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The attitude of potentially less mobile people towards demand responsive transport in a rural area in central Germany

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ABSTRACT

Demand Responsive Transport (DRT) systems are often discussed to expand public transport in rural areas, where conventional buses are often used below capacity. DRT systems can particularly improve the mobility situation for less mobile people or other people who depend on public transport and ultimately prevent them from social exclusion. This paper examines whether people who show characteristics that indicate a mobility deficit are more willing to access the DRT system EcoBus in a rural area of Germany. Using survey data from 156 respondents from households in the EcoBus service area and utilizing linear regression analysis, this study confirms that car availability harms the intended use of DRT and that physical impairment has a positive effect, as identified several times in the literature. Furthermore, the influence of age on the intended EcoBus use depends on the residence place's city size and hence on its offer of daily public services. While residents of a sub-centre of the region are significantly less willing to use the EcoBus with increasing age, there is an opposite tendency for small villages. Thus, in small inaccessible localities, the likelihood of using EcoBus increases with age, suggesting that DRT systems benefit the doubly constrained population, namely the elderly population in localities with few public services.

1. Introduction

In order to remain mobile in rural areas, owning a private car is usually essential (e.g. Dargay, 2002; Osti, 2010; Pucher and Renne, 2005). Unlike in agglomeration centres, the widely scattered population does not generate sufficient demand to make local public transport economically viable, traditionally organized in fixed routes and served by large buses (e.g. Li and Quadrifoglio, 2010). The high dependency on the private car is thus the consequence of an insufficient public mobility supply, but also the cause that a functioning public transport network cannot evolve. As soon as a person has invested in a private car, there are hardly any incentives to use public transport. However, this deadlocked situation, reminiscent of a vicious circle, jeopardizes the quality of life for those people that do not own a car or can no longer drive their car for health reasons, particularly concerning older people (Verma and Taegen, 2019; Shergold et al., 2012; Gilhooly et al., 2002). This group is restricted in their mobility, which means that they may not be able to satisfactorily cover both necessary journeys, as for shopping and medical appointments, and non-essential journeys which nevertheless have a considerable impact on their quality of life, such as visiting friends and family or pursuing a leisure activity (Metz, 2000).

Demand responsive transport (DRT) systems are often discussed as a possible solution to extend the range of public transport in rural areas and ensure accessibility of general interest services and ultimately prevent exclusion of the potentially less mobile population (e.g. Shrestha et al., 2017; Laws et al., 2009). Mostly minibuses are operating previously registered transport requests and, in contrast to taxis, journeys in similar directions can be pooled to save trips potentially. In recent years, the utilization of modern route algorithms and information technology has opened various new possibilities to bundle travel requests as

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efficiently as possible (Storch et al., 2021).

However, to accomplish its mission of enhancing the mobility of the less mobile population in rural areas, DRT systems must also be accepted by the relevant population group. Therefore, this paper addresses the following question: Are people who are less mobile, either because they do not have access to a car, because they belong to the elderly population or because they have a physical mobility limitation, more likely to use a DRT system? Perhaps they perceive a relative advantage in enhancing their personal mobility and are therefore more likely to use DRT systems.

In summer 2018, the software-based public ride-pooling DRT system EcoBus was tested for eight weeks in Northeim, a typical rural county in Southern Lower Saxony in Germany, characterized by an ageing population and a high car dependency. During the test phase, a survey was conducted in the test area to check the influence of characteristics that indicate a possible deficit in the individual mobility situation on the intention to use the EcoBus. Specifically, a simple linear regression model was used to examine the influence of the independent variables *car access*, *mobility-related disability* and *age*, as increasing age might also point to a lack of physical mobility (e.g. Rantakokko et al., 2013), on the stated intention to use the EcoBus, measured on a Likert scale depending on the level of likelihood. In addition to individual characteristics, we use another independent variable based on the size of the place of residence as a proxy for its ability to meet the daily needs of general services. The dummy variable *village* indicates whether a person lives in a locality with less than one thousand inhabitants, which typically has few facilities of general interest in this region, or in a larger locality that can be classified as a sub-centre of the region.

That a larger proportion of the population with car access harms the frequency of using DRT systems has already been shown by Wang et al. (2014) for the Manchester area. However, no significant influence of age could be found. This study, however, referred to spatially specific socio-economic characteristics, for instance, the average age of a district was used to explain the average number of trips. In another study whose approach is more comparable to ours, Wang et al. (2015) examined the extent to which individual user characteristics influence the frequency of DRT use in the case of a rural region in England. It turned out that disability is a positive determinant of DRT use. In terms of age, only the male population group showed increased DRT use at retirement age. In a user survey, Nelson and Phonphitakchai (2012) find that users of the LinkUp DRT system in a metropolitan area in England are predominantly old and often have some form of disadvantage characteristics. This includes people with low incomes and low levels of education, but also those who do not have access to a car or have a physical disability.

The insights gained in this study can empirically support the determinants *car* and *disability* already identified by the literature for a rural area in central Germany. Furthermore, when evaluating the influence of *age*, it was found that the sign depends on a third variable, namely a dummy on locality size of the residence place. It is the first time, to our knowledge, that a further potential user group of DRT systems has been identified, which is also affected to a high degree by possible social exclusion, namely the elderly living in the smallest settlements, characterized by a minimal supply of daily care facilities such as supermarkets, medical services and bank branches. Although rural areas are internationally and nationally very heterogeneous in their physical geography as well as socio-economic composition, the results may also be transferable outside this study area with limitations, since an ageing population and a high car dependency is a general trend in industrialized nations (Viñas, 2019). The results of this study help to better understand an important user group of DRT systems in rural areas. This would identify them as an essential user group of DRT whose desires and requirements should be given particular emphasis. On the one hand, this important customer group utilizes the capacities of the DRT system to the benefit of economic viability. On the other hand, the social benefit of the DRT system would be great if these individuals were to expand their mobility.

The next section presents the literature relevant to this study. The literature review includes which problems the elderly population faces concerning mobility in rural areas, how DRT can help to overcome these challenges, and which factors influencing the use of DRT systems have already been presented in the literature. Section 3 describes the conduct of the survey and the variables gathered in detail. The study area is presented in Section 4. Section 5 presents the regression analysis. Finally, Section 5 discusses the implications of the findings for DRT in rural areas for social policy goals and concludes.

2. Literature review

2.1. Limited mobility, age and social exclusion in rural areas

According to Vitale Brovarone and Cotella (2020), a dispersed population and often the physical nature of rural areas result in greater distances to the closest services of general interest. Measuring accessibility is a complex issue, as Handy and Clifton (2001) show. However, regardless of the choice of accessibility measure, Geurs and Van Wee (2004) attest that the true nature of rural areas is poor accessibility as the number of opportunities is relatively small compared to urban centres. Rauhut and Komornicki (2015) explain the quantity of services of general interest offered from an economic perspective. Most services have some form of fixed cost, so a minimum number of consumers is required to reduce per capita costs. For this study, it is useful to refer to rural areas by using a concept of a simple "cumulative opportunities measure" according to Handy and Niemeier (1997), as recently applied by Kelobonye et al. (2020), for example.

The entire study area is located in the very rural region Northeim, which according to Küpper (2016), is characterized by poor accessibility to major centres and low settlement density. In the context of this study, it is worth noting that even within an already very inaccessible rural area, different levels of accessibility exist for each locality. For example, while in rural areas, according to the classification of the German Federal Institute for Research on Construction, Urban Affairs and Spatial Development (see Einig (2013) for a description), medium-sized centres and basic centres are emerging, which may, in fact, have an extensive set of services of general interest, the situation is entirely different for very small localities consisting of a few hundred inhabitants, since often there is not even a possibility to buy groceries within the locality. Therefore, the locality in which a person lives within the study area makes a difference to the degree of accessibility. People who live in the smallest villages are even more at risk of potentially being less mobile than people who live in a sub-centre with basic services. People who are potentially less mobile because of their age and live in a less accessible location are considered particularly at risk, which is why we are interested in the interplay between residence size, age, and intended DRT use.

Terminologically, in this paper, people are considered as potentially less mobile if they do not have access to a car, have a physical mobility-related impairment or belong to the elderly population. We add the term potentially because the individual characteristics do not necessarily lead to reduced mobility, but they definitely represent risk factors. That persons without access to a car in rural areas are less able to meet their mobility needs, i.e. are less mobile, is comprehensible and already intensively addressed by the literature (Osti, 2010; Pucher and Renne, 2005; Ahern and Hine, 2012). It is also plausible that individuals with a physical mobility-related disability may be less mobile, even more so if it means they can no longer drive a car (Kett et al., 2020; Lucas, 2012). Besides, according to Wood (2002), the ability to drive tends to decrease with age, and overall, according to Webber et al. (2010), increasing age leads to limitations in the movement. As a result, the elderly population is particularly dependent on their own cars, and the problems of reaching critical facilities and social contacts become even more severe once people are no longer able to drive themselves due to age (Ahern and Hine, 2012; Verma and Taegen, 2019; Gilhooly et al., 2002).

According to Fransen et al. (2015), an inadequate public mobility service that cannot meet mobility needs leads to a mobility deficit for the less mobile population, especially those without a private car, which can lead to social injustice. Farrington and Farrington (2005) even claim that increasing the mobility of the less mobile population is one of the main challenges in rural revitalization. When addressing the mobility-impaired population, Shergold and Parkhurst (2010) argue that the implications of high car dependency in rural areas for the older people should be discussed, especially since the proportion of rural households without cars tends to be higher for pensioners in the UK. According to Nobis and Kuhnimhof (2018), the same is true for Germany since the proportion of the population with a private car as their primary means of transport from the age of 49 years steadily decreases with increasing age. Furthermore, Shergold et al. (2012) warn that any policy aimed at expanding the car availability rate in rural areas is neither compatible with environmental policy objectives nor takes sufficient account of the oldest population who can no longer drive a car for health reasons.

High car dependency deteriorates the social capital of a region. Conceptually, Gray et al. (2006) illustrate the mobility problems of the older people in rural areas with the concept of a region's social capital by relating the degree of mobility of the population to the level of social exclusion. In their view, the strong dependence on the private car in rural areas causes local social networks to lose importance and strength due to a higher mobility radius, as described by Urry (2002). At the same time, according to Gray et al. (2006), a reliable local social network is particularly crucial for mobility-impaired people to receive adequate support and maintain participation in a community worth living. However, Plazinić and Jović (2018) show for the rural area in Serbia that with increasing age, mobility decreases for all types of localities.

As mentioned in the introduction, there is concern that the mobility-impaired population in rural areas may not be able to make both necessary and unnecessary journeys, which nevertheless enhance their quality of life, to the desired extent. Davey (2007) notes that for the necessary journeys, there can be found in most cases an alternative to the private car, such as a shared-ride. However, it is mainly for the fun of pleasure journeys that are not realized to the desired extent without a car. Therefore, the absence of a car harms the quality of life. While the enhancement of virtual mobility for the elderly proposed by Kenyon et al. (2002) promises to improve the situation for necessary matters, for instance, online medical appointments, it can hardly replace these purely social journeys. Shergold and Parkhurst (2012) conclude after a survey that although the older population does not feel socially excluded, participation in community activity is considerably more difficult. Furthermore, in contrast to the Davey (2007) study, Shergold and Parkhurst (2012) judge that even the accessibility of critical services of general interest is quite challenging for the elderly population.

The implementation of a DRT system has the potential to address these social issues. The composition of the term sustainable mobility into the three dimensions of economic viability, social contribution, and environmental friendliness, which Ryley et al. (2014) have chosen, helps determine the objectives of different DRT systems. In an evaluation of established DRT systems in rural England and Wales, Laws et al. (2009) found that most DRT projects were associated with social aspects, such as preventing mobility-impaired groups' social exclusion. Davison et al. (2014), in an extensive study of DRT systems in Great Britain, established that the financial sustainability of DRT systems is in some cases better compared to conventional public transport in the same region. However, according to Ryley et al. (2014) and Davison et al. (2014), financial viability is the major hurdle for DRT to become mainstream public transport in rural areas. The evidence on willingness to pay is mixed. While Kim et al. (2017) found a 30% higher willingness to pay for DRT than for conventional public transport, Nyga et al. (2020) could not find a significant difference with respect to the EcoBus. Velaga et al. (2012) propose to combine new mobility forms, such as ride-pooled DRT systems, with modern technology to make rural mobility more efficient. While Leistner and Steiner (2017) point out that lack of smartphone affinity is a barrier to exploring new forms of mobility, Sörensen et al. (2020) emphasize the high acceptability and willingness to use the smartphone app for EcoBus bookings. However, in the EcoBus case, it is unclear whether the propensity to use the smartphone app differs between specific age groups.

2.2. Factors influencing the use of DRT systems

König and Grippenkoven (2020) found for two rural areas in Germany that the personal opinion about firstly the expected performance and secondly about the expected individual and regionally related added value of the DRT system is a potent estimator for the intended use of the DRT system. From this point of view, persons with impaired mobility should recognize the benefit of extended mobility possibilities and be more willing to utilize DRT systems. A similar conclusion is reached by Nelson and Phonphitakchai (2012). They examined individual user characteristics of the DRT system LinkUp in the UK to better understand why DRT systems have not yet developed their full potential. They also discovered that recognizing the relative advantage of DRT compared to the alternative, the traditional public transport, is a prominent characteristic of the traditional DRT user. Regarding an individual barrier, Alonso-González et al. (2020) found in their investigation that in Dutch urban areas almost 30% of the respondents have a strong aversion to sharing their ride, making ride-pooling DRT use unlikely for this "it's my ride" group.

Wang et al. (2014) carried out a study in the urban Greater Manchester, which should identify area-wide influencing factors of the DRT use in order to be able to find potential areas in the future where a DRT implementation is meaningful in the form of sufficient demand. For this purpose, the influences of different socio-economic variables on the variable average number of trips made by DRT per year was examined within the framework of multilevel analysis. A significantly lower DRT use in areas with a high car ownership rate was determined, whereas areas with low population density generated more DRT demand. They also found that more DRT is used in higher social deprivation areas, measured by income, employment, education, housing and services, health and disability, and living environment. However, no significant correlation between age and frequency of DRT use could be found. A study explicitly for individual user characteristics was conducted by Wang et al. (2015) based on survey data of DRT users in a rural area in Lincolnshire, England. Using ordinal regression analysis, they identified individual determinants that significantly impact the frequency of DRT use within a week. Concerning the area-based variable population density, the negative correlation between population density and the frequency of DRT use could also be demonstrated in rural areas. Regarding individual characteristics, it was shown that women and persons with disabilities use DRT more often. Overall, it could not be established that people of retirement age use DRT more frequently. However, this is true for male pensioners as a subgroup. Finally, people who use DRT for commuting to work tend to use DRT systems more frequently during the week (Wang et al., 2015).

Current findings on the association between age and DRT use suggest that the relationship tends to be non-linear, as the younger population on the one hand and the older population, on the other hand, have been identified as frequent DRT users (Mageean and Nelson, 2003). Laws et al. (2009) identified the retired population and those with a physical disability as frequent DRT users. However, in the urban context, Gilibert et al. (2019) showed that it was predominantly the younger age group of 18–29 years that was the primary user group of the MOIA DRT ride-pooling scheme in Hanover, Germany.

Based on the evidence that DRT users tend to be mobility-limited, easy access to buses, ideally barrier-free, often appears as demand for the vehicles used by a DRT system in rural areas. Jittrapirom et al. (2019) conducted a requirements analysis of DRT systems in rural areas in the Netherlands and emphasized the importance of wheelchair access. Barrier-freedom was also identified by Johnson et al. (2017) and

Shrestha et al. (2017) as a particular aspect of making it easier for the elderly and physically disabled people to access the vehicle. Finally, Avermann and Schlüter (2019) found in a passenger survey conducted for a different EcoBus pilot in a larger rural area in Germany that the ease of entry has a significantly positive effect on passenger satisfaction.

To summarise, rural areas are inherently inaccessible, even if they are anything but homogeneous in nature. Owning a car is essential due to infrequent traditional public transportation. However, this is problematic for less mobile people because they either do not have a car available, have a physical mobility limitation, or are generally part of the elderly population or live in a small locality with few daily services. DRT systems can increase the mobility of that population group. Thus, the extent to which a DRT system can realize the social benefits depends on that population group's willingness to take advantage of the service. A higher willingness theoretically results from the fact that less mobile persons recognize the advantage of this system for themselves. Understanding individual user characteristics is vital to address the needs of the target audience in order to maximize the social benefits of the DRT system. This study, therefore, seeks to enrich the limited empirical literature on individual determinants of DRT use with particular attention to the less mobile rural population.

3. The survey

This study was conducted during the first test phase of the EcoBus project. In summer 2018, the software-based public ride-pooling DRT system EcoBus was tested for eight weeks in the two municipalities Bad Gandersheim and Kalefeld located in Northeim, a rural county in Southern Lower Saxony in Germany. Like many rural regions of industrialized nations, Northeim is also affected by demographic change, so a further increase in the already high proportion of older people is expected in the future. The provision of public transport in the two municipalities is limited. Therefore, this region was chosen in cooperation with the responsible local transport authorities. The low availability of public transport has also led to a high dependency on private transportation, which is particularly critical in the light of the ageing population, as already discussed in Section 2.

The data collected on the intention to use DRT (EcoBus) and individual characteristics indicating restricted mobility is based on a questionnaire survey in the EcoBus service area. The survey was distributed to all households in the area on June 9th 2018. A total of about 10,000 copies were distributed. In order to allow multiple people from the same household to take part in the survey, a digital version of the questionnaire was also available on the internet, which was referred to in the cover letter of the questionnaire. In the end, a total of 156 evaluable questionnaires were collected, 38 of which were filled out digitally.

One component of the questionnaire was recording all journeys made in the last three days with characteristics such as purpose, destination, time of day, travel distance, and means of transport. The results served firstly to gain insights into the mobility patterns of people in the region and secondly to examine the importance of the private car as the main means of transport. Another part of the questionnaire asked for the mobility wishes inhabitants would like to cover with the DRT system EcoBus, divided into the purpose of the journey, the destination, the day of the week, and the days' time. The results section contains an overview of the purpose for the 376 trips provided. This part was closed by the question that formed the dependent variable *Intention for DRT use* (EcoBus), with the following question:

"If you currently use a car for your journeys, and assuming the journeys described above could be realized at a reasonable price for you: How likely would you abandon your car for these journeys and use the EcoBus instead?"

The question was answered on a five-level Likert scale with the labelled ends "very unlikely" and "very likely". Since the five levels had no explicit labelling, we considered the variable numeric rather than ordinal, so we decided to use the ordinary least squares estimation method instead of ordered logistic regression, which Wang et al. (2015) employ to identify individual user characteristics.

Finally, the questionnaire asked for socio-economic standards, including the independent variables. By asking about the place of residence, we were able to determine whether the respondents live in a locality with more or less than one thousand inhabitants and therefore in a *village*, using the population figures of the local governments (Bad Gandersheim (2018) and Kalefeld (2018)). The motivation of the variable *village* and the determination of the population limit of one thousand inhabitants is discussed in Section 4. Besides, it was asked whether one possesses an own car and, if not, how often there is a car at free disposal with the answer options always, occasionally, or never. The dummy variable *car* takes on the value of 1 if either one owns a car or always has one at free disposal. Respondents should also indicate whether they are dependent on a wheelchair or a walker in two separate questions. If at least one question was answered affirmatively, the dummy variable *disabled*, which refers to movement-related disabilities, was given the value 1. Finally, there was the possibility to provide comments in a blank text field. We present a small selection of them to complement the argumentation and the results qualitatively.

4. The study area –demographic change, low accessibility and high car dependency

The household survey was carried out in the two municipalities of Bad Gandersheim and Kalefeld in the, according to Küpper (2016), very rural district of Northeim, where the first test pilot of the ride-pooling DRT system EcoBus was performed. This region is exemplary for rural areas in Germany affected by demographic change. The rural district of Northeim has been experiencing negative population growth for more than two decades, so the population has fallen by 14% between 1995 and 2019 (LSN, 2020a), while the average age rose from 41.6 years to 47.3 years in the same period (LSN, 2020b). This trend is also clearly reflected in the two municipalities, with the negative net balance of born and deceased people being further reinforced by net outflows of the younger population (Bertelsmann Stiftung, 2020).

Examining the influence of age depending on the size of the residence place on the intention to use the EcoBus is central to this study. Hence an explanation is needed why the binary variable village was introduced and why one thousand inhabitants were chosen as the population threshold. As explained in the literature review, each individual place of residence in the study region has a different level of accessibility, primarily determined by the number of opportunities within a certain radius of movement. The four localities of Bad Gandersheim, Kalefeld, Echte and Kreiensen play a special role in providing services of general interest in the test area, hence we call them sub-centres. First of all, according to the central places monitoring of the Bundesinstitut für Bau- Stadt- und Raumforschung BBSR (2021), Bad Gandersheim is a medium centre and Kalefeld a basic centre, as they have considerable supply facilities and accessibility is ensured. Furthermore, to include the remaining two localities, these are the only four places with at least one of the respective facilities: supermarket, bank branch, post office and a doctor's surgery. Finally, as the analysis of the trips revealed, these are the four most frequently visited places within the study area, indicating the great importance of these four places in the region. All four sub-centres have more than 1000 inhabitants, whereby the number of inhabitants is less important than the ability to meet daily needs.

Besides the four sub-centres, there are several small villages with almost no facilities for daily public services, i.e. in most cases, there was not even the possibility to purchase food in a supermarket, so that the inhabitants have to travel to the nearest sub-centre for this basic need. The same applies to matters in medical practices, banks and post offices, and similar destinations. All these villages have less than one thousand inhabitants, so this is the upper limit to be still considered as a small, relatively inaccessible village. This cut-off point is probably very location-dependent and should therefore be chosen individually in any

other study, depending on the localities' ability to meet the daily needs. The service area is shown in Fig. 1 with a solid line. The four sub-centres, indicated as red points, are Bad Gandersheim, Kalefeld, Echte and Kreiensen, whereas Kreiensen can only be reached by the EcoBus to use the local railway station.

In addition to demographic trends and the emergence of sub-centres that have to be reached to meet daily needs, a third feature applies to the region, namely the high dependence on private cars. The first factor is the scarcity of public transport. Although bus lines connect all the locations, the frequency of these lines is strongly dependent on the needs of the pupils and is therefore very low within a day. Moreover, bus services are entirely suspended for the minor lines that connect small villages with the sub-centres during the holiday period. The numbers confirm the low relevance of bus transport as a mode of transportation in this region. 90% of the respondents stated that they either rarely or never travel by bus, and only 3.4% of all the routes reported were travelled by bus as their primary mode of transport, determined by the longest distance travelled by a transport mode in a trip. This contrasts with the high presence of the private car in the region. Here the share is 71.8% of all trips made by car as the primary means of transport. Furthermore, 82.1% of the respondents stated that they own a car and a driving licence, and another 1.9% always have access to a car in the household despite no car ownership. The average age of those who do not have a car is 62.1 years in our sample, and the median age is 72. At this point, however, it should be noted that the population under 18 years is strongly underrepresented in our data set.

5. Results

The dependent variable *intended EcoBus use*, from here on *ecobus*, and the set of independent variables have already been discussed in Section 3. An overview of the variable definitions and descriptive characteristics can be found in Table 1.

Besides, a look at the survey participants' age distribution is particularly important to interpret the results of the regression analysis correctly. As already noted in the literature review, the influence of age is probably non-linearly related to the intended DRT use, since on the one hand, the younger population without a driving licence and on the other hand, the older population was often identified as an essential user group. Fig. 2 compares the survey participants' age distribution with the actual age distribution of the study area (LSN, 2018). It becomes clear that the age group under 18 years is hardly represented, which must be considered when interpreting the variable *age*. The low proportion of the younger population is probably related to an eligibility criterion since pupils with public transport season tickets should initially be excluded from using the EcoBus. Due to the resulting unwillingness of younger people to participate in the survey, the respondents' average age of 59.83 years is high compared to the actual average age of 47.3 years. Furthermore, without the younger population, an approximately linear relationship between age and intended DRT use can be assumed if there is one at all.

To avoid biased estimates due to multicollinearity, the extent to which the independent variables correlate was checked. Table 2 shows that the correlation coefficients of the regressors of interest are of a

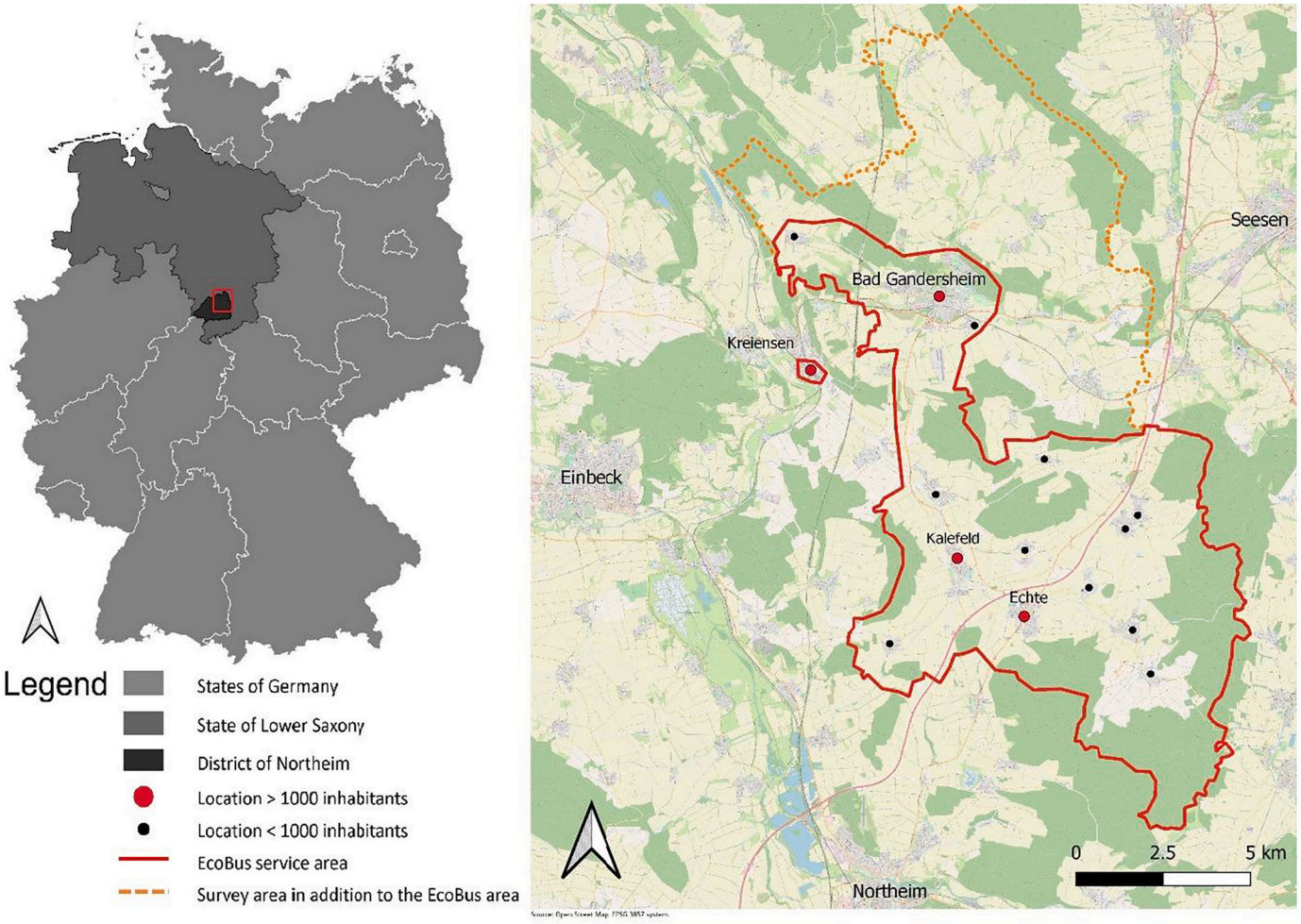

Fig. 1. EcoBus service area and survey area.

Table 1
Variable description.

Variable	Descriptive Statistics						Definition
Panel A:	*Quantitative variables*						
	Obs.	Mean	SD	Med.	Min	Max	
EcoBus	123	3.50	1.35	4	1	5	Indicated probability of using the EcoBus, expressed on a 5-point scale ranging from very likely to very unlikely, with no named intermediate points
Age	147	59.83	16.43	61	16	90	Age in years
Panel B:	*Binary variables*						
	(1)	%	(0)		%		
Retired	69	46.00%	81		54.00%		Being retired indicated as occupational status (1)
Village	76	52.78%	68		47.22%		Living in a settlement with less than 1000 inhabitants (1)
Car	131	86.75%	20		13.24%		Owning a car or having at least permanent access to a car (1)
Disabled	6	4.08%	141		95.92%		Mobility related disability, i.e. relying on a wheelchair or a walker (1)
Oldest	18	12.24%	129		87.76%		Being at least 80 years old (1)
Gender	60	40.54%	88		59.46%		Being male (1), being female (0)

Note: See Section 3 for a detailed discussion of the variables. Panel A contains selected descriptive statistics for quantitative variables, Panel B for binary variables. EcoBus represents the dependent variable of the regression analysis.

manageable order of magnitude, except for the two variables *age* and *retired*. This seems plausible but does not pose a problem, as these variables were only used alternatively in regression analysis and therefore are not considered together in one specification.

Table 3 shows the results of the linear regression analysis, which is used to identify the dependencies between variables indicating restricted mobility and the intended EcoBus use, based on the following main regression specification:

$$ecobus_i = \beta_0 + \beta_1 age_i + \beta_2 village_i + \beta_3 age_i{*}village_i + \beta_4 car_i + \beta_5 disabled_i + e_i \quad (1)$$

The included independent variables vary, so a total of six different specifications are shown. Specification (1) measures the influence of the variables *age* and *village* separately, with no variable showing a significant effect. By including an interaction term in specification (2), it is allowed to measure a separate slope parameter for the variable *age*, depending on whether one lives in a *village* with less than one thousand inhabitants. Only if one allows for a different relationship between *age* and *ecobus* depending on the localities size reveals the statistically significant relationship. The coefficient of *age* here refers to the influence of the age of people who do not live in a small *village* on the intended EcoBus use and is significantly negative. When it comes to the interpretation of the coefficient *age* for people living in a *village*, it is helpful to take the first derivative of *ecobus* with respect to *age*:

$$\frac{\partial ecobus}{\partial age} = \beta_1 + \beta_3{*}village \quad (2)$$

Adding the coefficient of the interaction term *age*village* β_3 to the coefficient *age* gives the influence of an additional year of life on the intended DRT use by the population in villages with less than one thousand inhabitants.

From Eq. 2, it follows that the marginal effect of an additional year of life on the intended EcoBus use of people living in a sub-centre (*village* = 0) corresponds to the coefficient β_1 and is therefore significantly negative at a level of 1%. The influence of *age* in the population from the villages is larger compared to the population in the sub-centres since the coefficient of the interaction term β_3 is significantly positive. Furthermore, each additional year of life's marginal effect is positive compared to the population in the sub-centres since $\beta_1 + \beta_3 > 0$.

The coefficient for the variable *village* is significantly negative. However, the actual influence of living in a small village on the willingness to use the EcoBus can only be interpreted depending on age:

$$\frac{\partial ecobus}{\partial village} = \beta_3 + \beta_1{*}age \quad (3)$$

With each additional year of life, the influence of *village* becomes smaller in absolute terms until an age threshold is exceeded, at which point it has a positive effect on the intended DRT use if one lives in a small village. This theoretical age threshold can be derived by setting the derivation of the intended EcoBus use with respect to the variable *village* to zero and resolving it by *age*. Consequently, living in a *village* contributes positively to EcoBus usage once one is approximately 63 years old. In contrast, for people younger than 63, the willingness to use the EcoBus decreases, ceteris paribus, when living in a village.

Solely from the regression table, it cannot be concluded that the positive influence of *age* in the population in the small villages is also significant. For this purpose, an F-test is performed to check the joint significance of the coefficients β_1 and β_3, i.e. $H_0 : \beta_1 + \beta_3 = 0$. If the F-test is performed for joint significance for specification 2, the test result with a *P*-value of 0.071 can only be rejected at a significance level of 10%. If the test is based on specification 4, the P-value increases to 0.111. Ultimately, it can be stated that the effect of the fact that inhabitants of sub-centres are less willing to use the EcoBus with increasing age outweighs the effect of the positive correlation between age and intended EcoBus use by inhabitants in small villages. However, there is also a clear tendency in this direction.

Specifications (3) and (4) successively show that access to a *car* has a significantly negative effect and being mobility-related *disabled* in the form of the use of a wheelchair or a walker has a significantly positive impact on *ecobus*. The correlation found between *age*, *village* and *ecobus* is stable since the estimation coefficients retain their significance and fluctuate only marginally in their magnitude when additional variables are included in the model. Specification (4) shows the lowest residual variance and the highest adjusted R^2 by including the significant variables *car* and *disabled*. Therefore, this is the preferred specification in the discussion of the results. Specification (5) shows that the same relationships apply when the dummy variable *retired* is used instead of *age*.

Column (6) is the most comprehensive specification and includes all independent variables except the dummy variable *retired*, which is used exclusively as an alternative to the variable *age*. This specification makes clear that in our data set, there is no significant influence of *gender* on *ecobus*, which is not directly connected with the problem discussed in this article but is of general interest in the DRT literature. Furthermore, there is no significant influence of the variable *oldest*, a binary variable that indicates people aged at least 80 years. Overall, the regression's explanatory power in the form of adjusted R^2 is reduced compared to the main specification (4). Additionally, the influence of three other variables that resulted from the survey but were not included in Table 3 was also checked for control purposes. There was no statistically significant

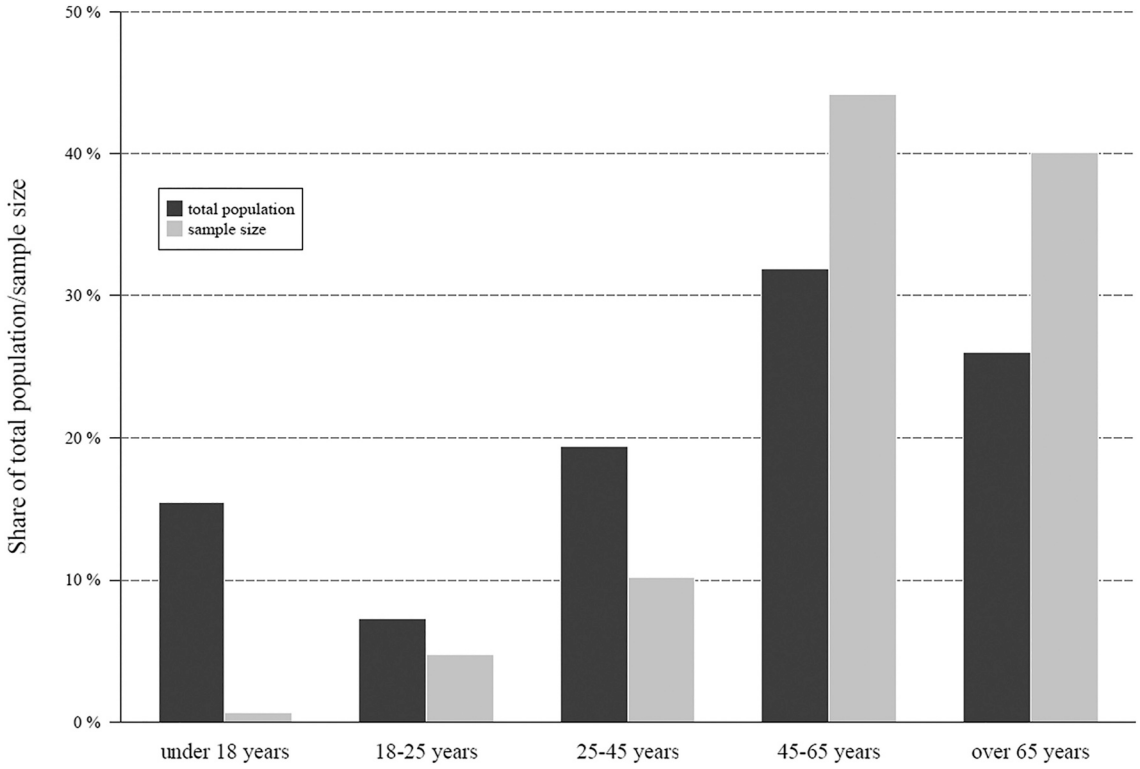

Fig. 2. Age distribution of respondents (dark gray) and the total population (light gray).

Table 2
Correlation among independent variables.

	Age	Retired	Village	Car	Disabled
Age	1	0.7998	0.0324	0.0394	0.0996
Retired	0.7998	1	0.0888	−0.0498	0.1723
Village	0.0324	0.0888	1	0.0640	−0.0112
Car	0.0394	−0.0498	0.0640	1	−0.1269
Disabled	0.0996	0.1723	−0.0112	−0.1269	1

Note: Correlations are calculated using the Spearman method. The variables with Age and Retired are only used alternatively.

effect on *ecobus* if public transport was used at least occasionally before. Furthermore, the level of the stated monthly budget for mobility (the sum of the cost of the car and local public transport) as a simplified proxy for income had no significant impact. Finally, although the examination area is slightly larger than the EcoBus service area, controlling for living in the service area shows no significant effect because a pre-selection might already have taken place in the decision to fill in the questionnaire. Based on the dependent variable's characteristics, one could discuss whether an ordinal logistic regression is preferable to an ordinary least squares regression. For this reason, the results of the otherwise identical specifications are given in the appendix in Table A.1. It turned out that the results do not differ in sign and significance of individual variables.

Finally, Fig. 3 shows the frequency of purposes of the specified routes respondents can imagine using the EcoBus. From a total of 326 collected tips, the most frequent purpose was *leisure* (27.66%), closely followed by *shopping* (25.53%) and *medical issues* (25%).

As a qualitative complement to the premises and the results, we present below some striking statements from the open text fields of the questionnaire. The selection is, to some extent, representative of comments with similar content that were frequently mentioned. The older population constantly made a connection between increasing age and decreasing mobility, also through the possibility of not being able to drive a car anymore later on due to health reasons: "In view of increasing age and thus decreasing mobility or perhaps also the ability to drive a car myself, […]". Concerns about not being able to drive a car soon were also expressed in terms of not seeing an alternative in traditional public transportation: "I am a big supporter of the EcoBus project because, at my age, I don't know how much longer I can drive a car. I live alone, my children live far away, and public bus transportation is disastrous in Kalefeld." They partially accuse the mobility situation of the elderly population: "Seniors must be enabled mobility in old age; this is currently not applicable." Sometimes they still drive their own cars, but only because there is no alternative. If there were, they would gladly give up the car for health reasons: "I am constrained in terms of mobility and use two walking aids. I always travel by car a lot because there is no other option." Another survey participant puts it this way: "Due to age, I would like to stop driving myself. Since we live on a mountain, I would want to reach all destinations outside the house by EcoBus. This way, I would not only be able to go to the most necessary destinations, but I would also be able to reach leisure destinations again." This statement also highlights the importance of leisure travel to the quality of life of the elderly population. One participant raises the difference in mobility between the population in the smallest villages and in the sub-centres, which illustrates what is meant to be expressed by our variable *village*: "As a shopping shuttle for seniors in the core city, I think it's superfluous, because the villages have more of a mobility problem, especially on weekends you can't get away without a car here: Saturday shopping is a no-go!"

6. Discussion and conclusion

DRT is certainly not the panacea for all rural problems (see Vitale Brovarone and Cotella, 2020); in particular, financial sustainability is a major challenge (Davison et al., 2014). However, DRT can extend the public transport supply in rural areas and is therefore an excellent opportunity to remain mobile and maintain the standard of living of less mobile people, for instance, due to a missing car, a physical or age-

Table 3
Factors influencing intended EcoBus use.

	Dependent variable: Intension to use the *EcoBus*					
	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	4.0821***	5.7918***	6.5699***	6.5838***	4.8607***	6.6229***
	(0.5042)	(0.6730)	(0.7442)	(0.7457)	(0.4906)	(0.7574)
Age	−0.0069	−0.0365***	−0.0324***	−0.0353***		−0.0372***
	(0.0081)	(0.0113)	(0.0112)	(0.0113)		(0.0120)
Retired					−0.7632**	
					(0.3703)	
Village	−0.2595	−3.5243***	−3.2506***	−3.3269***	−0.8790***	−3.2716***
	(0.2581)	(0.9365)	(0.9269)	(0.9332)	(0.3233)	(0.9499)
Car			−1.0736**	−1.0021**	−1.0500**	−0.9428*
			(0.4731)	(0.4697)	(0.4791)	(0.4857)
Disabled				1.0172*	1.0975*	1.0090*
				(0.5832)	(0.5965)	(0.5905)
Oldest (≥ 80)						0.3180
						(0.5072)
Gender (male)						−0.0263
						(0.2526)
Age*Village		0.0557***	0.0505***	0.0521***		0.0512***
		(0.0154)	(0.0153)	(0.0155)		(0.0158)
Retired*Village					1.3663***	
					(0.5056)	
Standard error	1.363	1.293	1.269	1.253	1.276	1.268
R^2	0.01648	0.1225	0.1628	0.2037	0.1697	0.2075
Adjusted R^2	−0.001569	0.09809	0.1315	0.1651	0.1302	0.152
Obs.	112	112	112	109	111	108

Note: Regression coefficients and their standard errors in parentheses based on eq. 1 with different specifications. Specification 1 to 3 are meant to develop the main specification 4. Specification 5 controls whether the results differ when using the binary variable Retired instead of the quantitative variable Age. Specification 6 demonstrates the non-significance of the variables Oldest and Gender.

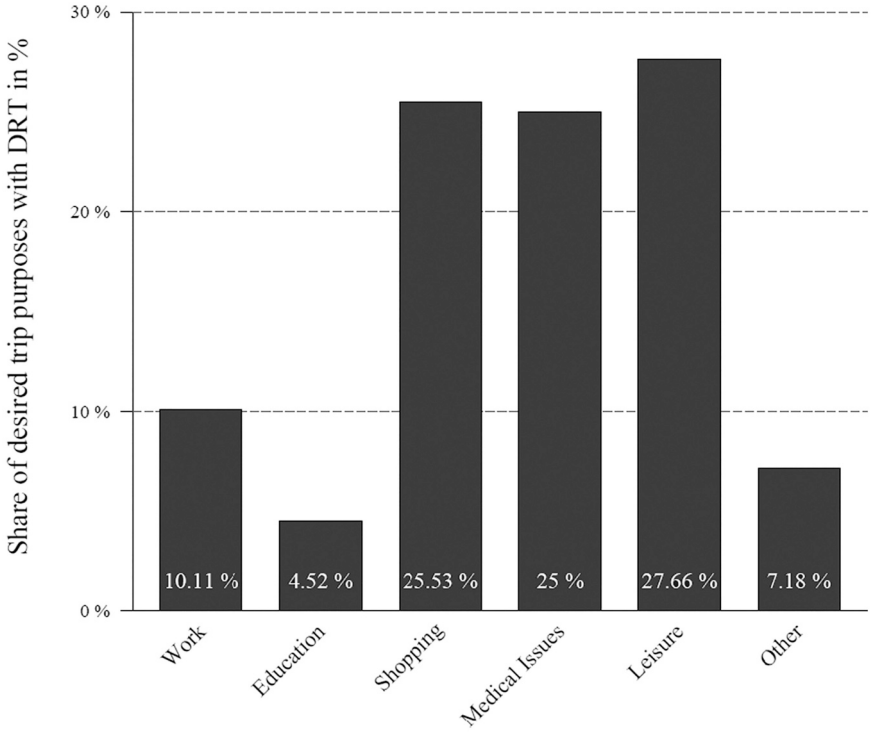

Fig. 3. Distribution of purposes of the desired trips by the DRT system EcoBus. Respondents could state numerous trips. A total of 326 desired trips was collected.

related impairment or living in an inaccessible locality. In this paper, it was examined to what extent individual factors which point to a mobility deficit influence the intention to use the DRT system EcoBus. For this purpose, a household survey was conducted in the rural test area that is characterized by demographic change and a high car dependency. We are aware that rural areas are nationally and internationally very heterogeneous and that definitions vary at the international level. However, to a certain extent, the results of this case study can be transferred to other rural areas since the region under consideration has some of the typical characteristics of a rural area in industrialized nations. These include a low population and settlement density, a high car dependency as well as an insufficient offer of public transport and an ageing population.

Firstly, as already shown by Wang et al. (2014) on a regional level,

having access to a car is also negatively associated with the intended DRT (EcoBus) use on an individual level. We decided to use the binary variable "car access" instead of the counterpart "no car access" for consistency with the literature. In the context of our research question, however, it should be explicitly emphasized that, conversely, people without car access are more likely to use DRT systems because they may see them as an enrichment of their individual mobility situation.

Secondly, a mobility-related physical impairment favours the intended EcoBus use. Since an exceptionally high social benefit is expected from this group of people, their needs in the form of easier access and the door-to-door feature should not be neglected. This result is consistent with the frequent call for facilitating the entry of the DRT vehicle (e.g., Avermann and Schlüter (2019), Jittrapirom et al. (2019), Johnson et al. (2017) and Shrestha et al. (2017)).

Thirdly, we contribute to the discussion of the still ambiguous role of age in DRT use (e.g., Mageean and Nelson (2003), Laws et al. (2009), and Wang et al. (2015)). The older population plays an essential role in generating sufficient demand for a DRT system due to the expected reduced physical mobility, a lower car ownership rate and the increasing predominance due to the demographic process. Only after we allowed for an interaction between age and the size of the place of residence by inserting an interaction term in the regression analysis, it becomes apparent that the influence of age on the intended EcoBus use depends significantly on whether a person lives in a locality below or above one thousand inhabitants. While people who live in a locality with more than one thousand inhabitants are significantly less likely to use the EcoBus with increasing age, people in smaller villages with less than one thousand inhabitants tend to use the EcoBus with increasing age. Therefore, a novel target group of DRT systems in rural areas appears in our data, namely the elderly population living in small villages with little offer of daily public services. While a minimum of daily life facilities is within somewhat accessible reach for the older people in the subcentres, the elderly immobile population in the smallest villages, which often do not even offer an opportunity for grocery shopping, is doubly troubled. This might be the reason why that particularly vulnerable group has an even more positive attitude towards DRT use.

Two major aspects should be taken into account when assessing the significance of the results. First, the younger population is underrepresented in our data set. On the one hand, this favours the assumption of a linear connection between age and intended DRT use. On the other hand, investigations are just as desirable in how far DRT systems make the younger population without driving licence more mobile and possibly increase their quality of life. Second, the results refer to the intended use of the DRT system, which does not result necessarily in actual use. It is also possible that the population would like to express with the answer of the questionnaire that they welcome the EcoBus project and consider it an enrichment of the region, but will probably not use it themselves, since the own car is still the more comfortable alternative. In addition, it is worth noting that our individual variables potentially suggesting a mobility deficit are not a closed set and can be augmented by characteristics such as low household income. Also, our variable disabled, which is an indicator of whether the respondent uses a wheelchair or a walker, is incomplete. It does not cover various health reasons that also lead to not being able to drive a car, such as vision impairment.

Overall our results suggest that people with a lower degree of mobility are more likely to use the DRT system EcoBus, as they may see an additional benefit in the extended mobility offer. For these people, the improved mobility situation makes it easier to participate in social life. Besides, a quarter of all trips that people would like to take with the EcoBus are medical matters, which again underlines the urgency of improving this population group's mobility. In a similar vein to an economically motivated market potential analysis, the results can help to identify regions where implementation will generate the highest possible social benefit and improve the quality of life of those who suffer from reduced mobility in rural areas. Yet, it is also important in terms of capacity utilization and ultimately the cost-effectiveness of the DRT system to recognize an important customer group, namely those who are potentially less mobile.

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Declaration of Competing Interest

None

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Appendix

Table A.1
Alternative ordered logistic regression.

	Dependent variable: Intension to use the *EcoBus*					
	(1)	(2)	(3)	(4)	(5)	(6)
Age	−0.0084	−0.0559***	−0.0511***	−0.0566***		−0.0610***
	(0.0110)	(0.0183)	(0.0182)	0.0187		(0.0200)
Retired					−1.0304*	
					(0.4638)	
Village	−0.2898	−5.3679***	−5.3833***	−5.5597***	−1.2432***	−5.5145***
	(0.3391)	(1.4897)	(1.4844)	(1.5326)	(0.4638)	(1.5639)
Car			−2.1934**	−2.2417**	−2.0328**	−2.1321**
			(0.8989)	(0.9084)	(0.8537)	(0.9312)
Disabled				2.1217*	22474*	2.1023*
				(1.1662)	(1.1737)	(1.1727)
Oldest (>80)						0.6818
						(0.8970)
Gender (male)						0.1321
						(0.3776)
Age*Village		0.0870***	0.0852***	0.0871***		0.0865***
		(0.0245)	(0.0244)	(00252)		(0.0259)
Retired* Village					1.8834**	

(*continued on next page*)

Table A.1 (*continued*)

	Dependent variable: Intension to use the *EcoBus*					
	(1)	(2)	(3)	(4)	(5)	(6)
					(0.7372)	
Residual Deviance	341.57	327.62	319.89	305.51	319.05	302.01
AIC	353.57	341.62	335.89	323.51	337.05	324.01
Obs.	112	112	112	109	111	108

Note: Estimating the specification of Table 1 with the method of ordered logistic regression instead of ordinary least squares.

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