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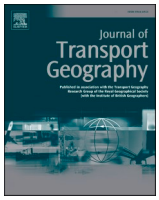

E-bike use and ownership in the Lake District National-Park UK

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ABSTRACT

E-bike use in rural and tourist areas is under-researched and has potential to replace car journeys reducing greenhouse gas emissions and other impacts of car use. We studied the rural use of e-bikes in a tourist area (the Lake District National Park, UK) through Covid-19. Mixed methods were used; two waves (2020 & 2021) of a semi-panel quantitative survey; including open responses; supplemented by self-study field trips.

Key findings include high levels of e-biking in a wet and hilly area by generally older individuals, including a high proportion of female respondents. Usage was higher in 2020, partly due to lower traffic levels during Covid restrictions, but relatively high usage was maintained in 2021.

Users are substituting more car journeys than active travel and public transport trips, and amongst women, more errands than commutes. We found support for restraint of car use in the study area, along with support for secure e-bike parking, e-bike share schemes, and integration with public transport.

The implications for planners and policymakers are that policies supporting rural e-biking may be well received if they form part of greener transport plans including e-bike facilities, integration with public transport and car restraint. Promotion of e-bike use needs to shift from an urban commuting focus, to also consider rural areas errands and leisure trips. National parks and other rural tourist areas may confidently assume that hills and weather do not always act as barriers.

1. Introduction

E-bikes can aid transport decarbonisation, energy demand reduction and provide other co-benefits. Although there are many studies examining e-bike use in urban areas, several recent papers point out that there is less work understanding e-bike use in rural areas (Bruzzone et al., 2021; Hu et al., 2021; Wang et al., 2017) representing a research gap. There is some research suggesting that e-bikes have potential to deliver carbon savings in rural areas and should be further researched (Brand, 2021; Philips et al., 2022). In addition, Covid-19's potential positive effects on sustainable travel behaviour in rural areas of the UK have been studied for other modes, but not, as far as we know, for e-bikes. Finally, rural roads and tourist areas have specific issues that increase the potential impact of our research. These rationales for our research are explored below, before the methods are outlined and the findings are presented and discussed.

This paper thus makes several distinct contributions. First, by focusing on a UK national park it contributes to knowledge of rural mobility options and travel in recreational and tourism areas, applicable to similar locations nationally and internationally. Second, it furthers understandings of rural e-bike users, including different user groups such as visitors and residents. Our paper provides insights into similarities and differences in patterns of e-bike use and modal shifts between residents and visitors, their desire for facilities such as secure e-bike parking as-well as attitudes towards car restraint. Thirdly, it identifies changes in e-bike use during disruptions (i.e. Covid-19).

2. Background

2.1. Transport decarbonisation and energy demand reduction

As stated in the introduction, e-bikes can aid transport decarbonisation, energy demand reduction and provide other co-benefits. Decarbonising the transport sector is essential (IPCC, 2022). Demand reduction is important (Brand et al., 2020; Gota et al., 2019; Lefèvre et al., 2021) alongside modal shift to low carbon modes, fleet electrification and correct sizing of vehicles (Gkiotsalitis and Cats, 2021). *E*-bikes contribute to the latter three aspects of decarbonisation. E-bike adoption can reduce emissions (Jenkins et al., 2022; McQueen et al., 2020). There is literature discussing a range of potential benefits of e-

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bikes, including: carbon reduction (Brand et al., 2021; McQueen et al., 2020; Philips et al., 2022); health benefits (Jenkins et al., 2022; Sundfør et al., 2020); overcoming barriers to cycling such as hilliness (Behrendt et al., 2021), traffic and safety (Gu et al., 2021; Rérat, 2021; Weber, 2014); and aiding mode shift (de Haas et al., 2022), with particularly high levels of use for utilitarian purposes (Bourne et al., 2020). In the UK there have been some academic trials of e-bike use (Cairns et al., 2017) demonstrating considerable mode shift and potential for increased future use. A UK-wide survey of 2092 e-bike users by (Melia and Bartle, 2021) noted how e-bikes are used to overcome hilliness, as a replacement for the conventional bike for those with health constraints, and for some as a mode shift from car use. They note a higher than expected proportion (30%) of female respondents, which contradicts previous studies in low cycling level Western countries which suggested e-bike users were predominantly older-educated males.

2.2. Urban and rural studies

There are a number of differences in the way e-bikes may be considered by transport planners in rural and urban areas. In this paper, we refer to e-bikes which may be used legally on the road in the UK under the same highway rules as bicycles, they have an electrical motor which provides a maximum of 250 W assistance whilst the rider is pedalling and does not provide electrical assistance at speeds above 15mph/24kmh. This class of e-bikes is also known as Electric Pedal Assisted Cycles (EAPC).[1] *E*-bikes can deliver greater decarbonisation per person in rural rather than urban areas (Philips et al., 2022); car trips in cities are generally shorter than in rural areas, so mode shift to e-bike for journeys in rural areas will replace more car kms and thus achieve greater CO_2 reductions. Due in part to poor public transport, rural areas are more vulnerable to car dependence and associated costs (Mattioli et al., 2019). Poor public transport may also reduce the proportion of substituted public transport trips in rural areas compared to cities (Clark and Parkin, 2022; Winslott Hiselius and Svensson, 2017). E-bike trips are more likely to replace conventional bike trips in urban areas, which risks a reduction in physical activity (Winslott Hiselius and Svensson, 2017) further suggesting an advantage of using e-bikes in rural areas. In hilly areas - such as the Lake District study area and other national parks, e-bikes are appropriate for journeys difficult to make by conventional bicycle (Behrendt et al., 2021). Bruzzone et al.'s (2021) study in a hilly rural landscape found the same potential suitability, citing Sun et al. (2020) finding that "those living in rural areas were among the most likely to forgo their cars in favour of e-bikes" (ibid p2). Winslott Hiselius and Svensson (2017) state that "the potential for e-bikes to replace car trips is as great in rural areas as it is in urban areas.", while Kairos (2010) suggests that e-bikes might substitute for middle-range trips in rural areas that would otherwise be undertaken with a car" (ibid p819), and Gu et al. (2021) similarly hypothesise that rural e-bikes substitute car journeys more, due to the 'e-bikable' distances of most journeys, and a safer, more enjoyable cycling experience outside cities.

Studies that directly compare urban and rural e-bike use find that rural cyclists (including e-bikers) were significantly older and younger (40–65 and < 23) than urban cyclists (Weber et al. 2014), and rural e-bikers were found to wear helmets more often (Weber et al. 2014). The older profile of e-bike users being confirmed by Winslott Hiselius and Svensson (2017) who also found that rural e-bikers had more driving licences and access to cars (consistent with the rural population generally), and used e-bikes proportionately more for leisure rather than for commuting or school trips. Gender differences are noted, with higher than expected representation of women found in rural areas (Hu et al., 2021), which is also seen in studies comparing e-bikers with conventional cyclists (Melia and Bartle, 2021; Rérat, 2021).

However, research on e-bike and micro-mobility use more generally over-concentrates on urban and commuting uses (Department for Transport, 2022). The International Transport Forum (ITF, 2021) argues for greater sustainable transport focus on rural areas (including tourist areas), and leisure and non-work/non-commuting travel, which contributes to increasing shares of travel (Department for Transport, 2020; Guiver and Stanford, 2014; Marsden, 2019; Peeters et al., 2019).

2.3. Disruptions and sustainable transport

The context of the research needs stressing. There is much published about the impact of the Covid19 pandemic[2] on travel, e.g. on public transport, flights, or urban transport in general (Anable et al., 2022; Calderón Peralvo et al., 2022). This body of research contributes to the understanding of disruptions, and their potential to leverage the transition to sustainable transport (Marsden et al., 2020). There was a stated desire for a 'green recovery' in the early phases of Covid (Climate Assembly UK, 2020; Climate Change Committee, 2020) and continued evidence of the need for 'post-Covid' planning to lead to rapid decarbonisation including transition to a more sustainable transport system (IPCC, 2022). *E*-bikes in rural areas has not been specifically included in literature on a green transition in travel resulting from disruption, presenting a further research gap.

2.4. Tourist area as research setting

Rural roads and tourist areas provide specific interest for sustainable travel research. Rural roads and motor traffic are associated with issues such as wildlife mortality, effects on water flows, pollutants and nutrients, which affect the structure of ecosystems (Coffin, 2007; Spooner, 2015). Additionally the visual impact of roads and traffic may alter the character of rural areas such as national parks (Flad, 1997). Further issues such as congestion, manifest themselves differently in rural areas to cities; congestion and access to rural honeypots and leisure destinations have been issues for some time with analysis and policy considering both residents and tourists (Hall, 1999).

Studies of rural e-bike use suggest that they can help reduce congestion in national parks (Curtale et al., 2021) with strong potential for their integration with other rural transport services (Bruzzone et al., 2021; ITF, 2021; Pangbourne, 2020). While much research on tourism and transport remains in separate silos (Hopkins, 2020), investigating sustainable transport in specific rural and tourist geographies offers benefits both academically and to rural stakeholder groups developing place-based sustainable transport visions (Büscher et al., 2022). In addition to having positive sustainable transport outcomes, cycle-friendly facilities can boost retail and entertainment footfall (e.g. Bosworth et al., 2020). In national parks, e-bikes may be used for utility and on-road leisure, as well as e-mountain-biking. The latter presents an economic opportunity, but also exacerbates recreational user conflicts, may cause erosion and other impacts while allowing easier access to wilder places (Hardiman and Burgin, 2013).

3. Methods

This study uses a sequential mixed methods approach (Ivankova et al., 2006; Tashakkori and Teddlie, 1998) consisting of a two wave survey (analysed cross-sectionally, and as a panel for a sub-sample of participants) and a self-study field visit of the researchers undertaking e-bike use in the Lake District. The surveys were completed between August to October 2020, and August to October 2021. We describe the different elements of the methods below.

[1] https://www.gov.uk/government/publications/electrically-assisted-pedal-cycles-eapcs/electrically-assisted-pedal-cycles-eapcs-in-great-britain-information-sheet.

[2] Henceforth referred to as 'Covid', for brevity.

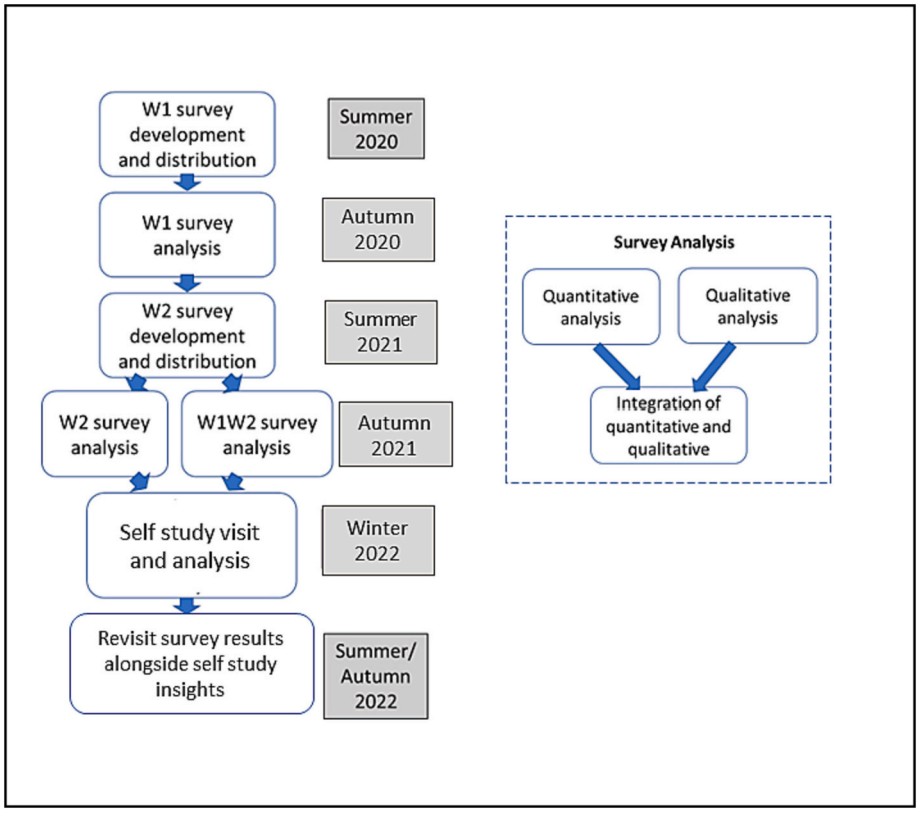

Fig. 1. Mixed-methods approach undertaken in this study.

Table 1
Survey sample sizes split by different groups and fieldwork dates.

	Segment					Survey Total
	% Resident e-bike owner	% Visitor e-bike owner	% *E*-bike hirers	% Resident non e-bikers	% Visitor non e-bikers	
Wave 1 (August – October 2020)	16.6	16.6	4.5	8.5	53.7	$N = 523$
Wave 2 (August – October 2021)	9.7	17.1	7.9	4.9	60.3	$N = 567$
Wave 1 and Wave 2 respondents (Panel)	29.2	22.1	9.7	8.8	30.1	N = 113

3.1. Study area

This study examines e-bike use during Covid in a rural tourism-focussed area: the Lake District National Park in northern England. The following contributed to our choice of study area: in terms of generalisability, it is part of a network of 15 rural national parks in the UK. Internationally it is relevant to those interested in the use of e-bikes and sustainable transport in national parks and more generally in rural areas. The study importantly differentiates between different e-bike users in tourist areas (e.g. residents, visitors and hirers). This World Heritage Site, chosen for its accessibility to researchers during Covid restrictions, attracted 28.6 million visitor days in 2018 (Lake District National Park, 2022). Visitor numbers were 23% lower in 2021 (Cumbria Tourism, 2022) but with visitor numbers more concentrated in July–September than in other years. The Park's resident population is approx. 40,000 people and private car use dominates travel by both tourists and locals (Cullinane and Cullinane, 1999; Davies and Weston, 2015; Eckton, 2003; Whitlegg, 2013). On busy summer days the visitor population outnumbers the resident population several times over, exacerbating traffic issues including congestion, poor parking and blocking of access, including emergency access (ITV, 2021; Kirkbride, 2022).

3.2. Survey development, distribution and analysis

The first wave survey was designed in May and June of 2020 whilst the UK was in Covid lockdown. For information on the dates and types of restrictions in the UK during the study time periods please refer to Institute For Government (2021). Covid presented unique circumstances and methodological challenges for transport researchers. The extreme disruption presented a unique opportunity, but also a challenging scenario with the uncertainty as to how long travel restrictions would continue. Consequently, research projects including this study were developed at short notice, which placed considerable limitations and constraints on research design. This study had limited opportunities for survey piloting, with minimal survey distribution and feedback channels. Survey items were developed quickly without a full literature review e.g. specific rural and tourism related research. However, to counteract these limitations, care was taken to develop a survey which incorporated questions from existing surveys such as the National Travel Survey and TRANSAS.[3] Feedback on survey design was also obtained

[3] National Travel Survey https://www.gov.uk/government/collections/national-travel-survey-statistics

Table 2
Demographic characteristics of respondents (cross-sectional and panel respondents).

Respondents	Survey	Segment					Survey Total %
		% Resident e-bike owner	% Visitor e-bike owner	% E-bike hirers	% Resident non e-bikers	% Visitor non e-bikers	
Age 55+	2020	76	65	38	61	62	60
	2021	73	66	25	47	59	61
	Both waves	76	84	27	90	65	70
Female	2020	62	46	58	46	54	49
	2021	59	44	61	40	47	53
	Both waves	55	20	45	40	38	40
Earning over £30,000	2020	56	62	79	72	65	48
	2021	79	75	72	61	66	48
	Both waves	77	67	55	44	71	60
Retired	2020	45		4	29		35
	2021	49	52	22	25	42	42
	Both waves	55	68	18	40	47	50
E-mountain bike user	2020	32	32	65	n/a	n/a	36
	2021	38	34	48	n/a	n/a	36
	Both waves	39	28	55	n/a	n/a	36
Regular (conventional) cyclist	2020	40	43	43	62	35	40
	2021	25	35	44	39	26	30
	Both waves	39	32	45	50	59	45

from experienced travel and transport survey researchers, and a Lake District sustainable transport consultant. Whilst this research was carried out under unprecedented conditions, much of the same conditions applied globally. We discuss the generalisability of research findings later in this paper.

Survey questions mostly comprised of quantitative grid or 5-point Likert scale questions. A copy of the 2020 and 2021 surveys is included in the supplementary materials S1. Both surveys finished with an open-ended qualitative question asking: '*If you have any other comments about using e-bikes in the Lake District during [lockdown or summer 2020/Covid (March 2020 until 2021)], please share them here*'. This question had a high completion rate ($n = 158$ in 2020; $n = 135$ in 2021) and provided valuable qualitative insights. Questions asked in the 2020 survey related to the first lockdown (March–June 2020), and summer 2020, and the 2021 survey asked principally about spring and summer 2021. To reduce the potential impact of seasonality, wave 2 dates replicated wave 1: The 2020 survey was open August – October 2020 and the 2021 survey August – October 2021.

The two-wave nature of the survey allowed comparison of views and travel behaviour change between 2020 and 2021. Cross-sectional analysis was conducted on all responses. The survey company (more information below) also sought to recruit respondents to complete both survey waves, by asking for e-mails of participants and recontacting 2020 respondents in 2021 (303 of 523 respondents provided e-mail addresses in 2020). A subset of respondents ($n = 113$) completed both survey waves. The survey company carried out a matching exercise. It is possible that a small number of 2 wave respondents are not included in the panel analysis, but this cannot be verified due to data protection rules. In the panel analysis we only use the 113 respondents that the survey company confirmed had completed both waves. We analysed the panel data to gather insights on whether any differences noted between 2020 and 2021 were because of changes in the population in the two cross-sectional samples or changes in personal behaviour by individuals who completed both waves.

We segmented the respondents by their use/non-use of e-bikes and whether they were residents or visitors. We did this based on advice from the Lake District sustainable transport consultant who stated that these segments would be of interest to local businesses and policy makers. The consultant also had input into the question design regarding the services and facilities that respondents were asked about. Questions and categories on journey purposes and substitution modes were developed in reference to existing surveys such as the National Travel Survey and the TRANSAS survey, and from feedback from experts we consulted with.

We hired a Lake District based market research company (Red Research) to administer the survey. They were the data controller; they handled the matching of panel survey responses and the incentive prize draw. The researchers received only anonymised data with names and contact details removed. The survey was distributed and promoted online as, due to Covid restrictions, face-to-face engagement was not possible. Red Research distributed the survey to the Cumbria Tourism membership mailing list in their newsletters (database of approximately 110,000 with 34% of newsletters opened by recipients) which includes UK and overseas recipients. Cumbria Tourism also communicates with local businesses and residents. The survey was also promoted through the Cumbria Tourism visitor-facing social media channels (320,000 followers: breakdown by nationality unknown). The survey was promoted in the monthly newsletters in August and September of each year and at intervals on social media channels. Additional promotion took place including posting on the researchers' Twitter accounts and cycling Facebook groups based in the UK. Links to the survey were sent to bicycle shops, e-bike providers and cafés in the Lake District. We were not provided with a breakdown of response by promotion method. The primary promotion methods through Cumbria Tourism are aimed at all those interested in the Lake District, but these communication channels are not specifically aimed at cyclists or e-bike users. This explains the high proportion of non-e-bike users responding. A prize draw incentive of a £100 shopping voucher was offered for participation in each wave. Each survey took approximately 15 min to complete.

Data analysis was carried out using the R language (R Core Team, 2021). We visualise the data using tables, graphs and Likert plots. To further analyse a number of questions based on 5-point ordinal Likert scales we used non-parametric tests (Mayer et al., 2012), specifically Kruskall-Wallis tests with a Dunn post-hoc test to identify statistically significant differences ($p < 0.05$) between multiple segments in the same year. To compare whether there was a statistically significant difference in response from the same segment between 2020 and 2021 we used a Mann Whitney test with the cross-sectional data and a Wilcoxon paired

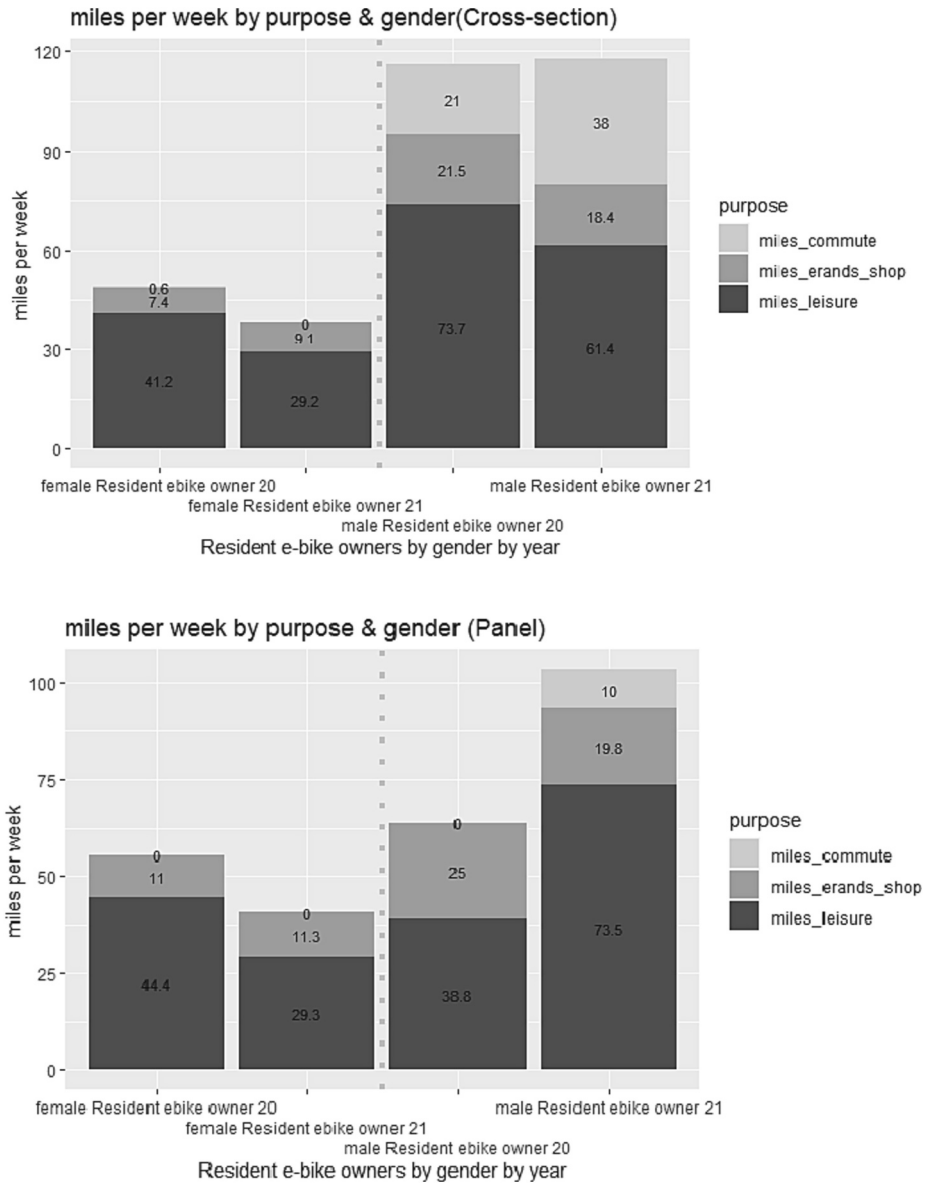

Fig. 2. Weekly distance travelled by resident e-bike owners by purpose and gender.

'We use a camper van as a base and bikes where we stay. We don't use the van once we're at our site.' [ID 283]

'Living at the top of a steep hill the e-bike is very useful for both forays into town and for leisure/exercise. Using the e-bike for town visits avoids use of a car with the ensuing parking issues/congestion/emissions etc. and promotes my exercise levels.' [ID 54]

Fig. 3. Quotes illustrating use of e-bikes for non-commute purposes.

test with the panel responses. We made use of the non-e-bike using segments to compare behaviours and attitudes with our e-bike using groups. The statistical tests used, account for variations in the number of respondents in each segment. We report demographic differences between the cross-section and panel respondents. Where there are considerable differences between cross-section and panel results we present them and discuss whether or not this may be due to demographic differences in the sample.

The qualitative/open survey responses were analysed both independently and then in combination by the researchers. Thematic analysis was used for qualitative analysis. For a concise presentation we have not included all plots, tables and statistical output in the paper. A code listing and output is available in a Github repository.[4]

3.3. Self-study and mixed-methods integration

Fig. 1 illustrates the sequential mixed-methods approach undertaken in this work and the mixed methods integration. Results from each survey influenced the development of the next stage of data collection. Towards the end of the process results were re-reviewed and further analysis conducted based on findings from both the self-study findings

[4] https://github.com/DrIanPhilips/ebikes_Lake_District

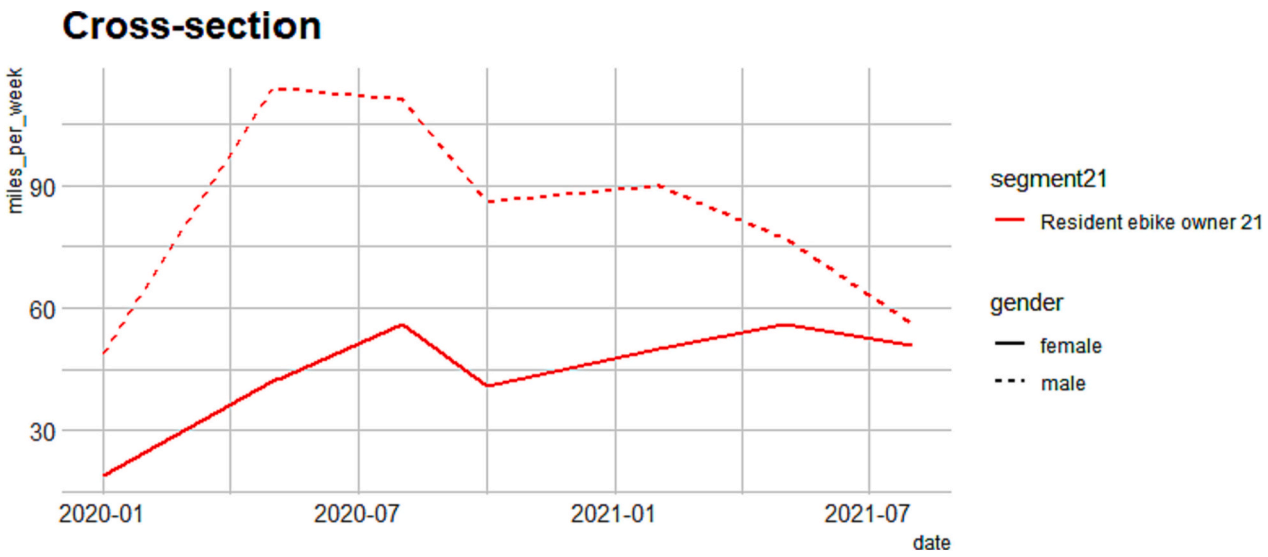

Fig. 4. Self-reported total distance travelled at different time points (cross-section data). Question asked of resident e-bike owners retrospectively in wave 2 (2021).

'It was a delight to travel on car free roads during lockdown. I did many routes such as the A66 which normally I would avoid' [ID 115]

'[riding an e-bike] was a way to go out all day in spite of restrictions' [ID 20]

'It was lovely to be able to ride my e-bike during lockdown, due to the lack of cars on the road I felt a lot safer. This made it much easier to get my daily exercise' [ID 95]

Fig. 5. Responses to the open-ended question which refer to recreational riding during Lockdown in spring 2020.

and survey analysis. Auto-ethnography is an approach that "seeks to describe and systematically analyse personal experience in order to understand cultural experience" (Ellis et al., 2011), and has been applied to cycling mobility and its wider interactions with place and culture (Jones, 2005; Larsen, 2014; Popan, 2020). Self-study is a more limited genre of auto-ethnography (Hamilton et al., 2008) which we used to gain interactive and reflective understanding of user experiences and provide deeper understanding of survey results. Limitations on full auto-ethnography were imposed by the Covid restrictions during the study period. However, researchers wanted to understand survey findings and provide a complementary triangulation of user experiences. Self-study provided an opportunity to do this.

The self-study part of this research involved researchers hiring e-bikes from Whinlatter Forest, approximately 5 miles from Keswick, in November 2021. Researchers created a route from Whinlatter to Keswick, incorporating a variety of different cycling infrastructures such as the National Cycle Network, B (minor) class roads, and A (major) class roads with cycle infrastructure and cycle lanes. The route was selected as both Whinlatter and Keswick are popular tourist destinations in the Lake District and Whinlatter had hiring facilities. It involved a mix of tarmac roads, paths, and sections of off-road (gravel/hard-packed) surfaces. Researchers replicated a typical visitor experience with a walk around Keswick with bikes with a refreshment stop. Video and audio recordings were made during the e-bike hire experience and fieldnotes written afterwards.

4. Results

This section describes the survey results, alongside related qualitative responses to the open-ended questions which contextualise the quantitative findings. Additional self-study findings are presented later in this section.

4.1. Respondent characteristics

Table 1 details the total survey responses to each survey wave, along with the proportion of each survey split by segment.

Table 2 shows our sample has a high proportion of respondents aged 55+, and a high proportion of female responses. This is higher than the 30% reported in Melia and Bartle's (2021) survey.

Demographically the panel respondents are older (higher % over 55) and more often male. In the cross section and panel data the majority of e-bike owners are not e-mountain bikers. In the panel data the proportion with household incomes of over £30,000 is lower for all except Visitor non-e-bikers.

4.2. (Changes in) E-bike usage

Resident e-bike owners ride a lot and not only for leisure. Amongst resident e-bike owners in the cross-sectional data, women ride on average over 30 miles per week, while men ride over 100 miles per week (Fig. 2). Women commuted very little in 2020 and not at all in 2021. Men increase their commuting mileage from 2020 to 2021. In 2021, 44% of women and 48% of men were working so the difference in commuting rates is unlikely to be due to differences in employment status. Women increase their errands distance from 2020 to 2021. Men ride further for errands than women. Men decreased their errands distance slightly in 2021, but not as much as they increase their commuting. Both men and women decrease their weekly leisure mileage between 2020 and 2021. In wave one, 53% of resident e-bike owners said its availability during lockdown allowed them do things that would have been more difficult without one.

Examining the panel data (those that completed both surveys) we note that no women reported commuting in either wave. Men increase commuting from 2020 to 2021, which is a similar pattern to the cross-

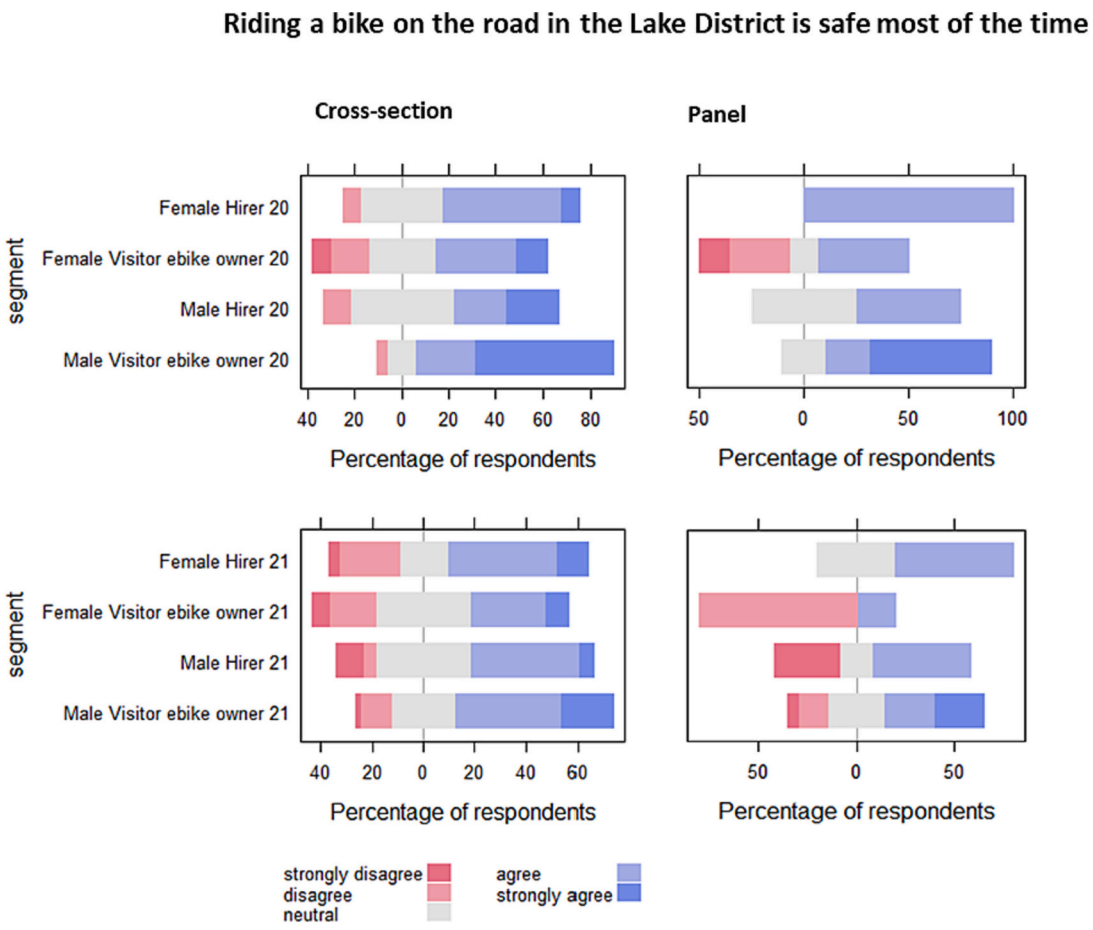

Fig. 6. Perception of safety by segment and gender Likert plots.

> "Motorists speeding and close passing is still the major problem on narrow Lakeland roads. It is particularly bad near population centres such as Windermere, Ambleside and Keswick." [ID 2]
>
> "There has to be something done to reduce the number of cars on the roads in the Lake District; cycling is horrendously dangerous on many roads and cyclists are treated as second priority to cars. there are no incentives not to use your car. I think the idea of restricting car use in some valleys (e.g. Langdale and Borrowdale) is a fantastic idea. A combination of Park & Ride and E-bike/cycling schemes would be great!" [ID 229]

Fig. 7. Qualitative comments relating to safety and inadequate bicycle infrastructure in the Lake District.

sectional data – which may be due to a reduction in working from home in 2021. Change in errands mileage between survey waves in the panel data is similar to the cross-sectional data, however men increased leisure miles in the panel data. This may be explained by the high proportion of retired people over 55 in the panel data (Fig. 2).

We found that e-mountain bikers travelled less for utility trips than other e-bike users in both waves. They were more likely (but not statistically significantly) to travel to the Lake District by car / van than other e-bike users (91% vs 81%) and have the same mean travel distance from home to the Lake District (113 km). There was no statistically significant difference in the proportion of e-mountain bike users by gender in any segment. Qualitative comments suggested e-bikes were being used as a transport mode to access destinations for other leisure activities, especially by tourists (Fig. 3).

In the cross-sectional data, there was a decline in weekly mean leisure miles between spring 2020 and 2021 for both resident and visitor e-bike owners. In 2021 we asked a further question asking people their total average distance travelled by e-bike in different phases of the pandemic (Fig. 4). We compared the results from this question with Fig. 2. Results for resident e-bike owners in the cross-sectional data are relatively consistent between Fig. 2 and Fig. 3 (<2% difference in mean distance 2021 and < 10% difference in 2020). It is interesting to note that though there were differences between male and female distances travelled in 2020 they appear to be converging by July 2021 – male usage appears to have spiked and returned to a level slightly above pre-covid levels, where female usage had less of a spike and more of a rising trend. Figure 5 shows qualitative comments providing further context. The panel data show a similar pattern. In the 2021 question asking about total average distance travelled, for visitor owners the trend is not the same as in Fig. 2 - consistency is poor in 2020 (49% difference) and moderate in 2021 (29% difference). This may be because in this question we were asking participants to reflect over a longer period – which may be less reliable (Panter et al., 2014).

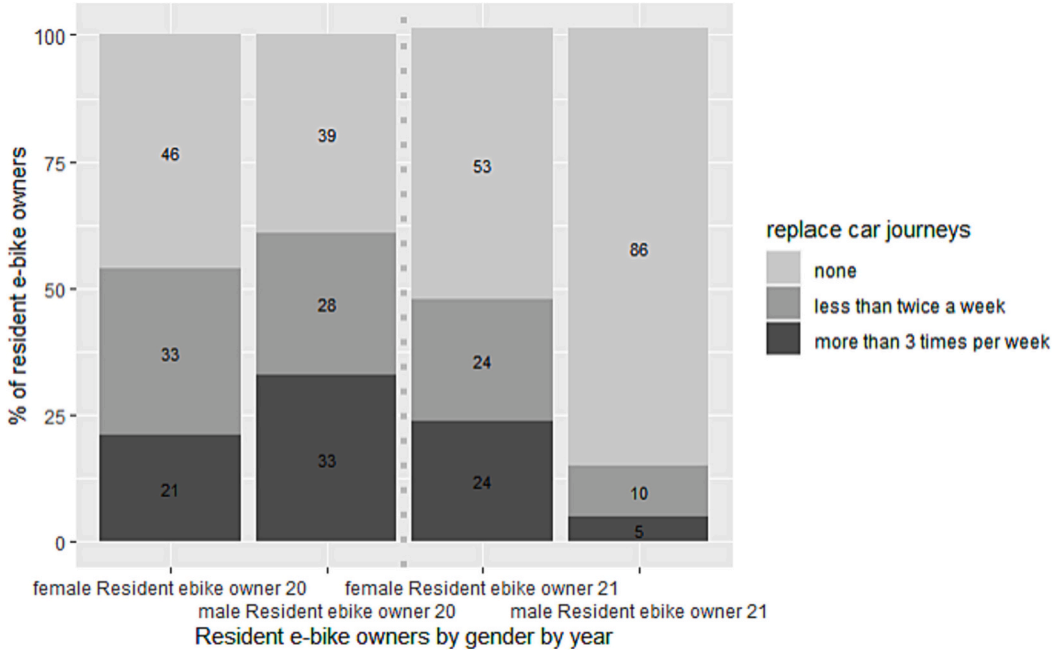

Fig. 8. Self-reported trip substitution from car to e-bikes spring 2020 and 2021 (due to rounding columns may not sum to exactly 100%).

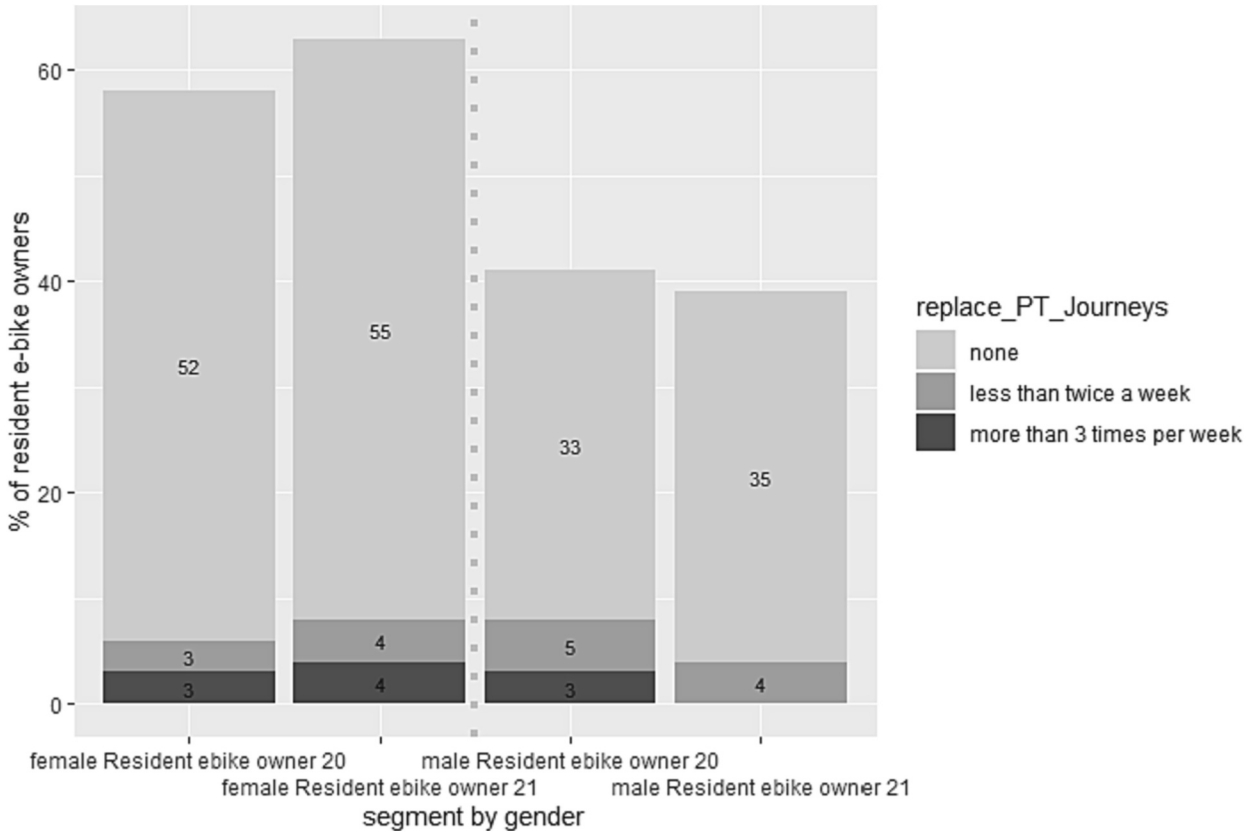

Fig. 9. Self-reported trip substitution *from Public Transport to e-bikes spring 2020 and 2021.*

4.3. Perceived safety

In the cross-sectional data the majority of respondents (in all segments) agreed or strongly agreed with the statement "Riding a bike on the road in the Lake District is safe most of the time" with a net percentage of 38% (Fig. 6). Net percentage is the percentage difference in responses either side of neutral e.g. % strongly agree + % agree - % disagree - % strongly disagree. In the cross-sectional data, male visitor e-bike owners felt statistically significantly safer on the roads in 2020 than other segments in 2020. In the cross-sectional data female visitor e-bike owners were the only segment where there was a statistically significant decrease in perceived safety between 2020 and 2021. However, for all

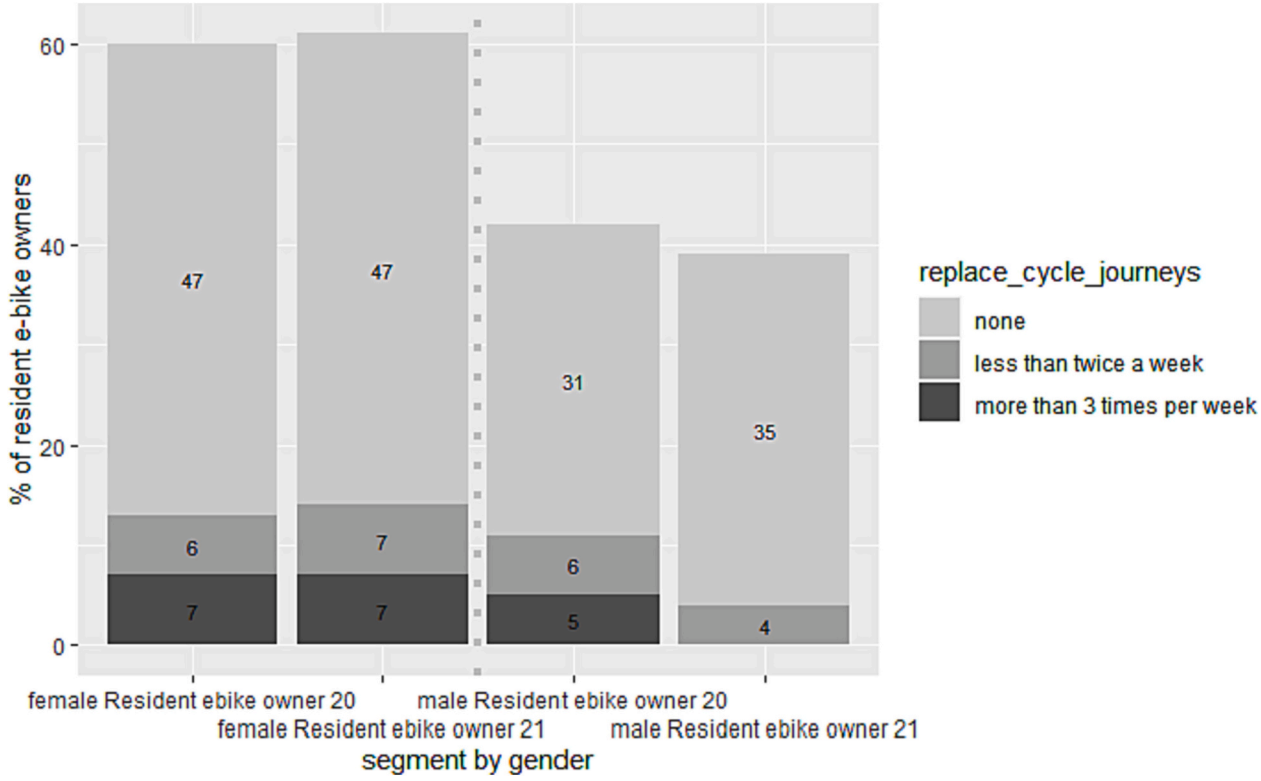

Fig. 10. Self-reported trip substitution *from conventional cycling to e-bike.*

segments the net agreement was 46% in 2020 but decreased to 30% in 2021.

In the panel data, for all segments the net agreement decreased from 57% in 2020 to 12% in 2021. Results also show female visitor e-bike owners in 2020 reported feeling statistically significantly less safe on the roads than the male visitor owners. A Wilcoxon paired test on the panel data, shows no significant change within segments between years. The panel data contained a higher proportion of people over 55 and a lower proportion of people who regarded themselves as regular cyclists on conventional bikes. This suggests age and or lower cycling skill levels in conjunction with gender (which is established as a factor reducing perceived safety) may contribute to female visitor e-bike owners feeling less safe on the roads.

Safety was one of the most common themes of the qualitative comments in both 2020 and 2021. These can be summarized into the following sub-themes: a) a general user fear for safety on the road network and criticism of poor driving behaviour (Fig. 7); b) comments relating to a noticeable reduction in motorised traffic during the Spring 2020 Covid lockdown and how cycling during this time felt a lot safer (Fig. 5); c) lack of cycle network and segregated cycle ways; and d) issues associated with the dominance of motorised travel and high levels of traffic.

4.4. Trip substitution

E-bikes more commonly substituted car trips than sustainable modes of transport in the cross-sectional data. In 2020, 57% of resident e-bike owners stated they replaced one or more car trips with an e-bike trip compared to 34% in 2021; 26% did this regularly (3 or more times per week) in 2020 compared to 16% in 2021. Substituting a conventional cycle trip was done by 17% of resident e-bike owners in 2021 (7% regularly), and only 4% replaced a public transport journey regularly. In terms of distance, of those who replaced car journeys, 58% in 2020 and 65% in 2021 were over 5 miles. When broken down by gender, female resident e-bike owners slightly increased their rate of car trip substitution from 2020 to 2021. For men it decreased, but they still replaced car trips more often than bus or cycle trips (Figs. 8–10).

4.5. User experiences

In both the cross-sectional and panel data there was a high net level of agreement that e-bikes help people to overcome hills or access places they could not have reached with a conventional bicycle in almost all segments. Male hirers were statistically significantly less in agreement in the 2020 cross-sectional data and the 2021 panel data than other segments, possibly due to hirers being younger on average than owners. There were no statistically significant changes within any segment between 2020 and 2021 (Fig. 11). Hills and overcoming them were also popular themes in open responses (see Fig. 12).

Fun, enjoyment, positive impacts on physical and mental health, and how e-bikes enabled access to experiences and new places were also mentioned by participants in the qualitative comments (examples in Figs. 12 and 13).

4.6. Conflict

We observed two types of conflict in the qualitative comments (Fig. 14). Firstly, there was some anti-cycling sentiment from non-e-bike users (fewer mentions than positive comments about e-bikes and active travel more generally). Secondly, there were comments directed specifically at e-mountain bikers. There was concern about use of e-mountain bikes on trails (footpaths and legal trails called bridleways in England), relating to erosion, conflict with walkers and trail use etiquette. As e-bikes make steep gradients and mountains more accessible there were concerns that some riders may be ill-prepared in terms of skills or equipment. There were also comments that e-mountain bikes are perceived by some conventional mountain bikers to be intimidating due to their speed on purpose-built mountain bike trails at mountain bike trail centres. Further comments were made about the car or rather van-dependent nature of e-mountain biking, though we did not find a

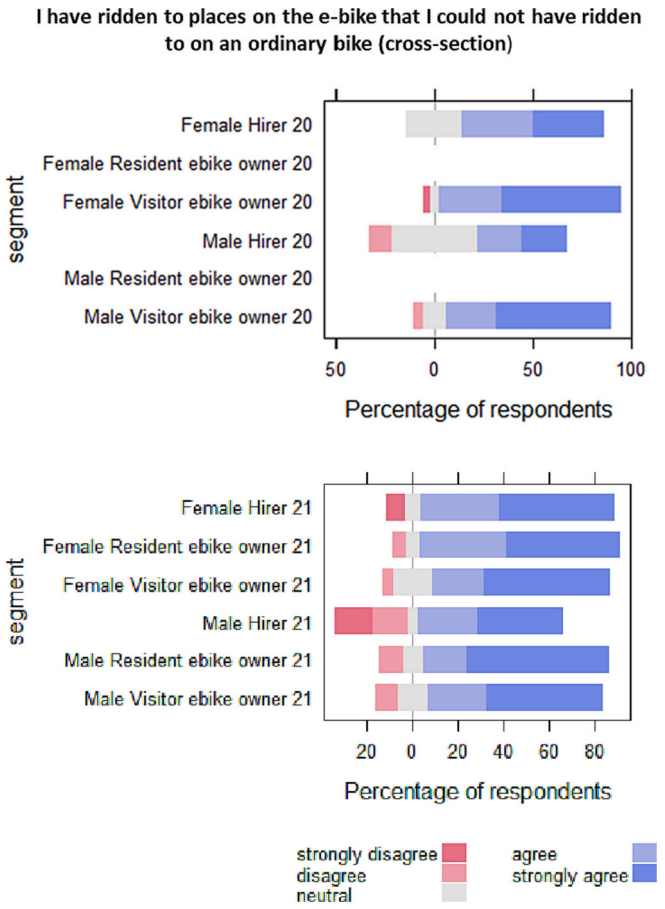

Fig. 11. Perception of how e-bikes help accessibility by segment and gender Likert plots.

storage facilities than female resident owners. There were no statistically significant differences in the panel data. Qualitative comments corroborate this (Fig. 16). Other comments referred to a lack of available accommodation with secure storage, range anxiety of e-bike batteries and lack of facilities to charge e-bikes.

4.8. Future rural mobility options

In the cross-sectional data, support for a shared e-bike hire scheme was highest for hirers in 2020 but considerably lower in 2021 (Fig. 17), but it is not a statistically significant difference. Visitors who do not own e-bikes had a net positive view towards using an e-bike share scheme. E-bike owners had a low net likelihood of using shared e-bikes. Male e-bike owners were statistically significantly less likely to use a shared e-bike scheme compared with other segments. No segments showed statistically significant differences between the two years in the cross-sectional data. In the panel data, there was a statistically significant reduction in support amongst female resident e-bike owners from 2020 to 2021.

In the cross-sectional data, visitors were statistically more likely to use e-bikes as part of integrated ticketing or MaaS[5] schemes than residents (Fig. 18). The Likert plot shows some similarities in the panel data. In the panel data there was a statistically significant increase in interest in using this amongst male visitor e-bike owners between 2020 and 2021.

There were no specific questions in the survey about public transport, however there were open responses in both waves (Fig. 19) on the theme of public transport (see Discussion).

4.9. Attitudes

We asked eight attitudinal questions in the survey. There was a high level of similarity in the cross- sectional and the panel data in both years. Three general attitudinal statements had a very high level of agreement. We also asked three questions relating to attitudes to personal behaviour and two questions about car restraint. Of these, attitudes towards personal behaviour change was somewhat less positive than attitudes towards car restraint. Some further detail is provided in the following paragraphs and summarized in Fig. 20.

The three general attitudinal questions were as follows and asked the extent to which respondents agreed with the statements: "After Covid, transport and tourism should be greener", "The Lake District national park would be more beautiful if more people travelled by bike or e-bike and fewer people travelled by car/van" and "e-bikes are a good way to replace some car journeys". All three questions had a high degree of net agreement with 52–100% agreement/strong agreement in the cross-sectional data. In these general attitudinal questions, the segments with the highest proportion of disagreement were male. However, there

'I hired an e-bike … It was fantastic for getting up hills. Allowed me to cycle further than normal.' [ID 220]

"E-biking is so much more pleasurable for me than unpowered cycling. [Hills] always made cycling difficult for me … I can go out on a ride … without holding my companions back and without having to get off and walk up hills … I can cycle up hills with full paniers which means that I can shop … then cycle back up the hill to my home" [ID 45]

"I bought my e-bike because I have always done local shopping by foot for environmental reasons. I live on a hill and now, after 40 years of dragging shopping up 150 steps I have osteoarthritis … So I got an e-bike - I love it. I get fresh air, exercise, feel in touch with my environment and can see people … and I can still do my shopping journeys and errands in a green way" [ID 96]

Fig. 12. Examples of qualitative comments where e-bikes help people overcome hills and make the Lake District more accessible.

statistically significant difference in distance travelled from home to the Lake District by e-mountain bike users, and users of other types of e-bikes, nor a statistically significant difference in the proportion travelling to the Lake District by car / van, though it was slightly higher.

4.7. Services and facilities

The survey asked questions about how likely respondents would be to use particular facilities and services. There was strong support in both waves for secure e-bike storage (Fig. 15). There was a high net likelihood of using secure storage and parking amongst the e-bike using segments (66% cross-sectional, 69% panel). There were no statistically significant differences within segments between 2020 and 2021 (cross-sectional or panel). In the 2020 cross-sectional data male hirers and male resident e-bike owners were statistically significantly less likely to use parking and

[5] Mobility-as-a-Service.

"e-bikes are really fun. the kids really enjoyed being on the tag-alongs. It was really easy to get up hills. I could imagine carrying a big load of shopping home from town to our village if we had one. We used them on a really rainy day and they were ace fun…" [ID 201]

"In July we hired e-bikes for the first time, as a family. It was a revelation, we loved it, even in the rain. … because of this experience, we are planning on making all our future holidays e-bike holidays. Travel to a place (probably by car) and go e-bike exploring." [ID 342]

"Using my 'e-bike daily during Covid had a massive positive impact on my physical and mental health." [ID 7]

"I was diagnosed with severe heart failure in September 2020 hence the sudden reduction. I eventually persuaded my consultant that using my e bike was easier than walking. Getting back on my e-bike has been a huge boost to my mental health. E -bikes can really be a good way to take exercise for people with heart disease so long as they are careful.'" [ID 31]

Fig. 13. Illustrative qualitative comments highlighting enjoyment associated with using an e-bike.

"Too many cycles whether e bikes or not. People live and work in the Lake District the roads do not need to be clogged up with more cyclists." [ID110]

"It's dangerous cycling in wet grey conditions. My usage is mainly weather dependent and I'm an avid e bike owner. Also, you can't start to restrict cars and expect people to cycle everywhere. You can't do a weekly shop, pick your kids up from school, that sort of thing. Encourage leisure use for sure but removing cars affects livelihoods." [ID135]

"I would not want to encourage large groups of usually older males going too fast uphill on 'e-bikes. They monopolise the bridleways this way because they would normally be too unfit to go up these routes. They tend to all arrive in vans and drive dangerously." [ID 001]

"My only experience with 'e-bikes has been conflict with them using trails designed for normal bikes but going faster, causing more erosion and discouraging normal bike use." [ID 247]

"I was run into by two e-bikes from behind on an off-road climb. I am now nervous about using lake trail centres where I might encounter 'e-bike. I am quite old don't climb very fast but still value riding a conventional bike I don't want to have my day ruined by inconsiderate trail users. [ID 237]

Fig. 14. Illustrations of conflict in qualitative comments.

is no statistically significant difference between segments. The panel data shows a high net level of agreement in both years. In neither the cross-sectional data nor the panel data was there a statistically significant change in the attitude of any segment between 2020 and 2021. Statistical summary tables and code used are available.[6]

Visitors were asked two questions about attitudes towards changing personal behaviour: "I would consider travelling to the Lake District without a car if public transport were improved between my home and the Lake district" and "I would like to travel less by car in the Lake District". There was only weak net positive support for travelling to the Lake District by public transport (13%), but relatively strong support for travelling with public transport within the Lake District (55%). This was the mean response from all cross-sectional respondents across both waves. There were no statistically significant differences between segments in the cross-sectional or panel data when asked "I would consider visiting the Lake District without a car if public transport were improved between my home and the Lake District". The only statistically significant change between 2020 and 2021 was an increase in support for this statement amongst female visitor e-bike owners in the panel data.

Car restraint was more positively viewed than personal behaviour change. All segments showed high levels of support for the idea that car restraint would enhance the beauty of the Lake District (net support 63% cross-sectional data and 67% panel data). There was no significant difference between years for any segment in the cross-sectional data. Male visitor e-bike owners across both years and in the cross-sectional and panel data had a significantly higher net agreement than male visitor non e-bikers. In the panel data female hirers showed a statistically significant decrease in support for this statement between 2020 and 2021. Residents were given two further statements "Restricting tourist cars and vans in some Lakeland valleys (e.g. Langdale, Borrowdale) would be good for the tourism industry / non-tourist businesses". Male resident e-bike owners in 2021 in both the cross-sectional and panel data were significantly less in agreement than female resident e-bike owners. In the panel data there was a statistically significant decline in support from male resident e-bike owners between 2020 and 2021. We considered the age of the segments regarding the attitudinal statements and did not find clear evidence of association between age and attitude.

4.10. Self-study findings

We here briefly summarise self-study observations congruent with other results presented above:

Storage: At the hiring location there was no secure storage. In Keswick there was a lack of places to lock bicycles, with those that did exist often tucked away off the main street, with no security measures and poor street lighting.

Hills and enjoyment: Travelling by e-bike from Whinlatter to

[6] https://github.com/DrIanPhilips/ebikes_Lake_District

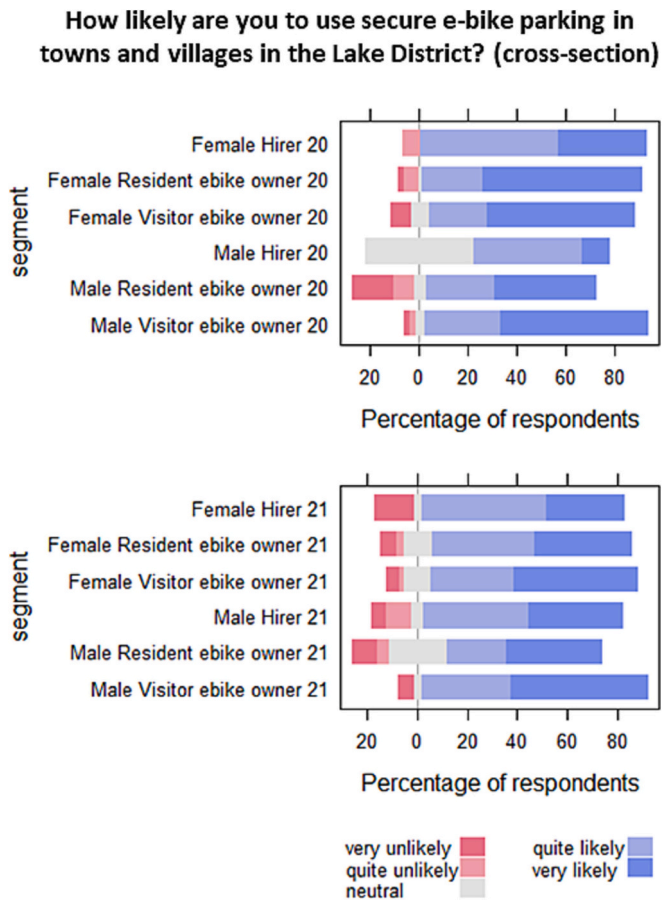

Fig. 15. If it became available, how likely are respondents to use secure e-bike parking in towns and villages in the Lake District. Likert plots by segment and gender.

Keswick and back was a fun and social experience, and physically easy considering the hilly nature of the route. Researchers felt it could be an accessible mode for people of differing abilities.

Cycle infrastructure: The researchers noted a disjointed approach to the cycle infrastructure on the route between a cycling activity attraction (Whinlatter forest) and a tourist honeypot (Keswick). There was a lack of signage beyond 'cyclists dismount' signs at road crossings. Some infrastructure was poor, including painted sections on roads which disappeared where the road narrowed, and a traffic island crossing a major road (A66) that was narrower than a bike's length (Fig. 21).

User experience: At the hiring location, there was a lack of information provided on how to use the bike, directions/sharing of local knowledge of routes, how to deal with mechanical issues/problems, and bike security, all of which would have improved the user experience. One researcher could identify several off-road family-friendly routes that were available, that were not obvious to hirers from a lack of signage and publicity. This may mean that e-bike hirers may opt for routes they are familiar with e.g. routes they would take by car, which might not be as safe or as enjoyable. Researchers noted an opportunity for businesses, accommodation providers and tourism networks to promote recreational routes for e-bikes and also to work with hiring locations to encourage e-bikes as a form of transport.

5. Discussion

Methodologically, the research was developed in a rapid, responsive mode, to investigate the impacts of Covid on e-bike usage, but also served to provide an analysis of user profiles and attitudes, and to investigate whether or not known barriers to cycling in rural and tourist areas were overcome by e-bikes. Empirically, the findings confirmed some known issues and challenged others, which will now be discussed.

Regarding the profile of users, there was unexpectedly high representation of female e-bike users in both samples, with several potential explanations, including bias in the survey company's marketing or e-bikes appealing particularly to women. Despite the reasons being unclear, rural e-biking may be particularly accessible for women. The older profile might be expected due to a similar skew in Lake District National Park populations compared to UK averages, and older people being a target market for e-bike use. Within our survey segments, e-bike hirers have the lowest proportion of 55+ respondents, suggesting e-bikes are important for older residents and for younger tourists.

Regarding known barriers to e-bike use, there were concerns in both waves about traffic levels. Traffic safety was an issue with comments regarding poor infrastructure and road safety. Issues of congestion and car-parking were raised in the 2021 wave. Respondents were very positive about reduced traffic levels in Spring 2020. The survey data suggests that perceived safety improved briefly during the disruption of the Covid lockdown, but motor traffic remains a barrier to active travel. Poor cycling infrastructure, speed and volume of traffic are all well documented barriers to active travel (e.g. Weber et al. 2014, Rérat, 2021, Gu et al., 2021) which are noted in the qualitative comments and field observations.

Lack of e-bike specific infrastructure is another barrier to e-bike use. We found support for increasing services, particularly e-bike parking and secure storage, which presents an opportunity for accommodation providers and other businesses. Some studies find cycle-friendly facilities can boost retail and entertainment footfall (e.g. Bosworth et al., 2020). There was also support for e-bike sharing schemes and an integration with public transport.

Age, terrain and weather do not appear to be barriers to e-bike use. Across both the 2020 and 2021 surveys e-bikes have been used extensively in the Lake District, providing user enjoyment and health benefits. Generally, our older respondents (Table 2) are riding a long way in a hilly wet place, much further than the average Briton who cycles only 54 miles per year (Department for Transport, 2019). This contradicts the notion that hills and rain make active travel 'impossible'. People have considerable physical capability for active travel even in wet hilly places (Behrendt et al., 2021; Philips et al., 2018, 2022). The surveys asked questions about services and facilities, and also received a number of qualitative comments. Support for shared e-bike schemes was higher in

"*More safe places to park. E-bikes are easily stolen and very expensive. We need to feel they are safe.*" [ID 454];

"[It's hard] *finding a safe place to leave the bike when stopping for shops/coffees etc.*" [ID 358].

"Running out of charge in such a hilly env is catastrophic. Need available charging points everywhere to help extend the poor range of most e-bikes. Stop for a coffee? Excellent, charge the bike while doing so. Needs to be second nature" [ID 343].

Fig. 16. Qualitative comments about desire for secure parking.

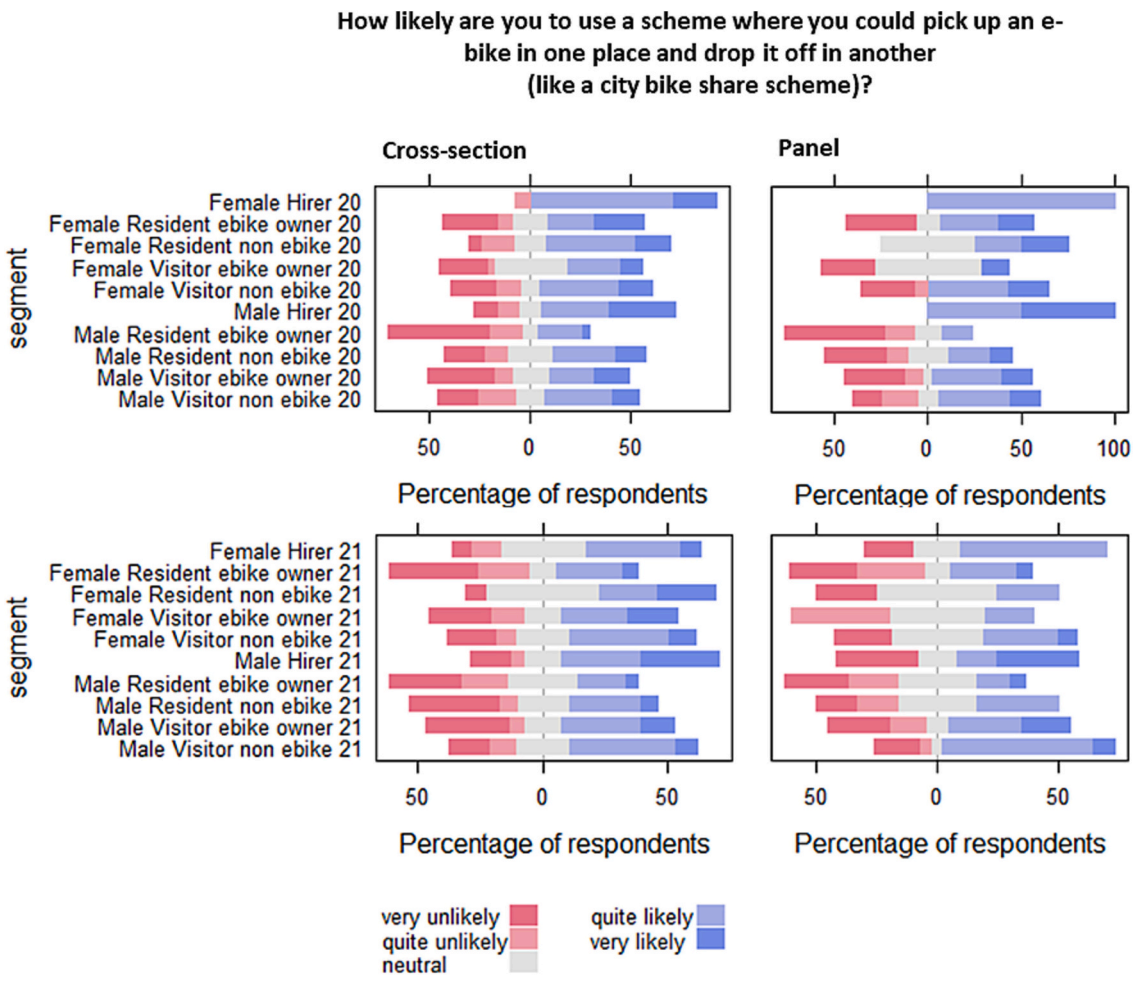

Fig. 17. Respondents self-reported likelihood of using an e-bike share scheme in the Lake District if it became available. Likert plots by segment and gender.

visitors and female non e-bike owners, and represents a direct opportunity to promote usage. Secure storage provision and better general cycling infrastructure along with integration with public transport were also supported by respondents.

On substitution potential, e-bikes are hypothesised to substitute for car trips more in rural areas. In our findings, there was a higher rate of substituting car trips than substituting bus and conventional bicycle use. Over 80% of e-bike trips that replaced public transport use were over 5 miles, possibly explained by poor public transport service provision, or a desire to avoid it during Covid (Kazemzadeh and Koglin, 2021). Our data suggests potential for e-bikes to substitute for longer trips than typical active mode use (Philips et al., 2022; Sun et al., 2020). This may highlight a difference in rural and urban e-bike use. In urban areas e-bikes and other active and micromobility modes are seen as solutions for short journeys typically under 5 miles (8 km), whereas our data is suggesting e-bikes in rural areas are being used for somewhat longer journeys in some cases. Whilst e-bike use is not possible for some, many could substitute some car journeys with e-bike use with appropriate consideration of issues of inclusion. There is discussion amongst policy-makers about car restraint in the Lake District (Pidd, 2021). The generally high levels of support for some form of car restraint in some tourist hotpots in our data further suggest that a successful policy, incorporating e-bikes as part of the solution, could be developed to support further mode substitution away from private car /van use.

The data and the qualitative comments highlight the range of journey purposes being carried out with e-bikes. Amongst women, errands were responsible for a greater utility trip mileage than commuting is. Amongst men there is a high number of errands miles per week. The implication of this for policy makers is that planning for active travel in rural and tourist areas may need to focus less on commute trips and more on other utility, errands and leisure trips. Leisure trips declined during the research period which could be explained by the low motor traffic conditions in the spring 2020 lockdown, which encouraged some to use their e-bikes more, as detailed in the qualitative comments (Fig. 5). In 2020 many UK workers were 'furloughed', especially in tourist areas, which means they had greater leisure time than during wave 2 (2021). This may also partly explain the reduction in leisure miles in the cross-sectional data. The panel data shows an increase in leisure miles between 2020 and 2021, however the proportion of over 55 s was higher in the panel than the cross-sectional sample. As there are a higher proportion of retirees amongst panel respondents this may explain there being less reduction in leisure miles between 2020 and 2021.

Results also illustrate known co-benefits of active travel: during the Spring 2020 lockdown, resident e-bikers reported easier access to activities, and comments from several respondents noted physical and mental health benefits. The quantitative data supports this with the high level of recreational cycling in spring 2020. Fig. 4 suggests that whilst there was some reduction in use between 2020 and 2021, it is still higher than the national average. Qualitative comments suggested conditions were more conducive to cycling during spring 2020 with quiet roads impacting perceived safety and likely willingness to cycle in general, and there was concern about returning traffic in 2021. However, there were some comments suggesting continued use even when traffic increased. The implication is that some increase in e-bike use was maintained into 2021. Furthermore, for most segments within the panel data, most questions show that there is no statistically significant

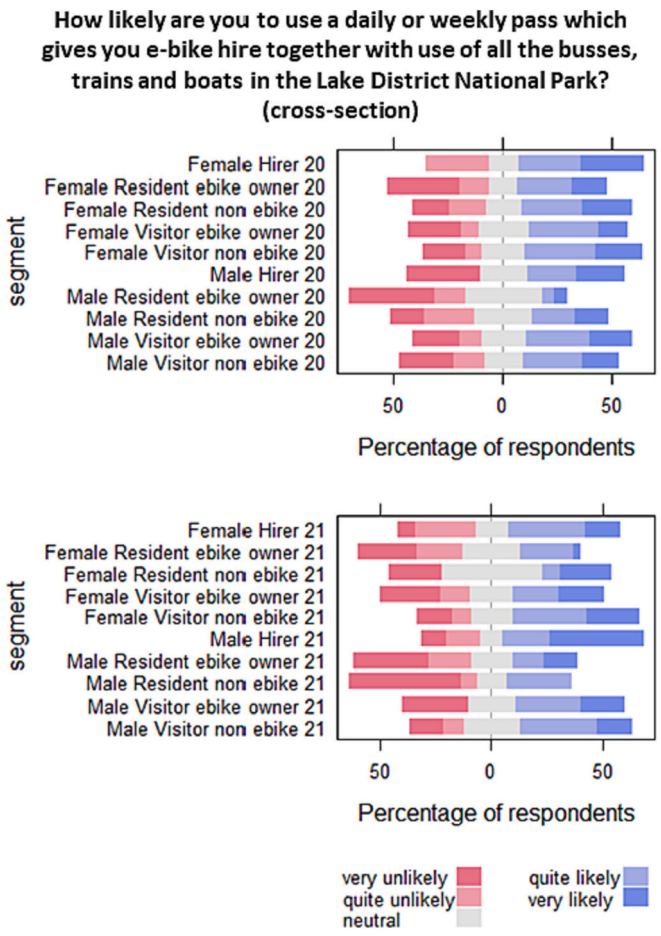

Fig. 18. Respondents' self-reported likelihood of using e-bikes as part of an integrated ticketing or MaaS scheme if it became available. Likert plots by segment and gender.

difference between panel respondents in the two waves. This is suggestive that generally high use of and positive attitudes towards e-bikes in 2021 were not purely shaped by the Covid lockdown phenomenon, suggesting the long term post-covid potential of e-bikes in rural areas such as national parks. The challenge for policy makers is how to capitalize on this to engender long term behaviour change.

Public transport was criticised in the open comments. Poor public transport was noted as a barrier to e-bike use or reducing car dependence. One outlier comment praising the public transport may be due to their accommodation being served by one of few regular bus routes. Respondents gave examples in the comments about provision of services and park-and-ride in some other countries being better. The findings replicate stated desires to switch mode from car to public transport, frustrated by costs, low frequency and limited geographical coverage, found by others (e.g. Eaton and Holding, 1996; Guiver and Stanford, 2014). An implication of qualitative comments is that where bus services exist, they can provide an alternative to car use and that there may be latent demand (Fig. 19). However, services need to be more widespread, lower cost (perhaps through long term adoption of the £2 fare on most UK busses after these surveys were conducted) and allow bikes to be carried.

Conflict between e-bikers and others was not examined in the quantitative questions, however it was a theme present in the qualitative comments. Some comments were made about e-mountain bike use off-road. Comments were made about e-mountain biking being an even more car dependent practice than cycling in general, specifically reliant on large cars or even vans to transport them. *E*-mountain bikes are a fast growing segment of the e-bike market (Garidis, 2023) suggesting it is an issue that should be considered further. Our data also showed that e-mountain bikes are used less for utility trips than other types of e-bike and users are more likely (though not statistically significantly) to travel to the Lake District by car / van than other groups. This suggests that in rural, and particularly tourist areas, it is important to differentiate between different types of e-bikes.

In terms of e-bikes' role in disruption-response sustainable transport policy, attitudinal questions suggested a support for green post-Covid policies. Survey questions showed overall a support for the ideas of motor traffic reduction and car restraint in some parts of the Lake District National Park. There was also an overall positive attitude towards individuals changing behaviour, but this was slightly weaker than for general environmental attitudes, perhaps illustrating an attitude – behaviour gap. Our open response data confirmed some sustainable behaviour intentions (Anable, 2005) that are constrained by (perceived) car dependence (Mattioli et al., 2016), i.e. inability to cycle due to age, health or inexperience; the 'cargo function' of the car; or accessibility to the district. Another factor in car dependence (higher in rural areas) may relate to the critiques of public transport reported above or a reduced willingness to use public transport during Covid.

We acknowledge a number of limitations in this work. The survey was devised during lockdown in 2020, this created limitations in terms of how the survey could be distributed which in turn limited the breadth of response – we relied to some extent on the Cumbria Tourism mailing list and social media channels. Though the promotion used social media channels we were not provided with a breakdown of response by channel which could have helped with targeting and distribution. Relying mainly on a general tourism channel resulted in a high

'I have to travel by car to get to the Lakes, because of carrying walking equipment and self-catering equipment etc, but once there I never use my car as public transport in the Lakes is really good, I just use the 'e-bike for fun in the Lakes, but don't feel safe on the roads.' [ID 501]

'I saw a bus near a Scottish trail centre which allows bikes on. That should be the norm in UK national parks: The Swiss do it with their post bus system. I'm also worried that building more roads like the A66 dual carriageway near Penrith will mean the Lakes gets even more swamped with cars in future making it more dangerous for bikes / e-bikes.' [ID 241]

'What about a park and ride from junction 36 for day trippers to reduce traffic on the A591? In parts of the Dolomites in Italy there are free, regular buses for tourists and locals to use. This has a massive effect on reducing traffic. The buses are always very well subscribed. Funding for this could be raised through a park and ride scheme. In the Bohinj valley in Slovenia (not dissimilar to Langdale), cars are banned and everyone has to use the park and ride scheme which is free. Cycling there is a pleasure.' [ID 267]

Fig. 19. Qualitative comments were mostly critical about public transport, with suggestions on park and ride schemes, and facilitating bikes on busses.

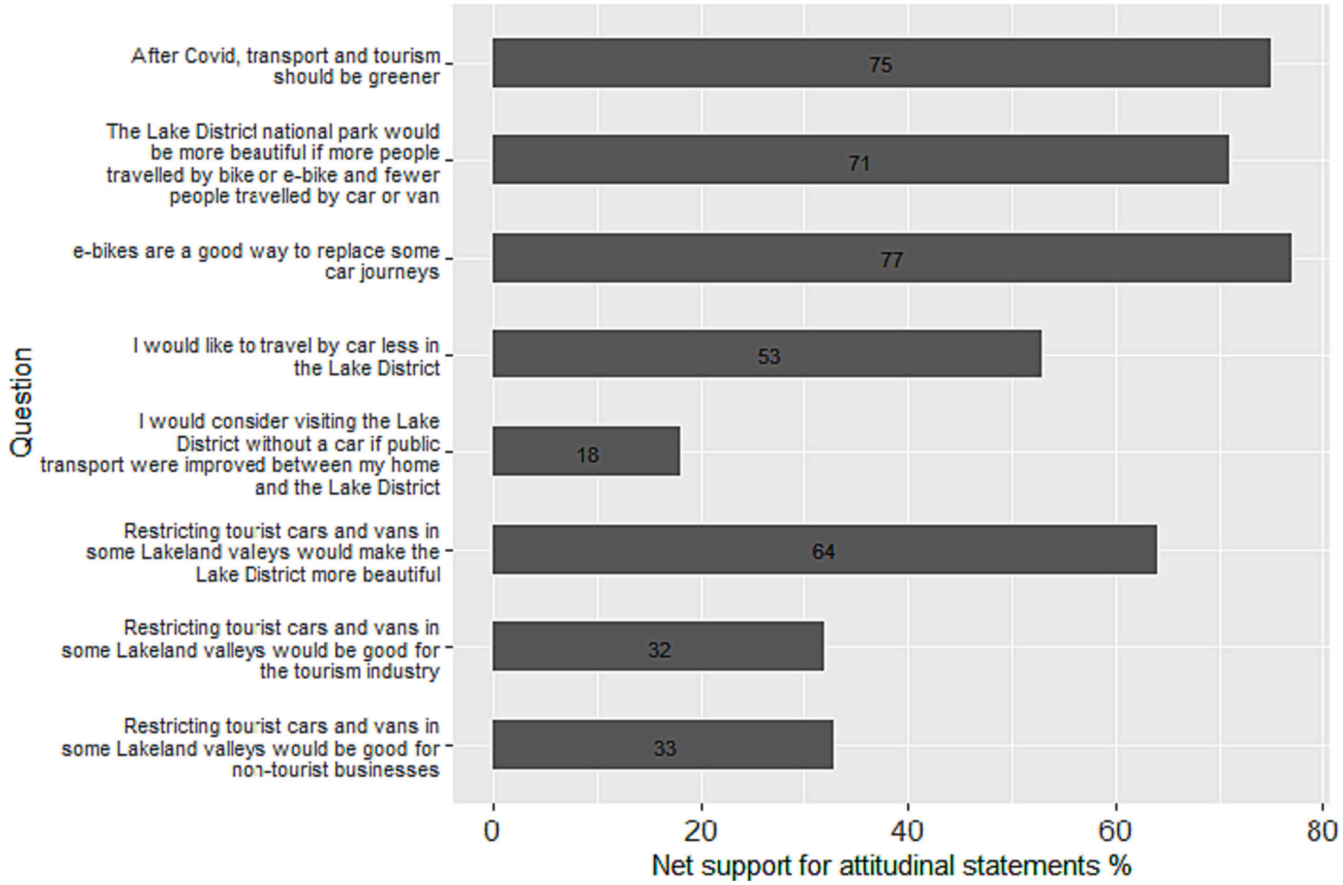

Fig. 20. Summary of the net level of support (net percentage being the percentage difference in responses either side of neutral) for cross-sectional respondents (mean values for all segments 2021).

proportion of non-e-bike user respondents. Had there been no restrictions it would have been useful to boost the e-bike user sample with face-to-face data collection in the Lake District. The need to rapidly develop the survey also resulted in some limitations of questionnaire design. Though the authors and the experts who commented on our draft surveys have a knowledge of the active travel, e-bike and rural transport literatures, our design could have been bolstered by a more in-depth literature review had more time been available. Despite the limitations of the study, it demonstrates considerable potential for e-bikes to substitute for a range of car trips by traditionally car-dependent groups in car-dependent areas, representing an important opportunity for the decarbonisation of transport in such areas.

6. Conclusion

Our survey contributes evidence on the use of e-bikes in rural and tourist areas, confirming some existing knowledge and hypotheses, and challenging others.

Overall usage for utility trips, evidence of substitution of car trips and the high distances travelled in a hilly area suggest that e-bikes have potential over and above that of conventional (non-electric) bicycles, in highly car-dependent areas such as the Lake District. High mileage and respondents' view that e-bikes allow them to get to places that a conventional bike could not, suggest e-bikes may have greater decarbonisation potential in hilly rural areas than conventional bikes (similar to the findings of Philips et al., 2022). Results show higher mileages of e-bike use for errands and shopping trips than commuting. This suggests that understanding more about non-commute e-bike trips may be useful, as potential demand for access to services by active modes may be more important in areas such as the Lake District. However, non-commute travel is often not well considered in traffic models, appraisal and planning tools aimed at justifying resources for active travel based on demand for commuting.

Considering e-bikes specifically in planning should also consider how e-bikes differ from conventional bikes, for example, their greater range and the assistance they give over hills means that consideration of longer distance inter-settlement infrastructure becomes more important. Additionally secure storage becomes more important because of the higher cost of e-bikes compared with conventional bikes, and e-bikes benefit from charging facilities at destinations which are not required by conventional bikes.

Our findings suggest that e-bikes, deployed effectively could contribute to the Lake District's sustainable transport policy objectives: "Creating a more enjoyable, relaxing and healthier visitor experience; Reducing impacts of traffic on communities and the landscape; Reducing carbon emissions; Increasing spend in the visitor economy" (LDNPA, 2018). Some specific suggestions arising from the findings include:

- Extending and further developing traffic-free valleys and schemes which restrict car access.
- Improving secure parking and charging provision to make day-to-day e-biking easier.
- Improving and expanding the cycle infrastructure network.
- Increasing regular maintenance on existing cycle infrastructure, such as fixing paths, removing weeds and ensuring paths are not overgrown with hedgerows.
- Considering how e-bikes could form part of rural Mobility as a Service (MaaS) and integrate with public transport; to, from, and within the Lake District. Schemes should consider both residents and

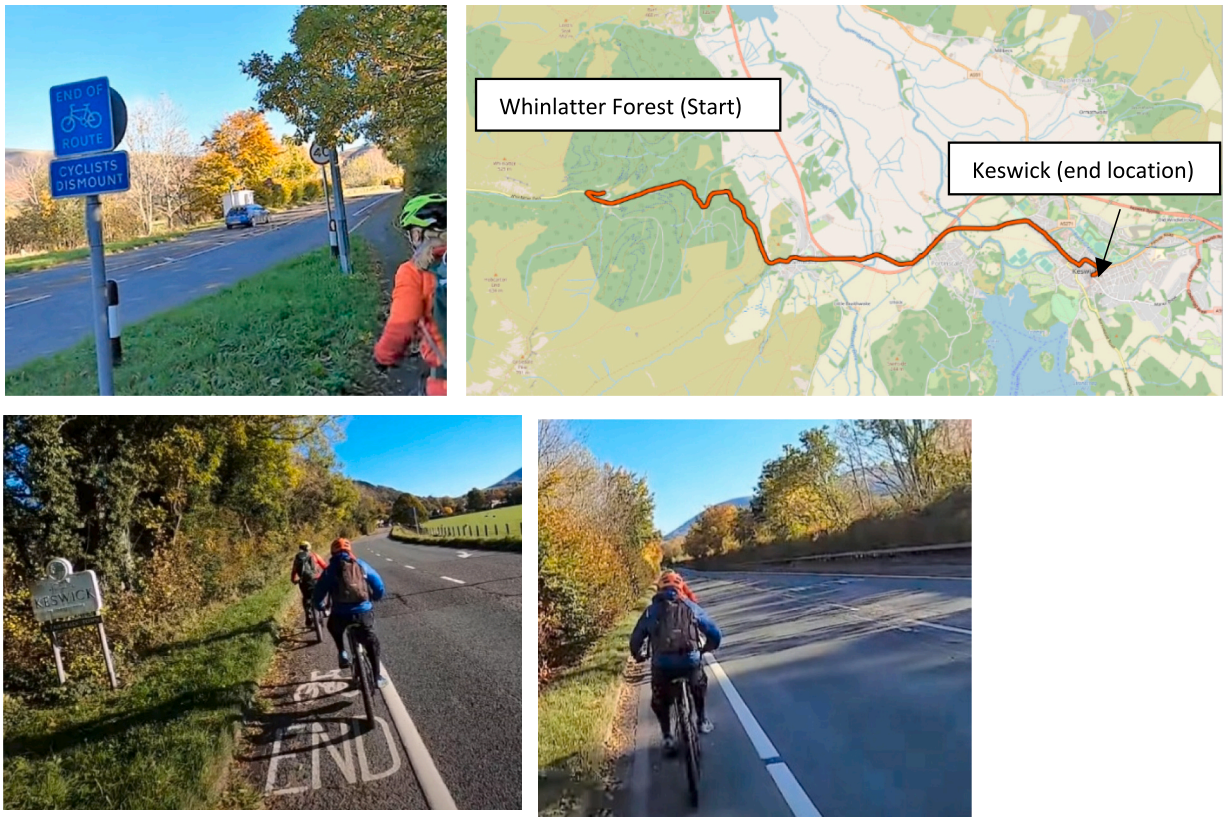

Fig. 21. Photos and map of exploratory self-study fields visits. The route was ridden in both directions.

visitors and include park and ride for e-bikes and a hire scheme across numerous locations including accommodation and visitor hotspots.

Developing evidence on e-bike use in rural areas, especially tourist areas and for non-commuting purposes, is important for making the case for cycle infrastructure, facilities and car restraint in those areas (ITF, 2021). *E*-bike research and policy in national parks, however, needs to differentiate clearly between e-bikes used for utility and on-road leisure, and e-mountain-biking. The latter presents an economic opportunity, but also exacerbates recreational user conflicts. *E*-bikes on-road offer a viable component of a far less car dependent system of access in the Lake District. Communication tools for sustainable transport planners/advocates to effectively make the case whilst addressing concerns raised should be developed.

The utility and leisure markets are not separate – a large proportion of users are using e-bikes for multiple purposes. Whilst the interest in e-bike sharing schemes and secure parking at destinations is more popular amongst visitors, residents were not completely without interest, so whilst there may be some differences in need between these segments they are not completely separate.

Our results suggest that Covid is not the only reason for high use of e-bikes in the Lake District. However, disruptions can be a spur to a change in behaviour. Covid was a UK and indeed worldwide event. We see this in our data. Though we observed the highest levels of e-bike use in 2020, our data also suggests some retention of this increased level of use. The timing of our surveys does not undermine the generalizability of the results particularly as far as other UK national parks and rural areas.

Further research into rural e-bike use has been argued for by previous research (Brand et al., 2021; Philips et al., 2022). Suggested further research resulting from our study may include extended trials and evaluation of e-bike use in the Lake District and interviews with governance actors. Further examining gender differences in rural e-bike use may be of value, using methods to avoid potential skewing of responses: perhaps by using sales and hiring data to establish exact gender splits and targeting a representative sample. There is potential to develop the survey tool further but it would require greater resource to reach a greater number of e-bike users – possibly across multiple national parks. It may be of value to further investigate actual and perceived similarities and differences in, usage, attitudes and levels of car dependence between users of different types of e-bikes.

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CRediT authorship contribution statement

Ian Philips: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Llinos Brown:** Methodology, Writing – original draft, Writing – review & editing. **Noel Cass:** Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jtrangeo.2024.103813.

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