data is considered in this analysis. A statistical analysis of the relationships between trip chains, socio-demographic characteristics, the activities carried out and other influencing factors provides new insights into the mobility behavior of the Austrian population. As a first step in this analysis, the anonymized data set is used to determine the trip chains of the interviewed persons. This is to provide an overview of the most common trip chains carried out in Austria as well as the total length and total duration of travelling. The influence of additional activities within a trip chain on the choice of means of transport is examined. Subsequently, the characteristics of these trip chains are compared with certain variables such as certain socio-demographic characteristics in regard to the complexity of trip chains, the total trip length and the choice of means of transport.

Definition of Trip Chains

As a first step, the definition of trip chains needs to be specified. In summary, two definitions of path chains is mostly used in the literature (Primerano et al., 2007): (1) Trip chains describe a sequence of trips outside the home, with the beginning and end of the respective chain being the place of residence. (2) Trip chains are defined as a sequence of trips between certain "anchor points" such as the place of residence or the workplace. In this paper trip chains are defined as (1), i.e., only the place of residence is a starting and ending point of a trip chain.

Another important distinction in the methodology of trip chains is that between "simple" and "complex" trip chains. Simple chains of trips are those that consist of only one trip from home to one activity and back again. If trip chains include at least one additional trip, they are classified as complex trip chains.

Literature Research

Brunow and Gründer (2012) address the connection between the chaining of activities and the duration of the activities. Using "Mobility in Germany" data from 2002 it is shown that the number of activities carried out significantly influences their duration. Additional activities in trip chains lead to shorter durations. Furthermore, model calculations show that age, income and the

number of children in the household also have an impact on the duration of the activities. Spatial aspects and the means of transport used also influence them. Activities that one travels to by means of public transport take a particularly long time. If several trip chains are carried out in one day, the duration of activity also decreases. The chaining of paths within a trip chain thus influences the travel time and the time that one spend on the activities.

The focus of McGuckin and Murakami (1999) is on the gender-specific differences in relation to trip chains. US data from 1995 show that women travel more of the shopping and delivery trips than men with the same marital status. It is shown that many of these daily supply trips are covered by women when starting a family, while the average trip chain for men is simpler. In particular, mothers of children not yet independent in their mobility often have complex trips. In contrast, the duration of activities in men increases in the same households.

Gottardi et al. (2007) deal with the interdependency between the choice of means of transport and the chain of trips. The microcensus from Switzerland from 2000 was used as the database. Binary, discrete decisions (e.g., use of private car trafic: yes / no) were simulated by using probit and logit models. Based on the results of these models, Gottardi et al concluded that the choice of activities within a chain of trips usually takes place before that of the means of transport. Data from a Belgian survey serve as the basis for the work of Vande Walle and Steenberghen (2006). In it, they deal with the connections between subjectively perceived travel time and choice of means of transport in trip chains. For each trip, an alternative with public transport was calculated using a route planner, the travel times of this and the actual trip were then compared. When considering paths, a connection between the waiting and walking time and the use of public transport was found. Most often, footpaths and paths were combined as private car passengers. Vande Walle and Steenberghen show that in the case of trip chains, individual trips can often not be covered by public transport, and therefore a different mode of transport must be selected for the entire chain. Furthermore, it is shown that when considering the influence of travel time on the choice of means of transport, the travel time of the entire trip chain and not that of an individual trip is important.

Methodology

In order to create trip chains based on the data of the Austrian mobility survey, all sequences of trips that were covered by a person on a predefined day. A total of 84,041 chains could be determined. The data record was then cleaned up for those entries that contained invalid trips (i.e., trips without specifying the origin or destination). In the course of this procedure, 6,525 (7.76%) lines had to be deleted from the data record. In a next step, those chains of trips that did not start or end at home were removed. This eliminated a further 4,368 entries (5.63%). From the remaining 73,148 route trips, 701 strolling walks were finally eliminated (routes from home to home without

additional activity, 0.95%). In the final data set, 72,447 trip chains were ultimately preserved, which were formed from the originally 196,604 trips.

The chi-square test was used to calculate the relationship between the characteristics. Using the measure chi-square ($\chi 2$), where the actually observed frequencies of the characteristics with the frequencies expected when they are independent of each other are compared. A prerequisite for the chi-square test is an expected minimum frequency of all values of 1 and in a maximum of 20% of cases less than 5. Thanks to the sample size of almost 200,000 routes and over 72,000 trip chains, these conditions were met in all analyses (Duller, 2018). In addition, the p-value is also determined. If this p-value is greater than a previously defined level of significance α, it is assumed that the two characteristics considered are independent. The value for the level of significance was set in this work with $\alpha = 0.05$.

Characteristics of Trip Chains

The Austrians cover a distance of 36 kilometres of total trip length on an average weekday which equals a total duration of travelling of 68 minutes. The average number of journeys made every day is 2.6 journeys per person and 3.3 for mobile person (Tomschy et al., 2016).

Table 1 shows the distribution of trip chains by number of trips. Trip chains consisting of only 2 paths form the main share of the daily excursions with more than 75%. Less than a quarter of the trip chains exceed a number of 2 trips and more than half of these complex chains consist of only 3 trips. The frequency of the trip chains decreases sharply with increasing number of trips. The maximum number of trips within a trip chains determined shows a number of 13 different trips, but only 5 such trip chains are included in the data set. The average trip chain comprises 2.42 trips, this value confirms the dominance of simple chains. On average, a chain of trips cover an average total distance of ca. 30 kilometres and 58 minutes.

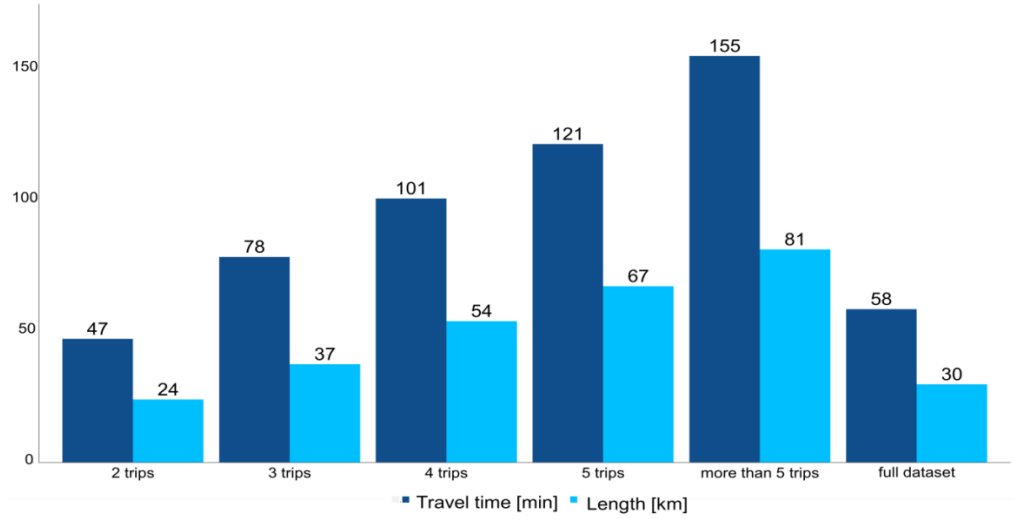
Table 1. *Number of Trips per Trip Chain, Average Weekday*

Number of trips within a chain		**[%]**
2 trips	54.890	75.77%
3 trips	9.511	13.13%
4 trips	4.703	6.49%
5 trips	1.911	2.64%
6 trips	822	1.13%
7 trips	368	0.51%
8 trips	148	0.20%
≥ 9 trips	94	0.13%

As expected, the travel time required to cover the chains increases steadily with increasing number of trips (Figure 1). For an average simple trip chain, the respondents travelled around 47 minutes. If a third trip is included, the travel time increases by more than half an hour to around 78 minutes. If further

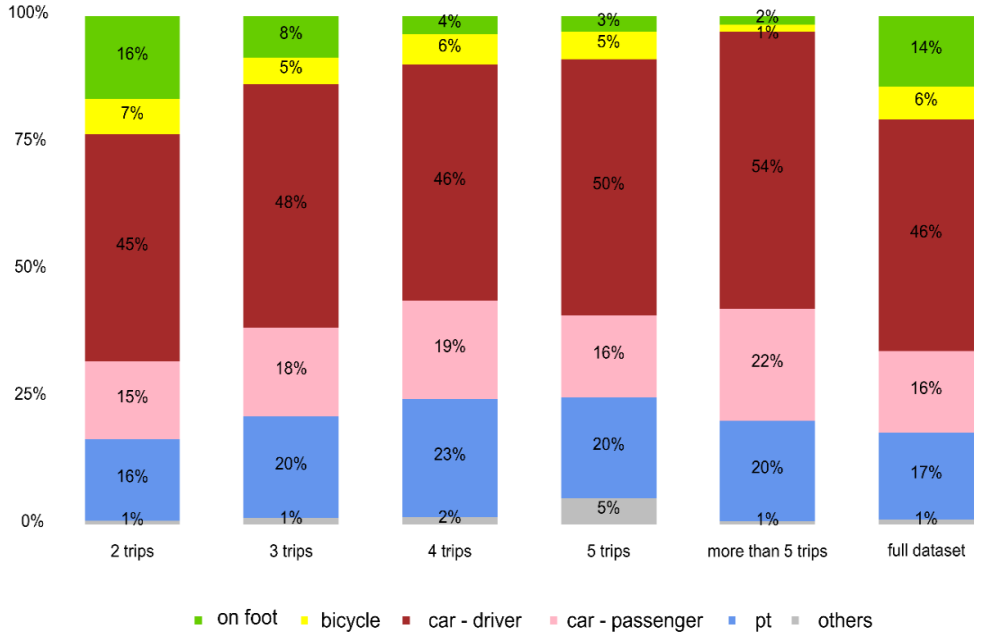
activities are carried out, the journey time is slightly over 20 minutes for each additional trip. With trip chains including more than 5 routes, the average total travel time is already above 2 hours. The distance that is covered within a trip chain behaves similarly to the travel time with increasing length of the route chains. A trip chain of 2 trips covers on average 24 kilometres, a third trip increases the distance by a little more than 50%, i.e., around 37 kilometres. With other additional trips, the distance increases evenly by approximately 15 kilometres per additional trip.

Figure 1. *Average Total Travel Time and Length of the Trip Chains According to the Number of Trips within the Chain (n = 72,447 Trip Chains)*



If one looks at the modal split, dividing the trip chains according to the number of trips made, some trends in the choice of means of transport can be identified (Figure 2). The proportion of chains covered on foot decreases sharply as the number of trips increases. Reasons for this can be caused by the longer distances within an increasing number of trips, which cannot be covered on foot and the “captive vehicle usage”, although one single trip may be very short within the trip chain but the bicycle or especially the car need to be moved as well. The bicycle share remains relatively constant with up to 5-part chains. However, the proportion of motorized modes increases as the number of trips increases. In particular, the share of public transport rises sharply up to a chain length of 4 routes, but decreases again with even longer trip chains. The share of private car usage is steadily increasing and reaches the highest values for the chains with the highest number or trips - more than three quarters of the trip chains over 5 trips are carried out as private car driver or passenger. Furthermore, the majority of peoples´ excursions (88.3%) not more than one main transport mode within the excursion itself was combined (only in 10% of the excursions, two modes were combined and less than 1% of the excursions, more than 2 modes).

Figure 2. *Modal Split According to the Number of Trips of the Trip Chains in Percent (n = 72,447 Trip Chains)*



Patterns of Trip Chains with Regard to Trip Purpose

In total, the variety of all excursions includes 2,544 different trip chain patterns (e.g., living-working-shopping-living). Most of these trip chains, however, are very rare. Simple trip chains that lead back home after just one activity outside the home are very common. On an average weekday, the proportion of these simple chains is 76.2% (Figure 3). With around 20%, almost every fifth exit leads from home to work and back again. The second most common trip chain pattern is living-leisure-living with approx. 14% share, living-shopping-living lies with approx. 12% in 3rd place, followed by an excursion to carry out a personal errand (9%). The proportion of all complex trip chains (i.e., longer than 2 trips) all together is around 24%. The most common complex route chain (living-leisure-leisure-living) has a share of just over one percent (in relation to all trip chain patterns), all other trip chain patterns are carried out less frequently than 1 %t of all cases. If one restrict the consideration to the complex trip chains that comprise at least 3 trips, one will notice that they are distributed much more evenly (see Figure 4).

Figure 3. *Most Common Trip Chain Patterns in Percent (n = 72,447 Trip Chains)*

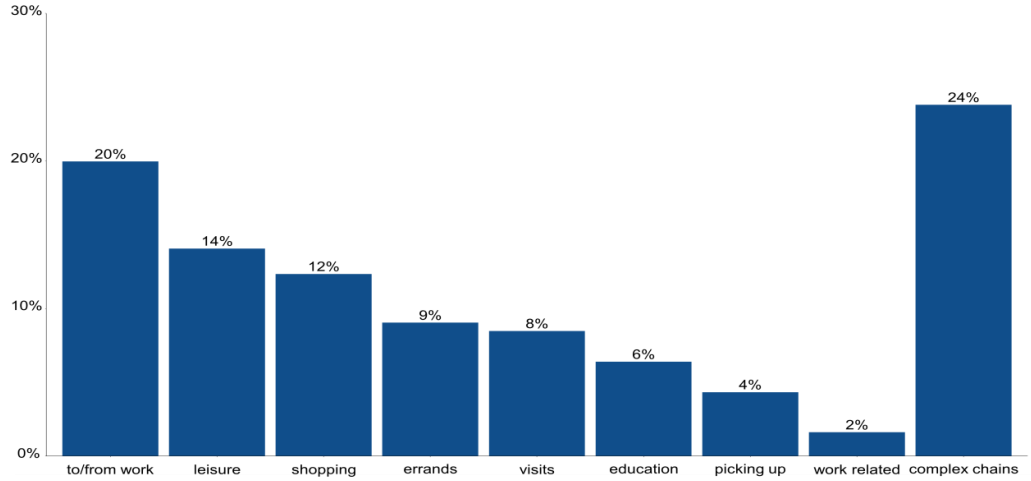
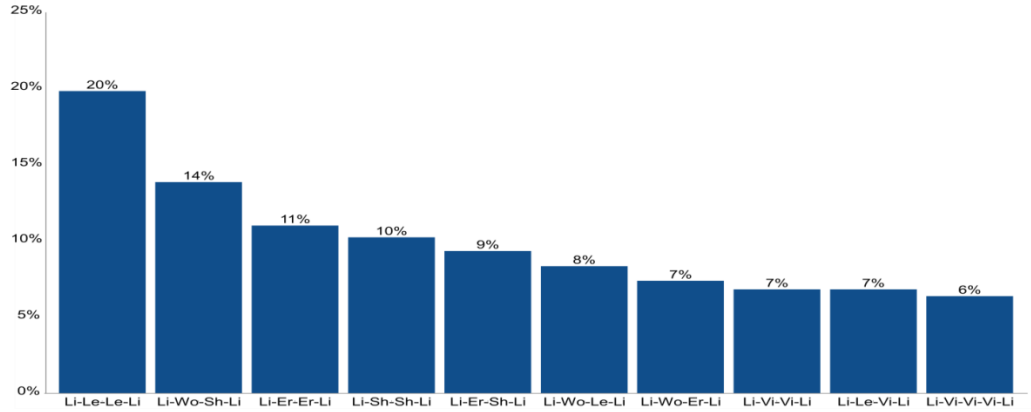


Figure 4. *Most Common Complex Trip Chain Patterns in Percent (n = 4753 Trip Chains)*



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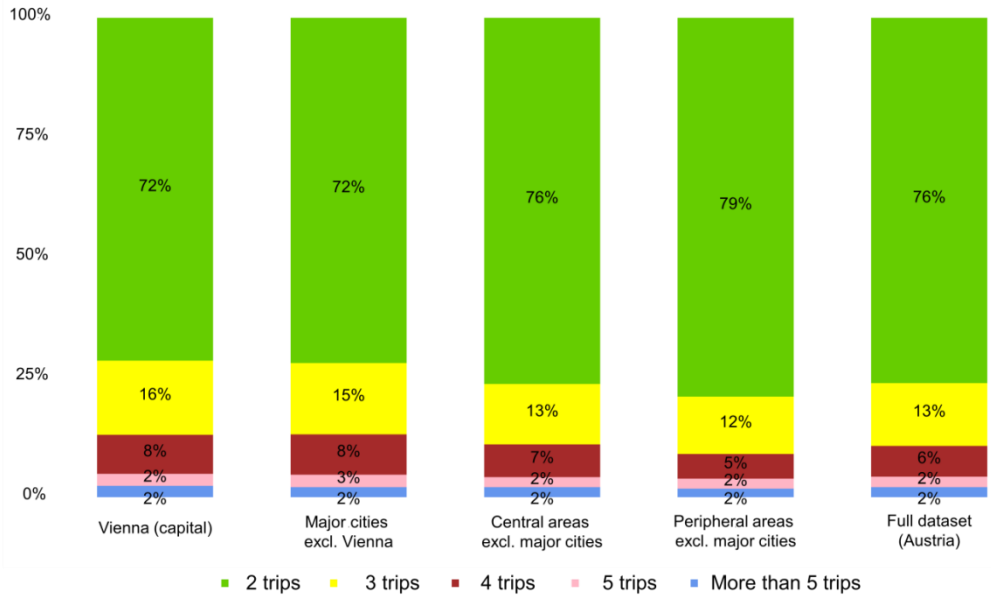
10 most common trip chain patterns are covering around 27% of all complex trip chains only. Austrians most often bundle two leisure trips in one excursion, followed by a commuting to work and then shopping on the way home. Work routes are also often linked to subsequent personal errands and leisure activities. Personal errands and shopping are often carried out in various combinations in the course of a trip chain. As the only trip chain with a number of trips of more than 3 routes, the pattern living-leisure-leisure-leisure-living is among the 10 most common complex trip chains. While the route purpose "work" is by far the most common for simple trip chains, three activities are almost equally at the top at complex trip chains. Leisure time, shopping and commuting all are included at a third of all complex chains. With almost 30%, private errands within an excursion are linked to other activities.

The Correlation of Trip Chains and Area Type of Residence

The Austrian political districts were divided into 4 different area types: (1) Vienna (the capital and the only one city in Austria above 1 Million inhabitants), (2) the major cities without Vienna, (3) central districts and (4) peripheral districts. The subdivision of the political districts in central and peripheral was based on the accessibility of the main centres by means of motorized private transport and public transport. The aim was to analyse the relation of the different framework conditions in terms of space and infrastructure and the mobility behavior. However, no distinction was made between the spatial and settlement structures in the respective districts, although the quality of development in the districts can be very different within the same group (Tomschy et al. 2016). In addition, the size of the sample varies for the various room types, which is due to the unequal distribution of the resident population. While 20% of the population live in Vienna, this value is only 10% for the cities without Vienna. Another 24% of the Austrian population lives in the central districts and almost half of Austrians live in peripheral districts (46%).

The number of trips per trip chain decreases the more the region is peripheral. In the Austrian average, the share of simple road chains is around 76%, with the value in Vienna being around 72%. This value rises to 79% in the peripheral districts (Figure 5). Accordingly, the proportion of complex trip chains in the periphery is steadily decreasing. The average route frequency per trip chain also drops slightly in the regions with less accessibility, from a value of 2.51 trips in Vienna to 2.37 trips in the periphery. Nevertheless, simple trip chains, which consist of two trips and one activity, dominate in all regions of Austria. Regional differences can also be seen in terms of total trip length and duration. In Vienna, where activities are most often combined, the total duration of trips per trip chain time is 69 minutes, a value that is more than 10 minutes above the overall Austrian average of around 59 minutes. In the other major cities, the travel time is just under an hour at 59 minutes and it drops to 56 minutes in central and 55 minutes in peripheral districts. In contrast, the total distance covered within the trip chains increases the more rural the district is settled. In the peripheral districts, an average of 33 kilometres are covered, in Vienna only around 25. It follows that the average speeds in rural areas are higher than those in large cities. This is due to the different modes of transport in the different regions. If looking exclusively at the longer, complex trip chains with more than one activity, it is noticeable that in all regions of Austria, two leisure trips are often covered in combination in a trip chain. This trip chain pattern is particularly common in the central districts. However, in central districts the combination of two leisure activities in one trip chain is clearly above average (26% of all complex trips and 18% on average in the other areal types). In Vienna and the other major cities, a work related activity followed by a leisure activity or a personal errand is more often executed than in the central and peripheral districts.

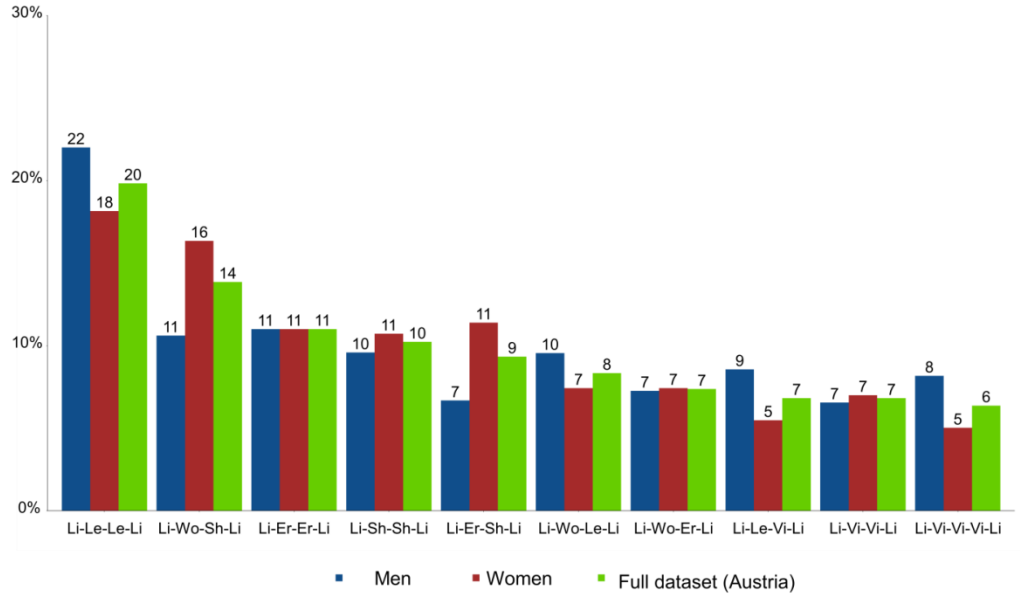
Figure 5. *Number of Trips per Trip and Area Types in Percent (n= 72,447 Trip Chains)*



The Correlation of Trip Chains and Gender

In this section, the gender-specific mobility behavior is evaluated at the route chain level, there are significant differences between women and men. The number of trips made in the course of a trip chain differs only slightly between the sexes. The proportion of simple trip chains is around 78% for men and 75% for women. As a result, women tend to have longer chains. Men cover an average of total 33.5 kilometres within a trip chain, while women only cover a little more than 26.2 kilometres. The journey time for men is around 61.5 minutes, for women it is 6 minutes less. Women therefore often have many short trips, while men cover fewer and longer journeys. There is a significant difference between men and women when it comes to the choice of means of transport. Men cover more than 54% of their trip chains mainly as private motorised drivers, (women 38%). However, women travel almost 21% of their chains as private motorised passengers, which is almost twice as high as for men.

Figure 6. *Most Common Complex Trip Chain Patterns by Gender (n = 72,447 Trip Chains)*



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Furthermore, women with over 16% above average travel distances only on foot - for men this value is only around 11%. Public transport is also chosen a little more often by women than men for their chains. If looking exclusively at the longer, complex trip chains with more than one activity (Figure 6), there are differences between the sexes. The share of more complex tours including more than two trips is higher within the female population, especially in combining three trips within one tour (females 14.4% of all tours, whereas males 11.9% of all tours). Most often, two leisure activities are combined both by men and women with a higher share by men. Shopping in combination with other activities (errand or working) in particular have strong gender-specific differences. In the case of women, the combination of the work and a shopping route roughly reaches the value of two combined leisure routes with around 16%, compared to men, they carry out shopping a little less frequently after work (11%).

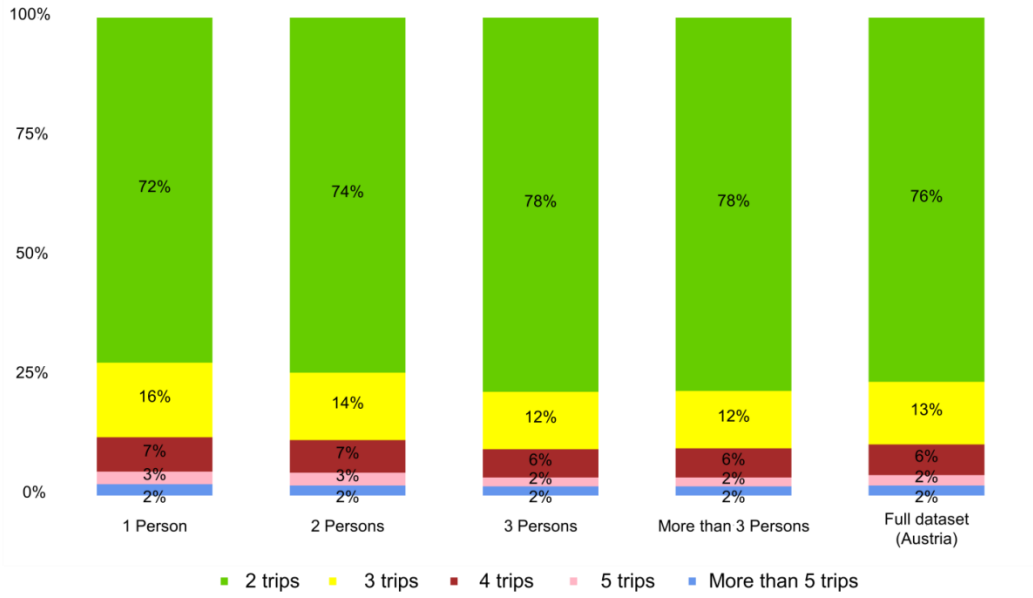
The Correlation of Trip Chains and Household Size and Children

The differences in the mobility behavior of households of different sizes are examined in this section. In addition, the influence of children and adolescents in the household on the mobility behavior of residents is dealt with. As can be seen in Figure 7, people in smaller households tend to combine trips within an excursion more often. 72% of people who live alone travel along simple chains; in households with at least 3 people, this value is over 78%. Single-person households also have the highest values for trip chains, which

consist of 3 or 4 trips. The proportion of simple trip chains increases with household size, but the distribution of the number of trips per trip chain remains constant from a size of 3 people. It is significant that people in households with children under the age of 6 are the least likely to cover simple trip chains only and show up the highest average number of trips within chains. In households with children between the ages of 6 and 17, the complexity of trips do not differ so much in comparison to households with no children at all. There are only very small deviations between the different groups considered in relation to the distance covered and travel times within the route chains. In particular, the distance for all groups is around 31 kilometers, very close to the Austrian average. Households in which only adults live with an average travel time of 60 minutes have slightly longer travel times than those with children in the household. If looking exclusively at the longer, complex trip chains with more than one activity, there are also some differences between the groups. People without children in the household often cover two leisure routes or two errands within one excursion. After-work leisure activities are performed more frequently by this group than by the other two groups. People with children under the age of 6 most often combine trips accompanying the children with additional activities. Here, the group with children aged 6 to 17 years shows only slight deviations from those with younger children.

The behavior of the two groups with children and adolescents under the age of 18 in the household is very similar when it comes to choosing the means of transport. At around 60%, most of the trip chains are mostly private motorised drivers. The situation is different for people in households without children. At around 49%, they comparatively cover chains by means of drivers private motorised drivers less frequent. To this end, the share of other modes of transport, particularly public transport and pedestrian share, is increasing in this group. The choice of main means of transport chain also varies between the different groups of household size. People who live in single-person households cover most of the routes by public transport (23%) and on foot (19%). At around 8%, the bicycle share is also the highest of all groups. Contrary, the value of motorized transport is the lowest of all household sizes, less than half of the chains are mainly covered by motorized private transport. In households with two residents, the proportion of private motorised passengers increases significantly, while foot and especially public transport trip chains decrease. The highest level of private motorised drivers is reached at around 51% in three-person households. These also have the lowest proportion of trips covered on foot or by bike. For even larger households, the proportion of drivers will decrease slightly, while all other modes of transport will increase at same shares.

Figure 7. *Number of Trips per Trip and Household Size in Percent (n = 72,447 Trip Chains)*



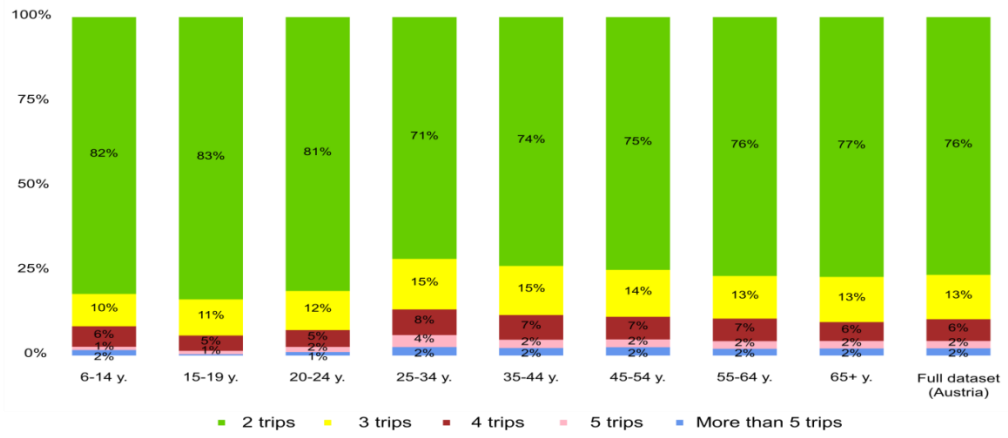
The Correlation of Trip Chains and Age

Another socio-demographic characteristic that affects traffic behavior is age. With advancing age, the availability of means of transport generally changes, preferred activities such as education in childhood and adolescence or work for age groups 20-60 years of age. In the following section, therefore, the differences in the mobility of different age groups with regard to chains of trips will be explored in more detail. In the course of the survey 2013/2014, only people living in Austria over 6 years have been asked to report on their mobility. Figure 8 shows the number of trips per trip chain for the different age groups. The graphic shows that the frequency of trips within a trip chain changes with age. Children, adolescents and young adults under the age of 25 have the highest proportions of simple trip chains. The proportion of simple trip chains is more than 80% for each of these groups. The next older age group of 25 to 34 year olds, on the other hand, is the one with the most complex trip chains. Approximately 30% of the trip chains in these groups are exceed 2 trips. With increasing age of the Austrians the proportion of the complex trip chains decreases again somewhat. For people over 64 years of age it is only around 23%. The proportion of trip chains with a number of trips of at least 4 trips varies between 6% for the group of 15 to 19 year olds and 12% for 25 to 34 year olds.

The shortest trip chains with regard to travel times are shown by people under 20 years of age. The distance of the trip chains in kilometres is also comparatively short for this group. The group of 25- to 34-year-olds, on the other hand, travels the longest chains of all ages in terms of distance and travel

time. Both values decrease somewhat with age. The group of over 65-year-olds travels the shortest routes with around 22 kilometres. In general, the average distance travelled across the various age groups changes more than the required travel time budget, which differs only slightly from the average of around an hour travel time per trip chain. When looking at the main means of transport chosen for the individual groups, there are big differences (Figure 9). The youngest group of 6 to 14 year olds does not yet have a driving license and therefore covers most of their journeys as a private motorised passenger, but public transport is also chosen over average. The share of pedestrians is high at 20%, as is the bicycle share with an above-average 9%. With the advent of the capability to drive motorised vehicles in the group of 15 to 19 year olds, the non-motorized modes in particular decrease significantly. Public transport is used particularly frequently by this age group with 40%. In the group of 20- to 24-year-olds, the proportion of cyclists and passengers has already dropped to a third of the value for the youngest group, for which more than half of all the chains are driven with a motorised vehicle. The share of public transport also shrinks by half compared to the next younger group. With advancing age, more and more trip chains are executed by means of private motorised vehicle as driver, public transport is chosen less frequently. Only in the groups aged above 55 the share of public transport is increasing again, and the number of footpaths covered increases slightly, and the proportion of bicycles increases as well. In the group of people over 65 years of age, the share of private motorised drivers drops to around 38%. This group travels particularly often on foot (around 23%).

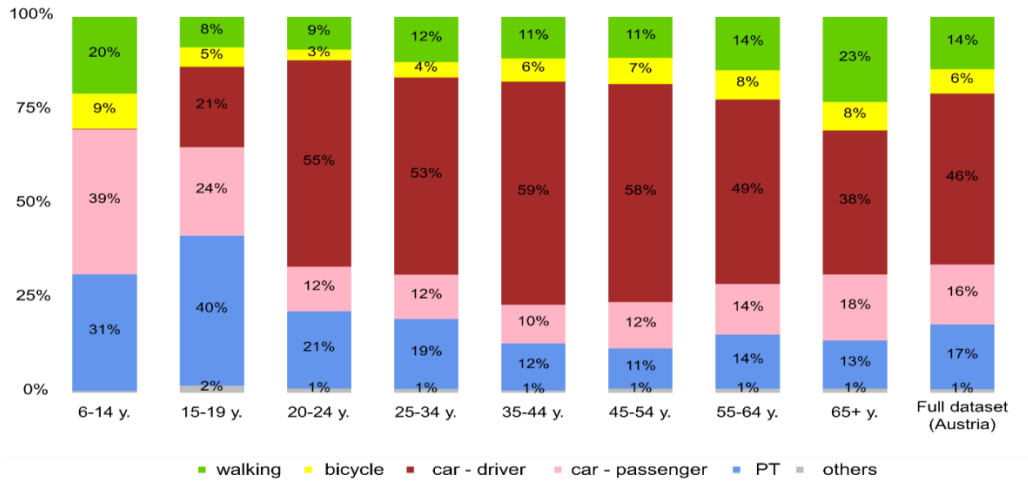
Figure 8. *Number of Trips per Trip and Age Group in Percent (n = 72,447 Trip Chains)*



As expected, the trip purposes in the complex trip chains differ greatly according to age groups. People under the age of 20 most often combine education and leisure activities. The groups between 20 and 65 years of age are dominated by trip chains with the purpose of work. With increasing age, people of working age increasingly combine their commuting with other activities within one excursion. As with the simple trip chains, the over 65-year-olds have the

highest proportions of shopping and errands. The only complex chain of trips that has a high proportion across all age groups is that in which two leisure activities are carried out within one excursion.

Figure 9. *Modal Split According to the Number of Trips of the Trip Chains and Age Class in Percent (n = 72,447 Trip Chains)*



Conclusions

The aim of the study work was to gain new insights into traffic behavior by analysing the chains based on the Austrian population using the the data set of the mobility survey "Österreich unterwegs 2013/2014". By evaluating the data set, it was possible to show that the vast majority of the chains in Austria consist of only two paths: the path from the place of residence to an activity and the subsequent path back home. The choice of means of transport at trip chain level is as simple as most route chains. In approximately 8 out of 10 cases, a trip chain is covered with only one means of transport. Furthermore, it could be shown that not only the travel times and the distances to be covered influence the choice of means of transport, preferred means of transport could also be determined for the activities carried out. For example, the activity of accompanying other people is particularly biased by the use of private motorised vehicles.

With regard to the influence of socio-demographic characteristics on mobility, it could be determined that there are some significant differences between different groups. Based on the results of this work, however, it is assumed that not one characteristic, such as age, alone dominates the choice of means of transport, but a combination of the different influencing factors. A possible focus of further research could be the creation of a logistic model in order to be able to calculate the influence of the combination of variables on the trip chains. As mentioned before, a closer look at intermodal route chains and their stages could provide further insights. With regard to the most

frequently travelled route chain living-working-living, the daily commuting and commuting trips could be examined and checked for an optimal connection of means of sustainable transport.

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