Article

Usage and User Characteristics—Insights from MOIA, Europe's Largest Ridepooling Service

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Abstract: New, i.e., shared and digitized, mobility services have been entering urban mobility markets around the globe. Among these new offerings is ridepooling, a mobility solution that bundles requests from passengers with similar routes in real-time and matches them with a vehicle. Ridepooling is quite novel in Germany and knowledge about users, changes in travel behavior, and impacts on the urban traffic system is scarce. To address this gap, we conducted an online survey among users and non-users of MOIA, a German ridepooling provider. Over 12,000 respondents completed the survey. The article presents results on ridepooling users' characteristics and usage patterns. We found that MOIA users cover all age groups and are multimodal travelers—which leads us to assume that ridepooling enriches mobility portfolios and also serves as an alternative to the private car. MOIA is mostly used occasionally and, in particular, during the evening or the night. A specific focus of the article lies on users with mobility impairments as well as how and by whom ridepooling is used on work-related trips. Both topics are particularly relevant in light of changing travel patterns and transforming urban transport systems towards more sustainability.

Keywords: ridepooling; shared mobility; user analysis

1. Introduction

Within a few years, the number of shared mobility providers offering their services in cities all over the world has been steadily increasing. They attract customers with user-centered and demand-responsive mobility services that are supplementary to other modes. Users can either share a ride or a vehicle (e.g., a car, a bicycle, or an e-scooter). The development has been enabled by digitalization trends in the transportation sector [1], and can furthermore be seen as a reaction to increasing user requirements in light of the individualization of travel behavior. These new services pose the potentials to change individual travel patterns and, hence, to contribute to more sustainable transportation systems by reducing private car usage.

Among these shared mobility offerings is ridepooling (sometimes also called 'shared ridehailing' or just 'ridesharing'), a digital mobility solution which bundles "spatially and temporally corresponding transportation requests" [1] (p. 1), thus allowing for 'pooling' of rides within one vehicle. It is important to differ this form of transportation from 'ridehailing', where drivers and users are usually matched on an individual basis, i.e., one vehicle serves one rider (or one group of riders that requested the trip without detours through one account). Ridepooling can additionally be distinguished from (peer-to-peer, or casual) carpooling, a mobility service that connects riders with drivers that are heading the same direction and want to share travel costs, often on long-distance, commuting or other reoccurring trips, and usually self-organized or organization-based [2].

Ridepooling as a form of mobility offering has in general existed for decades already. Under the terms 'demand-responsive transport' (DRT), 'microtransit', or 'paratransit', flexible booking and routing schemes have been deployed specifically in rural and underserved

areas all over the world [3,4], in many countries of the global South [5], or for transport users with special needs [6]. It is only recently, though, that this form of transportation has gained increased attention. While established services have been operated mostly through basic computer-aided systems, and telephone booking processes, ridepooling service performance in its 'new', i.e., digitalized, form is enhanced by real-time routing and dispatching as well as more flexible ways of booking and payment [4]. Foljanty [7] presents an overview from around the world on services currently running.

This modern form of ridepooling is presumed to offer potentials to foster public transportation use because it serves as an attractive supplement to public transit and increases the overall variety of transportation options. In turn, the service may enhance inter- and multimodal travel behavior patterns. By optimizing routes, matching users to vehicles and providing information in real-time, customers benefit from an individualized, flexible, and comfortable product. Furthermore, several transportation simulation studies have already shown beneficial effects on urban transportation systems, if ridepooling was introduced hypothetically, and on a large scale (cf. [8–12]).

A German ridepooling provider is MOIA, a 100% subsidiary of the Volkswagen Group. The company currently operates in the German cities of Hamburg and Hanover in close cooperation with the local authorities and public transportation providers, however, commercially and not under public contract, as is usual in Germany. The drivers are employed under social security conditions by the company. MOIA's ridepooling fleet is all-electric and consists of around 500 vehicles which makes it the largest fleet in Europe [7]. The vehicles, with a maximum of six passengers, are custom-made and specifically designed for ridepooling purposes, e.g., with a large luggage compartment, an in-vehicle screen, USB ports, and headrests that provide more privacy, see Figure 1. The provider offers a fully-fledged service that covers the technical infrastructure, algorithms, applications, in-vehicle components, as well as the fleet management. Similar to other on-demand ridepooling providers around the globe, MOIA uses routing, pooling, and dispatching algorithms to deploy its service. Customers book a ride through a mobile app and are subsequently assigned to a vehicle and a virtual stopping point. Along their rides, other users with similar origins and destinations may join. Through a service API, MOIA is additionally integrated into Hamburg's public transit aggregator application hvv switchh.
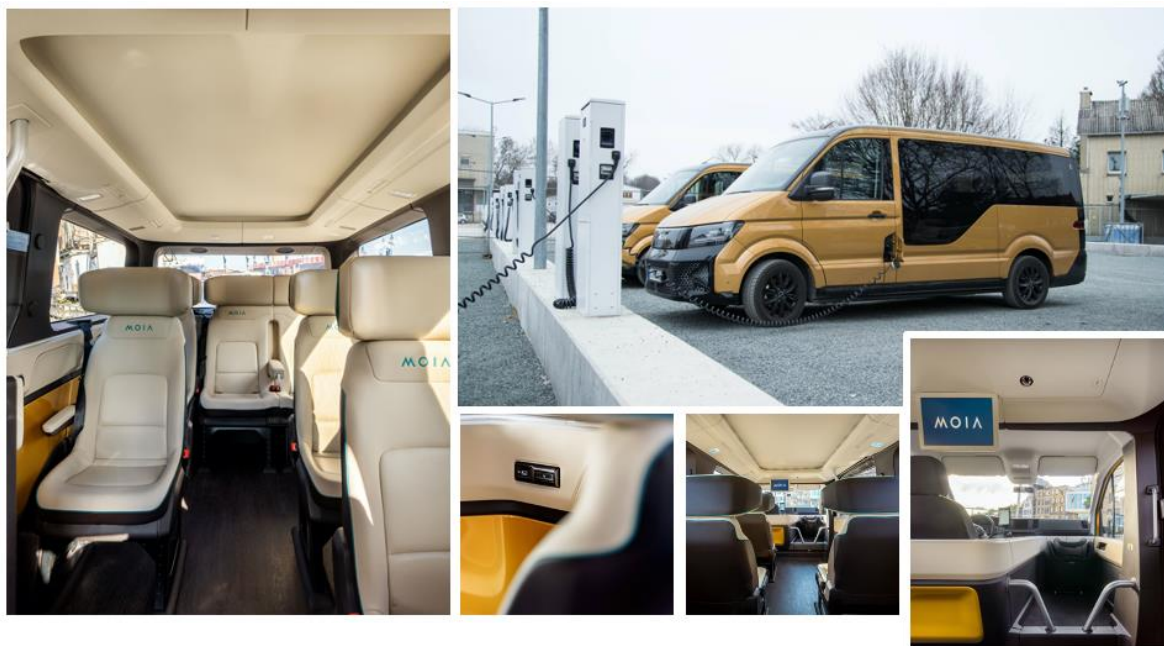
Figure 1. The MOIA ridepooling special-purpose vehicle (pictures provided by the authors).

In order to understand who MOIA ridepooling users are, and how ridepooling influences individual travel patterns as well as the urban transportation system, MOIA is cooperating with the Karlsruhe Institute of Technology (KIT) and the Technical University of Munich (TUM) on a two-year accompanying research project to analyze the implications of ridepooling. Throughout the course of the project, quantitative and qualitative research as well as travel-demand modelling will be applied. The findings will help to determine the transport-related potentials of ridepooling by the support of a vast body of empirical data that is currently missing in most studies. Research like this one is an important cornerstone in policy and planning processes on the road towards more sustainable transport in cities and municipalities, and furthermore, it will help to provide a scientific base for a sometimes emotional discourse on ridepooling.

This article focuses on an empirical survey that was conducted in light of the project and presents selected results for users and usage of MOIA ridepooling, mainly for the Hamburg case. Understanding travel behavior with regard to new mobility concepts is key to identify willingness as well as obstacles to use these services [13,14]. To complement the existing research on ridepooling, we will present results from the survey, addressing the following research questions:

- Who are MOIA ridepooling users? What are their sociodemographic and mobility-related characteristics?
- How do they differ from people who do not (yet) use ridepooling?
- What does MOIA ridepooling usage look like?
- How do MOIA customers assess the mobility service and other transport modes?

The paper is structured as follows: first, we review findings from previous studies on ridepooling and subsequently identify research gaps. In the 'Results' section, we compare users to non-users and analyze their travel behavior and MOIA usage reasons. Two topics are highlighted that we find particularly relevant for the current debate on new mobility modes and their implications: we focus on ridepooling users with mobility impairments—a user group of growing relevance that is oftentimes overlooked when it comes to potentials that new mobility modes can offer—as well as customers that use MOA for work-related trips. Commuting is a particularly major factor for high traffic volume, and understanding potential changes in mobility behavior of commuters is thus key to be able to achieve more sustainable travel patterns as well as the positive implications of 'new' on-demand and shared modes like ridepooling. Concluding, we discuss the results presented.

2. Background

In general, demand-responsive transport has been serving areas with low demand where traditional public transportation has not been cost-efficient in Germany for several decades. The metropolitan region of Hamburg alone counts almost 60 offerings that operate on an on-demand level, mostly provided by taxi companies, and operating with the help of dial-a-ride booking schemes [15]. However, ridepooling in its current, digitalized form is still a novelty in Germany, and knowledge about current users, their characteristics, as well as how ridepooling influences travel behavior (and vice versa) is scarce. Even in an international context, research in the ridesharing realm often focuses on the above-mentioned 'ridehailing'—a mobility offering in which "individuals can hail and pay for a ride from a professional or part-time driver through an app" [16] (p. 4). Previous studies have shown that this kind of service can lead to an increase in vehicle kilometers traveled (cf. [16–18]) while the utilization rates of public transportation and active modes decrease (cf. [16,19]). Conversely, different studies indicate that ridepooling might be better suited to help reduce the negative externalities of urban transportation. Bundling passengers that have similar routes could decrease vehicle miles traveled (VMT) and congestion caused by individual motorized transportation, and lead to efficiency gains (cf. [20,21]).

Where studies analyze ridepooling usage, users, or usage motivation specifically, they often rely on hypothetical situations. Respondents are faced with scenarios, via stated preference experiments, and are asked to imagine their usage behavior. In one of

these studies, Alonso-González et al. [22] analyzed the time-reliability-cost trade-offs for a hypothetical pooled on-demand service in the Netherlands. Firstly, they discovered a higher willingness to pay for pooled on-demand services than for traditional public transit. Secondly, they found the value of times (VOT) for the waiting and in-vehicle stage to be lower than the respective values of reliability (VOR). They differentiated between working and non-working individuals, as well as between different trip purposes, and found significant effects for all characteristics. A latent class model confirmed further heterogeneity among the respondents. However, they mention that their findings for the VOR are lower than findings from previous studies that showed unexpected delays to be more penalized, which might be one of the effects of the hypothetical scenario.

Morsche et al. [23] also looked into people's preferences for demand-responsive transport (for several service variations) in the Netherlands. They applied a stated choice experiment, and found that the willingness to use of what the authors call "collective taxi" is positively influenced by flexible stops, small pick-up and drop-off time windows, respondents' mobility-related variables (e.g., possessing a driver's license), as well as their attitudes. In sum, and comparing the different service options, they found that the more flexible and demand-responsive the service is the more attractive it is perceived by the (hypothetical) users, and that existing travel patterns—mainly if people are regular public transport users or rather car-savvy—are also strong predictors for the alternatives that respondents chose in the experiment.

Lo and Morseman [24] argue that pooling is not only beneficial for cities and the environment, but also for providers, drivers and customers. While providers can serve more passengers with less vehicles, customers benefit from less detouring when more people use the service. Moreover, prices decrease for users when they share a ride. As a consequence, the service could be affordable for a broader mass of travelers—whereas ridehailing is currently mainly used by young, well-educated urbanites (cf. [16,25–27]. Spurlock et al. [28] already provide evidence that "low- to middle-income people [...] adopted pooled ride-hailing" [28] (p. 39), whereas non-pooled ride-hailing is rather used by those with higher income. Aberle also points towards "the interrelation of ride-pooling services and the opportunity of access for economically deprived urbanites" [29] (p. 32). In the GIS-based study on four ridepooling services in Hamburg, he identifies an apparent trade-off between equitable access and operational considerations that point toward the necessity of municipal authorities governing the implementation of the services while also having to subsidize it in areas with low-income population and lower demand.

Lo and Morseman [24] as well as König et al. [30] analyzed service attributes of ridepooling offerings. Both found the price to be the most important factor—for existing customers but also for people who have not yet used ridepooling. Lo and Morseman [24] further found that people are willing to compromise and would accept longer waiting times or accessing pick-up points which are not at their doorsteps for reduced fares and less detouring. However, König et al. [30] state that walking distances are more important to older people whereas younger people stress the price. Long-term customers tend to be more discerning in general while new customers are more price-sensitive. The authors indicate that previous users of ridepooling systems assess service characteristics differently than non-users. While non-users consider the travel time to be highly relevant, actual users focus more on departure shifts, information provision, and booking time.

Knie and Ruhrort [31] conducted a survey among customers of the German ridepooling provider Clevershuttle. They found that customers are generally of young age: 45% are below 30 years and another 40% are between 30 and 45 years old. Of these, 60% used the service for leisure and 25% for work-related trips. The mobility offering is mainly used in the evenings and at night and offers a convenient 'door-to-door' option that makes traveling without a private car more attractive, according to the authors. A share of 45% of the surveyed households that own a car indicated that they could imagine forgoing their car in the future.

Gilibert et al. [32] surveyed users during the testing phase (October 2017–July 2018) of MOIA ridepooling in Hanover. They found that the service was particularly used by multimodal people, mostly for leisure trips or to access mass transit stations. Respondents without a driving license used it also sometimes for commuting, e.g., when weather conditions were too bad to cycle. The authors inferred that ridepooling has the potential to replace the private car if there is no direct connection with public transportation and the distance is too far to go by bike, for instance. They also emphasized that further research is needed, and the findings might have limited validity as the service was available at a very low price, during their study phase.

Some other ridepooling pilot operations were scientifically accompanied, too. Between 2012 and 2015, the publicly subsidized on-demand ridepooling service Kutsuplus operated in Finland's capital region of Helsinki [33]. After the service was shut down, due to financial reasons, a user survey was conducted [34]. The analysis showed that Kutsuplus attracted a broad range of users of all age groups, women and men alike. Customers specifically stated the lack of other public transport options, the low cost, and car-related issues (such as the lack of parking space) to be the main reasons why they used the service. Leisure trips were indicated to be the most common purpose when Kutsuplus was used, followed by work-related trips.

Jittrapirom et al. [35] specifically looked into elderly users of a Dutch ridepooling service to identify service attributes that are of relevance for transport users who potentially suffer from mobility impairments. Using a mixed-method approach, they discovered that short walking distances and waiting times as well as reliability are of particular importance for users aged 65 years and older. Furthermore, they found that the elderly are more likely to use the service for medical purposes and less likely for leisure purposes; they also use the app less often to book a ride but use the telephone booking system or let others book a ride for them instead.

We would like to stress that, to date, ridepooling-user requirements are still fuzzy, as are current customers' characteristics. Among the few existing studies, several rely on research from small and/or short-term test operations [32], surveyed people who have not experienced ridepooling yet [22,30], or make a comparison to the MOIA ridepooling service difficult because the service level parameters differ significantly (e.g., prices, departure time windows, operating hours) [13,34]. These studies can provide initial relevant indications but validity for customers of a real service needs to be verified. In addition, understanding users is a prerequisite to further developing the service, tailoring it to users' needs, and—most importantly—to determining potentials as well as implications on the urban transportation system as a whole.

3. Data Collection and Survey Description

To allow for wide-ranging, exploratory analyses, we carried out an online survey from November to December 2019. An email was sent to all people registered at MOIA, who gave a so-called marketing permission; additionally, a call for participation was also spread via social media platforms but gained only very limited attention there. Consequently, not only users from Hamburg or Hanover participated in the survey but also customers from other parts of Germany and some few from foreign countries. All respondents went through the same survey set-up, whereby the questionnaire was adapted dynamically. Depending on the previous usage of MOIA, the respondents faced different questions. Participation was not compensated or otherwise incentivized for those participants. To ensure the overall sample consists not only of ridepooling users, 1000 respondents living in Hamburg were recruited through an online access panel. Due to the exploratory approach of the survey and the recruiting through MOIA, the results are not necessarily representative for non-users. Hence, we also refer to other sources, mainly the German household travel survey 'MID 2017' [36] when comparing users and non-users, as MID 2017 might better represent characteristics and travel behavior of the average population from Hamburg, which are

mostly non-users. This way, sociodemographic characteristics of users and non-users could be contrasted as well as mobility tool ownership.

The research topics incorporated in the survey are shown in Figure 2. The survey was implemented in the software Questback Unipark. Participation was feasible on computers and mobile devices. Due to a personalized ID in the link, we could check how many times a link was used to fill out a survey and thus avoid any bias through multiple participation. Apart from that, processing time, free text fields, and contradictory answers served to check for plausibility. In total, 12,082 respondents completed the survey (63% completion rate), of whom 11,372 remained after plausibility checks.
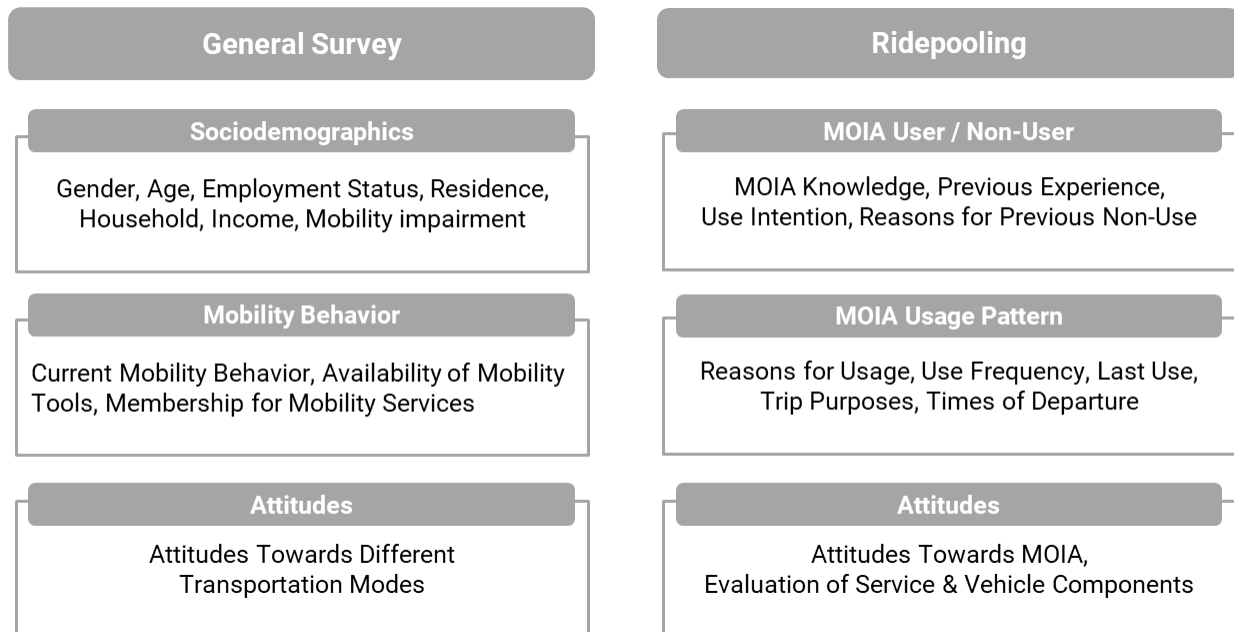
General Survey	Ridepooling
Sociodemographics	**MOIA User / Non-User**
Gender, Age, Employment Status, Residence, Household, Income, Mobility impairment	MOIA Knowledge, Previous Experience, Use Intention, Reasons for Previous Non-Use
Mobility Behavior	**MOIA Usage Pattern**
Current Mobility Behavior, Availability of Mobility Tools, Membership for Mobility Services	Reasons for Usage, Use Frequency, Last Use, Trip Purposes, Times of Departure
Attitudes	**Attitudes**
Attitudes Towards Different Transportation Modes	Attitudes Towards MOIA, Evaluation of Service & Vehicle Components

Figure 2. Research topics that were translated into questions for the online survey.

4. Results

In the following, we present a selection of our survey results with a focus on Hamburg, a metropolitan city in the north of Germany with around 1.9 million inhabitants. MOIA operates its biggest fleet in Hamburg and most of the survey respondents (71%, N = 8012) live there. A share of 15% (N = 1746) of respondents lives in Hanover, and 14% (N = 1614) live somewhere else, mainly in other parts of Germany. Of the respondents, 81% (N = 9232) had already used MOIA before completing the survey, whereas only 1% had never heard of MOIA before (N = 122).

In Hamburg, gender is almost equally distributed among the users. The share of male users (55%) is only four percentage points higher than the share of men in Hamburg's overall population (51%). With its considerable fleet size, its conspicuous vehicles, and an already large customer base, MOIA has a high visibility. Thus, we suppose that the service is already relatively 'mature' and has presumably left an 'early adopter' stage for Hamburg's citizens. In similar studies on users of shared and on-demand mobility services, early adopters are characterized by a high percentage of male users (cf. [37]). Table 1 displays additional sociodemographic characteristics of MOIA users in comparison to non-users and the general Hamburg population.

Table 1. Sociodemographic characteristics of the respondents in comparison with Hamburg's population.

	User (N = 6417)	Non-User (N = 1595)	Hamburg (Population) [36]
Gender			
Female	45%	45%	49%
Male	55%	55%	51%
Diverse	0%	1%	
Age [years]			
18–29	18%	12%	19%
30–39	31%	20%	19%
40–49	24%	21%	18%
50–59	19%	26%	17%
60(+)	8%	20%	29%
Occupational Status			
Working full-time	75%	60%	35%
Working part-time	11%	14%	13%
Retired	4%	13%	19%
Homemaker	1%	3%	3%
Unemployed	1%	3%	5%
In education	7%	7%	17%
Household Size			
1 person	25%	27%	23%
2 persons	45%	42%	33%
3 persons	15%	16%	18%
4 persons	12%	11%	18%
5(+) persons	3%	4%	8%
Equivalized Disposable Income [€]			
<900	3%	9%	n/a
900–1499	8%	16%	n/a
1500–1999	15%	20%	n/a
2000–2999	25%	24%	n/a
3000–3999	26%	16%	n/a
4000(+)	14%	6%	n/a

Unlike Clewlow and Mishra [16] as well as Knie and Ruhrort [32], who found that ride-pooling or ridehailing is especially used by younger people, we see that MOIA customers cover all age groups up to over 75 years. While the biggest share of users in Hamburg is covered by the group of 30-to-39-year-olds (31%), one out of four users is older than 50 years.

The large majority of MOIA users in Hamburg works full-time (75%), another 11% work part-time. This share is much higher than the average as only 43% of Hamburg's residents are employed [36]. The share of students and apprentices (in total 7%) as well as retired people (4%) among the users is, on the contrary, lower. For the latter, an under-representation of people above the age of 60 might be causal, see Table 1. However, also homemakers (1%) and unemployed people (1%), that are usually at the age of our sample, are not very common among MOIA users. These differences concerning the occupational status can also be found when analyzing income. To reduce the effects of household size,

we calculated the so-called "equivalized disposable income" per person in a household [38] and found that MOIA users have a significantly higher income than non-users.

Next, we analyzed ownership and availability of mobility tools, such as transit pass or car ownership, as well as general mobility behavior. Overall, MOIA users are very mobile and multimodal; they own several mobility tools and have signed up for various mobility services (e.g., carsharing, bikesharing, e-scooter sharing). Among the users, 72% have access to at least one car in their household and 24% to even more than one. This is more than the average in Hamburg, where 67% have access to at least one car and only 14% to more than one [36]. Correspondingly, car usage frequencies are also higher among MOIA users than among Hamburg's average. Over 50% use their car at least once per week. However, public transport is also used frequently. Of customers from Hamburg, 45% own a transit pass and 55% use rail-based public transport at least once a week, 34% even on an (almost) daily basis. Bus use was inquired separately, due to the large supply in Hamburg: 24% use buses (almost) daily and 19% 1–3 times per week. Another indicator of overall high mobility is the use of long-distance public transport: 22% of MOIA users in Hamburg use long-distance public transport at least once per month, whereas only 13% of non-users do (Hamburg in general: 12% [36]). In sum, 73% of all MOIA customers in Hamburg use different transport modes throughout the course of one week, characterizing them as 'multimodal'.

This clearly differs from the Hamburg population, where half of the transport users can be marked as multimodal [36]. MOIA users are significantly more interested in other new mobility services. In the panel-subsample as well as in the German household travel survey [36], only 17% over the age of 18 years are registered for carsharing. In contrast, 58% of MOIA users from Hamburg are registered for one or more carsharing providers; 67% are registered for bikesharing, 53% are registered with other ridepooling services than MOIA, and 38% for e-scooter providers, see Table 2. When comparing the actual use of these services, the results correspond to the findings for membership: MOIA customers use these services significantly more frequently.

Table 2. Mobility characteristics of the respondents in comparison with Hamburg's population.

	User (N = 6417)	Non-User (N = 1595)	Hamburg (Population) [36]
Mobility Tools			
Driving License	92%	87%	80%
Transit Pass	45%	42%	46%
BahnCard (member-ship card for German railway)	37%	25%	n/a
Vehicle Ownership			
Bicycle	80%	72%	75%
Car	72%	73%	67%
Membership			
Carsharing	58%	34%	17%
E-scooter	38%	18%	n/a
Bikesharing	67%	39%	n/a
Other Ridepooling than MOIA	53%	24%	n/a

We further asked respondents to evaluate statements concerning different modes of transport on a 5-point Likert scale (1 = "I totally agree", 5 = "I totally disagree"), see Figure 3. Independent from their previously stated usage frequency, every respondent faced the same item set. Only respondents without a driving license or access to a car were additionally given the option to answer "I do not know" as the assessment of driving a car might not make sense to someone without a driving license. The items were adapted from

Hunecke et al. [39] and Steg [40] and complemented with further statements for our case study. MOIA users seem to be more flexible concerning their car use, as they agree more often to the statement that the parking situation and parking costs influence their car use. They also confirm that an advantage of public transportation is not having to search for a parking space. This result corresponds well with our finding that they are multimodal and consider many mobility options when deciding for a mode and is further supported by them stating to be able to manage their daily lives without a car a little better, whereas non-users find it more difficult to manage their daily trips by public transport.
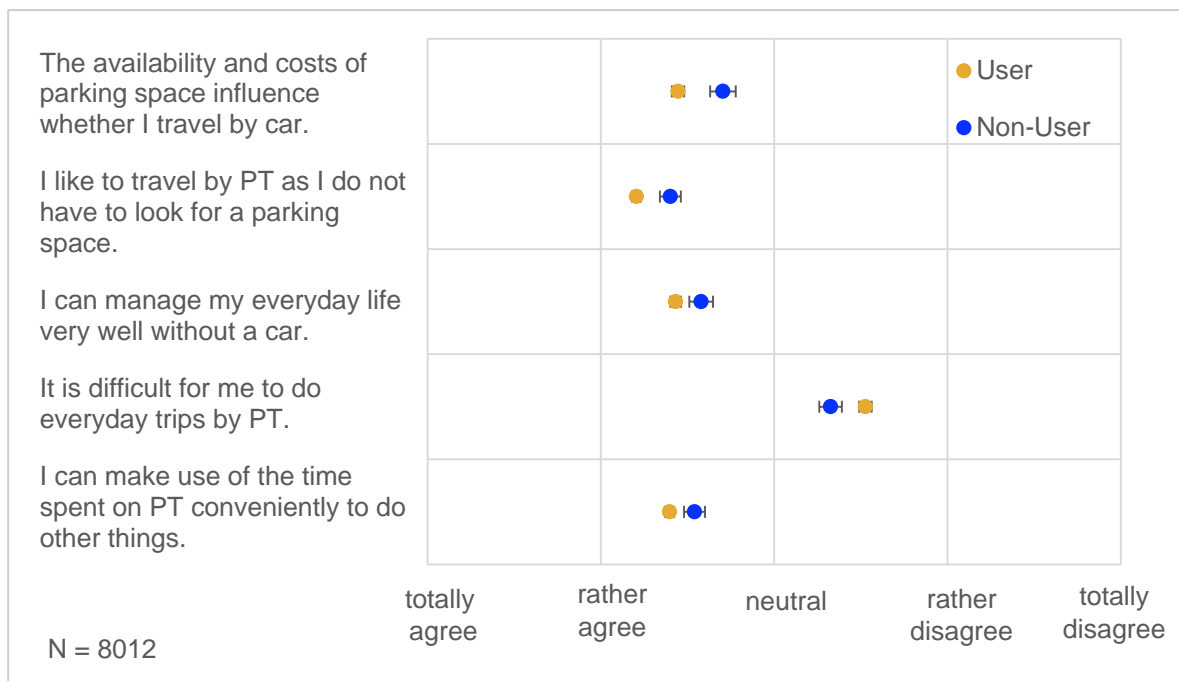
Figure 3. Comparison of the average assessment of selected items from users and non-users (including 95% confidence interval).

4.1. MOIA Usage Patterns

The MOIA ridepooling service is rather used as an occasional mode: most customers from Hamburg use MOIA one to three times per month (48%), followed by the ones who use it less than once per month (39%). Only 9% use MOIA once per week or more often. Due to the nature of limited availability (i.e., as they can only use MOIA when visiting Hamburg or Hanover), customers from elsewhere use the service even less frequently.

Of the respondents from Hamburg, 60% stated that their last ridepooling trip was related to a leisure activity, see Figure 4. Apart from leisure, 19% used MOIA for work-related trips, either for commuting or for business purposes. Another 11% used it for rides to/from the airport or the train station. MOIA trips for pick-up and drop-off, running errands, going shopping, anything education- or health-related are rather rare to date.

When analyzing the time of use, we found that most reported trips took place in the evening or at night (regardless of weekend or weekday) which corresponds well with the high share of leisure trips. The vast majority of passenger trips in Hamburg (as well as in other cities), in contrast, usually occurs between 8 am and 6 pm, see Figure 5.

The analysis of influencing factors when choosing MOIA reveals the importance of convenience. MOIA is used instead of a private car when driving is not possible, due to fatigue or previous drinking, when the car is not available, or when parking space is scarce. Furthermore, when facing bad weather conditions or when public transit is not available or implies changing modes, MOIA is an appreciated alternative.
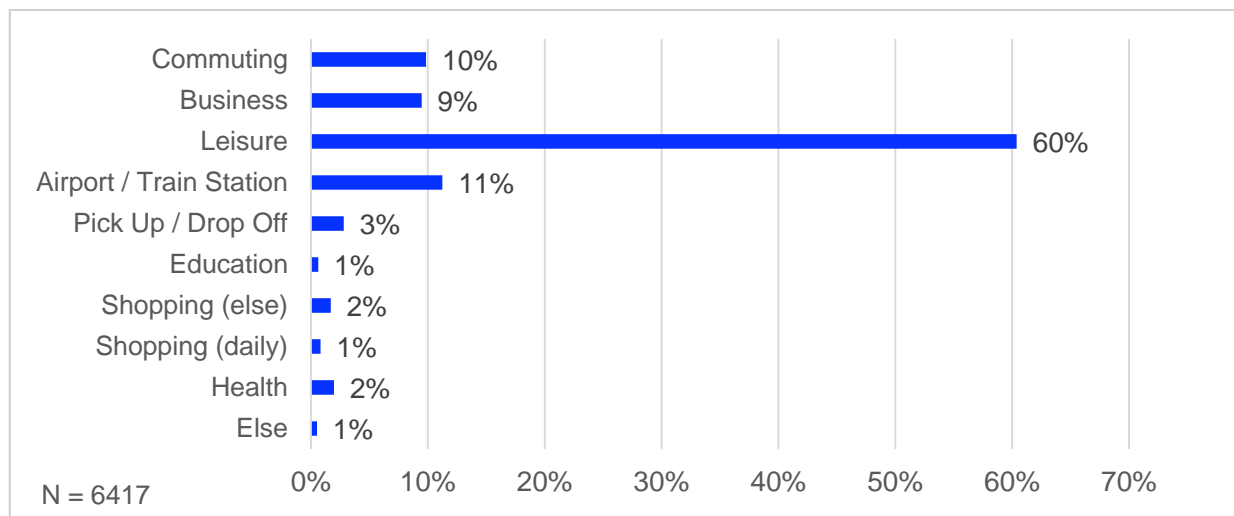
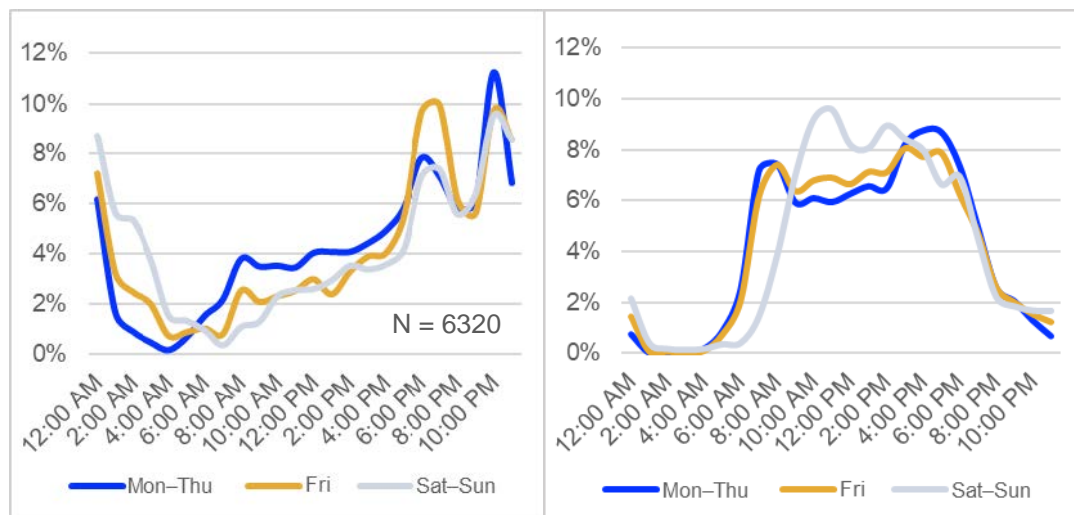**Figure 4.** Activity related to the last MOIA ride of customers from Hamburg.

Figure 5. Reported departure times of the last ride with MOIA (**left**) and of trips reported in the German household travel survey (**right**) [36].

In the following, we introduce different user groups: impaired users, commuters, business travelers, and users who use MOIA for leisure purpose.

4.2. Mobility Impairment

Of the 6417 MOIA users from Hamburg, a share of 4% stated to have some kind of mobility impairment, see Figure 6 for further details. Although this is still a small share among the users, understanding needs and requirements of transportation users with mobility impairments is key to be able to meet standards and to address a growing customer segment (as mobility impairment is in general clearly correlated with age [36]). We will thus necessarily take a closer look at this specific group: Who are the mobility impaired MOIA customers and how do they differ from non-impaired users? How do they use and perceive MOIA?
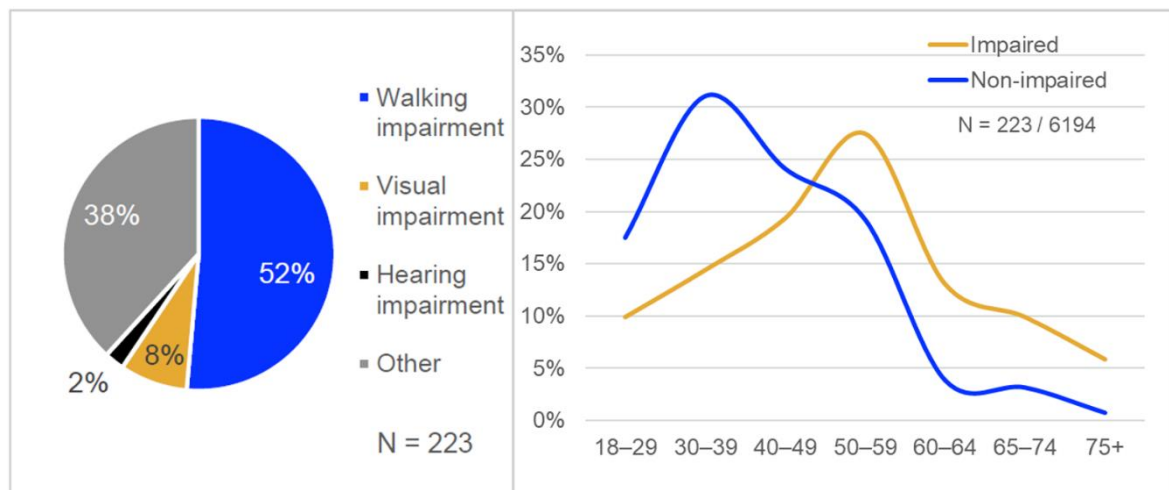
Figure 6. Type of mobility impairment and age of impaired and non-impaired MOIA users from Hamburg.

In Germany, 7% of the travelers suffer from some kind of health restriction that also leads to an impairment in their mobility—from 50 years on, that share starts to increase drastically [36]. The seniors among the mobility impaired travel less, are more likely to be passengers in a private car, and use public transport less [36]. On average, German transport users with mobility impairments are 67 years old, exceeding the non-impaired by 25 years. Women suffer more often from a mobility impairment than men: 59% of the impaired are female, while the average distribution for transport users is 50/50. Despite the vast age difference, mobility impaired people vary in other sociodemographic as well as behavioral aspects from the non-impaired. They are less often employed and have a lower household net income than the non-impaired. While average trip distances and travel times are very similar for the two groups, impaired transport users have a higher travel time for the same trip distance which leads to the assumption that they have a higher effort of getting from A to B [41].

People with mobility impairments use the car often for daily trips—significantly more than the non-impaired. However, they are more often passengers in a car. Besides the car, usage frequency is also high for walking, around 40% of the impaired walk every day [41]. In our survey, ridepooling users who suffer from a mobility impairment are also significantly older than the rest of the sample. The average impaired MOIA user is 51 years old whereas the average non-impaired user is 42 (overall in Hamburg: 67 to 42 years [36]), see Figure 6.

Apart from age, impaired MOIA customers—similar to what can be stated for the overall German impaired traveler—also differ significantly in terms of net household income. Of all impaired users, 50% of all impaired users have a monthly household income below 3000 EUR—this holds true for only around 30% of the non-impaired. Clear differences are also shown in occupational status of impaired and non-impaired users: while 75% of non-impaired Hamburg customers work full time, this is the case for only 50% of the impaired. Additionally, 20% are already retired, which comes as no surprise given their higher average age.

In terms of the typical trip purposes MOIA is used for, impaired customers show differences in two aspects: with 50% stating they used MOIA for leisure purposes, they differ from non-impaired by 10 percentage points. However, 11% indicated that they used their ride for some kind of health-related purpose, e.g., going to/from the doctor, hospital, or similar, which is a trip purpose almost never mentioned from non-impaired users, see Figure 7.
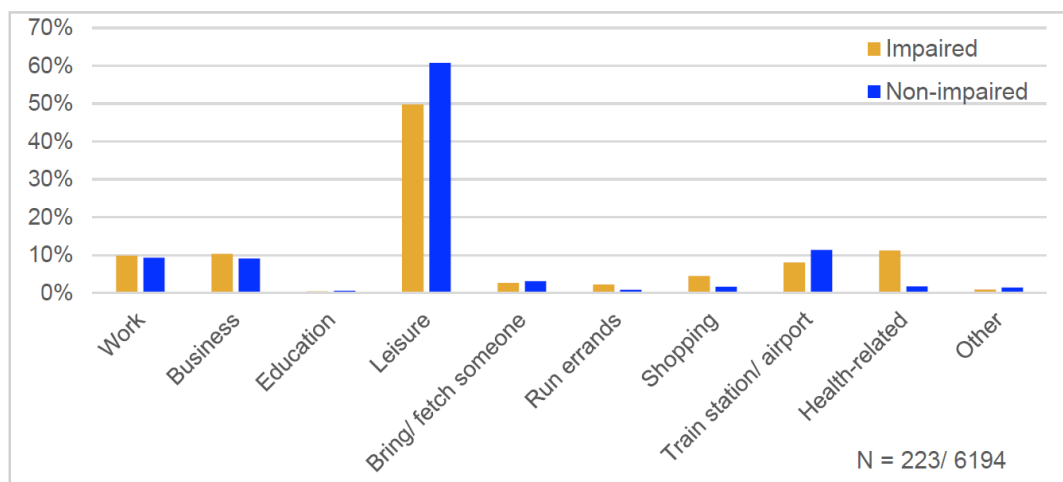
Figure 7. Comparison of trip purposes of last MOIA rides from impaired and non-impaired customers.

When comparing usage frequencies for impaired and non-impaired customers, we discover that the impaired use MOIA more often than the rest of the sample. Of these, 17% can be categorized as frequent users—meaning people that use MOIA at least once a week, whereas only 9% among the non-impaired respondents are frequent users.

We asked respondents in the survey to rate various service and vehicle components of MOIA on a five-star scale. The results show almost no difference in the answers between impaired and non-impaired users, see Figure 8. In general, all MOIA customers seem to be fairly satisfied with vehicle and service—only availability, routing, stops, and wait time could slightly improve from the users' point of view. Interestingly, although the differences are small, mobility impaired customers rate the components overall even better than the non-impaired. A plausible explanation (that should be analyzed in more depth) could be that MOIA offers a comfortable, convenient, and safe solution for transport users that experience mobility in general often as burdensome—particularly public transport. This assumption corresponds well with the higher usage frequencies.
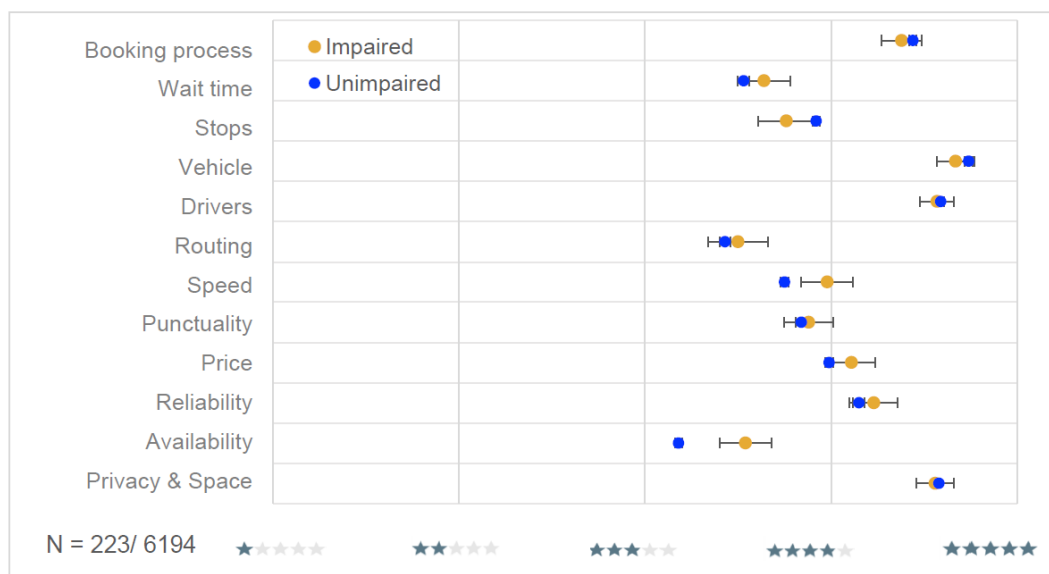

Figure 8. Average of the five-star rating of service- and vehicle-related aspects by impaired and non-impaired MOIA users (including 95% confidence interval).

4.3. Work-Related Trips

Streets in larger cities are particularly suffering from congestion caused by commuter traffic. Additionally, trip diaries reveal that 90% of commuting and 81% of business trips in Germany are conducted alone. In contrast, only 40% of leisure trips occur alone [36]. As particularly commuters and business travelers that go by car mostly drive alone, bundling these into fewer vehicles could relieve some of the congested streets, and users might find ridepooling an attractive additional mobility option. Work-related trips in general have a different (i.e., more routinized) character than leisure trips. Hence, we assume different ridepooling user profiles and mobility patterns for these purposes. We will usually differentiate between commuting and business trips; where useful, we also compare with leisure or overall ridepooling trips.

Among Hamburg's citizens, 14% of all passenger trips are commuting trips while 12% are related to business [36]. To date, about 19% of the respondents' MOIA trips in Hamburg are related to work, either for commuting (10%) or business (9%) purposes. We see a significant difference in gender distribution on work-related trips in comparison to leisure trips. Male customers use MOIA more often for commuting (60%) and even more for business trips (69%) than female customers. This trip-related gender gap is even stronger for MOIA users with non-Hamburg residences (78% of the stated business trips are done by men) and can furthermore also be observed in the general Hamburg data on work-related trips from [36].

When analyzing the average age of the trip-purpose subsamples from Hamburg, we find that customers who use MOIA for commuting tend to be slightly younger (40 years) than the sample-average (41.3 years), comparably aged to leisure users (40.6 years), and they are significantly younger than customers who use MOIA for business trips (44.6 years), see also Figure 9. When comparing the average monthly net income for the different groups by trip purpose, we discover that customers who use MOIA for business trips have a significantly higher income than the others, on average approximately 500 €. Surprisingly, the income of those who use MOIA for commuting does not differ significantly from those who use MOIA for leisure trips, even though commuters in general use MOIA more frequently than others.
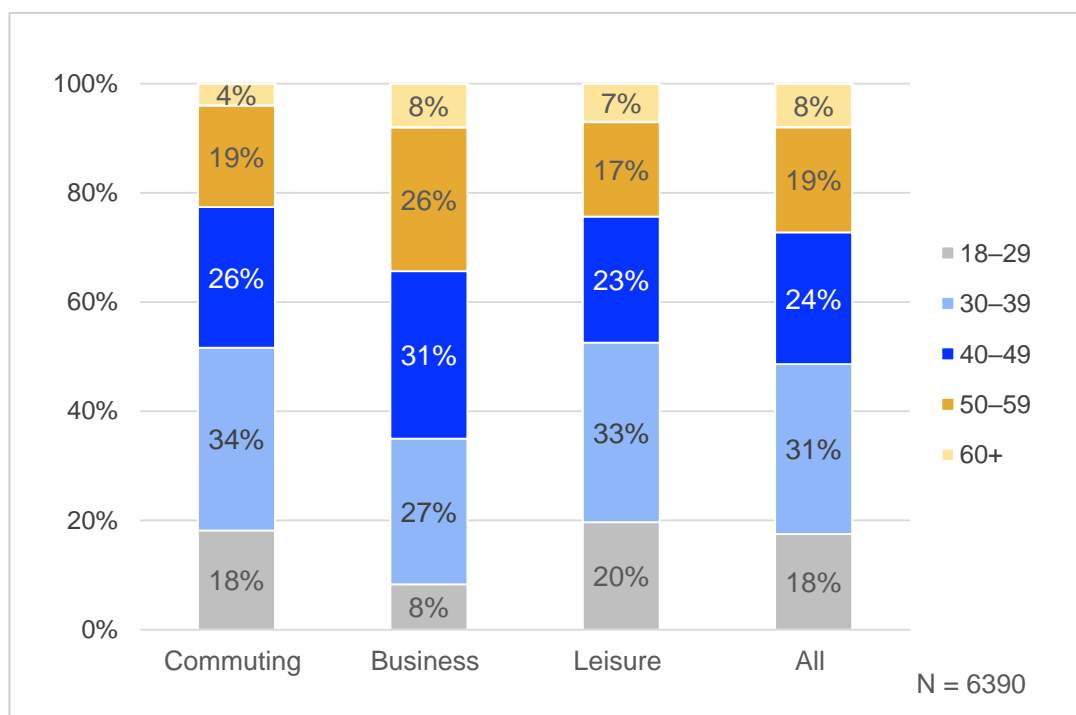

Figure 9. Age distribution of MOIA users with different trip purposes.

Respondents living outside of Hamburg show significantly higher tendencies to use MOIA for business trips compared to all other trips. The share of respondents who have stated to live "elsewhere" and who used MOIA for business purposes is almost twice as high compared to respondents from Hamburg (9% vs. 19%). In contrast, commuting trips are more often done by residents of Hamburg (10% vs. 6%).

Trip distances with MOIA were not explicitly reported but all respondents who stated to be employed were asked to report their commuting distance. When analyzing these distances, we find that customers who do not live in Hamburg have longer commuting distances (10 km vs. 40 km on average) which corresponds with our finding that many of these customers live in rural or suburban environments. As MOIA currently only operates inside the city, we can assume that they do not use MOIA for the whole trip to work but only for a certain part of the trip, e.g., from a public transportation station to the office.

In general, we find that MOIA users are very car-savvy (see above). However, among the users from Hamburg, business travelers have the highest car usage frequencies: 62% use it at least once a week. On the other hand, 38% of the commuters stated to not own a car, which is more than the average MOIA user (25%). Regarding their MOIA usage patterns, commuters use MOIA ridepooling more frequently than other customers: over 60% use MOIA at least several times a month. However, 42% travel (almost) every day by rail-based public transport, whereas only 27% of MOIA business travelers and 33% of Hamburg's residents do. On average, business travelers use public transportation less frequently than other MOIA users. Similar results are obtained when comparing the use of busses.

As expected, commuting and business trips usually take place on weekdays, whereas leisure trips are particularly conducted on the weekend. When studying the departure time of MOIA trips reported by the respondents, we find that commuting trips usually have two peaks. Most of these trips take place in the morning between 6 and 10 am, corresponding well with the time when people usually travel to work. The second peak in commuting trips generally occurs between around 3 and 6 pm [36]. For MOIA users, we can see the rather typical evening peak between 4 and 7 pm. In comparison to the commuting case, business trips are spread rather evenly over the course of the whole day, see Figure 10.
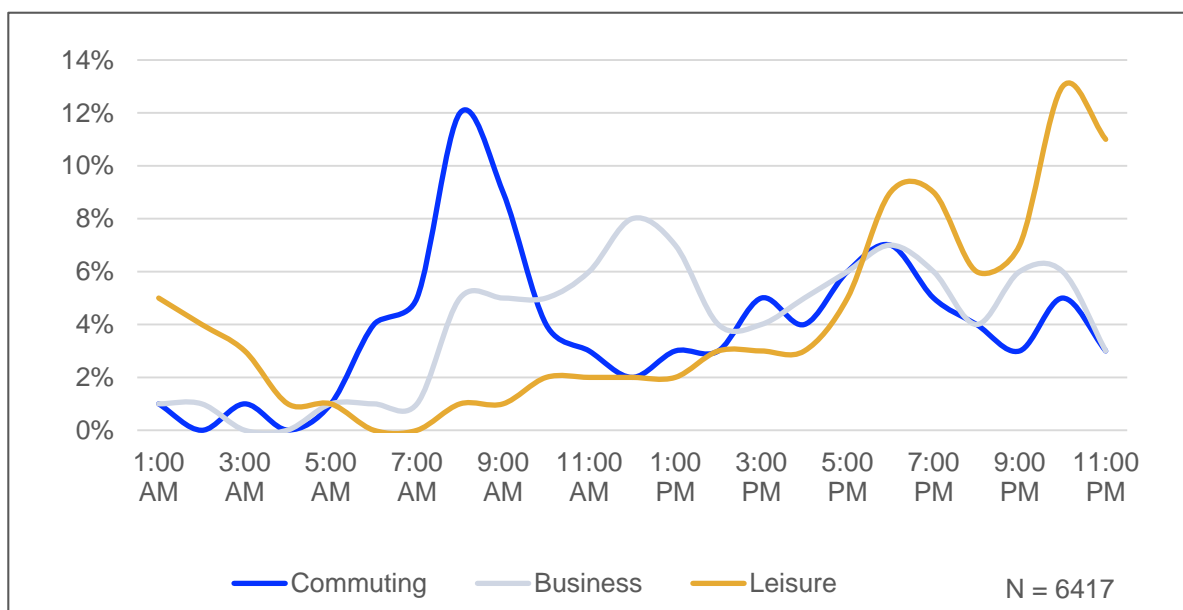
Figure 10. Departure times for MOIA trips with different purposes, reported by users from Hamburg.

5. Discussion

Analyzing data that is based on a real-world ridepooling service is key to developing a comprehensive understanding about this new mobility offering—it eventually serves as a foundation for assessing the implications of ridepooling on the overall transportation system. To examine usage and user characteristics of MOIA ridepooling, we applied an explorative approach, using an online survey that aimed to reach as many respondents as possible. Additionally, our sample was complemented with a non-user sample that we recruited through an online panel. As survey participation was voluntary, a self-selection bias of our sample cannot be completely avoided. Nevertheless, we believe that the large sample, containing more than 11,000 respondents, should represent the user structure adequately. To further eliminate bias, we compared the answers for the last trip in the survey with general booking data and found good correspondence. Furthermore, we complemented our survey results with information on Hamburg's citizens from the German household travel survey 'MID 2017' [36]. Comparing the user study at hand to results from previous studies is applicable only in a very limited way, due to the reasons mentioned in Section 2. Where possible, we will in the following discuss our findings in relation to those from other studies.

In contrast to what Morsche et al. [23] found in their study on hypothetical ridepooling usage, MOIA is not only an attractive option for people who are familiar with this form of shared mobility—like public transport users. Among the MOIA customers, the shares of car usage frequency as well as ownership rates are considerably higher than for the Hamburg average—pointing toward an important future potential to reduce car usage and ownership by offering a large-scale ridepooling service. These initial indications, however, have to be further complemented by (qualitative) research that should more comprehensively investigate usage motivations and reasons as well as how ridepooling is integrated into users' everyday travel patterns.

Opposed to other studies on ridehailing and ridepooling (e.g., [16,31]), our analysis shows that MOIA ridepooling is not only used by young urbanites. It instead seems to address needs of a much broader range of customers, which is more in line with findings from Weckström et al. [34], who also discovered a diverse group of customers. Firstly, we found that a substantial share of 25% of MOIA ridepooling users is older than 50 years. Secondly, our analysis of how mobility impaired customers assess service- and vehicle-related aspects as well as how often they use ridepooling revealed that MOIA is specifically attractive as an additional mobility option for customers who might have specific or high requirements towards their transport modes, or that experience travelling as more burdensome than others. Thirdly, we could identify that a considerable proportion of customers lives in the hinterland of Hamburg, i.e., outside of MOIA's current service area. This additionally indicates how ridepooling addresses the interest and potentially the needs of a broad variety of transportation users. These findings are, from our point of view, an important result regarding planning for and implementing future on-demand and shared mobility options.

The results of our study, at first sight, did not reveal certainties regarding service- or vehicle-related aspects of the different user groups—e.g., we could barely find differences in the evaluation of waiting times, stopping points, or pricing assessment. This is not very much in line with the findings from Morsche et al. [23] and König et al. [30] who discovered significant differences in the perception of importance of several service parameters (e.g., like price, walking distance, booking). Subsequent research should look into these specific requirements in more depth, through qualitative and/or explorative methods rather than standardized ones.

Our analyses show that current MOIA ridepooling customers clearly display multi-modal travel behavior. A vast majority uses several modes a week and already possesses a variety of mobility tools which they potentially apply according to their individual requirements. As many users own a car but appear to be quite flexible in their mode choice, a promising potential to substitute a certain number of car trips and to change travel behavior

towards sustainability can be assumed. Usually, car ownership is a strong determinant for unimodal usage patterns. It is thus important to offer a reliable, attractive and customized alternative to the private automobile. In addition, as can be seen in our findings related to ridepooling usage reasons (where MOIA users indicated that parking costs as well scarce parking space positively influence their ridepooling usage), so-called 'push factors' might play a relevant role in changing unsustainable mode choice behavior. This initial assumption should be investigated in more detail, potentially using (microscopic) travel demand modelling.

While MOIA ridepooling is mostly used for leisure-related purposes, a share of almost 20% of rides were stated to be work-related—equally distributed between commuting and business purposes (a similar distribution was discovered by Weckström et al. [34] for the Kutsuplus service). However, as these two trip purposes differ in general, so do the users. The commuters among the MOIA customers are more likely frequent ridepooling and public transportation users, they travel during typical commuter peak times, have the lowest car ownership and car usage rates as well as the youngest age among all MOIA users. Additionally, we could identify a significant share of customers who use ridepooling as part of an intermodal trip, as they indicated they live outside of the service area and have longer commuting distances. Such intermodal travel behavior could be particularly promising with regard to bundling commuters during typical peak times and in return relieving streets from congestion. MOIA business customers show quite opposite characteristics and usage patterns compared to the commuters. They are the most male, old, affluent, and car-savvy among all respondents from the survey, and it is likely that they have different residences than Hamburg or Hanover. While this might be the reason that they use MOIA less frequently than other customers, their usage times are more evenly distributed throughout the whole day. Both commuters and business travelers could in general contribute to a more balanced utilization of ridepooling vehicles over the course of the day which, from an operational standpoint, is an important factor regarding the efficiency of a ridepooling service.

To find out more about the cause-and-effects of ridepooling on the urban transportation system, or how these services perform under real-world conditions, and what parameters influence the performance, though, the empirical findings will have to be supplemented by travel demand and traffic simulations to investigate the effects of fleet sizes, service areas or service parameters as well as other changes in transportation conditions.

6. Conclusions

In the present study, we analyzed ridepooling users, and examined for what reasons, when, or where they use the service, as well as how customers differ from other transportation users. These are our key findings highlighted:

- The results in general show that MOIA addresses the needs of a heterogenous user group.
- Customers cover all age groups from 18 years on, and one out of four users is older than 50 years.
- In Hamburg, where MOIA operates its biggest fleet, the share of men and women corresponds well to the distribution among the citizens.
- A large section of users is highly mobile and more often multimodal than non-users as well as the Hamburg average.
- MOIA is an attractive option for transportation users with high car usage and ownership rates.
- The customers appreciate MOIA's convenience and comfort and assess the (special purpose) vehicle, the drivers, as well as the privacy and space to be most to their liking.
- Mobility-impaired people assess the service and the vehicle very good and sometimes even better than the non-impaired—they also use ridepooling much more frequently.
- Despite being otherwise mostly used for leisure purposes, every fifth trip reported in the survey is work-related.

- MOIA ridepooling is an occasional transportation mode for most users and mainly used on a monthly basis. Certain user groups, however, show higher usage frequencies.

Ridepooling in its 'new', digitalized form poses a chance for individualizing mobility beyond the private car and in addition to public transportation. It can supplement public transportation when buses, metros, and trains are spatially and temporally not available (e.g., during the night), or if they are perceived as burdensome or inflexible (e.g., because no direct connection is available). With our study, we broaden knowledge about users of ridepooling. After investigating who these users are, what travel characteristics they have, and how MOIA is used in general, future research should particularly focus on the effects of the new mobility offering on the overall traffic system and also changes in travel behavior. As a next step of the project, we will thus develop a microscopic, multimodal travel demand model for Hamburg. Final results of the transportation simulation studies can be expected by mid-2021.

Author Contributions: Conceptualization, N.K., E.F., M.K.; methodology, N.K.; validation, N.K., E.F., M.K.; formal analysis, N.K., E.F.; investigation, N.K., E.F.; writing—review and editing, N.K., E.F., M.K.; visualization, N.K., E.F. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data are not publicly available due to legal reasons.

Conflicts of Interest: The authors declare no conflict of interest.

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