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Mobility-as-a-Service and unsustainable travel behaviour: Exploring the car ownership and public transport trip replacement side-effects of the MaaS paradigm

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ABSTRACT

Car-centred development adds significantly to the climate change threat our planet faces. Mobility-as-a-Service (MaaS) is a concept looking to generate modal shift via the digital and physical integration of alternative on-demand transport services. Recent research raises concerns, however, that contrary to the hype, MaaS may result in unsustainable travel behaviour. On the one hand, future MaaS users that are now primarily drivers may not be ready to shift away from their cars, while, on the other hand, people regularly using public transport may substitute some of these journeys with MaaS-enabled car-sharing, ride-sharing and ride-hailing services. Herein, we study the effects of MaaS on intentions to own a car and to substitute public transport trips with car-centric services, via a UK-based quantitative survey. We use Principal Component Analysis and Ordinal Regression Modelling to see how MaaS-related perceptions referring to *Added Value*, *Car Use Convenience and Enjoyment*, *Human Element Externalities*, *Trust in Functionality*, *Cost Incentives*, *Car Use Morality*, *Trust in Enabling Technology* and *Car Ownership Necessity* affect usage intentions. Our results highlight some, typically less discussed, grey areas of MaaS and inform the design of policies, including car service disincentivitisation, responsible user benefits, MaaS rebranding and public transport investment prioritisation.

1. Introduction

Mobility-as-a-Service (MaaS) is an innovative app-based transport tool, which provides door-to-door multimodal mobility solutions on either pay-as-you-go or subscription basis (Nikitas et al., 2020; Smith et al., 2020). It promises to fight a car-centric transport paradigm that has been linked to negative effects on the grounds of societal, environmental, and economic sustainability (Nikitas et al., 2024). One of the most prominent beliefs behind MaaS is that its adoption will contribute to decarbonisation goals (Labee et al., 2022), as its users, given easy, digitalised access to integrated mobility services, will no longer own private modes of transport but instead purchase multimodal mobility service solutions that cover all their travel needs (Alyavina et al., 2022; Dadashzadeh et al., 2022). The actuality, however, may be very different to the expectations: according to recent research, over 40% of potential MaaS users do not even hypothesise refraining from car ownership (Liljamo et al., 2021) with these numbers going beyond 60% for potential MaaS users who already own a car (Kamargianni et al., 2018).

To compete with the convenience of private car, MaaS tries to enhance the reaches of public transport, combining the latter with car-based shared use mobility services, such as taxi, car-sharing, ride-sharing, ride-hailing (Jittrapirom et al., 2017) and even electric car-sharing (Hensher et al., 2022). By focusing its offering on promoting public transport ridership, with publicly shared cars used only in the cases of emergency, as first- and last-mile solutions, or as “neighbourhood feeders” (Alyavina et al., 2020; Knowles et al., 2020), MaaS could disrupt the private car travel market and swing people into ‘the hands’ of public transport service providers, thereby reducing congestion and air pollution (Alyavina et al., 2022). However, with public transport at its core, MaaS not only limits transport users’ “unfettered freedom” (Pangbourne et al., 2020) but is also unlikely to become economically viable (Hensher et al., 2022; Sochor et al., 2015).

What is also known is that individual car-based shared use mobility schemes largely serve densely populated urban areas (Barajas and Brown, 2021) which puts at question their capability as “neighbourhood feeders” within MaaS offering. Moreover, these car-centric services are often used as a sole mode for the trips that would be otherwise executed

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by a personal car or not take place at all (Lavieri and Bhat, 2019) and, what is worse, usually do not complement public transport as first- and last-mile solutions (Tirachini and del Rio, 2019) but compete with it (Silvestri et al., 2021). For instance, and as a baseline, Qiao and Gar-On Yeh (2023) reported that as many as 38% of ride-hailing trips alone could have been operated via public transit. To this end, existing MaaS operators rarely restrain the use of "monetisable" car-based solutions for the sake of facilitating the use of more sustainable transport options (Pangbourne et al., 2020). As a result, MaaS testers already demonstrate significant increases in the reliance on publicly accessible cars (ESP Group, 2018; Smile Mobility, 2015; Sochor et al., 2016), with the latter often used to fully substitute private car trips (Storme et al., 2020) and showing strong potential to supersede public transport trips (Kamargianni et al., 2018) even when accessed as a part of an integrated MaaS offering. In such MaaS scenario, where car use remains the dominant transport choice, a meaningful reduction in emissions is unlikely (Labee et al., 2022).

It is, though, worth noting that MaaS still offers potential for a positive change; public transport ridership, both prospective (Hasselwander et al., 2022; Kamargianni et al., 2018) and actual (Smile Mobility, 2015; Sochor et al., 2016), often increases alongside the growing use of car-based shared use mobility schemes, while trialing MaaS affects reasoning, at least, around the need (or a lack thereof) for a private car (Alyavina et al., 2020; Karlsson et al., 2020). This means MaaS may be a "loosely bundled innovation" that allows its users a great degree of "re-invention" and can be flexibly suited to their specific "conditions" (Rogers, 2003, p. 186). Hence, MaaS-induced car use behaviours and intentions range from positive, where car ownership and overall car use decline in favour of public transport, to negative, leading, in the best-case scenario, to no change in car agglomeration, or, at worst, to an increase in the latter at the expense of public transport as well as an increase in total vehicle-kilometres travelled by cars.

Given this, our study is set to answer the following research question: **Is a shift to unsustainable travel a side-effect of transitioning to a MaaS paradigm?** More specifically, our work is aimed at building an understanding of MaaS' potential to induce *intention to refrain from car ownership*, and *intention to shift away from public transport onto car-based shared use mobility services*. Our work, therefore, has three research objectives.

(i) to investigate the theoretical underpinnings of travel behavioural intentions in response to MaaS;
(ii) to establish the relationships and dynamics between the identified drivers and the intentions affecting and reflecting the possible adoption of MaaS; and
(iii) to propose policies for preventing the unsustainable travel behavioural outcomes of MaaS adoption.

The rest of this manuscript is organised as follows. In Section 2 the possible theoretical underpinnings of car use and ownership intentions with MaaS are identified through a comprehensive analysis of MaaS literature, and the theoretical framework guiding further our investigation is developed. In Section 3 the methods used for collecting and analysing our data are defined. Section 4 then presents the original findings of this study and Section 5 discusses them in line with theory and the state of the art. Section 6 concludes the paper.

2. Theoretical background

Transport literature recognises that efforts to address unsustainable travel behaviour involve a detailed understanding of the reasons for travel behavioural choices (Anable, 2005). The travel behavioural decision-making process is a complex phenomenon that integrates various components, the precise origins of which are difficult to pinpoint (Biehl and Stathopoulos, 2020). To this day, the research into the drivers of specific travel behaviours (and intentions) with MaaS is rather limited and generally focuses on MaaS adoption decision (i.e., acceptance or willingness to accept) among potential users, including in pay-as-you-go and subscription formats, and/or the preferences for inclusion of various modes of transport in MaaS bundles (e.g., Alonso-González et al., 2020; Caiati et al., 2020; Feneri et al., 2022; Fioreze et al., 2019; Ho et al., 2018; Hoerler et al., 2020; Jang et al., 2020; Keller et al., 2018; Matyas and Kamargianni, 2018, 2021; Mola et al., 2020; Reck and Axhausen, 2020; Schikofsky et al., 2020; Van t' Veer et al., 2023; Ye et al., 2020; Zijlstra et al., 2020). There is also a number of studies that determine the drivers of general travel behaviour through the observation of MaaS users (Ho et al., 2021; Karlsson et al., 2020; Sjöman et al., 2020; Sochor et al., 2015, 2016; Storme et al., 2020; Strömberg et al., 2018; Wright et al., 2020), and studies that establish the drivers of general travel choices with MaaS in an inductive manner (Alyavina et al., 2020; Lopez-Carreiro et al., 2020; Matyas, 2020; Polydoropoulou et al., 2020).

The existing body of literature has already generated some insights into the drivers of MaaS adoption and use decisions (e.g., Kamargianni et al., 2018; Liljamo et al., 2021; Hauslbauer et al., 2024); however, no studies look specifically at the intentions not to own a car or the intentions to substitute public transport journeys with car-based shared use mobility in the MaaS domain. For these reasons, the theoretical basis for this study is founded in the review of the literature that looks at all possible behaviours with MaaS (including a simple decision to accept) as well as the drivers of these behaviours, but also considers general travel behaviour research. The analysis of the literature resulted in the identification of three topical pillars discussing the drivers of either MaaS acceptance or travel behaviour with MaaS, namely socio-demographics, attitudes, and past behaviour. These three pillars formed the theoretical framework, displayed on Fig. 1, that guided this study's research approach.

2.1. Socio-demographics

The importance of socio-demographics in travel behaviour formation has been investigated in numerous studies and seems to be significant (e.g., Veterník and Gogola, 2017). The socio-demographic features were found to have an influence on acceptance and travel behavioural response to MaaS. Matyas and Kamargianni (2018), for example, discovered that individuals aged 65 and over were less likely to include taxi in their MaaS bundles as opposed to younger individuals, suggesting that *age* has a role to play in MaaS use. Caiati et al. (2020) signified the role of *gender* in the MaaS adoption by discovering that males were more likely to choose e-car-sharing for their MaaS bundles, while females preferred ride-sharing. They also argued about the importance of the *level of education* as highly educated individuals were found to be more likely to include ride-sharing in their MaaS bundles. Zijlstra et al. (2020) found that couples with children living at home had higher potential to adopt MaaS, highlighting the importance of *household composition*. They have also found people living in denser environments to have higher potential to adopt MaaS, identifying the role of *residential location* in the MaaS acceptance and travel behaviour determination. With regards to *employment status*, Alonso-González et al. (2020) discovered that full-time workers and self-employed individuals were more likely to go for demand-responsive options like car-based shared use schemes when considering MaaS. Jang et al. (2020) discussed the role of *household income* suggesting that high-income individuals preferred to use taxi as a part of their MaaS subscription. Therefore, age, gender, level of education, employment status, household composition in the form of marital status and the number of children at home, household income and residential location were considered as possible socio-demographic drivers of the two intentions (i.e., car ownership and car use) explored in this study.

2.2. Attitudes

Although socio-demographics play an important role in interpreting

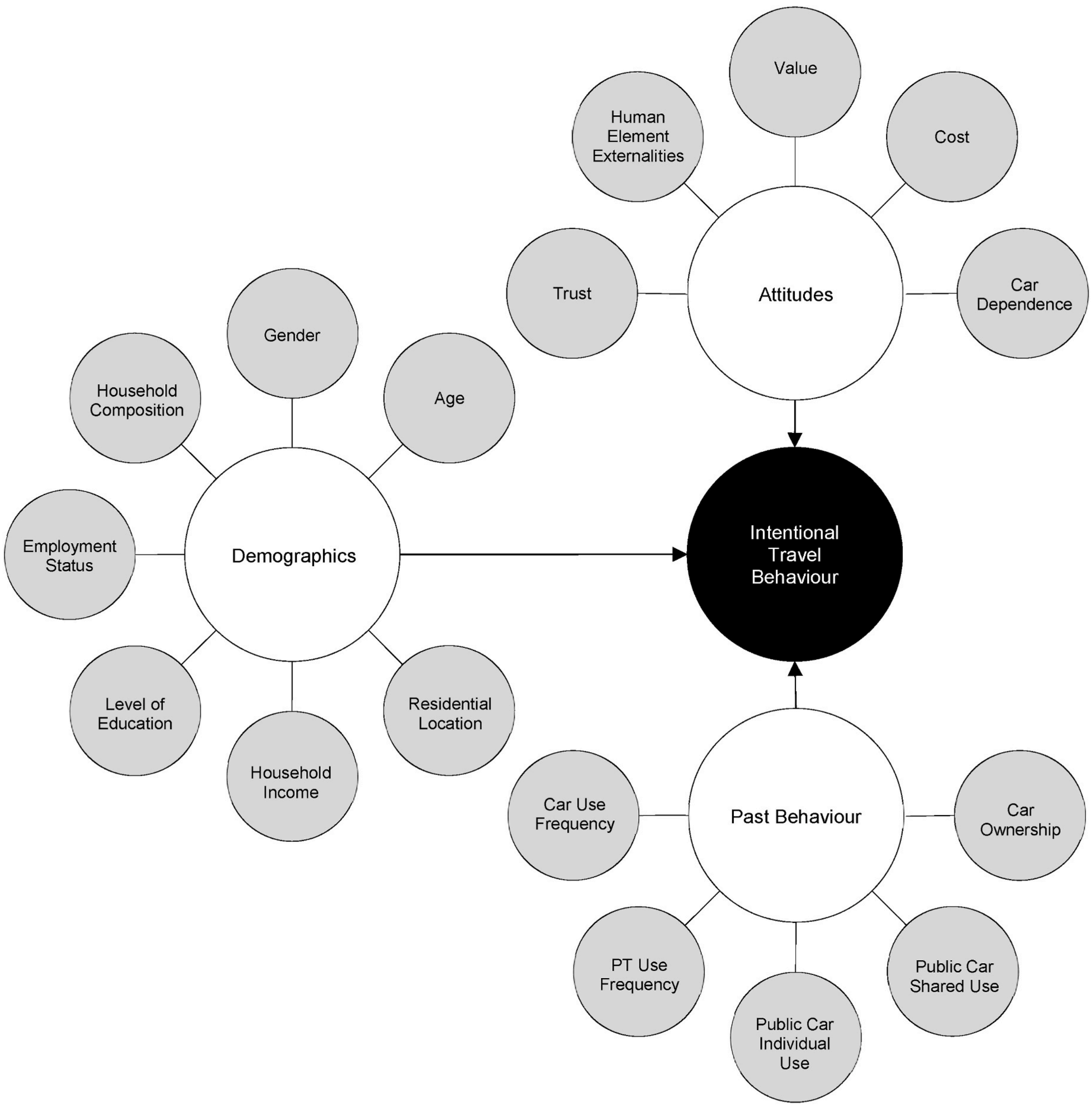

Fig. 1. Theoretical framework.

travel behaviour, general attitudes and perceptions are thought to bear explanatory power over and above socio-demographic characteristics (Anable, 2005; Haustein and Hunecke, 2013; Hunecke et al., 2010). Attitudes were also the first psychological constructs utilised in travel behaviour research (Gärling et al., 1998). These psychological factors play a crucial role in MaaS acceptance (Schikofsky et al., 2020) and may be important in prompting an interest in becoming MaaS customers (Karlsson et al., 2020). Most of these attitudes in the MaaS domain are derived from the established theories, such as Rogers (2003) Diffusion of Innovations (DOI) (Karlsson et al., 2020; Sochor et al., 2015), Davis's (1989) Technology Acceptance Model (TAM) (Mola et al., 2020) and the consequently developed by Vekantesh et al. (2003) Unified Theory of Acceptance and Use of Technology (UTAUT) (Ye et al., 2020). Other attitudes include cyber-security concerns (Keller et al., 2018) and concerns with MaaS-enabling technology (Polydoropoulou et al., 2020), attitudes towards personal car (Matyas and Kamargianni, 2021) and alternative modes of transport (Matyas, 2020), attitudes towards MaaS components and features (Fioreze et al., 2019; Hoerler et al., 2020), as well as environmental attitudes (Alonso-González et al., 2020) and cost considerations (Ho et al., 2021; Liljamo et al., 2021).

Our previous work (Alyavina et al., 2020), where primary qualitative research was performed to develop a framework of attitudes specific to MaaS adoption and use, in a way summarises all the previous findings but also enhances them with additional attitudinal constructs. We argue that MaaS acceptance and travel behavioural response are driven by five attitudinal constructs, namely *car dependence*, *trust*, *human element externalities*[1], *value*, and *cost*, each of them with a number of sub-dimensions enhancing their meaning. These were considered the key attitudinal drivers of the intentions explored in this study.

2.3. Past behaviour

Past behaviour, often equated with habit, is known to be a good predictor of future actions (Fishbein and Ajzen, 2010). Once performed

[1] Human element externalities: is an umbrella term that summarises some of the grey areas underpinning the usage of shared transport that relate to anti-social behaviour and social environment barriers including factors like *negligence*, *discourtesy* and *disobedience*.

behaviour delivers the desired outcome, through repetition, it becomes habitual (Hoffmann et al., 2017), decreasing the level of individual consciousness when responding to behaviour specific stimulus cues (Triandis, 1980). Many studies have shown that travel is also a habitual behaviour driven by pure repetition (Matyas and Kamargianni, 2018), especially in the case of mode choice (Keynon and Lyons, 2003). Habits and existing travel practices were found to potentially discourage overall MaaS adoption (Karlsson et al., 2020) and determine the choice of transport configurations within MaaS bundles (Matyas, 2020; Reck and Axhausen, 2020). It is also known that future MaaS consumers classify the use of MaaS based on similarities with their travel related habits and typical mobility patterns, such as previous use of personal car (Schikofsky et al., 2020).

Considering the reiterative nature of past behaviour, it is safe to assume that future (or intentional) behaviours explored in this study, namely car ownership and use of car-based shared use mobility in place

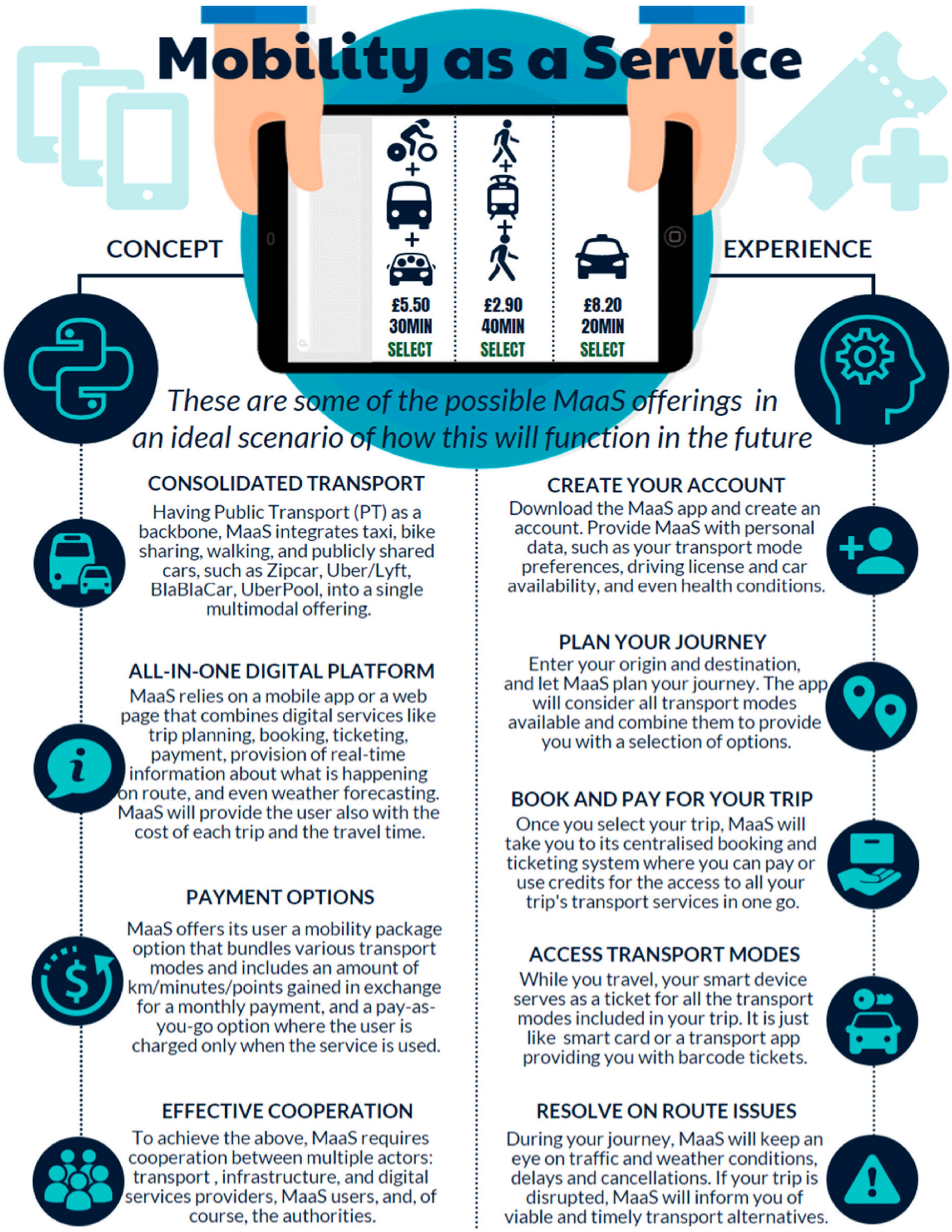

Fig. 2. MaaS Infographic adopted from Alyavina et al. (2020).

of public transport, would be associated with similar behaviours in the past/present, which is also justified by the MaaS literature. *Car ownership* prior MaaS, for example, was found to negatively affect the decision to subscribe to MaaS (Alonso-González et al., 2020) or to push individuals to include car rental in their MaaS bundles (Caiati et al., 2020). *Frequency of personal car use* was found to have an impact on the decision to obtain a MaaS subscription (Ho et al., 2018) and the likelihood of altering travel behavioural practices (Feneri et al., 2022). Travel behaviour and mode selection with MaaS was also found to be determined by the *frequency of public transport use* (Alonso-González et al., 2020; Matyas, 2020) and the *use of publicly shared cars* (Caiati et al., 2020; Ho et al., 2020; Matyas and Kamargianni, 2021). Therefore, *car ownership*, *frequency of personal car use*, *frequency of public transport use,* and the *use of publicly shared cars* were considered the possible past behaviour drivers of the two intentions, explored in this study.

3. Methodology

3.1. Survey design

An online self-administered quantitative survey was chosen as the data collection instrument, due to its time- and cost-efficiency merits (Bryman and Bell, 2011) and the merit of completion at a time, place, and pace convenient for respondents, with an increased sense of security – all factors contributing to higher data quality (Fielding et al., 2017). This instrument also offers the benefit of wider reach, targeting populations distributed across a large geographic region (Van Selm and Jankowski, 2006).

The survey for this study was developed using Qualtrics in line with the theoretical findings of this work, which imply the study of transport users' *intentions*, *general attitudes*, *past behaviour*, and *socio-demographics*. To ensure respondents' awareness of MaaS and its key features and cohesion and consistency in the way these concepts are regarded by our respondents, an *infographic*, developed by Alyavina et al. (2020) and presented in Fig. 2, was used within the survey.

The attitudinal statements were composed using the findings of our qualitative work (Alyavina et al., 2020), and a total of 40 attitudinal statements were generated. To ensure rigour in the above process, we utilised the *joint display* strategy (Harrison et al., 2020); joint displays link qualitative and quantitative inferences in a form of a table or a graph and show how the results from one research stage influence the data collection in the subsequent research stage (Creswell and Plano Clark, 2017). The details of our joint display efforts can be found in **Appendix 1**.

Whilst the key thematic structure presented in Alyavina et al. (2020) was retained, additional data extracts (marked with an asterisk (*) in Appendix 1), gathered at the Thematic Analysis stage, were used to generate attitudinal statements that comprehensively, and non-contextually, represent each sub-thematic dimension. The *Convenience* sub-theme under the theme of *Car Dependence*, for example, covered a variety of convenience attributes, discussed by interviewees, such as comfort in harsh weather conditions, ability to carry shopping, luggage and other belongings, and independence of public transport timetable, among others. Some of the attitudinal statements were intended to cover more than one thematic/sub-thematic dimension (e.g., IV_16). The reason for the latter is twofold: first, the themes in our qualitative work are not independent of one another but, on the contrary, are logically interlinked; second, we aimed to optimise the number of statements to avoid making our survey too lengthy and repetitive, which could challenge data collection. The attitudinal statements were presented in Likert-scale format, developed to measure attitudes in a scientifically accepted and validated way (Joshi et al., 2015). Each of the attitudinal statements offered five points for respondents to select from: *strongly disagree*, *disagree*, *nether agree nor disagree*, *agree*, and *strongly agree*.

Following the literature-inspired aim of this study, two intentional statements were tested in the survey, namely *"With MaaS I would consider not owning a car"* and *"With MaaS I would replace some of my public transport trips with publicly shared cars"*. Similar to the attitudinal statements, the intentional statements were presented as five-point Likert-scales, with the points for selection being *extremely unlikely*, *unlikely*, *neither likely nor unlikely*, *likely*, and *extremely likely*.

To allow for building an understanding of past travel behaviour, survey respondents were asked to specify their car ownership status and the frequency of using personal car, public transport, and publicly shared cars on both individual (e.g., Taxi, car-sharing, Uber) and collective (e.g., UberPool, BlaBlaCar, Taxi share) basis. The frequency options for participants' choice included *daily*; *few times a week*; *once a week*; *at least once a month*; *rarely*; and *never*. At the end of the survey, participants were asked to provide their socio-demographic characteristics in line with our literature findings. The step-by-step surveying process is outlined in Fig. 3.

3.2. Recruitment and data collection

Non-probability sampling methods are best suited for conducting online surveys as achieving a probability sample - considered appropriate for making inferences generalisable to a finite population (Brick, 2014) - may become expensive and time-consuming, or result in a small sample size if the studied phenomena are new, and the comprehension of the latter among general public is low (Fowler, 2014; Lehdonvirta et al., 2021). Thus, non-probability sampling approaches, in line with the work of Wolf et al. (2016), were adopted. These included: *self-selection in web* sampling, where individuals volunteered to take part in the study once the calls for participants were posted on various web pages and social media channels; *convenience* sampling, where researchers' social ties were recruited for the study; and *snowballing* sampling, where researchers' social ties already recruited passed the call for participants onto their own connections or via their personal social media means.

For reasons of accessibility, the population under investigation was the adult general public of the UK. Thus, the sample was *screened* (Bryman and Bell, 2011), as presented in Fig. 3, to ensure that only responses from the eligible population would be obtained for the analysis. Survey participants were questioned whether they were at least 18 years old, and whether at the time of completing the survey they resided in the UK; if the participants did not fulfil at least one of the required criteria, their responses were set to be discontinued.

The surveying process took place between February and July 2020. Prior full-scale implementation, the survey was piloted to ten students at the University of Huddersfield. The piloting helped make the wording of the statements more comprehendible and also allowed us to determine whether the length of the survey was appropriate. After minor adjustments, the survey was distributed using the link and the barcode generated by Qualtrics. When following the link or scanning the barcode, survey respondents were first directed to the *participant brief*, which explained the nature of the study and the right to withdraw, but also included a consent form asking for permission to record, store, and use the survey output for academic and research purposes; participants gave their consent by clicking the "proceed" button. Although there was no set limit for the survey response time, each response took 10–15 min from start to completion, and a total of 427 useable responses were obtained.

3.3. Sample demographics

A total of 427 useable responses from UK transport users aged 18 and above were collected. Fig. 4 displays survey respondents on the map of the UK in accordance with the place of residence named in the survey. The majority of responses were gathered from Southern and Northern England, followed by the Midlands. Although comparatively less than other parts of the UK, a number of responses from Scotland (<5%) were also received. Transport users from Northern Ireland were not captured.

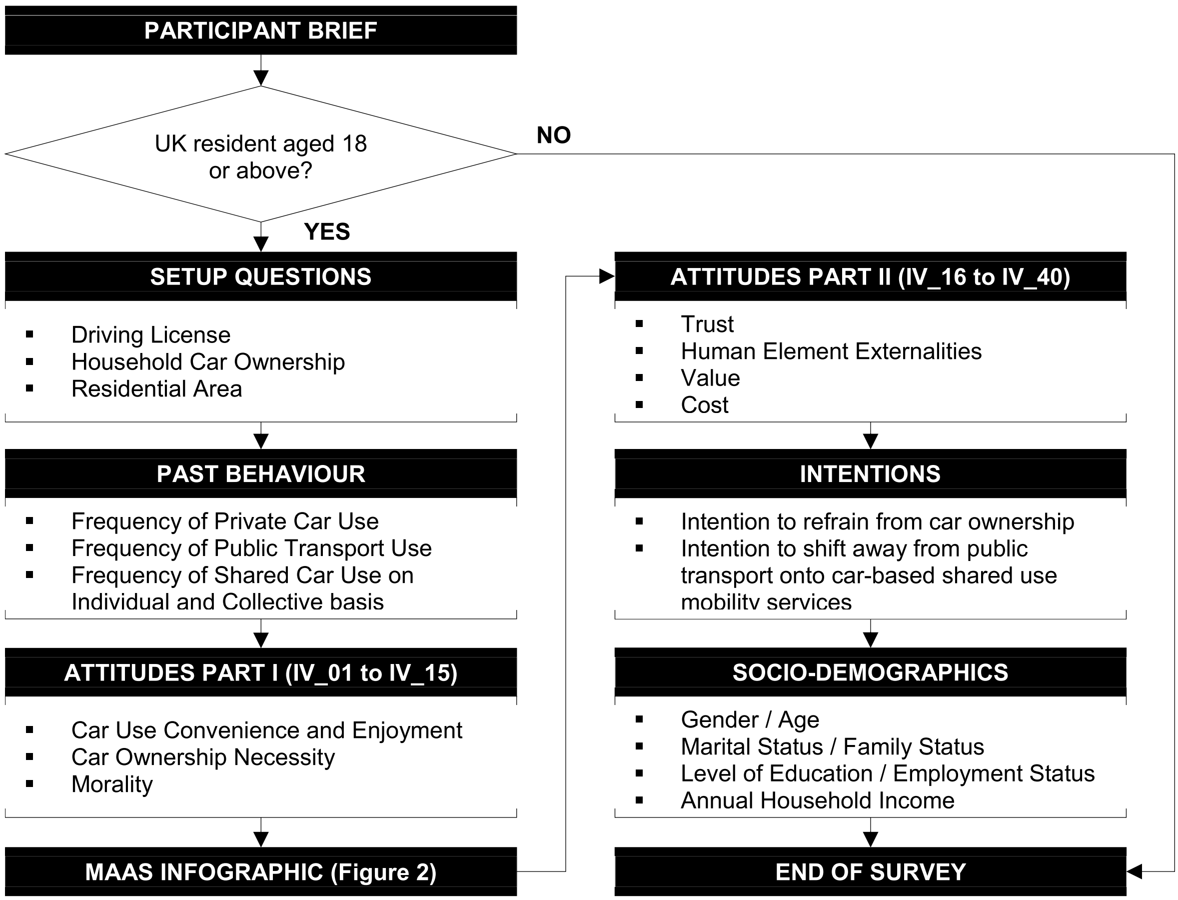

Fig. 3. Survey outline.

The majority of survey respondents were based in London, with 55 out of 427, or 12.9%, identifying themselves as capital based. The residents of Huddersfield represented the second largest group of respondents (36 out of 427, or 8.4%). The town of Doncaster, and the cities of Leeds and Manchester were, too, among top performing locations in terms of number of responses.

The sample characteristics are presented in Table 1 and show the distribution of different demographic characteristics against the UK population. The national statistics values for gender (Roskams, 2022c), age (ONS, 2023a), marital status (Roskams, 2022b), family status (Roskams, 2022a), status of employment (ONS, 2023b), and annual household income (Webber and Mann, 2020) were either generated using relevant Census 2021 and other data sets or gathered from Census (2021) bulletins provided by the Office for National Statistics. Only the statistics for England and Wales were used for comparison; this is due to having very low proportion of survey responses gathered from Scotland (<5%) or Norther Ireland (0%). The education criteria could not be compared to national splits due to significant differences in categories used within our survey and the Office for National Statistics data set categories and due to inclusion of children in the latter (Waddington, 2023).

The gender split of our sample is representative of the national statistics. It is important to note, however, that our survey contained the option *Other* for the participants and, therefore, has a small proportion of genders not represented in Census 2021. Some deviation from Census 2021 statistics can be seen in *age* distribution of our survey sample. Our sample includes a much higher proportion of transport users aged 18–34 and a much lower proportion of individuals aged 45+, with the 35–44 age group closely represented. It is also evident that in our sample the *student* population is predominant. Interestingly, though, younger individuals, including students, are argued to be less dependent on private cars (Konietzka and Neugebaurer, 2023) and have less polluting travel practices (Colli, 2020; Grzesiuk et al., 2023), whilst being more ecology-oriented (Suchanek and Szmelter-Jarosz, 2019) and having more favourable views of innovative mobility technologies (Asgari et al., 2023; Rahimi et al., 2020) and shared use mobility options within MaaS (Narayanan and Antoniou, 2023). Thus, given the context of our work, the dominance of the younger generation within our sample may work in favour of more sustainable MaaS adoption intentions. Our sample is also overrepresented by single individuals and individuals without children. Single person households, although inclined towards car dependence when transport options are limited, generally adopt more environmentally sustainable travel behaviours (Young and Lachapelle, 2017). Therefore, this deviation from national statistics again may work in favour of more sustainable MaaS adoption intentions considering that a multitude of easily accessible transport options is the core idea behind MaaS. Lastly, our sample has a prevailing number of *high-income* households, with £50k or more at their disposal. This again may result in support for more sustainable MaaS uptake intentions in our study as high income was found, for example, to have a positive influence on the decision to substitute private car with shared use mobility (Rizki et al., 2021) as well as the decision to uptake MaaS bundles (Caiati et al., 2020).

3.4. *Sample travel behaviour*

There were four transport options for which survey respondents had to specify the frequency of use whilst also providing information regarding household car ownership. These responses are summarised in Table 2. Using private car as a driver was the most popular travel option, with 31.6%, of survey respondents incorporating it into their trips on a daily basis. The next most popular travel option was public transport,

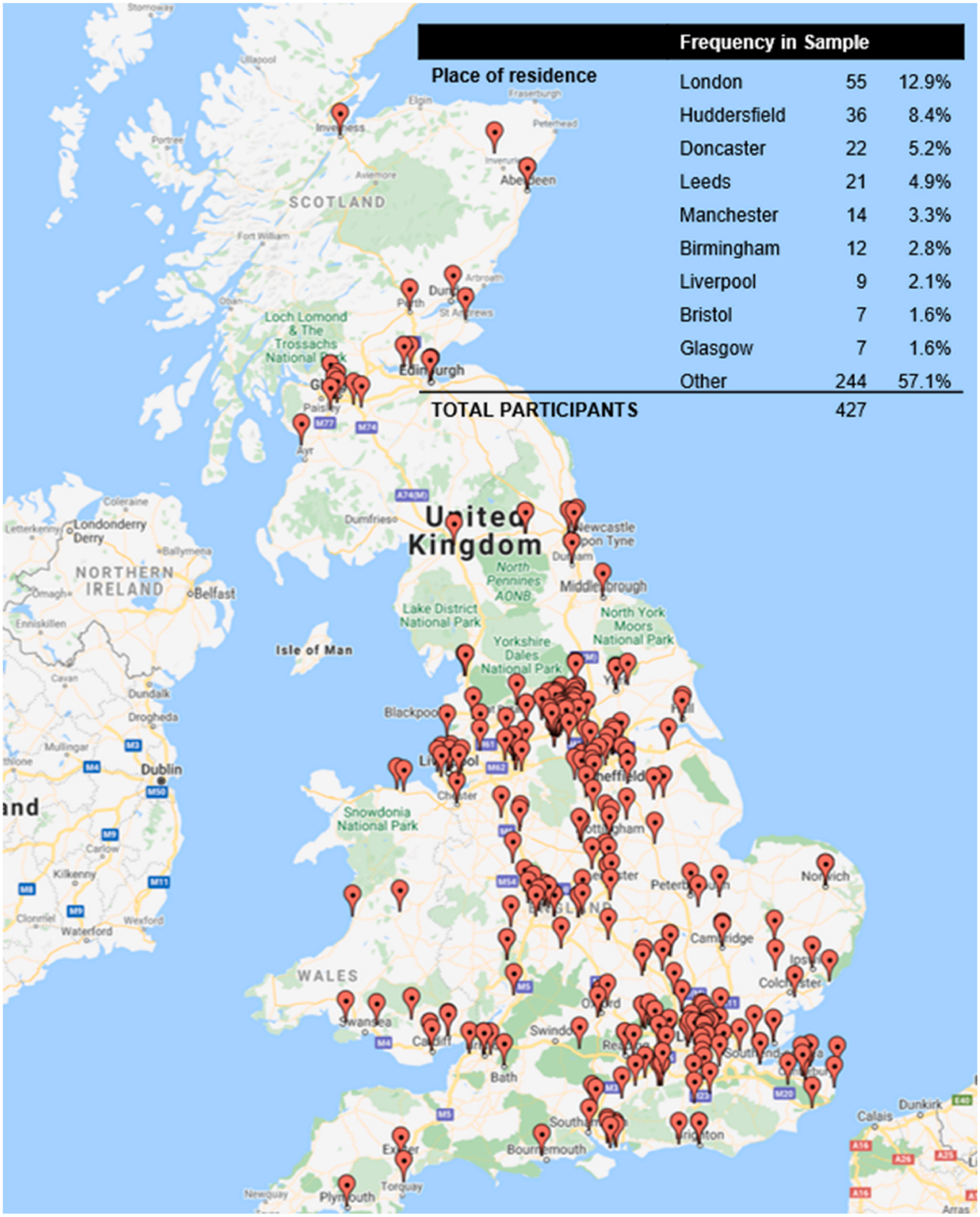

Fig. 4. Distribution of survey participants around the UK.

with 14.1% of the respondents reporting its daily use. Publicly shared cars were among the least popular travel options.

3.5. Statistical analysis

Statistical analysis methods are commonly used by behavioural and social scientists to work through quantitative survey data. To facilitate the statistical analysis procedures, presented in our work, IBM SPSS Statistics was used. First, our survey data went through a "cleaning" process, where incomplete and unusable responses were removed. This was followed by labelling and coding the data for further use in SPSS. The items focusing on participants' demographic characteristics and past behaviour were labelled as nominal, with each response category being coded as an index number. The items representing attitudinal and intentional Likert-scale statements were labelled as ordinal, and the response options were coded as follows: *strongly disagree/extremely unlikely* as 1, *disagree/unlikely* as 2, *neither agree nor disagree/neither likely nor unlikely* as 3, *agree/likely* as 4, and *strongly agree/extremely likely* as 5. Next, the number of categories for some of the past behaviour items had to be reduced. Because of the small size of the groups reporting *daily*, *few*

Table 1
Sample demographics.

Demographic Characteristic	Demographic Sub-Characteristic	Frequency in Sample		ONS Estimates
Gender	Male	194	45.4%	49%
	Female	230	53.9%	51%
	Other	3	0.7%	N/A
Age	18–24	144	33.7%	10.5%
	25–34	138	32.3%	17.1%
	35–44	75	17.6%	16.4%
	45–54	40	9.4%	16.8%
	55+	29	6.8%	39.3%
	Prefer not to say	1	0.2%	N/A
Marital status	Single	230	53.9%	37.9%
	Married/Domestic Partnership	170	39.8%	44.6%
	Divorced	10	2.3%	9.1%
	Widowed	0	0.0%	6.1%
	Prefer not to say	17	4.0%	2.2%
Family status	Without children	291	68.1%	46.9%
	With children under 18	85	19.9%	25.7%
	With children over 18	35	8.2%	10.6%
	Prefer not to say	16	3.7%	16.8%
Level of education	Secondary/High School	19	4.4%	N/A
	College	52	12.2%	N/A
	Bachelor's degree	161	37.7%	N/A
	Master's degree	140	32.8%	N/A
	Doctorate	54	12.6%	N/A
	Prefer not to say	1	0.2%	N/A
Status of employment	Student	146	34.2%	7.9%
	Employed full time	195	45.7%	39.8%
	Employed part time	52	12.2%	15.7%
	Unemployed looking for work	17	4.0%	2.8%
	Unemployed not looking for work	7	1.6%	12.1%
	Retired	10	2.3%	21.6%
Annual household income after tax	£0-£15,000	62	14.5%	20.9%
	£15,000-£30,000	92	21.5%	30.6%
	£30,000-£50,000	117	27.4%	28.7%
	£50,000+	107	25.1%	19.8%
	Prefer not to say	49	11.5%	N/A
TOTAL PARTICIPANTS		**427**		

Table 2
Sample travel behaviour.

Travel Behaviour		Frequency in Sample	
Car Ownership	No	102	23.9%
	Yes	325	76.1%
Private car as a driver	Daily	135	31.6%
	Few times a week	79	18.5%
	Once a week	17	4.0%
	At least once a month	10	2.3%
	Rarely	49	11.5%
	Never	137	32.1%
Public Transport (Bus/Tram/Train/etc.)	Daily	60	14.1%
	Few times a week	81	19.0%
	Once a week	45	10.5%
	At least once a month	75	17.6%
	Rarely	121	28.3%
	Never	45	10.5%
Publicly shared car for my own use (Taxi/Uber/Zipcar/etc.)	Daily	1	0.2%
	Few times a week	18	4.2%
	Once a week	25	5.9%
	At least once a month	89	20.8%
	Rarely	145	34.0%
	Never	149	34.9%
Public car shared with others (Taxi share/UberPool/BlaBlaCar/etc.)	Daily	3	0.7%
	Few times a week	7	1.6%
	Once a week	11	2.6%
	At least once a month	39	9.1%
	Rarely	100	23.4%
	Never	267	62.5%
TOTAL PARTICIPANTS		**427**	

times a week, and *once a week* use of publicly shared cars on both individual and collective basis, the decision was made to retain only three response categories, with all the responses representing more frequent use moving to *at least once a month* category.

To establish the relations of attitudinal, behavioural, and socio-demographic variables to intention variables, ordinal logistic regression modelling was adopted as it is a multiple regression modelling technique used specifically for ordinal dependent variables (Nikitas, 2018; Warner, 2008). However, to discard the possible unreliable variance in the attitudinal Likert-scale variables (Thompson, 2004), a smaller set of explanatory variables was developed first, by employing exploratory factor analysis (EFA).

When conducting EFA, the key steps of choosing a factor extraction method and rotation method and deciding on the number of factors to retain were followed, in line with Costello and Osborne (2005). The selection of extraction method was based on the research question and the ease of interpretation of the produced results, but the ultimate goal of factor analysis to account for as much variance as possible in an initial set of variables with a smaller set of latent variables (i.e., variance explained) was also taken into consideration (Hayton et al., 2004).

With regards to rotation methods, options included orthogonal, which produces an uncorrelated set of factors, or oblique, which produces a set of factors that are allowed to correlate with one another (Costello and Osborne, 2005). In social sciences research, correlations among factors are generally expected, so it is advised to use the oblique rotation; when the factors are uncorrelated, the EFA with either oblique or orthogonal rotation produce similar results (Costello and Osborne, 2005). The family of multiple regression techniques, including ordinal logistic regression, are, however, very sensitive to correlations among explanatory variables, a phenomenon called multicollinearity (Tabachnick and Fidell, 2013). Thus, to avoid multicollinearity issues orthogonal rotation methods were employed. As for the factor retention method, we employed an approach where the factors (that were developed through EFA) are tested for internal reliability using Cronbach α (e.g., Anable, 2005). There is no consensus as to what value of Cronbach α should be considered a benchmark for factor retention; it is typical, though, that factor reliability below 0.7 is not acceptable (O'Leary-Kelly and Vokurka, 1998).

In EFA, however, the size of the sample also affects the results. A prevalent rule-of-thumb, which suggests having at least 10 sample representations for any one empirical indicator (attitudinal statement in the case of this study) (Costello and Osborne, 2005), was used to determine the a-priori factor analysis sample size. The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy, according to which the sample is adequate for EFA if the value of measure achieves a bare minimum of 0.5, and Bartlett's Test of Sphericity, which indicates whether sample's scores on the attitudinal Likert-scale statements make the latter related to one another (Hadi et al., 2016), were also considered.

Thereby, all 40 attitudinal Likert-scale statements went through principal component analysis (PCA) with varimax rotation, extracting a set of 10 factors with the variance explained at 62.344% - the highest

Table 3
Results of Factors Analysis using PCA with Varimax Rotation.

Factor	Statements	Load	α
Added Value	IV_32: *I would use MaaS if I were informed about the availability of seats on different transport modes*	0.796	0.865
	IV_33: *If I could see, through MaaS platform, rating and feedback for drivers and fellow travelers, I would use MaaS*	0.791	
	IV_31: *I would use MaaS if it offered me a more frequent and flexible public transport service day and night*	0.767	
	IV_30: *I would use MaaS if I knew I was contributing to the reduction of overall congestion levels*	0.698	
	IV_34: *My decision to use MaaS would depend on people who already used it*	0.685	
	IV_29: *I would use MaaS if I were informed about my contribution to reducing carbon footprint*	0.628	
	IV_40: *I would use MaaS if I were offered bonus points and discounts for trips through MaaS app*	0.537	
Car Use Convenience and Enjoyment	IV_10: *I travel by car to have the privacy I don't get on other transport*	0.730	0.823
	IV_12: *I travel by car because I enjoy driving/being in a car*	0.718	
	IV_04: *I travel by car to avoid harsh weather*	0.702	
	IV_05: *I travel by car because I feel safe this way*	0.701	
	IV_02: *I travel by car because I can carry luggage/shopping/all the things I need without hassle*	0.665	
	IV_07: *I travel by car to be independent of public transport*	0.662	
Human Element Externalities	IV_26: *I would stress about the inconsiderate behaviour of fellow travelers*	0.739	0.797
	IV_25: *I wouldn't like to share the transport with people I don't know*	0.734	
	IV_27: *I wouldn't like to be in a crowded environment*	0.711	
	IV_28: *Having to rely on other people for my transport would concern me*	0.692	
Trust in Functionality	IV_21: *I would not want to share my personal data with MaaS*	0.814	0.752
	IV_22: *Cyber-security behind MaaS system would concern me*	0.782	
	IV_23: *I would not trust the travel information coming through MaaS app*	0.636	
	IV_20: *I would worry whether I am being charged correctly for my trips*	0.541	
	IV_16: *I would struggle to use a mobile device and an app to access different transport modes*	0.488	
Cost Incentives	IV_38: *If government increased the cost of car ownership and private car use, I would use MaaS*	0.728	0.724
	IV_39: *If government offered financial reliefs for switching from private car to MaaS, I would use MaaS*	0.727	
	IV_35: *I would use MaaS if travelling with it worked out cheaper than what I currently spend on my transport*	0.488	
	IV_37: *I would use MaaS if travelling with it would cost me about the same as what I currently spend on my transport*	0.450	
Car Use Morality	IV_13: *The environment does not concern me*	0.776	0.718
	IV_15: *I think congestion is not an issue for the environment*	0.766	
	IV_14: *I think me using a car has little to do with climate change*	0.723	
Trust in Enabling Technology	IV_18: *I would worry whether my mobile device has got enough battery*	0.833	0.714
	IV_19: *I would worry about the quality of internet coverage where I am going*	0.779	
Car Ownership Necessity	IV_08: *It's necessary to own a car if you have a family*	0.806	0.702
	IV_06: *Having your own car is necessary for cases of emergency/disruption*	0.712	
	IV_09: *Owning a car is good because it's having your own thing*	0.529	
Miscellaneous 1	IV_36: *I would pay more for MaaS than what I currently spend on my transport*	0.766	0.354
	IV_11: *I would own a car because people, important to me, also own cars*	0.451	
Miscellaneous 2	IV_03: *I travel by car because it is cost-effective*	0.646	0.575
	IV_01: *I travel by car to have more predictable journey times*	0.508	
	IV_24: *I would worry whether there would be a publicly shared car or bike available for me at the time I need it*	0.484	
	IV_17: *I would struggle to travel by a combination of transport modes*	0.480	

value compared to the EFA results obtained using alternative combinations of extraction methods and methods of orthogonal rotation. The KMO Measure of Sampling Adequacy resulted in the value of 0.853, meaning the sample of 427 subjects was a great fit for EFA (Hadi et al., 2016). Bartlett's Test of Sphericity had also shown significant results ($p < 0.05$), suggesting the data provided by the sample of 427 was adequate for EFA as the attitudinal items were proven to somehow correlate. Out of 10 factors extracted, eight were found to have sufficient internal reliability (Cronbach's $\alpha > 0.70$) and, for the above reason, were retained for further statistical analysis, with the variance explained reduced to 54.432%. These results are presented in Table 3.

To be used in ordinal logistic regression models, each of the factors generated through EFA had to be given a score. One of the simplest ways to compute factor scores is sum scores (DiStefano et al., 2009). The sum scores method is desirable when the scales used for data collection are exploratory, not previously tested and, thus, have little evidence of reliability or validity (Hair et al., 2006), which applies to the items tested in this quantitative inquiry. Thereby, the scores to each factor were given by calculating the average (DiStefano et al., 2009), or in other words mean (McNeish and Gordon Wolf, 2020), of all the items loading on each of the eight factors retained. As these new factorial variables were continuous, they were labelled as *scale* in IBM SPSS Statistics.

When all the explanatory variables (i.e., attitudinal factors, past behaviour items, and socio-demographic features) were transformed into an IBM SPSS-appropriate format, ordinal logistic regression models were developed to quantify the relationship between those explanatory variables and the two intentional statements (Warner, 2008). The modelling process assumed that attitudes have more explanatory power over travel behavioural intentions than socio-demographic and past behaviour characteristics (Anable, 2005). Thus, for each intentional Likert-scale statement various models were generated by testing the same combination of attitudinal variables (i.e., factors), but different combinations of socio-demographic and past behaviour variables, with only those resulting in significant relationships (with $p < 0.05$) retained. The models were generated using the PLUM procedure for ordinal logistic regression, embedded in IBM SPSS Statistics. Only the best fit models, or the models achieving the strongest associations among explanatory variables and the studied dependent variables, i.e., with the highest values for Cox and Snell Pseudo-R^2 with Nagelkerke correction (Best and Wolf, 2015; Smith and McKenna, 2013), but also passing the commonly used to define quantitative rigour likelihood ratio Chi-square test (Petrucci, 2009), were used for further statistical inferences.

4. Results and discussion

4.1. Intentions and attitudes across the sample

The results presented herein reveal the MaaS-induced travel behavioural intentions and the MaaS related attitudes of the UK general public. As evident from Table 4, our survey respondents were, on average, unlikely to intend to not own a car with MaaS (mean of 2.39). Survey respondents, on the other hand, were generally likely to replace some of their public transport trips with publicly shared cars (mean of 3.39).

Fig. 5 visualises the distribution of Likert-scale responses to intentional statements across our sample. As many as 61% of all survey respondents were unlikely or extremely unlikely not to own a car if MaaS was available to them while only 19% of them were to some extent likely not to own a car, and the remaining 20% could not decide. Interestingly, as many as 57% of all survey respondents were likely or extremely likely to replace their public transport trips with publicly shared cars if MaaS was available to them, while only around 20% of respondents were to some extent unlikely to adopt the studied intention, and the remaining 23% could not decide.

As for the attitudes, presented in Table 5, the respondents generally agreed that the added value of MaaS (mean of 3.7) and cost incentives (mean of 3.51) would motivate them, one way or another, to behave per specified intentions. Similarly, our participants agreed that human element externalities (mean of 3.48) and trust in enabling technology (mean of 3.28) would be the issues of concern in the MaaS era. Generally, the respondents agreed that the car was still convenient and enjoyable to use (mean of 3.76), and owning one was a necessity (mean of 3.63). The respondents, however, disagreed that trust in functionality (mean of 2.85) was a concern when shifting to MaaS based travel. The disagreement was even stronger in relation to morality issues associated with car use (mean of 1.9); given the reverse nature of the statements within the factor, this suggests survey respondents were concerned with car use morality aspects.

4.2. Intention not to own a car

The base category tested for the set of independent variables in this model was the intentional statement "*With MaaS I would consider not owning a car*", with the Parameter Estimates table for the model

Table 4
Sample intention scores.

	N	Min	Max	Mean	SD
DV_1: With MaaS I would consider not owning a car	427	1	5	2.39	1.14
DV_2: With MaaS I would replace some of my public transport trips with publicly shared cars	427	1	5	3.39	1.05

Table 5
Sample attitude scores.

	N	Min	Max	Mean	SD
Added Value	427	1	5	3.7	0.7
Car Use Convenience and Enjoyment	427	1	5	3.76	0.8
Human Element Externalities	427	1	5	3.49	0.87
Trust in Functionality	427	1	5	2.85	0.74
Cost Incentives	427	1	5	3.51	0.72
Trust in Enabling Technology	427	1	5	3.28	1.03
Car Ownership Necessity	427	1	5	3.63	0.88
Car Use Morality	427	1	5	1.9	0.77

presented in Table 6.

The studied intentional statement was found to be significantly correlated with eight out of ten explanatory variables used in the model. The factor *Added Value* is a significant predictor of the intention not to own a car when equipped with MaaS ($\beta = 0.709$, Wald x2 = 13.766 and $p < 0.05$), meaning that the more transport users appreciate the incentivising features of MaaS, the more likely they are not to own a car when MaaS is available.

The factor *Human Element Externalities* is likewise a significant predictor of the studied intention but has a negative relationship with the latter ($\beta = -0.318$, Wald x2 = 6.164 and $p < 0.05$). This means that transport users holding negative attitudes towards relying on others for the transport service or towards using shared means of transport are less likely not to own a car when MaaS is available. This is expected as personal safety (e.g., crime avoidance) and provision of personal space were some of the previously identified drivers of car ownership and use (Alyavina et al., 2020).

The factor *Trust in Functionality* was another significant predictor in the model ($\beta = 0.950$, Wald x2 = 20.046, $p < 0.05$), suggesting that an increase on the factor also increases the odds of falling at a higher level of likelihood of adopting the studied intention. This result is somewhat counter-intuitive, though. For the context of car ownership in the MaaS era it can be argued that, by agreeing not to own a car, to go about their daily business transport users have no other choice but to rely on applications and share information despite being concerned with the latter. Similarly, Caiati et al. (2020) and Schikofsky et al. (2020) argued that privacy and cyber-security issues have no "real" influence on MaaS adoption intentions. However, such an outcome may also be the result of collecting data via a web-based survey that in essence targets digitally literate individuals who have access, and use on regular basis, smartphones and computers and are likely familiar with the operation of digital applications and the associated risks.

The factor *Cost Incentives* ($\beta = 0.846$, Wald x2 = 20.944 and $p < 0.05$) had the strongest positive influence on the studied intention. Car ownership decisions have been long known to be influenced by car purchase costs, costs of car use, and fares of alternative transport modes (Dargay, 2002). In a way supporting the above, this study's findings suggest that the more transport users are driven by the cost benefits integrated MaaS travel may offer, either in the form of reduced overall

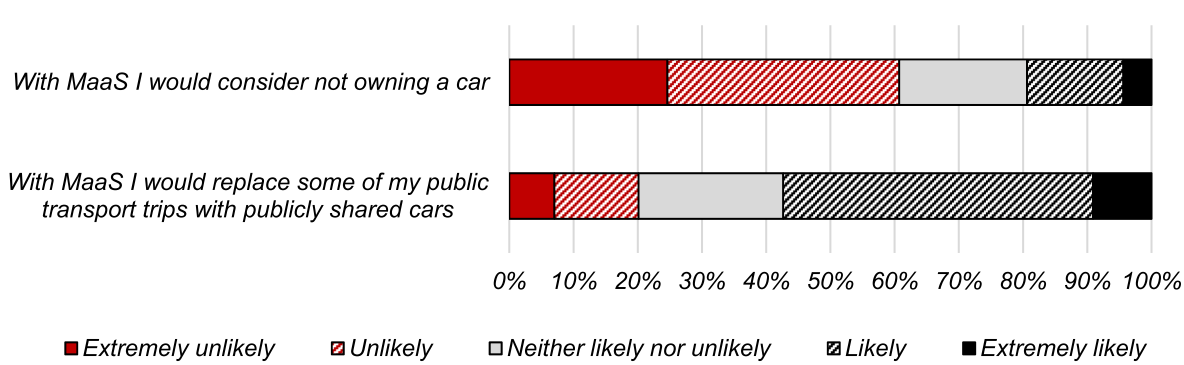

Fig. 5. Distribution of responses for studied intentions.

Table 6
Parameter Estimates for Intention not to own a car.

			Est. (β)	Std. Error	Wald	Df	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
Threshold	With MaaS I would consider not owning a car	*Extremely unlikely*	1.925	0.989	3.789	1.0	0.052	−0.013	3.863
		Unlikely	4.134	1.006	16.887	1.0	0.000	2.162	6.106
		Neither likely nor unlikely	5.453	1.018	28.724	1.0	0.000	3.459	7.448
		Likely	7.412	1.046	50.227	1.0	0.000	5.362	9.462
Location	Added Value		0.709	0.191	13.766	1.0	**0.000**	0.335	1.084
	Car Use Convenience and Enjoyment		0.062	0.142	0.189	1.0	0.664	−0.217	0.340
	Human Element Externalities		−0.318	0.128	6.164	1.0	**0.013**	−0.570	−0.067
	Trust in Functionality		0.660	0.148	20.046	1.0	**0.000**	0.371	0.950
	Cost Incentives		0.846	0.185	20.944	1.0	**0.000**	0.484	1.209
	Car Use Morality		−0.023	0.135	0.029	1.0	0.865	−0.287	0.241
	Trust in Enabling Technology		−0.199	0.099	4.038	1.0	**0.044**	−0.393	−0.005
	Car Ownership Necessity		−0.686	0.131	27.383	1.0	**0.000**	−0.943	−0.429
	Do you have a car in your household?	*No*	0.816	0.272	9.000	1.0	**0.003**	0.283	1.349
		Yes	0[a]	.	.	0.0	.	.	.
	Private car as a driver	*Daily*	−0.718	0.289	6.160	1.0	**0.013**	−1.285	−0.151
		Few times a week	0.109	0.306	0.126	1.0	0.722	−0.491	0.709
		Once a week	0.177	0.510	0.121	1.0	0.728	−0.822	1.177
		At least once a month	0.533	0.621	0.738	1.0	0.390	−0.683	1.750
		Rarely	0.348	0.313	1.233	1.0	0.267	−0.266	0.961
		Never	0[a]	.	.	0.0	.	.	.

N = 427, Model Chi-Square = 211.869, $p < 0.01$, -2log likelihood = 1032.435, Nagelkerke *Pseudo*-R^2 = 0.414.
[a] This parameter is set to zero because it is redundant (the reference for comparisons).

transport spending or in the form of governmental reliefs and motives, the more likely they are not to own a car when equipped with MaaS.

The factor *Trust in Enabling Technology* resulted in significant but negative relationship with the studied intention (β = −0.199, Wald x2 = 4.038 and p < 0.05). This means that transport users who are more likely to be concerned with the MaaS enabling technology are, as a result, less likely not to own a car in the MaaS era. Indeed, by losing access to MaaS enabling technology transport users lose not only the means of access to transport but also access to information necessary to execute non-private-car-based trips without concern (Beirão and Sarsfield Cabral, 2007).

The last of the significant attitudinal predictors in the model was the factor *Car Ownership Necessity* (β = −0.686, Wald x2 = 27.383, p < 0.05). The negative estimate suggests that transport users who are more likely to consider owning a car a necessity are, as a result, less likely not to own a car even if equipped with MaaS for travel. Thus, as previously stated by Mulley (2017), the attitudes to car ownership among transport users must change first; only then new consumer preferences regarding travel mode choice, and new, non-private-car- dependent, travel behaviours will emerge with MaaS.

Another two statistically significant explanatory variables referred to past behaviour and included *Car Ownership* (β = 0.816, Wald x2 = 9.000, p < 0.05), and the daily use of private car as a driver (β = −0.718, Wald x2 = 6.160 and p < 0.05). Given that the base category for the car ownership item was the presence of car in the household, the latter means that transport users who do not currently own a car are more likely not to own a car in the MaaS era, as opposed to those who are in possession of one, which supports the findings of Kamargianni et al. (2018). Our results also indicate that transport users who *drive their car on daily* basis are less likely not to own a car when equipped with MaaS than the individuals who never drive. Thus, daily car use, on top of negatively affecting MaaS acceptance (Ho et al., 2018, 2020; Fioreze et al., 2019; Caiati et al., 2020), also has negative implications for MaaS' car ownership reduction goals.

4.3. Intention to replace public transport trips with publicly shared cars

The base category tested for the set of independent variables in this model was the intentional statement "*With MaaS I would replace some of my public transport trips with publicly shared cars*." The modelling results are presented in Table 7.

The factor *Car Use Convenience and Enjoyment*, unlike in the previous model, appeared a significant predictor of the studied intention (β = 0.450, Wald x2 = 9.610, p < 0.05). This means that transport users holding positive evaluations of general car use, with respect to privacy, independence of public transport, weather, carrying capacity, safety, but also enjoyment, are more likely to replace public transport trips with publicly shared cars when shifting to MaaS-based travel. While the convenience of car use has been brought up in the MaaS agenda as a barrier to its acceptance (e.g. Ho et al., 2018) and use (e.g. Storme et al., 2020), to the best of our knowledge, the effect of car use convenience, and moreover, enjoyment, on travel behavioural response to MaaS this far has not been investigated.

The factor *Human Element Externalities* was also a significant predictor in the model with a negative influence on the studied intention (β = −0.581, Wald x2 = 17.484, p < 0.05). This means that the more concerned individuals are with the negative aspects of sharing the means of transport with other travellers, and relying on others for the service, the less likely they are to replace public transport trips with publicly shared cars in the MaaS era. This is not surprising as, for example, ride-sharing companies have little control over the drivers, vehicles, or the rides and, thus, are unable to take strict measures against harassment, assault, and robbing events, frequently experienced by ride-sharing users (Chaudhry et al., 2018). Furthermore, as stated by Evans and Wener (2007) it is not the number of passengers in a vehicle per se, but the immediate proximity of strangers, as in the case of sharing a seat, that causes transport users to experience stress during travel; while it is possible to avoid the latter on public transport, shared rides do not offer such capacity.

The effect of factor *Cost Incentives* (β = 0.513, Wald x2 = 7.908, p < 0.05) means that transport users who fall at a higher level of likelihood of being influenced to use MaaS by cost benefits are more likely to replace public transport trips by publicly shared cars. Thus, giving affordable access to a multitude of mobility options, and car-based shared use modes in particular, at no "extra" cost to get transport users out of personal cars, may result, whilst reducing car ownership and private car use levels, in an increase of the shared vehicle fleet in order to meet demand, and also facilitate the growth of vehicle kilometres travelled (Pangbourne et al., 2020).

The last three statistically significant explanatory variables in this

Table 7
Parameter Estimates for Intention to replace public transport trips with publicly shared cars.

			Est. (β)	Std. Error	Wald	df	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
Threshold	With MaaS I would replace some of my PT trips with publicly shared cars	*Extremely unlikely*	1.655	1.019	2.638	1.0	0.104	−0.342	3.653
		Unlikely	3.169	1.027	9.514	1.0	0.002	1.155	5.183
		Neither likely nor unlikely	4.614	1.040	19.665	1.0	0.000	2.575	6.653
		Likely	8.009	1.081	54.878	1.0	0.000	5.890	10.128
Location	Added Value		0.860	0.190	20.530	1.0	**0.000**	0.488	1.232
	Car Use Convenience and Enjoyment		0.450	0.145	9.610	1.0	**0.002**	0.166	0.735
	Human Element Externalities		−0.581	0.139	17.484	1.0	**0.000**	−0.853	−0.309
	Trust in Functionality		−0.045	0.150	0.091	1.0	0.763	−0.339	0.248
	Cost Incentives		0.513	0.182	7.908	1.0	**0.005**	0.155	0.870
	Car Use Morality		0.014	0.136	0.011	1.0	0.918	−0.253	0.282
	Trust in Enabling Technology		−0.152	0.103	2.175	1.0	0.140	−0.354	0.050
	Car Ownership Necessity		0.058	0.130	0.199	1.0	0.655	−0.197	0.312
	Public Transport (Bus/Tram/Train)	*Daily*	0.690	0.405	2.896	1.0	0.089	−0.105	1.485
		Few times a week	−0.327	0.372	0.773	1.0	0.379	−1.055	0.402
		Once a week	1.477	0.440	11.300	1.0	**0.001**	0.616	2.339
		At least once a month	0.155	0.375	0.170	1.0	0.680	−0.581	0.890
		Rarely	0.550	0.342	2.589	1.0	0.108	−0.120	1.221
		Never	0a	.	.	0.0	.	.	.
	Publicly shared car for my own use (Taxi/Uber/Zipcar)	*At least once a month*	0.532	0.262	4.121	1.0	**0.042**	0.018	1.045
		Rarely	−0.161	0.248	0.417	1.0	0.518	−0.647	0.326
		Never	0[a]	.	.	0.0	.	.	.
	Public car shared with others (UberPool/BlaBlaCar)	*At least once a month*	0.806	0.328	6.023	1.0	**0.014**	0.162	1.449
		Rarely	0.666	0.265	6.321	1.0	**0.012**	0.147	1.184
		Never	0[a]	.	.	0.0	.	.	.

N = 427, Model Chi-Square = 187.109, $p < 0.01$, -2log likelihood = 973.276, Nagelkerke Pseudo-R2 = 0.380.
[a] This parameter is set to zero because it is redundant (the reference for comparisons).

model again referred to past behaviour. *Using public transport once a week* is significantly, and positively, correlated with the studied intention (β = 1.477, Wald x2 = 11.300, $p < 0.001$), while more frequent or less frequent use were not found to have a significant impact. Given that the base category for this item was never using public transport, the latter means that transport users who use public transport once a week are more likely than those who never use it to replace public transport trips with publicly shared cars when equipped with MaaS. This adds to the findings of Alonso- Gonzalez et al. (2020) suggesting that individuals using some kind of public transport on a weekly basis are more likely to adopt MaaS for their travel but are also more likely to use the tool for accessing car-based mobility services to replace public transport with this, thus developing unsustainable travel behavioural practices.

Individual *use of publicly shared cars at least once a month* is also significantly, and positively correlated with the studied travel behavioural intention (β = 0.532, Wald x2 = 4.121, $p < 0.05$). Given that the base category for this item was never using publicly shared cars on individual basis, the latter means that transport users who have experience using publicly shared cars on individual basis once a month or more are more likely to replace public transport trips with publicly shared cars when equipped with MaaS, than individuals who never use these services. The *collective use of publicly shared cars* was found to be significantly, and positively, correlated with the studied intention, both *on rare occasions* (β = 0.666, Wald x2 = 6.321 and $p < 0.05$) and *at least once a month* (β = 0.806, Wald x2 = 6.023 and $p < 0.05$). Given that there was a total of three categories, and the base category for this item was never using publicly shared cars collectively, the latter means that transport users who share public cars with strangers are more likely to replace public transport trips with publicly shared cars when travelling with MaaS than those who never use those services. These findings, related to the use of publicly shared cars on both individual and collective basis, support previous MaaS research, where experience with publicly shared cars was found to have an influence on the acceptance of MaaS (Alonso-González et al., 2020; Caiati et al., 2020), also in a bundle form (Ho et al., 2020). But again these findings also suggest that individuals with the experience of using such services are the ones likely to not only include these modes in their MaaS subscriptions, as recognised by Matyas and Kamargianni (2018), but also develop unsustainable, car-dependent, travel behaviours.

5. Conclusion

5.1. Reflecting on findings for policy recommendations

Although MaaS, as a whole, may be an attractive service for transport users, this interest does not guarantee its sustainable use. The majority of respondents are not willing to give up owning a car in the presence of MaaS; many of them could be tempted to use MaaS to replace public transport trips with publicly shared cars. Owning a car before MaaS as well as daily driving practices lower the potential of MaaS to create transport futures free of private cars. Car ownership is still considered necessary, at least for the cases of emergency and disruption – situations in which even a fully functioning MaaS provision might be of little help. These perceptions of owning a car, unfortunately, also limit the potential of MaaS as a tool able to reduce car ownership levels. It is not car ownership attitudes alone, however, but the general dependence on cars that hinders sustainable uptake of MaaS. So, perceiving the travel by car (even in shared conditions), as convenient, and enjoyable also has its implications for MaaS uptake: those, holding positive attitudes towards using a car, when equipped with MaaS will be more likely to substitute public transport journeys with publicly shared cars. Interestingly, the results of our analysis were not affected by the dominance of young, well-off financially, single household individuals, who are portrayed as more sustainable travellers in the literature.

Therefore, transport users' attitudes not only towards car ownership, as suggested by Mulley (2017), but also car use in general, must change to ensure sustainable transport choices are made when shifting to MaaS based travel, which could be achieved by government-led "push" strategies. As demonstrated by MaaS cases from Finland, *redesign of transport policy to focus on response to environmental challenges and climate change* offers potential to enable a more sustainable MaaS development (Kivimaa and Rogge, 2022). Within the range of "push" policies, *reduction or elimination of parking spaces* should also be considered as it could, per existing evidence (Smith et al., 2022), encourage transport users to re-evaluate their car ownership and use practices and increase their interest in trialing alternative transport options and schemes. Therewith, *increases in car* and *fuel prices* should be put in place: according to Yang et al. (2022), these do lead to a considerable decrease in car ownership and car use levels. *Congestion charging* schemes have also proven effective in reducing car traffic, however, might only target price-sensitive car drivers as the case of London Congestion Charge suggests (Metz, 2018).

These deterring strategies alone, though, are often met with public opposition; interventions that incorporate the so-called "carrots" – enablers of the desired transport behaviours – alongside the "sticks", or "push" measures, are more effective at encouraging positive travel behaviour change (Nikitas et al., 2011; Piatkowski et al., 2019). *Raising environmental awareness* among transport users could be one such complementary measure (Loukopoulos et al., 2005), where a MaaS app itself could be used as a means for *environmental education and sustainability promotion*. A number of experiments in Switzerland have demonstrated that *"gamification" of travel*, automatic *mobility tracking, eco-feedback*, and *social comparison* – mechanisms easily implementable within MaaS offering - can attract car drivers and persuade them to adjust their transport use in a way that results in a decrease of CO_2 emissions and energy consumption per kilometre travelled (Cellina et al., 2019, 2023).

Lack of trust in the information provision but also the cyber-security functions of MaaS, such as protection of personal data and monetary transactions, alongside individual readiness to use smartphones and applications appeared not to be of significance for the car ownership and public transport substitution effects of MaaS. Nevertheless, these issues should be considered by policy makers and transport providers to ensure the successful and sustainable MaaS transition as recent research discusses (Nikitas et al., 2024). First, businesses partaking in MaaS not only *need to be GDPR compliant* and process sensitive user data in accordance (Murati, 2020), but also must *make their compliance explicit* to transport users. Private and public MaaS stakeholders also need to *trial* out and work on refining MaaS through the use of pilots, trials and living labs; this will provide an opportunity to users to get accustomed with the novel tool and the means of its provision, thereby helping overcome the digital readiness concerns and negative perceptions about information provision risks that would not exist in a real-life scheme.

Concerns with mobile device battery life and quality of internet coverage around their travel area lowered transport users' willingness not to own a car when transitioning to MaaS. To positivise the attitudes towards non-car-based travel and overcome the MaaS enabling technology issues, *alternative means of access to MaaS* must be provided (Polydoropoulou et al., 2020). Whilst the access to transport offerings within MaaS could be backed up with the use of *smart cards*, for example, offering offline access to real-time information services remains a challenge. *Digital information boards* optimally located at interchange points, but also *street maps* and *increased signage* aimed at orientating transport users on the street (Ibraeva and Figueira de Sousa, 2014) could help eliminate some of the risks associated with the loss of access to information via smartphone applications. Another possible scenario is introducing *Mobility Hubs* around the MaaS coverage area prior its implementation; these recognisable transport interchange points can not only offer access to a variety of connected transport modes but also provide information features and other enhanced facilities (Arnold et al., 2023), which can include *mobile device charging points*. The MaaS apps themselves should be developed in a way that can help achieve power savings; a number of methods already exist that promote *more efficient use of within-app sensors* and close the gap between the actual user activity and the awareness of it by the mobile device (Khan et al., 2021; Perez-Torres et al., 2016).

On top of the capacity of MaaS to break existing travel habits via its carbon footprint information provision merits, and the ability to mitigate some of the sharing risks via account creation and feedback functions, the MaaS potential to induce improvements in the level of service provision, eliminate transport capacity bottlenecks via its analytical functions, and offer incentives such as travel-related discounts and bonuses are the features of value with an influence on travel behavioural choices. These, alongside the potential of MaaS to reduce overall travel spending, have a strong positive effect on both the intention not to own a car and replace public transport trips with car-based shared use mobility services. The public transport substitution intention was also found to be stronger among weekly public transport users and those experienced with the use of publicly shared cars. This likely indicates transport users' dissatisfaction with the public transport service and the consequent desire for access to the convenience of cars without the hassle of ownership. Therefore, value-adding features and the cost structure of MaaS should be organised in a way that promotes the use of public transport and active travel modes not only over private car but also over car-based shared use mobility services. This means that significant investments should be made in public transport in terms of increasing its available mass transit modes; increasing the frequency and reliability of its services; enhancing the size and comfort of vehicle fleets; prioritising its way of access, getting more road space from cars and having dedicated public transport infrastructure; and decreasing its fares.

We believe that the realistic function of MaaS and the expectations behind it, should not be about beating private car convenience, as widely proposed in existing MaaS research, but about outweighing the benefits of general car-based travel by creating a multimodal travel brand which provides transport users the chance to be part of a mechanism designed to craft more liveable, socially inclusive, and sustainable futures. This should be the focus of a thorough rebranding exercise that will make MaaS not an unrestricted promise of freedom to users enabled by digitisation (Pangbourne et al., 2020) but a tool for transitioning to societal prosperity that may need some (car) sacrifices and discipline from road users. Transport users should be incentivised to travel responsibly with MaaS through not only excessive charges for car users, but also bonuses and tax reliefs for those employing a more sustainable travel behaviour. In other words, public transport should be made the backbone of any MaaS system while the use of services like car-sharing and ride-sharing should be discouraged via monetary disincentives, and access to them should be permitted only in cases of emergency or as first- and last-mile enhancement to public transport services. This means, though, that major efforts should be put into encouraging well-integrated, demand-responsive, affordable, and timely but also easily accessible and socially inclusive public transit networks enhanced with reliable and effective real-time information provision services.

5.2. Study limitations and future research

Our work had some weaknesses that we acknowledge. For example: although appropriate we could have had a larger sample including less digitally literate people that could have been captured by a hard copy survey collection. We also recognise the potential presence of survey completion biases, such as self-reporting and social desirability which are part of every similar quantitative process (Nikitas et al., 2021). Respondents, despite a consistent MaaS presentation, might not have fully realised what this new transport paradigm actually is because they have never used such a technology before. However, we believe that our study still provides some original insights and important lessons that could potentially inform academia, policy-making and practice about the ability of MaaS to create non-car-centric development. Future work could involve more experimental studies where participants actually experience an early brand of MaaS; this way, their answers could be more reliable. Another future research avenue includes in-depth qualitative studies about how we can actually achieve making a non-uberised

MaaS more popular and powerful enough to tempt people away from owning private cars.

CRediT authorship contribution statement

Elena Alyavina: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Alexandros Nikitas:** Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Eric Tchouamou Njoya:** Supervision, Writing – original draft, Writing – review & editing.

Data availability

The data that has been used is confidential.

Appendix 1. Joint Display

Table 1
Joint Display - Likert-Scale statements developed using Thematic Map and related Data Extracts

Theme	Sub-Theme	Sample Data Extract		Survey Statement	
CAR DEPENDENCE	Convenience	H10	*"I don't have to wait around for other transport means. If I go shopping, I have the entire boot to put everything in it. I can plan my own trip when I want it, so I don't depend on any other time constraints from other transport means."*	IV_01	I travel by car to have more predictable journey times
				IV_02	I travel by car because I can carry luggage/shopping/all the things I need without hassle
		H06	*"If it was as a daily commute, I'm not sure you could make MaaS cheap enough to convince me. I'd rather just get in my car." (*)*	IV_03	I travel by car because it is cost-effective
		H02	*"Sometimes you do need to drive, if it's raining, for example." (*)*	IV_04	I travel by car to avoid harsh weather
		B12	*"Compared to public transport and other modes, car is a lot safer." (*)*	IV_05	I travel by car because I feel safe this way
		L09	*"If there was an emergency, whatever that might be, a trip to a hospital or going to see someone quickly, you've got your own car, you can drop everything and go, whereas with MaaS there is always going to be a lag"*	IV_06	Having your own car is necessary for cases of emergency/disruption
		H09	*"You know, with my car I'm not restricted to the timetables of trains, for example, and places where I can go. I get more choice." (*)*	IV_07	I travel by car to be independent of public transport
		B08	*"I think the convenience and the comfort for my family is more important here. For that, I would not want to swap my personal car for MaaS."*	IV_08	It's necessary to own a car if you have a family
	Enjoyment	B04	*"People feel secure when they have their own stuff, and having a car is having your own thing. You would prefer that and the benefits it brings any time of the day." (*)*	IV_09	Owning a car is good because it's having your own thing
		B02	*"The car is all my own environment, so I can turn on my Radio1 and relax more. You know, I've got my personal little bit of space." (*)*	IV_10	I travel by car to have the privacy I don't get on other means of transport
		H13	*"In my family everybody has got a car, so it would be quite weird if I didn't have one." (*)*	IV_11	I would own a car because people, important to me, also own cars
		H07	*"I enjoy driving because of the comfort of driving and because I love driving. I'm so happy when I drive, I'm so comfortable." (*)*	IV_12	I travel by car because I enjoy driving/being in a car
	Morality	L10	*"Whilst I am very aware that there is a problem, it's not a big enough problem for me to say that I'm not going to use my car anymore."*	IV_13	The environment does not concern me
		B05	*"If I cause emissions or something, that wouldn't make any difference to me. My car wouldn't make that much difference if I stopped driving." (*)*	IV_14	I think me using a car has little to do with climate change
		B11	*"If everyone uses a car that is environmentally safe in terms of emissions, like I do, then we would have a safer environment. So, on my part I know that I use something environmentally friendly."*	IV_15	I think congestion is not an issue for the environment
TRUST	Digital Readiness	B05	*"I don't think my brother has ever even used Uber. He calls taxis because he is not very good with phones."*	IV_16	I would struggle to use a mobile device and an app to access different transport modes
		H12	*"I suppose people who are a little bit older would probably struggle with the concept of using a mobile phone app to access different transport modes."*	IV_17	I would struggle to travel by a combination of transport modes
	Technology	H05	*"If your phone is not charged, you cannot get access to MaaS, and then you're lost. You can't just rely on it."*	IV_18	I would worry whether my mobile device has got enough battery
		B07	*"The only thing would be signal. It would be frustrating because there are still many places where the signal just wouldn't be good enough." (*)*	IV_19	I would worry about the quality of internet coverage where I am going
		H02	*"The only thing is Wi-Fi, the internet connection."*		
	Cyber-Security	L06	*"It's asking for payment through the app, and I would want some kind of reassurance that this is fine."*	IV_20	I would worry whether I am being charged correctly for my trips
		L14	*"As sad as I am, I don't like companies tracking me, having my data, and me not knowing what happens with that data." (*)*	IV_21	I would not want to share my personal data with MaaS
		H07	*"It could endanger lives one way or another if the hackers, terrorists break into MaaS system."*	IV_22	Cyber-security behind MaaS system would concern me
	Efficiency	L12	*""The only thing I find with using apps is when you've got an idea of a system, and you go on the app, and you go "how am I getting from A to B?" and the app tells you to go there, and you go there. And I think, well, actually, if I go that way it's better because it's cheaper, but because it's a minute longer than the other way, the app will tend to give you the quickest time, and it's not necessarily as flexible and giving you as many options."*	IV_23	I would not trust the travel information coming through the MaaS app

(*continued on next page*)

Table 1 (*continued*)

Theme	Sub-Theme	Sample Data Extract		Survey Statement	
	Capacity	B02	*"You may actually not have a chance of sharing a bike or a car because there are so many people using MaaS there isn't just one available for you." (*)*	IV_24	I would worry whether there would be a publicly shared car or bike available for me at the time I need it
		H08	*"If we imagine that everyone uses MaaS, we then need more public transport in terms of numbers; we need more taxis, buses, because everyone would use it. I'm thinking about peak times. If you want to book a taxi around school time in the morning, you won't be able to do it because it's so busy. If many people abandoned their cars, such things could become more frequent."*		
HUMAN ELEMENT EXTERNALITIES	Danger Anticipation	L10	*"I'm not very good with the sole security element, with not knowing who I'm with. I don't know how I feel about sharing."*	IV_25	I wouldn't like to share the means of transport with people I don't know
	Abuse & Disobedience	B07	*"For me buses are just not well looked after, you've got a lot of abusive people on there, you've got some people smoking in the back though smoking is clearly not allowed. There are also regular attacks on the bus against women."*	IV_26	I would stress about the inconsiderate behaviour of fellow travellers
	Discourtesy	H04	*"If the train was nice and quiet, it would be great. But you know, if it's really busy, you can't get a seat, and that's a pain, and then obviously if it's full of noisy people you can't concentrate on reading."*	IV_27	I wouldn't like to be in a crowded environment
	Negligence	B07	*"With MaaS you're still reliant on people, you're still reliant on someone for a taxi, a bus, a train, and anything can happen."*	IV_28	Having to rely on other people for my transport would concern me
VALUE	Appification and Integration	H02	*"It's easy enough. Anyone these days has a phone that can support it. I already have a few apps on my phone."*	IV_16	I would struggle to use a mobile device and an app to access different transport modes
		L12	*"Someone who is older or not so strong with IT might struggle with MaaS. But then they would also struggle to find a local bus or operator in a different town."*	IV_17	I would struggle to travel by a combination of transport modes
	Breaking Habits	L05	*"It would be interesting to put something in MaaS that would tell you about the carbon footprint. I think that would be a bit of an eye-opener for people and maybe influence their decision." (*)*	IV_29	I would use MaaS if I were informed about my contribution to reducing carbon footprint
		H05	*"MaaS might encourage people, if it's aimed that way, to walk or cycle more, if it could take them through routes which are more walking- and cycling- friendly."*	IV_30	I would use MaaS if I knew I was contributing to the reduction of overall congestion levels
	Level of Service Provision	H14	*"Public transport is not the same 24/7. That guarantee that I would have the opportunity to use public transport whenever I want, that would be something."*	IV_31	I would use MaaS if it offered me a more frequent and flexible public transport service day and night
	Analytics	L05	*"I think, in terms of trains, they could do some research and actually let you know on what train you are likely to get a seat, or at what time it is going to be less busy."*	IV_32	I would use MaaS if I were informed about the availability of seats on different transport modes
	Accounts & Feedback	H10	*"I think they should cover everything, not just the car, but also the people you share that car with. You may feel a bit safer that way."*	IV_33	If I could see, through MaaS platform, rating and feedback for drivers and fellow travelers, I would use MaaS
		B03	*"While I would consider what I hear about the advantages from the people I know, that would not ultimately make the decision for me. But, of course, that would elicit consideration." (*)*	IV_34	My decision to use MaaS would depend on the people who already used it
COST	Benchmarking against Status Quo	L01	*"I am topping up my Oyster card £30 a week and that's to cover all my transport. So, I would want to see that reduced."*	IV_35	I would use MaaS if travelling with it worked out cheaper than what I currently spend on my transport
		B06	*"I think people would pay that little bit more because it does more, and I'd be ready to pay a little bit more."*	IV_36	I would pay more for MaaS than what I currently spend on my transport
		H12	*"It is like £25 for me to get home on a train. If it was the same with MaaS, I would probably just get in my car."*	IV_37	I would use MaaS if travelling with it would cost me about the same as what I currently spend on my transport
	Incentives Reliefs & Motives	H09	*"But it can be an option the government could look at, increasing the cost of owning a car, and that could push people to use MaaS."*	IV_38	If government increased the cost of car ownership and private car use, I would use MaaS
		L02	*"The government should offer credits, where you get your money back, or you're not taxed as much because you don't have a personal car."*	IV_39	If government offered financial reliefs for switching from private car to MaaS, I would use MaaS
		B05	*"You could give people bonuses, something like reward points every now and then. Give people an incentive to use it. Bribe them. Freebies usually work."*	IV_40	I would use MaaS if I were offered bonus points and discounts for trips through MaaS app

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