

Article

Mobility Styles and Car Ownership—Potentials for a Sustainable Urban Transport

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Abstract: Decision-makers in cities worldwide have the responsibility to contribute to the reduction of greenhouse gas emissions in urban transport. Therefore, effective measures and policies that allow for a change in people's mobility towards sustainable mobility must be derived. To understand how different people respond to measures and policies, and to increase the effectiveness of such policies, individual mobility needs and mobility determinants have to be considered. For this, the definition of individual mobility styles as holistic descriptions considering travel behavior, attitudes, as well as life stages is useful. This study presents a segmentation approach that identifies eight urban mobility styles by using data from a multidimensional survey conducted in Berlin and San Francisco. We applied a cluster analysis with both behavioral and attitudinal characteristics as segmentation criteria. By analyzing the characteristics, we identified a mobility style—the Environmentally Oriented Multimodals—that is environmentally oriented, but not yet all people in this cluster are sustainable in their mobility. Thus, they are the group with the highest potential to accept and use sustainable mobility. Additionally, we found that within the Environmentally Oriented Multimodals, the change from one life stage to another is also likely to be accompanied by a car acquisition.

Keywords: mobility styles; travel skeleton; attitudes; travel behavior; sustainable urban mobility; life stages; car ownership



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1. Introduction

Given the persistently high level of car traffic in cities, decision-makers have the responsibility to make an important contribution to the reduction of greenhouse gas emissions in the transportation sector in accordance with the Paris Declaration. Restrictions, such as road pricing and parking management, are intended to limit car ownership as well as car use and instead promote multimodal behavior with bicycle and public transit use. Beyond car restrictions to induce a shift to other modes of transportation, the powertrain technology transformation to battery electric vehicles (BEV) is a promising development for unavoidable car use. Regulatory frameworks, such as subsidies, stimulate demand for BEVs. In addition, cities are planning to restrict the registration and use of conventional vehicles. For example, Paris is planning a ban on conventional vehicles for 2030 [1]. This raises the question of how residents react to such restrictions and how dependent they are on private cars. To understand how different people respond to interventions and to increase the efficiency of environmental interventions, a suitable segmentation of people from urban areas should be targeted. Mobility styles provide an appropriate and holistic approach to understanding different target groups. Depending on the application and the objective of the studies, the focus of mobility styles is on travel behavior, attitudes or life stages. Among them, however, is no approach that combines everyday and long-distance travel behavior with psychographic characteristics, such as motives for car use and environmental concerns, to identify potentials for sustainable travel behavior. Especially car ownership also depends on long-distance travel and represents a key challenge for electric mobility.

Mobility styles, resulting from such a holistic approach, would result in answers to the following research questions:

- Which mobility styles have an increased potential for accepting and using sustainable mobility solutions due to an ecological norm orientation?
- How do people with a sustainable mobility style, who own a car, differ from those who have the same mobility style, but do not own a car?

A comprehensive database is required to answer the diverse questions and to form multidimensional mobility styles. To meet this requirement, the concept of the travel skeleton was used, which focuses only on typical behavior in a “pseudo-longitudinal” approach instead of a travel diary. As the travel skeleton approach has a lower respondent burden, it allows to collect further detailed information (e.g., psychographic characteristics). As part of the study, 1200 people were surveyed in the two cities, San Francisco (U.S.) and Berlin (Germany), using face-to-face interviews. To derive two-dimensional mobility styles, we used a principal axis factoring in combination with a two-step cluster analysis. The life stage of people is used as a cluster-describing variable to explain differences between the mobility styles.

The following sections describe the outcome and conclusions of our analysis and are structured as follows: after a literature review and outline of the survey approach, we describe our methodology to identify urban mobility styles. The explanation of the cluster analysis follows. Based on the cluster solution, we identify and investigate a segment with a high potential of sustainable travel behavior through a car-less lifestyle in the future. Finally, we discuss our results and draw a conclusion.

2. Literature Review

Market segmentation is required to increase the efficiency of environmental interventions instead of using a “shotgun approach” and spread them across the whole population in urban areas [2]. Segmentation approaches have been used in transportation research since the 1970s. Fundamental work in this area goes back to Kutter [3,4], Pas [5] and Schmiedel [6]. By now, there is a large number of segmentation studies in travel behavior research and in the interdisciplinary fields of transportation. The segmentation criteria used in existing studies can be divided into three main categories in terms of content, following Stegmüller [7]: external (spatial, socio-demographic, socio-economic), behavioral and psychographic criteria.

2.1. Behavioral Typologies

Grouping individuals of similar behavior together is the most common one-dimensional approach, which has long been used in transportation research as well as planning. The purpose of the segmentation is not to explain the behavior of individuals on the basis of group formations. It is rather to simplify the complex reality so that other relationships can be recognized more easily [8]. Each segmentation of travel behavior is based, at its core, on Kutter’s [3] assumption that the variety of individual daily routines can be reduced to a few typical activities and patterns, given the present social structure. In the existing literature, behavioral segmentations in transportation have different objectives and include various characteristics, such as mode choice and activities. One focus of research are activity types. Various theories assume that the emergence of activity patterns does not depend solely on an expected utility. Moreover, the freedom of action is restricted by constraints (space and time) [8]. As a result, activity types are defined by activity patterns, which are characterized by trip purposes, schedule, duration and travel distance [9]. These types are used for complexity reduction and for realistic representation of differences in space-time behavior of individuals [10]. To identify activity patterns, one-day [9,11] and multi-day [8,10,12,13] travel diaries are mainly used. However, longitudinal surveys are preferable for their ability to capture intrapersonal variance [9]. In addition to activity-based segmentation, there are also approaches that focus only on mode choice. Their object is to study modality types [14,15] or the use of specific modes such as car use [16,17].

These approaches (activity and mode choice) focus mainly on indicators of everyday travel. In general, the consideration of long-distance travel plays a minor role in the segmentation of travel behavior. However, the consideration is reasonable, since a high proportion of the kilometers traveled is caused by long-distance travel, e.g., in Germany it is 45% [18]. Especially, when analyzing sustainable travel behavior of people, it is required to also capture their long-distance travel behavior. Segmentation studies show that there are discrepancies between everyday and non-everyday travel behavior of individuals in terms of sustainable mobility and environmental concerns [19,20].

Another limitation in behavioral segmentations is the lack of information on motives, attitudes and preferences. In recent years, studies by Anable [21] or Hunecke et al. [22] have shown the potential for combining psychological theory and market segmentation, using constructs from the Theory of Planned Behavior [23]. These constructs are considered in more holistic approaches, such as mobility styles.

2.2. Mobility Style Typologies

The multidimensional research concept of mobility styles is about combining methods of lifestyle research with those of travel behavior and relating them to problems of sustainability [24]. Proposed definitions of lifestyle range from quantitative to conceptual ones [25]. Early empirical frameworks operationalized the concept of lifestyles with socio-economic variables and life stages as indicators for lifestyle [26]. Sharp [27] defines lifestyle in terms of household size, age and the social roles as a concept for broad characterization of households. In general, the existing literature provides evidence that life stages have an influence on behavior. Kuhnimhof et al. [28] point out such differences as individuals experience an increase in mobility due to the formation of long-term configurations with regard to residential and work location as well as social networks and habits. Janke et al. [15] also highlight the influence of life stages on travel behavior in their study. Especially, life events (e.g., retirement, having children) trigger changes in travel behavior.

Götz and Ohnmacht [26] argue that lifestyle or mobility styles can be measured even better with orientations. This is also in accordance with the work of Weber [29] as well as Bourdieu and Russer [30], who see lifestyles as attitudes, orientations or preferences. Following Götz et al. [24], mobility styles only emerge through the relationship between orientations and behavior. Götz [31] describes this approach as closing the gap in transportation research through linking the micro-level of psychology with the macro-level of social theory. Attitudinal, motivational and lifestyle dimensions can provide an additional contribution towards explaining variance in travel behavior [26]. One of the early approaches was done by Götz et al. [32] in an urban ecological study on mobility concepts in two German cities in 1998. Redmond [33] performs a segmentation based on psychographic characteristics, such as stress or convenience, with six clusters on the one hand, and a segmentation based on a combination of personality and lifestyle with eleven clusters on the other hand. Both clustering solutions are compared in terms of socio-demographic characteristics. Hausteil [34] segments elderly people into four different groups based on car availability, income, facilities (e.g., shopping facilities) within walking distance, social network and five psychological factors. Based on the obtained groups, differences in travel behavior are investigated and, in particular, differences in car use are demonstrated. Further relevant contributions to the mobility style approaches with a partly strong focus on leisure mobility can be found in the study of Ohnmacht et al. [35].

Besides the mentioned studies about mobility styles, there are also studies in which attitudes and behavior were used as constituent variables simultaneously. These studies have the advantage that emerging segments can reveal dissonances between attitudes and behavior. The emerging segments are not always termed mobility styles. They are called urban mobility types, car dependence types or mobility cultures in the specific studies. However, these approaches are similar to the mobility styles described above. Why it is preferable to use attitudes and behavior simultaneously is also shown by Anable's [21] findings. She mentions that the same behavior can occur for different underlying motiva-

tions and that the same attitudes can result in different behaviors. The following studies use attitudes and behavior simultaneously to identify dissonances. Among five different segments of car owners, von Behren et al. [36] identified the “Car Captives”, who are objectively dependent on the car, but at the same time have a low affective motive. Haustein and Nielsen [2] use motives for mode choice, such as speed, convenience and price, as well as the revealed use of different modes, to find eight mobility styles at the country level in Europe. Consistent segments have emerged, such as the “Green Cyclists” or the “Convenience Drivers”. When considering subjective and objective dimensions, mobility styles with strong contradictions are also revealed. One such mobility style is represented by the “Busy Green Drivers”, of which 96% use cars in everyday life because of speed advantages. At the same time, however, they are concerned about the environment due to traffic pollution. Ramos et al. [37] use a similar two-dimensional approach to investigate differences between car sharing users and non-users in Sweden and Italy. Besides car and public transit use, the authors also consider environmental concern and personal norm as cluster-forming variables. The car sharing users named “Active Public Transit Green” have high environmental concerns and mainly use active modes and public transit. This segment consists of people with a higher income compared to the other four identified segments.

2.3. Theoretical Background for the Analysis

Based on the literature presented, we derive a methodological approach to identify mobility styles as target groups for sustainable urban transport. From the literature, it is known that symbolic-affective or instrumental motives for car use in combination with environmental concerns can explain frequent car use and car ownership in urban areas [38,39]. Further, attitudes were found to show an impact on modal switch [40], which is important for deriving sustainable mobility solutions. Considering the study of Götz and Ohnmacht [26], the inclusion of attitudes and orientations allows to consider lifestyles, which provide insights into understanding travel behavior. This is linked to the findings of Anable [21] that the inclusion of behavioral characteristics simultaneously to attitudinal characteristics allows for the identification of dissonances between both dimensions. Further, Prillwitz and Barr [41] suggest a comprehensive approach with including different aspects of individual mobility and attitudinal characteristics in segmentation to account for contrasting influences. Based on these findings, a segmentation approach that includes aspects of travel behavior and of psychographic characteristics jointly is promising to find distinct mobility styles. However, even if this two-dimensional approach is conducted, it remains unclear, in the context of sustainable urban transport, if there are still differences between car owners and non-car owners within the resulting mobility styles. This leads to our hypothesis for our study: People with a car have a lower ecological norm compared to people without a car. This hypothesis is tested in our study by applying a factor analysis on an item set to identify motives for car use and car ownership and a factor describing ecological norm as well as by selecting behavioral characteristics as cluster-forming variables in a segmentation approach. The resulting mobility styles are then analyzed and described by their specific characteristics. Differences between mobility styles with high car ownership compared to mobility styles with low car ownership will be discussed and implications for the potentials of electric vehicles are given. In addition, we present an in-depth analysis of the mobility style with the highest ecological norm regarding differences between car owners and non-car owners. The results of the segmentation of mobility styles and of the in-depth analysis provide insights on how to find and to address distinct target groups in order to improve a more sustainable urban transport.

3. Survey Design, Data Collection and Sample Description

In this section, we first introduce our study design to capture different aspects for identifying mobility styles in urban areas. Second, we describe our data collection and the sample used for our analysis.

3.1. Survey Design

The analysis of mobility styles requires extensive information (e.g., behavior, sociodemographic and psychographic characteristics). For capturing travel behavior, longitudinal travel surveys with travel diaries are usually used. However, these are expensive, highly time-consuming and result in a high respondent burden and subsequent low response rates [42]. An alternative to travel diaries is the concept of the travel skeleton. The idea of this concept is derived from the longitudinal travel survey of the German Mobility Panel (MOP). Instead of surveying every single trip within a random week by means of a diary, we ask the respondents about relevant activities, trips to these activities and their mode choice in a “typical week” as a “pseudo-longitudinal” approach. The everyday travel is captured through the relevant activities: work, leisure, chauffeuring, errands and shopping. Besides everyday travel, this approach also captures long-distance travel. Surveying travel behavior by means of such a less complicated approach reduces respondent burden considerably and thus allows to integrate psychographic item sets. Including both dimensions (behavior and psychology) allows for an improved understanding of the determinants of mobility [38]. The concept of the travel skeleton has already been tested in various international studies in the U.S., China and Germany [20,38,43–46].

To survey the psychographic characteristics to understand motives, attitudes and norms, we use two standardized item sets that are based on Likert scales. For high validity of the research instrument, we did not develop the used psychological items ourselves. To identify psychological constructs, we integrated comprehensively tested item sets from Hunecke et al. [47] and Steg [39] into our travel skeleton approach. Hunecke’s item set on the intrapersonal evaluation of mode use was drawn from the Theory of Planned Behavior [23] and other mobility-related attitudinal dimensions [22]. One of the constructs that emerges is the ecological norm orientation, which shows a strong relationship with sustainable mode use [47]. Steg’s item set is derived from Dittmar’s model of material possessions [48] and distinguishes the psychological functions of the car into three motive classes: instrumental, affective and symbolic. Steg’s research on motives for car use serves as the basis for numerous studies [38,49]. The three motive classes in relation to car use cannot always be completely separated, e.g., “affective-symbolic” factors also arise [39,49,50]. In summary, both item sets are well established in transport psychology and have been sufficiently validated.

3.2. Data Collection

This study is based on data collected by means of the travel skeleton in surveys with face-to-face interviews conducted in the urban areas of Berlin (Germany) and San Francisco (U.S.) between October 2016 and January 2017. Both cities are comparable by their similar urban mobility culture according to Priester et al. [51] who segmented 41 international cities into six different urban mobility cultures. San Francisco and Berlin are considered as “hybrid cities”, with dense, public transit-oriented urban cores with high levels of public transit and non-motorized transportation use, and are surrounded by low-density, car-oriented suburban areas [52]. In both cities, public transit has a share of more than 25%, walking more than 23%. However, also, a relevant share of car use is observable [53,54]. Differences can only be seen in cycling, as San Francisco has a hilly topography. The hybrid character is favored by sufficient transport infrastructure development, which can be described as a “push-and-push” policy. These cities have invested in both road infrastructure and public transit [51].

The survey had a focus on capturing the mobility-determining characteristics of urban living people in the course of market research. The survey instrument had the aim to provide comprehensive data for various use cases so that it allows to investigate different aspects of mobility. The total sample size from both cities is 1200 people, with 600 respondents from each city. The sampling approach of the professional market research firm in charge of data collection was based on age, gender, household size, spatial type of residence and net income. The distribution of the sample characteristics is also shown in

Figure 1. The resulting sample shows an underrepresentation of single-person households. The other characteristics, such as the distribution of gender and of the younger and middle age groups, are well met. In Berlin, we have a slightly lower share of people in the oldest age group (22%) compared to the external statistics (29%).

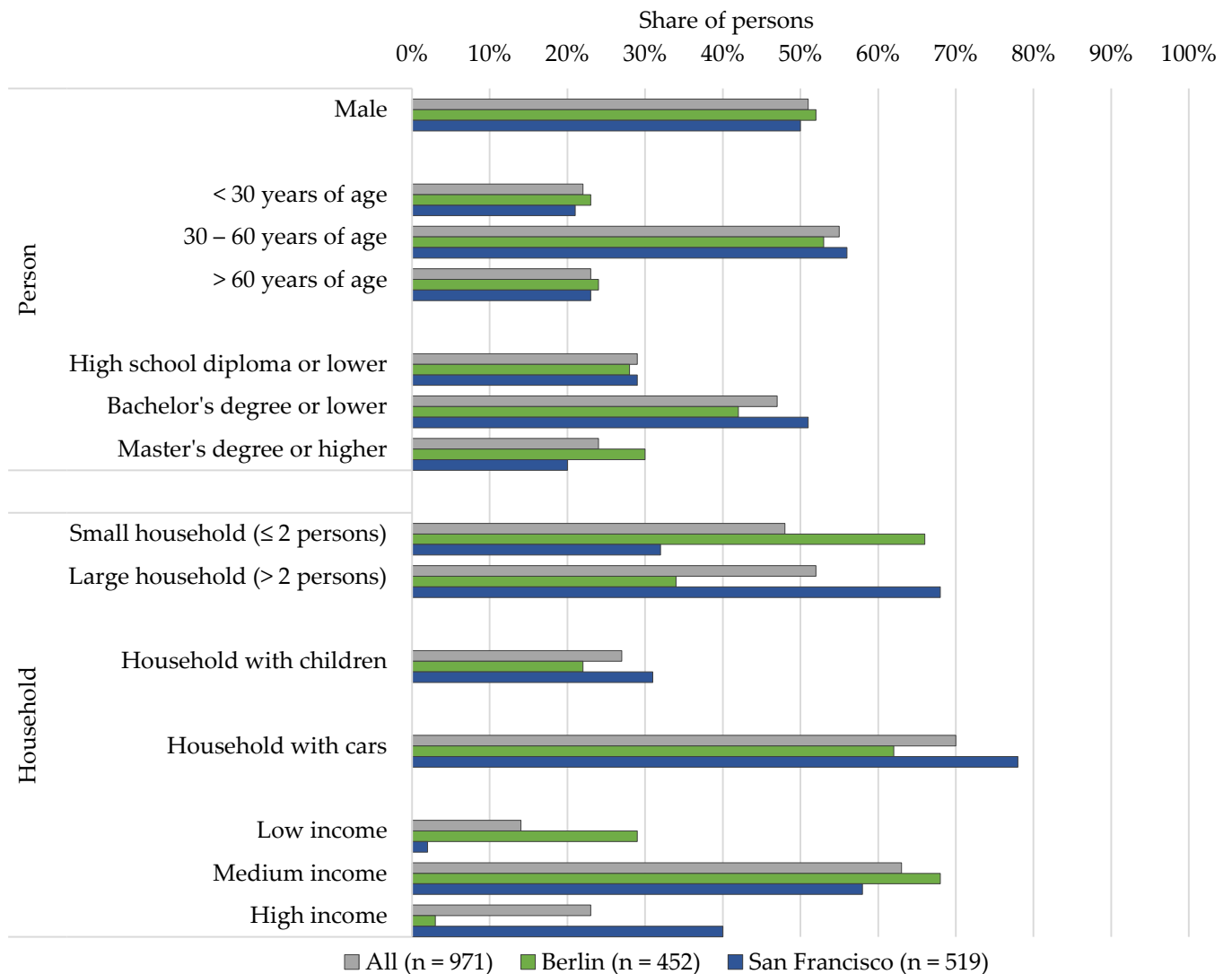


Figure 1. Sample characteristics.

In addition, we verified relevant travel indicators from our sample with travel statistics of both cities to validate our survey instrument. In our sample from Berlin (BER) and San Francisco (SFO), the indicator trips per day is slightly lower (BER: 3.0/SFO: 2.4) than the values from travel statistics (BER: 3.5/SFO: 3.0) [55,56]. This was expected due to the exclusion of random trips by using the travel skeleton approach. The modal shares of our sample in Berlin is nearly identical with the official statistics of Mobilities in Cities 2018 [55]. In our sample from San Francisco, we have a slightly higher share of car use than in the Travel Decisions Survey 2017 [53].

3.3. Sample Description

For the analysis, individuals with missing data were eliminated and a subsample of 971 individuals remained (see Figure 1): 47% of the individuals from the subsample live in Berlin and 53% in San Francisco. In each city, roughly half of the respondents are male. Further, age is equally distributed in both cities in our sample. The figure also shows that 40% of respondents in San Francisco live in a household with high income, whereas in

Berlin, this is only the case for 3%. Accordingly, in our sample from Berlin, a higher share of respondents live in households with low income.

4. Methodology

In this section, we present our methodological approach to identify mobility types. First, we prepare and select input variables for our segmentation. Second, we perform a clustering to segment individuals.

4.1. Data Pre-Analysis

A key challenge in segmentation lies in the selection of input variables (segmentation criteria), as these significantly influence the subsequent allocation in the segmentation process. In this study, we include input variables, both attitudinal and behavioral characteristics, to identify mobility styles that differ from each other in both dimensions.

4.1.1. Behavioral Characteristics

The travel indicators used as segmentation criteria are intended to address different aspects of mobility behavior (e.g., everyday and long-distance travel mobility). The selection of indicators describes four important aspects:

- Traffic volume
- Mode choice (multimodal behavior/importance of the private car)
- Choice of activities in everyday life
- Long-distance travel behavior

Five travel indicators were calculated to represent these different aspects. The selection of these behavioral indicators is adapted from previous studies [20,46]. First, we calculated the average number of trips per day, based on the given information about trips in a typical week. The second indicator captures the monomodal or multimodal behavior, which describes how many different modes are used. To calculate a measure of mode stability (monomodal behavior), we used the Herfindahl-Hirschman-Index (HHI), as used by Mallig and Vortisch [57]. This indicator has a range between 0 (high multimodal behavior) and 1 (monomodal behavior). The third indicator is the share of car use and includes all trips made by car (driver, passenger) and car-related on-demand services. This indicator represents the share of car use in the individual modal split in a typical week and shows the importance of the car. This indicator has a range between 0 (no car use) and 1 (car is the only mode used). The fourth indicator, share of mandatory trips, describes the share of trips to work or school out of all trips in a typical week. This distinction is adapted from Hilgert et al. [58]. The last indicator used was the calculated number of long-distance trips (overnight and daily trips with distances > 100 km) within a year. Since all five indicators showed some interpersonal variation across all participants, they were considered as cluster-forming variables for the following segmentation.

4.1.2. Psychographic Characteristics

Apart from behavioral characteristics, psychographic characteristics were also chosen as segmentation criteria. As a preliminary analysis to our segmentation and to reduce the complexity, we used a principal axis factoring (PAF) method based on selected attitudinal indicators. Before performing the PAF, we conducted Bartlett's test of sphericity (<0.001) which indicates that the data is suitable for the factor analysis as it proves if the correlation matrix, which underlies the analysis, is statistically significant [59,60]. Table 1 shows the results of the PAF with varimax rotated patterns. Based on the scree plot (elbow criterion) and the Kaiser's criterion, three factors were extracted: one describing the symbolic-affective motive and one describing the instrumental motive for car use and car ownership—these two factors correspond to the psychological constructs identified by Steg [39]—and in addition, we identified a third factor regarding the ecological norm of the people, which corresponds to the ecological norm orientation measured by Hunecke et al. [47].

Table 1. Principal Axis Factoring (PAF) based on 13 attitudinal indicators.

Questions \ Attitudinal Indicators	Symbolic-Affective Motive	Ecological Norm	Instrumental Motive
• The make of a car is important to me.	0.790		
• I feel free and independent when I drive a car.	0.775		
• I like to drive a car.	0.727		
• The characteristics of a car can show who and what I am.	0.702		
• A car can communicate status and prestige.	0.670		
• There are dream cars that I would like to drive once.	0.636		
• Due to my principles, I feel personally obligated to use eco-friendly means of transportation for the things I do in everyday life.		0.725	
• People who are important to me think that I should use public transportation instead of a car.		0.707	
• I feel obligated to make a contribution to climate protection via my choice of transportation.		0.704	
• People who are important to me think it is good if I would use public transportation instead of a car for things I do in everyday life.		0.661	
• A car is primarily a means to an end for me.			0.752
• I only use a car to get from A to B.			0.690
• The functioning of a car is more important to me than the make of a car.			0.617

The factor “symbolic-affective motive” describes whether people like to drive and whether the car can have a symbolic function. The factor “instrumental motive” describes whether people only use the car as a tool to fulfill their mobility needs. The factor “ecological norm” represents the social and personal norm concerning the choice of environmental-friendly transport modes. All three factors were found to have sufficient internal consistency (reliability) with a Cronbach’s alpha of 0.86 (“symbolic-affective motive”), 0.80 (“ecological norm”) and 0.73 (“instrumental motive”), respectively. The low value for Cronbach’s alpha of “instrumental motive” (0.73) only shows an acceptable reliability due to the number of attitudinal indicators for the measure. While this is sufficient overall, it must be considered in further analysis.

4.1.3. Life Stages

An individual life course can be divided into life stages. These stages describe periods with different life circumstances (e.g., having children, retirement) that influence behavior and attitudes [21]. However, in the existing literature, the definition of life stages is not uniform [61], as linear and non-linear approaches exist. Within linear approaches, the life stages are roughly in an age-dependent order. The stages are further distinguished by occupation, relationship status and parenthood. A common linear definition is given by Gilly and Enis [62], who define childhood, young adulthood, living with a partner, early career, marriage, parenthood and retirement as distinct life stage. More complex distinctions are non-linear approaches, which are less age-dependent and also include divorce and re-marriage [15]. In our study, we use a linear approach and define life stage groups depending on household structure, job situation and age. Therefore, we adapted the mentioned life stages from Gilly and Enis [62]. The more advanced distinction of life stages such as marriage, divorce or re-marriage is not possible due to lack of data. The following six life stages were defined: younger people without children (currently aged under 40 years) and not employed (people are independent and mainly students), younger people without children but employed (currently aged under 45 years in their early career), large household with children (obligations due to children under 18 years and job), large households without children aged under 18 years (obligations due to family

and job), middle-aged people (currently aged between 45 and 65 years) with employment (e.g., children left home) and elderly people without employment (e.g., retirement).

For the following segmentation, eight variables are used from the behavioral and psychographic characteristics (five behavioral and three attitudinal). The information about the life stages is not included in the segmentation process. This information is later used to explain differences between the identified segments.

4.2. Clustering

Segmentation approaches are basically divided into the two categories, supervised (a priori) and unsupervised (post hoc) methodologies [21]. The supervised methodologies are used when the segments are known or predefined and the main objective is to classify new observations into these segments. Unsupervised methodologies are used when the objective is to find homogeneous groups in multivariate data. Among the different methods of cluster analysis, hierarchical and partitioning cluster analyses are most common in transportation. To utilize the advantage of both methodologies, the hierarchical Ward's method is combined with the partitioning method of k-means in a two-step cluster analysis in transportation [12,20,21,60,63,64]. This two-step approach is also used in our study. To ensure that the eight cluster-forming variables do not have different weights, a linear transformation is performed with the procedure ACECLUS (Approximate Covariance Estimation for Clustering) in the software SAS [65]. Including the cluster-forming variables in our two-step cluster analysis, we first calculated the optimal number of clusters with the minimum variance method (Ward's method) [66]. Based on the Cubic Cluster Criterion (CCC) and Pseudo t^2 , we obtained an 8-cluster solution [65]. In the second step, the cluster centroids were then used as starting points in the following k-means clustering to improve the overall solution. This is because the k-means algorithm allows for a modified allocation or exchange of observations between the clusters [20].

5. Results

As a result of the selection of cluster-forming variables in combination with the two-step cluster analysis, we identified eight clusters. Each cluster represents a mobility style with distinctive characteristics that reflects a group of people from our survey. In the following, we statistically analyze the mobility styles by identifying significant differences between the means of the cluster characteristics through Welch analysis of variance (ANOVA) and Tukey post-hoc tests. For categorical characteristics, we applied chi-square tests. Based on the specific characteristics, we name the eight mobility styles. Subsequently, we conduct an in-depth analysis of the largest and (from a sustainability standpoint) most interesting group for future mobility solutions.

5.1. Cluster Description

Table 2 contains the mean values of different variables for all clusters. Significant differences in means to other clusters are given by superscripted numerals.

CL 1 and CL 4 show the lowest number of trips per day and a small share of mandatory trips. However, CL 1 has a significantly higher share of car use than CL 4. Furthermore, people from CL 4 do not perceive any instrumental or symbolic-affective motives in association with cars. CL 2 and CL 3 have a similar symbolic-affective motive for car use. However, they are significantly different in mode stability and their share of car use. People in CL 2 have a significantly higher share of car use than CL 3. Despite also using other means of transportation, people in CL 3 still have a high share of car use of 0.69. CL 5 and CL 7 both have a low share of car use. Interestingly though, they are significantly different regarding their ecological norm. Moreover, CL 7 is by far the largest cluster in our study and contains people with multimodal behavior. Lastly, CL 8 mainly distinguishes itself from the other clusters through its high number of long-distance trips per year, even if there is no significant difference of the ecological norm to CL7.

Table 2. Descriptive cluster characteristics.

Cluster	All	1	2	3	4	5	6	7	8	<i>p</i>
Number of observations in %	971 100%	85 9%	134 14%	133 14%	51 5%	80 8%	146 15%	258 27%	84 9%	
Cluster-forming variables										
Trips per day	2.54	1.03 ²³⁵⁶⁷⁸	2.64 ¹³⁴⁶⁷	3.32 ¹²⁴⁵⁶	1.17 ²³⁵⁷⁸	2.73 ¹³⁴⁶⁷	1.47 ¹²³⁵⁷⁸	3.24 ¹²⁴⁵⁶	3.03 ¹⁴⁶	
Mode stability	0.55	0.94 ³⁶⁷⁸	0.94 ³⁶⁷⁸	0.36 ¹²⁴⁵⁷	0.92 ³⁶⁷⁸	0.91 ³⁶⁷⁸	0.35 ¹²⁴⁵⁷	0.32 ¹²³⁴⁵⁶	0.34 ¹²⁴⁵	
Share of mandatory trips	0.33	0.01 ²³⁵⁷⁸	0.55 ¹³⁴⁶⁷⁸	0.44 ¹²⁴⁵⁶	0.00 ²³⁵⁷⁸	0.53 ¹³⁴⁶⁷⁸	0.01 ²³⁵⁷⁸	0.43 ¹²⁴⁵⁶	0.37 ¹²⁴⁵⁶	
Share of car use	0.44	0.94 ³⁴⁵⁶⁷⁸	0.93 ³⁴⁵⁶⁷⁸	0.69 ¹²⁴⁵⁶⁷⁸	0.14 ¹²³⁶⁸	0.09 ¹²³⁶⁸	0.37 ¹²³⁴⁵⁷	0.12 ¹²³⁶⁸	0.37 ¹²³⁴⁵⁷	
Long-distance trips p.a.	2.04	0.75 ²³⁶⁷⁸	1.81 ¹⁴⁵⁸	1.52 ¹⁸	0.96 ²⁶⁷⁸	0.91 ²⁶⁷⁸	1.76 ¹⁴⁵⁸	1.74 ¹⁴⁵⁸	7.63 ¹²³⁴⁵⁶⁷	
Symbolic-affective motive	0.01	−0.43 ²³⁸	0.49 ¹⁴⁵⁶⁷	0.64 ¹⁴⁵⁶⁷⁸	−0.62 ²³⁶⁷⁸	−0.26 ²³⁸	−0.10 ²³⁴	−0.22 ²³⁴⁸	0.19 ¹³⁴⁵⁷	
Ecological norm	0.01	−0.80 ²³⁴⁵⁶⁷⁸	−0.37 ¹³⁵⁶⁷⁸	−0.03 ¹²⁷	0.01 ¹⁷	0.02 ¹²⁷	0.07 ¹²⁷	0.41 ¹²³⁴⁵⁶	0.15 ¹²	
Instrumental motive	0.01	0.11 ⁴⁵	−0.15 ⁴⁷	−0.07 ⁴	−0.62 ¹²³⁶⁷⁸	−0.30 ¹⁶⁷⁸	0.13 ⁴⁵	0.20 ²⁴⁵	0.21 ⁴⁵	
Cluster-describing variables										
<i>Socio-demographic characteristics</i>										
Urbanity Index *	2.26	2.23 ⁵	2.29 ⁵	2.25 ⁵	2.24 ⁵	2.50 ¹²³⁴⁶⁷⁸	2.26 ⁵	2.17 ⁵	2.28 ⁵	
Cars in household	1.00	1.07 ²³⁴⁷	1.57 ¹⁴⁵⁶⁷⁸	1.53 ¹⁴⁵⁶⁷⁸	0.41 ¹²³⁵⁶⁸	0.89 ²³⁴	0.88 ²³⁴⁷	0.62 ¹²³⁶⁸	0.98 ²³⁴⁷	
Transit pass owners	40%	6%	5%	20%	53%	80%	40%	63%	45%	<0.0001
Km per day	21.47	7.11 ²³	44.34 ¹⁴⁵⁶⁷⁸	37.48 ¹⁴⁵⁶⁷	6.58 ²³	14.48 ²³	7.32 ²³	19.07 ²³	21.80 ²	
Male	51%	46%	54%	55%	49%	43%	49%	53%	55%	0.578
From Berlin	47%	13%	16%	28%	31%	33%	60%	75%	71%	<0.0001
<i>Mean frequency of use of transport modes</i>										
Walk **	3.52	6.28 ²³⁴⁵⁶⁷⁸	5.43 ¹³⁴⁶⁷⁸	3.54 ¹²⁵⁶⁷⁸	3.96 ¹²⁶⁷⁸	4.76 ¹³⁶⁷⁸	2.71 ¹²³⁴⁵⁷	1.96 ¹²³⁴⁵⁶	2.40 ¹²³⁴⁵	
Bike **	5.14	6.87 ³⁵⁶⁷⁸	6.52 ³⁶⁷⁸	5.44 ¹²⁷⁸	6.27 ⁶⁷⁸	5.96 ¹⁷⁸	5.18 ¹²⁷⁸	3.54 ¹²³⁴⁵⁶	4.05 ¹²³⁴⁵⁶	
Car as driver **	4.21	5.01 ²³⁴⁸	1.99 ¹⁴⁵⁶⁷⁸	2.37 ¹⁴⁵⁶⁷⁸	6.47 ¹²³⁶⁷⁸	5.73 ²³⁶⁸	4.26 ²³⁴⁵⁷	5.28 ²³⁴⁶⁸	3.63 ¹²³⁴⁵⁷	
Car as passenger **	4.65	4.04 ²⁴⁵⁷	4.88 ¹³	3.36 ²⁴⁵⁶⁷⁸	5.55 ¹³⁶⁸	5.34 ¹³⁶	4.32 ³⁴⁵⁷	5.21 ¹³⁶	4.61 ³⁴	
Public transit t **	4.09	6.69 ³⁴⁵⁶⁷⁸	6.48 ³⁴⁵⁶⁷⁸	5.34 ¹²⁴⁵⁶⁷⁸	4.37 ¹²³⁵⁷	2.14 ¹²³⁴⁶⁸	4.04 ¹²³⁵⁷	2.06 ¹²³⁴⁶⁸	3.69 ¹²³⁵⁷	
Carsharing **	5.22	5.00	5.57	5.29	5.33	6.00	5.07	5.15	5.18	
Ridesharing **	4.52	5.00	4.03	3.77 ⁵⁷	5.00	5.39 ³	4.63	4.96 ³	4.40	

* 1 = super urban, 2 = urban, 3 = suburban; ** 1 = daily, 2 = several times a week, 3 = once a week, 4 = several times a month, 5 = once a month, 6 = less than once a month, 7 = never. Significance of differences have been tested by chi-square tests or Tukey post-hoc test where noted with superscript numerals ($p < 0.05$). For example, the notation 1.03²³⁵⁶⁷⁸ (first cell) indicates that trips per day of Cluster 1 significantly differs from the other clusters. Individual percentages have been rounded up or down, so may not sum to 100.

The further cluster-describing variables in Table 2 allow for the analysis of additional cluster aspects. CL 2 and CL 3 show the highest car ownership and the highest mean travel distance per day. For people in CL 5, it is specific that they rather live in the suburbs. The frequencies of use of different transport modes highlight further significant differences between the clusters. People in CL 2 and CL 3 drive cars more often than all other clusters. In contrast, people from CL 7 and CL 8 cycle more frequently than other clusters. CL 5 and CL 7 are the most frequent public transit users among the mobility styles.

Table 3 highlights the socio-economic characteristics of the clusters. An important variable for interpreting mobility styles is the life stage. Since mobility needs change with each life stage with specific circumstances [28], it can help to understand why people have a certain mobility style. For example, it reveals that CL 1, CL 4 and CL 6 primarily consist of elderly and retired people. This explains why people from these clusters have few mandatory activities and are thus making the least trips per day. In contrast to this, CL 7 mainly contains young, independent people with a comparatively low income and a high ecological norm. This cluster is particularly relevant to the topic of sustainability, as it evidently represents the environmentally oriented generation of the future. It is therefore considered in more detail in the following Section 5.2. CL 2, CL 3 and CL 5 can be identified as mostly middle-aged families. Work obligations and chauffeuring of children explain their high need for mobility in everyday life.

CL 2 and CL 3 have the highest shares of people with high household income and these people can thus afford owning several cars (see Table 2). In combination with their strong symbolic-affective motive, this leads to them using cars for the majority of their trips. Lastly, CL 8 stands out as 88% of its people have a university degree and people in this cluster are from almost all life stages. Despite the high education, people from this cluster show a strong symbolic-affective motive and take the most long-distance trips by far. Thus, in this cluster, many peoples' symbolic-affective motive for car use seems to outweigh their environmental concerns.

Table 3. Socio-economic cluster characteristics.

Cluster		All	1	2	3	4	5	6	7	8	<i>p</i>
Number of observations in %		971	85	134	133	51	80	146	258	84	
		100%	9%	14%	14%	5%	8%	15%	27%	9%	
Life stage	1—Young, independent	7%	0%	1%	2%	2%	11%	4%	16%	5%	<0.0001
	2—Young, employed	13%	0%	10%	14%	8%	9%	8%	22%	23%	
	3—Household with children	27%	13%	37%	39%	6%	34%	21%	29%	18%	
	4—Large HH * w/o children	22%	31%	33%	26%	25%	24%	19%	13%	20%	
	5—Middle-aged, employed	14%	2%	18%	14%	0%	18%	5%	16%	30%	
	6—Elderly, not employed	17%	54%	1%	5%	59%	5%	43%	4%	4%	
Education	High School Diploma or lower	29%	36%	22%	21%	43%	36%	23%	37%	12%	<0.0001
	Bachelor's Degree or lower	47%	49%	50%	51%	43%	43%	58%	38%	49%	
	Master's Degree or higher	24%	14%	28%	28%	14%	21%	18%	25%	39%	
Income	Low	15%	0%	1%	6%	14%	14%	17%	30%	14%	<0.0001
	Medium	63%	79%	57%	56%	67%	73%	68%	56%	66%	
	High	23%	21%	43%	38%	20%	14%	15%	14%	20%	

* HH = Household. Significance of differences have been tested by chi-square tests. Individual percentages have been rounded up or down, so may not sum to 100.

Based on the analysis of the cluster-forming, cluster-describing and socio-economic variables, we can summarize each cluster's characteristic features (see Table 4). In addition, each cluster is given a concise name, to simplify the understanding of the clusters as mobility styles.

Table 4. Cluster (CL) names and brief descriptions.

CL	Mobility Style	Frequency	Brief Description
1	Low Mobile Car Users	9%	Low mobile well-off pensioners; car-only albeit little symbolic-affective motive for car use with low ecological norm
2	Car Addicts	14%	Highly mobile well-off families; car-enthusiasts with low ecological norm and little multimodal behavior
3	Car-oriented Everyday Performers	14%	Highly mobile (rather younger) well-off families; primarily use of car, but also multimodal behavior
4	Car-averted Low Mobiles	5%	Low mobile elderly with low car ownership; if mobile, then by public transit or on foot
5	Public Transit Enthusiasts	8%	Mobile younger people and families from the suburbs; public transit use and little multimodal behavior
6	Multimodal Travelers	15%	Middle-aged and elderly people with multimodal behavior; low car use and everyday mobility, but active in long-distance travel
7	Environmentally Oriented Multimodals	27%	Highly mobile young urban people with high ecological norm and multimodal use of eco-modes
8	Travel Addicts	9%	Highly mobile well-off professionals with many long-distance trips; multimodal behavior and average car use

Individual percentages have been rounded up or down, so may not sum to 100.

5.2. In-Depth Analysis of Cluster 7 (Environmentally Oriented Multimodals)

In the previous section, CL 7 was identified to likely include the environmentally oriented generation of the future as it mainly consists of environmentally oriented young people with multimodal behavior. They have the most progressive mobility style in terms of sustainability. However, in our subsample, half of these people own a car. This raises the question, what causes so many urban people with a high ecological norm to own a car they rarely use. To investigate this issue and our hypothesis presented in Section 2.3,

we differentiate people from CL 7 who own a car from those who do not and analyze the differences between the two groups.

Table 5 presents the descriptive characteristics of both groups within the cluster. It shows that car ownership is not explained by a lower environmental norm. In addition, no significant difference regarding the instrumental motive is revealed. Instead, people without a car have a significantly lower symbolic-affective motive for car use. Accordingly, they make very frequent use of walking or public transit in order to be mobile. However, even the car owners in this cluster walk and use public transit more frequently than they use their car. This explains the small share of car use of only 0.17 for this group's everyday travel.

Table 5. Descriptive characteristics of Cluster 7.

Cluster 7	With Car	W/o Car	<i>p</i>
Number of observations in % of total subsample	129 13%	129 13%	
Share of car use	0.17	0.07	<0.0001
Symbolic-affective motive	−0.03	−0.42	<0.0001
Ecological norm	0.34	0.48	0.1722
Instrumental motive	0.19	0.22	0.8069
Urbanity Index *	2.23	2.11	0.0119
Cars in household	1.25	0.00	
Walk frequency **	2.37	1.51	<0.0001
Bike frequency **	3.56	3.53	
Car as driver frequency **	4.22	6.34	<0.0001
Car as passenger frequency **	4.81	5.63	<0.0001
Public transit frequency **	2.28	1.84	0.0117

* 1 = super urban, 2 = urban, 3 = suburban; ** 1 = daily, 2 = several times a week, 3 = once a week, 4 = several times a month, 5 = once a month, 6 = less than once a month, 7 = never. Significance of differences have been tested by Welch analysis of variance (ANOVA).

The socio-demographic characteristics of the two different groups within the cluster are illustrated in Table 6. It becomes clear that for the Environmentally Oriented Multimodals, education has no apparent relation with car ownership. On the contrary, household income is related to car ownership. Nearly half of the people that do not own a car have a low income, whereas this is only the case for 13% of people that own a car.

Table 6. Socio-economic characteristics of Cluster 7.

	Cluster 7	With Car	W/o Car	<i>p</i>
	Number of observations in % of total subsample	129 13%	129 13%	
Life stage	1—Young, independent	6%	26%	<0.0001
	2—Young, employed	15%	29%	
	3—Household with children	35%	23%	
	4—Large HH * w/o children	20%	6%	
	5—Middle-aged, employed	20%	11%	
	6—Elderly, not employed	4%	5%	
Education	High School Diploma or lower	39%	36%	0.8119
	Bachelor's Degree	38%	38%	
	Master's Degree or higher	23%	26%	
Income	Low	13%	47%	<0.0001
	Medium	63%	50%	
	High	24%	4%	

* HH = Household. Significance of differences have been tested by chi-square tests. Individual percentages have been rounded up or down, so may not sum to 100.

Furthermore, the results indicate an impact of the life stage on car ownership: 55% of people without a car are young, while among car owners, 55% live in families and only 21% are young people. This indicates that even among Environmentally Oriented Multimodals, many families feel the necessity to own a car, which they only rarely use for certain mobility needs such as weekend excursions not accessible by public transit. Further, the results indicate that the additional consideration of life stages reveals differences within a mobility style, even if attitudinal characteristics were considered in the segmentation process.

6. Discussion

The analysis of the mobility style characteristics has yielded insights which allow for the research questions to be answered. The Car-averted Low Mobiles (CL 4) and the Multimodal Travelers (CL 6) are identified and described as people who, if they are mobile, already use public transit or other sustainable means of transportation such as walking and cycling. For the further discussion, we focus on the other identified clusters that have higher levels of mobility or car use. However, we underline that policy measures can also have an effect on CL 4 and CL 6, and, above all, care must be taken so that the attractiveness for these people to use public transit is not reduced. Low Mobile Car Users (CL 1), Car Addicts (CL 2), Car-oriented Everyday Performers (CL 3), Public Transit Enthusiasts (CL 5), Environmentally Oriented Multimodals (CL 7) and Travel Addicts (CL 8) can be identified as the main target groups to improve the sustainability of urban mobility due to their high mobility needs or car ownership. In total, 80% of the people we analyzed are assigned to these mobility styles. Car Addicts (CL 2) and Car-oriented Everyday Performers (CL 3) are by far the most frequent car users. Thus, these clusters are the least sustainable in terms of emissions in everyday travel. In contrast to this, Public Transit Enthusiasts (CL 5) mainly use public transit and are relatively independent from the car. Apart from being car-independent, most of these people still have a car in the household, which can consequently take up urban public space. However, it must also be considered that car ownership is often a decision on household-level. It is likely that other household members and their mobility needs are the reason for the car ownership and not the individual assigned to the Public Transit Enthusiasts (CL 5) in our analysis. The high car ownership of Low Mobile Car Users (CL 1) brings about the same problem regarding the use of public space. Similar to CL 5, half of the Environmentally Oriented Multimodals (CL 7) live in households with a car, although they mainly rely on the multimodal use of other means of transportation. Travel Addicts (CL 8) behave unsustainably in terms of emissions, considering their high number of long-distance trips.

To determine their potential for accepting and using sustainable mobility solutions, the identified mobility styles can be divided into four groups:

- Mobility styles with little potential
- Mobility styles that are already sustainable, but not due to their norms
- Mobility styles that are already sustainable due to their norms
- Mobility styles that are unsustainable, even though they have a high ecological norm

Low Mobile Car Users (CL 1) have a high share of car use in combination with a low symbolic-affective motive for car use. This shows their dependency on the car. Car Addicts (CL 2) and Car-oriented Everyday Performers (CL 3) mainly use a car because of their strong symbolic-affective motive. Thus, all three mobility styles have little potential to respond to sustainable mobility solutions due to their fixed motives for car use and their low ecological norm. Two appropriate measures to improve the sustainability in the mobility of these clusters might be financial incentives to switch to a BEV or restrictive regulation for cars with combustion engines in urban areas.

Public Transit Enthusiasts (CL 5) are already relatively sustainable in their mobility as they primarily use public transit and have a low share of car use. The reason for this behavior is that they neither have symbolic-affective nor instrumental motives for car use. However, since the ecological norm is also not strong, other motivations must play a role. These might be financial restrictions or the socialization with the use of public transit. This

cluster thus represents the group of people who are already largely sustainable in their mobility, but not due to their ecological norms. A problem with this group is the relatively high car ownership in comparison to the low share of car use in everyday travel, though it is likely that other household members and their mobility needs are the reason for the car ownership. One possible measure to motivate people to give up their unused cars might be higher parking fees in combination with the provision of a car-sharing system. As people in this cluster also rather live in suburbs, the provision of an electric bike sharing system as presented by Bieliński et al. [67] enhances the public transit services and thus could further support the use of public transit.

The in-depth analysis of CL 7 revealed that even among Environmentally Oriented Multimodals, there are differences in the sustainability of people's mobility. Half of the people with this mobility style do not own a car and make trips almost exclusively by foot, by bike or with public transit. They account for 13% of our subsample and can be identified as the only truly sustainable group in their everyday mobility. From the particularly high ecological norm and the low symbolic-affective motive for car use, it can be concluded that this behavior is caused by conviction.

The other half of Environmentally Oriented Multimodals (CL 7) are mainly people having families, who feel the necessity to own a car, because of certain obligations. They can be described as people who are environmentally oriented, but are not yet sustainable in their mobility. Thus, they have the biggest potential to accept and use sustainable mobility solutions. Although the Travel Addicts (CL 8) do not show a high environmental norm, we see potential to address them with sustainable mobility systems such as electric shared mobility systems as an alternative of car ownership, as they have a medium share of car use in daily travel and are rather multimodal. However, such systems have to be reliable and improved, as described by Turoń et al. [68], to meet the mobility needs of this cluster as it is primarily described by a high number of long-distance travel events.

7. Limitations of the Approach

The methodology applied and the discussion of the results presented led to a better understanding of mobility styles in urban areas. With our segmentation, we are able to identify different potentials for a more sustainable mobility for each mobility style. Nevertheless, the limitations of our study should not be overlooked. We see two limitations that need to be considered. Firstly, in this study, we examined people from Berlin and San Francisco only. However, it is likely that in other cities, for example in other cultures or cities with potentially other qualities of public transport infrastructure and services, we find other mobility styles and discover other potentials for sustainable mobility. Secondly, we only captured mobility at one point in time with our study. Our results show that people in different life stages are assigned to different mobility styles. However, we do not see whether people stay in their mobility style during their life cycle or whether they change to other mobility styles as they change into other life phases. This would require more in-depth studies of socialization and cohort effects, which cannot be answered with the provided data, since the survey did not follow a panel approach.

8. Conclusions

This study identified eight urban mobility styles by using data from a multidimensional survey approach and by applying a cluster analysis with both behavioral and attitudinal characteristics as segmentation criteria. The resulting segments describe the diversity of mobility of individuals in urban areas with their specific mobility-determining characteristics. For example, we found mobility styles who choose a particular mode of transportation out of conviction, and other mobility styles, who are led to the use of a particular mode of transportation by "external" constraints. These findings allow for a deeper understanding of mobility and thus the derivation of potentials for influencing these mobility styles with the goal of a more sustainable mobility in cities. The following conclusions can be drawn for the different steps presented in this study.

Our presented segmentation approach has many advantages. Since both attitudinal characteristics and behavioral characteristics were included in the segmentation at the same time, we found clusters that are similar in one dimension, but different in another. Furthermore, the descriptive analysis of the clusters made it possible to identify and describe the specific characteristics of each cluster. In this context, the examination of life stages is to be highlighted. We identified a link between the life stages and the mobility styles since certain life stages are overrepresented in some mobility styles. By considering life stages, we broadened our view from the person level to the household context and gained a better understanding of mobility. In this context, it also became apparent that a more in-depth analysis of mobility styles, as opposed to the usual mean-value approach, provides further insights into characteristics that influence mobility. Through our in-depth analysis of the cluster Environmentally Oriented Multimodals, we found that within this mobility style, the change from one life stage to another is also likely to be accompanied by a car acquisition. Against our hypothesis, the in-depth analysis of this cluster revealed that car owners are different to non-car owners primarily because of their symbolic-affective motive rather than because of a lower environmental norm.

By analyzing the characteristics of all mobility styles, we were able to identify the target groups for improving the sustainability of urban mobility: 80% of the people within our analyzed sample are assigned to one of these mobility styles. To answer the question of which of these mobility styles has an increased potential for accepting and using sustainable mobility solutions, we divided them into four groups. Two of the groups are already sustainable in their mobility and one group has little potential for adopting sustainable mobility solutions. The last group of people are environmentally oriented but are not yet sustainable in their mobility. People from the Environmentally Oriented Multimodals show these characteristics, and thus, they can be identified as the group with the highest potential to accept and use sustainable mobility solutions due to their ecological norm orientation.

The results presented in this study are based on an analysis from survey data from Berlin (Germany) and San Francisco (U.S.). Further research should address the question of what mobility styles exist in other cities. It should also investigate the influence of the built environment, especially the public transport infrastructure, and the influence of culture on mobility styles. In addition, further research should place a stronger focus on life stages. Of interest is whether individuals switch between mobility styles within their life cycle, or whether there is stability due to the habits and socialization of the individuals. This aspect can only be answered by surveying individuals at different points in time and thus potentially in different lifecycle stages, i.e., by means of a panel survey. However, existing panels, as far as to the authors' knowledge, do not have comprehensive information on attitudes and behavior, which would be necessary for the identification and description of mobility styles.

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