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Journal Article

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Publication date:
2020-11

Permanent link:
https://doi.org/10.3929/ethz-b-000447470

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Originally published in:
Transportation Research Part A: Policy and Practice 141, https://doi.org/10.1016/j.tra.2020.09.021
MaaS bundle design

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ABSTRACT

Mobility service bundling has received a lot of attention from researchers and practitioners due to its centrality to Mobility as a Service (MaaS) business models and potential to foster sustainable travel behavior. Stated choice studies have to date been used to explore the willingness to pay for MaaS bundles and their components. Despite an increasing number of academic studies and commercial trials, there is a surprising dearth of research on how to design MaaS bundles in the first place. Comparative learning is further limited as the designs of choice experiments and studied bundles differ widely. What are the underlying design dimensions and how can we separate differences in outcome from differences in design? We address this gap by (1) conducting an extensive literature review on MaaS bundle design and synthesizing ten fundamental design dimensions, (2) extending the Design of Designs literature to develop a framework to systematically relate and compare design, methods and outcome of stated choice studies in general, and (3) applying our framework to MaaS bundle design and developing a research agenda, structuring future endeavors in this field.

1. Introduction

Recent technological advances have led to a surge of shared transportation modes in cities worldwide with e-bikes and e-scooters being the latest additions. This development has inspired the concept ‘Mobility as a Service’ (MaaS), which seeks to integrate emerging shared modes with more conventional public transportation (PT) to facilitate seamless (intermodal) planning, booking and payment through a single app. While different stakeholders associate different objectives with MaaS, the concept is relevant from a societal perspective as it could induce sustainable changes in travel behavior such as decreasing private car ownership and increasing the use of shared, largely low emission-powered modes (Hensher and Mulley, 2020; Jittrapirom et al., 2017; Kamargianni et al., 2016; Mulley, 2017; Wong et al., 2020).

Under a MaaS scheme, users typically have the choice to pay per trip or subscribe to bundles of mobility services. How to design these bundles is central to their potential of inducing behavioral change (e.g., should more discount be granted for more sustainable modes?) and business models of providers (the ‘classic’ argument for bundling is price discrimination) and has therefore sparked the interest of both transportation researchers and practitioners. Perhaps surprising given the increasing number of stated choice studies on willingness to pay for MaaS bundles and its components (Caiati et al., 2020; Feneri et al., 2020; Guidon et al., 2020; Ho et al., 2018, 2020a; Matyas and Kamargianni, 2019a; Mulley et al., 2020) and the increasing number of commercial trials (e.g., UbiGo, swa Augsburg, WHIM, zengo), basic research on how to design MaaS bundles is missing. The result is a growing bouquet of varieties of
stated choice experiments and commercial bundle designs (in terms of included modes, ‘metrics’ to measure the consumption of mobility services, and discount schemes). This clearly hampers comparative learning (and indeed informed design of subsequent studies) as it is unclear what the underlying design dimensions are and how to disentangle differences in design from differences in outcome. For example, some studies report a negative average willingness to pay for carsharing (e.g., Matyas and Kamargianni, 2019a) when included in a MaaS bundle while others report the opposite (e.g., Guidon et al., 2020; Ho et al., 2018). A natural question to ask is whether this difference in outcome originates in differences in bundle design.

We contribute to the evolving literature and practice on MaaS bundles in several ways. First, we conduct an extensive literature review on MaaS bundle design (Section 2) and synthesize existing academic and commercial MaaS bundle designs towards ten fundamental design dimensions (Section 3). These can be used by practitioners, academics and policy-makers to design future MaaS bundles of which we will likely see many in different parts of the world in the coming months and years. Second, we develop a framework to systematically compare stated choice studies on MaaS bundle design and disentangle differences in outcome from differences in bundle design by expanding the literature on Design of Designs (DoDs) (Hensher, 2004, 2006a, 2006b; Caussade et al., 2005) to include not only ‘statistical’ design dimensions (how many alternatives, attributes, levels) but also ‘behavioral’ (which attributes and levels in which configuration) (Section 4). While this relationship remains to be empirically tested, it already proves useful in several ways: (a) to systematically compare stated choice studies and develop hypotheses as to the origin of differences in outcome, and (b) to systematically identify research gaps and thus establish a research agenda for stated choice studies on MaaS bundle design. Importantly, the extension of the Design of Designs literature and the resulting framework is not limited to MaaS bundle design. It applies to any topic stated choice studies are being conducted upon and thus serves as a useful meta framework for research using stated choice studies in general.

2. Literature review

2.1. MaaS

Though the term MaaS is generally perceived as having been conceived only in 2014 (Heikkilä, 2014), Caiati et al. (2020) note that it was previously described (in the non-transportation literature) by Meurer (2001, p. 48) referring to carsharing and carpooling as “mobility as a service” “readily available as well as highly attractive for potential consumers”, resulting in a new conception of mobility where “ownership and use do not necessarily have to be one and the same”. While the term may have thus already been conceived in 2001, the concept of mobility integration across several dimensions and modes is much older. Mulley (2017) argues that ‘Mobility Management’ is one predecessor, with the US Department of Transportation (DoT) stating as early as 1991: “The Mobility Manager accomplishes its goals by linking together all travel modes – bus, taxi, vanpools, express bus, specialized services, carpools etc. at an informational level and, in most cases, at a transactional level as well” (US DoT, 1991, p. 16). Indeed, one could argue that public transportation organizations were predecessors of Mobility Management, integrating planning, booking and payment across various public transportation providers as early as 1965 in Germany. Further examples include the train service provider (NS) in the Netherlands, which has integrated access to carsharing, bike sharing and taxi into their smart card system, and London’s Oyster card integrating public transportation with carsharing (Caiati et al., 2020; Kamargianni et al., 2016). Technological progress arguably enabled the current excitement around MaaS, most importantly innovating the access to new and shared transportation modes, intermodal trip-planning, booking and payment through a single app.

MaaS has garnered substantial scholastic attention during the past five years (for an overview, see Hensher et al., 2020a) ranging from demand-side research on the willingness to pay for MaaS bundles (e.g., Guidon et al., 2020; Ho et al., 2018, 2020a; Matyas and Kamargianni, 2019a) and motivations to subscribe (Alonso-González et al., 2020; Schikofsky et al., 2020) to supply-side research on business models (Kamargianni and Matyas, 2017; Wong and Hensher, 2019; Polydoropoulou et al., 2020) and future bus contracts (Hensher, 2017) to governance (e.g., Cottrill, 2020; Doherty et al., 2017; Hirschhorn et al., 2019; Pangbourne et al., 2020; Smith et al., 2020). Recent contributions aim to structure the field by actors and levels of integration. Sochor et al. (2015) first identified the emerging actor MaaS broker, aggregating services offered by mobility providers to end users. Smith et al. (2018) further split the MaaS broker into (potentially) two separate actors: the MaaS integrator and the MaaS operator. More recently, several authors introduced MaaS topologies (Hensher et al., 2019; Lyons et al., 2019; Sochor et al., 2018) to clarify the levels of integration. These typically range from no to full integration (see Fig. 1). Bundling mobility services into plans is typically seen as the step proceeding the full integration of operation, information and transaction, though this sequence is not necessarily followed in practice.\footnote{1 The MaaS pilot in Augsburg, Germany, is an example where a MaaS bundle was introduced before the operational, informational and transactional integration (Reck and Axhausen, 2019).}

2.2. Bundling

Despite the recent excitement in the context of MaaS, bundling is not a new idea and originated in many literatures, notably
Marketing. Stremersch and Tellis (2002) provide a comprehensive synthesis of its origins and definitions which is helpful to reiterate to align terminology. They define bundling as “the sale of two or more separate products in one package” (p. 56) with the term product used for goods and services. They further define bundling focus and bundling form as two main dimensions to structure the field. Bundling focus refers to the level of integration of the products in the package with price bundling defined as a package without any integration and product bundling defined as a package with value-adding integration. Bundling form is divided into pure bundling (“the firm sells only the bundle and not (all) the products separately”) and mixed bundling (“the firm sells both the bundle and (all) the products separately”) (p. 57).

Bundling is pervasive in many areas of life, such as fixed-price menus, telecom packages, and personal computers (Stremersch and Tellis, 2002). Besides one-off transactions, they might take the form of subscriptions such as mobile phone plans (e.g., voice, data, SMS, music streaming services) or fitness studio access (e.g., equipment, courses, spa). In the field of transportation, bundling frequently occurs in the form of travel packages (e.g., flight, hotel, car-rental, excursions) and public transportation season tickets (e.g., bus, tram, train).

As the commercial goal behind bundling is revenue maximization, various tariff structures can be considered to exploit consumer preference heterogeneity. Caiati et al. (2020) suggest four typical tariff structures for subscriptions in reference to the literature on multipart pricing (Lambrecht et al., 2007; Iyengar et al., 2008; Köhler et al., 2014): pay per use, two part tariffs, three part tariffs and flat rates. While pay per use and flat rates are common in everyday life (PT: single tickets and season tickets), two part tariffs include a recurring fixed charge and a variable (often reduced) usage charge, and three part tariffs include an additional allowance. Two and three part tariffs are often used for pricing shared mobility services (e.g., carshare, bikeshare).

### 2.3. MaaS bundling

The new multitude and increasing integration of transportation modes has inspired the idea of mobility plans (i.e., packages/bundles of mobility services) or MaaS bundles. In Stremersch and Tellis’ (2002) framework they would be categorized as mixed bundles, as singular mobility services (e.g., carsharing, bikesharing) would typically continue to be sold separately, and somewhere

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2 There is also a large literature in economics and law. For the many situations where bundling is observed, the reason why separate goods are sold as a package is explained by economies of scope in production or by reductions in transactions and information costs, providing benefit to the seller, the buyer or both. This is the presumptive explanation for bundling when it occurs in highly competitive markets (for a review, see Kobayashi, 2005).

3 We use this term subsequently to remain consistent with the Marketing literature.
between product and price bundles depending on the degree of integration (cf. MaaS topologies). Interestingly, and in contrast to current MaaS topologies (cf. Fig. 1), we argue that MaaS bundles do not depend on prior integration, i.e. there can be sole price bundles (cf. Footnote 1). Fig. 2 integrates MaaS topologies into Stremersch and Tellis (2002) bundling framework.

Three particularities apply to MaaS bundling. First, MaaS brokers/aggregators (e.g., WHIM) that sell MaaS bundles might be different entities from the original (i.e., disaggregated) mobility service providers (e.g., Mobike, Lime). Second, MaaS bundles are typically offered as subscriptions, through which a customer would commit to buying a certain amount of different mobility services on a recurring basis (e.g., fortnightly or monthly). Third, while profit maximization through price discrimination appears to be the main rationale for bundling in the Marketing and Economics literature, sustainability (or societal benefits) is an important reason for bundling on a recurring basis (e.g., fortnightly or monthly).

The configuration of MaaS bundles has become a topic of interest for transportation researchers and practitioners due to their centrality in business plans. This can be attributed to the possibility of price discrimination (the ‘classic’ Marketing argument for bundling) and the ‘flat rate effect’ (i.e., some people prefer a subscription even though they would pay less under a pay-per-use scheme) (Axhausen et al., 1998; Lambrecht and Skiera, 2006; Train et al., 1991; Wirtz et al., 2015). Most peer-reviewed academic research on the configuration of MaaS bundles has thus-far focused on eliciting consumer preferences using stated choice surveys (e.g., Caiati et al., 2020; Feneri et al., 2020; Guidon et al., 2020; Ho et al., 2018, 2020a; Matyas and Kamargianni, 2019a; Mulley et al., 2020), while only few researchers have followed other methods such as relating city characteristics to bundle contents/levels (Esztér-gár-Kiss and Kérényi, 2020) and (directly) relating current mobility costs to willingness to pay for MaaS bundles using linear regression analysis (Liljamo et al., 2020). In the following, we focus on studies implementing stated choice surveys and discrete choice modeling to explore consumer preferences and latent demand for MaaS bundles. Methodologically, most authors of these studies used surveys to present varying bundle configurations to participants and subsequently modeled the willingness to subscribe or the willingness to pay for bundles as a whole and individual components. Fig. 3 shows an example from a study recently conducted by the authors (Ho et al., 2020a).

In the following Section 2.3.1, we provide an overview of the main academic studies following a stated choice approach with a particular focus on MaaS bundle designs, relevant demand-side factors and overall study outcome, before briefly introducing existing commercially offered MaaS bundles Section 2.3.2. The heterogeneity of MaaS bundle designs employed in research and practice motivates a synthesis, which we introduce in Section 2.3.3, develop and expand into a framework for future research in the remainder of this paper.

2.3.1. Peer-reviewed academic studies following a stated choice approach

Ho et al. (2018) and Matyas and Kamargianni (2019a) were among the first to highlight and analyze the research gap on consumer preferences for MaaS bundles in the peer-reviewed academic literature. Ho et al. (2018) conducted a stated choice survey in Sydney, Australia, to analyze the potential uptake of MaaS plans and the willingness to pay for its components. In a design similar to their later study (cf. Fig. 3), they asked participants to choose between four options: their current travel record (as by participants prior questions), two MaaS bundles (‘Plan A/B’) and a ‘Pay-As-You-Go Plan’. MaaS bundles were structured by mode (PT, round-trip/one-way carshare, taxi, Uber Pool) with mode-specific attribute levels pivoted around participant’s current travel record. For example: a participant who specified 4 days of PT use in the past fortnight would see plans with 4, 6 or 8 days of unlimited public transportation included, while a participant who specified 8 days would see plans with 8, 10 or 12 days of unlimited public transportation included. Each bundle also included carshare (specified in allowance by hour, advance booking time and hourly rate beyond the allowance) and % discounts for every taxi and Uber Pool trip. Additionally, they tested a roll-over option for unused credit. Overall, the authors concluded that almost half of all participants would take up a MaaS bundle, while uptake varied substantially across the population and was correlated with current mobility tool usage (pattern of product demand). Bundles were most attractive to infrequent car users and least to car non-users, while discounts for taxi and ride-hailing only appealed to regular taxi/Uber users.

Matyas and Kamargianni (2019a) conducted a stated preference survey in Greater London, UK. They asked participants to choose among 3 MaaS bundles that were structured around 4 modes: public transportation, bikeshare, carshare and taxi. Additionally, they allowed customers to create their own bundle (Matyas and Kamargianni, 2019b). In contrast to Ho et al. (2018), public transportation...
levels were: none/unlimited bus/unlimited usage of all PT modes in ‘your zone’. Bikeshare levels were: none/unlimited access + 30 min use while carshare and taxi levels were pivoted around current usage (carshare in hours and days, taxi in miles). Interestingly, the authors also included extra features such as dinner and food delivery vouchers. Estimating a mixed MNL model, the authors found negative coefficients for shared modes besides PT (carshare, bikeshare, taxi), implying that respondents do not prefer any of these shared modes in their MaaS plans. Interestingly, −38% of all respondents would have still considered buying a MaaS plan, however, the authors note that this could be due to the hypothetical nature of the experiment. In their successive work, Matyas and Kamargianni (2019b, 2020) found a strong correlation between currently used modes and stated preferences (as did Ho et al., 2018) hypothesizing the reason to be habit persistence, as well as between bundle uptake and socio-demographics (i.e., age, occupation, income, education). The latter finding was confirmed and extended by Alonso-Gonzalez et al. (2020), who identified five latent clusters in attitudes and socio-demographics towards MaaS.

Guidon et al. (2020) conducted a discrete choice experiment in Zurich, Switzerland, to analyze the valuation of components in MaaS bundles vs stand-alone. Participants were shown several choice situations for individual services and service bundles. Once again, the bundles were structured around modes as attributes including public transportation (monthly ticket with varying geographical coverage), carshare (varying kilometers included), bikeshare (varying hours included), e-bikeshare (varying hours included) and taxi (varying minutes included). Additionally, the authors investigate park and ride (varying days included). The authors find a higher willingness to pay for public transportation and carshare, and a lower willingness to pay for bikeshare (normal and e-bike) and taxi in a bundle when compared to stand-alone services, suggesting that customers only prefer certain shared modes (carshare) in their plans. This finding resonates with the correlation between currently used modes and stated preferences found by Ho et al. (2018) and Matyas and Kamargianni (2019a). However, it stands in contrast with the overall negative evaluation of carshare in a bundle in London (Matyas and Kamargianni, 2019a). One can only speculate about the reasons, which may be due to regional or methodological differences in eliciting and analyzing customer preferences.

Ho et al. (2020a) later conducted a second stated choice survey in Tyneside, UK, to analyze differences and similarities in demand for MaaS bundles between the UK and Australia. Bundles were again structured around modes as attributes including public transportation (varying number of days with unlimited travel), round-trip/one-way carshare (varying allowance in hours, advance booking time and hourly rate beyond the allowance), taxi (varying % discount) and bikeshare (varying allowance in hours and rate beyond the allowance). The results of this study confirm the previous hypothesis of a strong correlation between current mobility use and potential bundle uptake, and further suggest that while participants value the convenience of MaaS apps, they are not (yet) prepared to pay for it as the willingness to pay for most modes in the bundle is below the market price and the pay-as-you-go plan exhibits a negative coefficient. This finding contrasts Guidon et al. (2020), who estimate a high and positive willingness to pay (between 104 and 127 CHF) for an integrated smartphone app and a higher willingness to pay for carshare, public transportation and park and ride in bundles vs stand-alone. Again, to-date we can only speculate about the reasons for this difference.

Caiati et al. (2020) pursued a different approach to investigate latent demand for MaaS bundles. While previous studies presented participants (variations of) predefined bundles, Caiati et al. (2020) allowed participants to design their own bundles from previously defined elements, thus following a ‘portfolio choice’ approach (Wiley and Timmermans, 2009). Participants could design their own bundles from a large variety of transport modes (PT, e-bikeshare, e-carshare, taxi, car rental, rideshare, on demand bus), pricing schemes (from pay-as-you-go to pay-as-you-go with discounts, allowances of different sizes up to flat rates), geographical scope.

\[ \text{Methodologically, threshold prices can be tested using methods detailed in Swait (2001) and Hensher and Rose (2012).} \]
(regional, national) and extra features (service level guarantees such as maximum wait time, maximum pre-book time, and additional information and payment integration services such as real time notifications, app synchronization with personal agenda, parking payment, mobility tracker with CO2/kcal information). Overall, estimation results indicate that the price of the monthly subscription and social influence variables have a strong effect on bundle uptake. In line with previous studies, PT appears to be the most preferred transportation mode, while preference for other modes depends on socio-demographic profiles and transport-related characteristics. Interestingly, this study further reveals that the design of discount schemes may have an influence on uptake. For example, while an allowance of 120 min e-carshare has a positive estimated coefficient (0.17), pay per use with a 20% discount on the standard fare has a negative estimated coefficient (−0.10). Similar effects can be observed for most other modes. This finding motivates a hypothesis explored later in this paper that expresses a possible relationship between the behavioral design (e.g., design of discount schemes) of a MaaS bundle, and outcome (e.g., in terms of willingness to pay or direct utility).

Mulley et al. (2020) also pursued a different approach from the previous papers in that they investigate whether MaaS in Australian community transport (CT) can provide a sustainable future, whereas most previous papers focused on younger generations in major cities. Specifically, they surveyed CT clients from five major providers in New South Wales and Queensland employing a stated choice experiment. Given the CT context of this study, MaaS bundles were structured differently (by common trip purpose) than in previous studies, thus comprising ‘shopping bus’, ‘social outings’, ‘medical transport’ and ‘emergency taxi service’. Attribute levels were ‘number of trips included in the bundle’ and pivoted around current usage of modes (i.e., participants were grouped into three groups, ‘frail’, ‘active’ and ‘mobile’ based on their responses). Overall bundle discounts varied between 0% and 20% of the added value of individual trips. The results of this study suggest that shifting the funding from CT operators to CT clients might pose a challenge for CT providers as willingness to pay estimates for each trip type were lower than CT providers’ unit costs.

Finally, Feneri et al. (2020) conducted a stated adaptation experiment in Rotterdam, Amsterdam, and Utrecht in the Netherlands. While previous studies focused on exploring consumer preferences in and willingness to pay for potential bundles, Feneri et al. (2020) investigated the intended behavioral change (of transportation mode) as a result of subscribing to a MaaS bundle. While studies with revealed preference data from the Sydney MaaS trial are on their way (Hensher et al., 2020b; Ho et al., 2020b), this study builds some first hypotheses, complementing previous evidence from the UbiGo trial in Sweden (Sochor et al., 2015; Strömberg et al., 2018). Participants were presented four MaaS bundles to choose from, which were structured around modes (PT, carshare, e-bikeshare, taxi). Levels for public transportation ranged from pay-as-you-go to 20/40% discount to flat rate, for carshare/taxi from pay-as-you-go to 10/20/30% discount, and for e-bikeshare between 75% discount and free usage. The authors then asked the participants how their mode of transportation would have changed imagining they had subscribed to a bundle. Results indicate that a combination of monthly fees and discounts for the different modes primarily influences the increase/decrease of each mode under the influence of a bundle.

2.3.2. Commercially available MaaS bundles

We identify four main providers of commercially available MaaS bundles: Whim (by far the largest and only international provider, now (as of May 2020) offering MaaS bundles in Finland and the Netherlands, pay-as-you-go in the UK and Austria, and rolling out in Japan and Singapore), UbiGo (Sweden), Stadtwerke Augsburg (Germany) and zengo (Switzerland).

UbiGo arguably has been one of the first providers to offer MaaS bundles in Gothenburg as early as 2013. Relaunched in Stockholm in 2019, they employ an innovative approach by offering their customers to customize bundles every month and targeting households instead of individuals (i.e., bundle allowances can be shared among all members of a household). Public transport day tickets can be

Fig. 3. Exemplary stated choice experiment (Ho et al., 2020a).
purchased in bulks of 10 (i.e., 10, 20, 30, 40) discounting price with increased quantity, carpool can be purchased in hours (i.e., 3, 6, 12, 18, 24, 30), again discounting price as purchase quantity increases, and car rental/taxis are charged per use.

Whim offers a variety of MaaS bundles depending on local availability. It first launched in Helsinki (Finland), where they continue to offer three MaaS bundles and a pay-as-you-go plan (as of 1 May 2020). Bundles, as in most academic studies, are structured around modes and include 1 to 3 levels ('Whim Urban 30' currently priced at ~60€ per month, 'Whim Weekend' priced at ~250€, and 'Whim Unlimited' priced at ~500€). Public transport is included either as a '30-day ticket' or as 'unlimited single tickets' (which can presumably be shared). Bikeshare rides are included up to a maximum duration of 30 min. Taxis show a wide variety of schemes, ranging from an allowance of 4 × 10€ (max. 5 km rides) to a flat discount of 15% on all rides to a flat rate. Car rentals also show a wide variety of schemes, ranging from a flat fee of 49€/day to free car rentals on weekends or flat rates for every day. Since very recently, e-scooters can be booked through the Whim app, however regular prices apply. Antwerp (Netherlands) is the only other market, where Whim offers a bundle to date, which is constituted of a monthly PT ticket for trams and buses, unlimited bikeshare, a cap on taxi trips up to 5 km of 10€ and a flat fee for car rental of 49€/day.

Stadtwerke Augsburg offer two MaaS bundles in the city of Augsburg (Germany). Both are structured around modes and include a monthly PT ticket (for unlimited trips in buses and trams), unlimited bikeshare trips up to 30 min, and a varying allowance of carshare (15 h/150 km for the smaller bundle priced at ~80€, 30 h/unlimited km for the larger bundle priced at ~110€).

Finally, zengo offers 3 MaaS bundles in the city of Geneva and Lausanne (Switzerland). Interestingly, they follow yet another operating model. While each bundle consists of a public transportation season ticket, the bundles contain a varying number of tokens ('jetons') (1 for their smallest bundle priced at 96 CHF per month, 2 for the medium bundle priced at 126 CHF and 4 for the largest bundle priced at 186 CHF), which can each be used for a taxi trip within the geographical scope of the city’s public transportation network, 12 h of car rental, or a 4 test month membership of the local carshare provider. In Lausanne, customers are additionally allowed to use bikeshare up to 30 mins (e-bikeshare up to 15 mins) for free.

2.3.3. Research gaps and motivation for the remainder of this paper

Our overview of academic stated choice studies investigating consumer preferences and latent demand for MaaS bundles (2.3.1.) and of commercially available MaaS bundles (2.3.2.) gives a first impression of the different ways MaaS bundles can be designed, and along which dimensions they can be varied. Without doubt, our stock-taking may also overwhelm interested readers, prompting to synthesize the main dimensions of variation. And indeed, this is one of the premier motivations for writing this paper and our first goal for the remainder of this paper (Section 3).

This synthesis further enables us to conduct a first systematic comparison of existing studies on MaaS bundle design. This is particularly useful to identify reasons for the partially contradictory outcomes of previous studies. For example, Guidon et al. (2020) find a positive willingness to pay for carshare in bundles (even higher then when offered as a stand-alone product), whereas Matyas and Kamargianni (2019a) find negative coefficients for carshare in their bundles. Another example is the willingness to pay for an integrated smartphone app, which is highly positive in one study (Guidon et al., 2020), and negative in another (Ho et al., 2020a). While differences might be due to location or methodological differences in data elicitation and analysis, could they also be due to more subtle differences in bundles design? One example is the ‘metric’ used to measure the ‘consumption’ of mobility services and the mobility allowance (‘budget’, cf. Hensher, 2017). While Guidon et al. (2020) use a distance-based metric (number of km) to define the allowance of carshare trips, Matyas and Kamargianni (2019a) use a time-based metric (number of hours), while others used trip-based metrics (number of trips). While our hypothesis of a relationship between the design dimensions of a MaaS bundle in a stated choice study and study outcome (e.g., willingness to pay) remains to be tested empirically, a recent study by Caiati et al. (2020) (summary see above) suggests such a relationship.

In Section 4, we explore this conceptual link between study design and study outcome by extending the Design of Designs literature (Hensher, 2004, 2006a, 2006b; Caussade et al., 2005) to consider not only statistical design dimensions, but also behavioral design dimensions. This conceptual extension enables us to conduct a systematic comparison of existing studies along statistical and behavioral design dimensions – a first approach to disentangle differences in design from differences in outcome. Second, and perhaps equally important, our comparison systematically identifies research gaps and thus serves as a framework for future research on MaaS bundle design.

3. Synthesizing the main design dimensions for MaaS bundles

Our synthesis of existing stated choice studies (cf. 2.3.1.) and commercial trials (cf. 2.3.2.) yields ten design dimensions along which MaaS bundles systematically vary (in their entity, we call them a first ‘master design’ for MaaS bundles). In the following, we first introduce each dimension in a practical way providing suggestions and lessons learnt from three projects the authors are involved in (3.1. and 3.2.). We then present an overview of how bundle designs from stated choice studies and commercial trials can be mapped and compared along these dimensions (3.3.).

In principle, we distinguish between necessary design dimensions and complementary design dimensions (cf. Table 1). Necessary design dimensions are those that form the essential core of a MaaS bundle (i.e., without defining these, it would be incomplete). They comprise modes, metrics (i.e., the measurement unit used to define the entitlement to each mobility service), the area of validity of the bundle (‘geography’), the market segment to offer the bundle to (i.e., individuals, households or any other chosen grouping) and the subscription cycle (i.e., weekly, fortnightly, monthly). Complementary design dimensions can, but do not necessarily have to, be defined. They comprise the incentive structure, caps to the subsidized use of modes, non-transportation add-ons, whether a bundle is customizable and roll-over options for unused budget.
3.1. Necessary design dimensions

Choosing which modes to include in a bundle involves clarity on a number of questions beyond availability. Common choices include public transportation, carshare, (e-)bikeshare, ridehail, taxi and car rental. Emerging modes such as shared e-scooters have not yet been part of stated choice studies on MaaS bundles or commercial trials. While the inclusion of more modes (and providers) on a pay-per-use scheme arguably increases the value of integration, willingness to pay for the overall MaaS bundle might decrease with more modes included (especially where modes are of little or no interest). Guidon et al. (2020) found that the willingness to pay in Zurich was higher for public transportation and carsharing in bundles than for stand-alone services, while the opposite was true for (e-) bikesharing and taxis. Depending on the desired degree of integration, including more modes might substantially increase the development costs of the software backend due to the complexity of each individual application programming interface (API), as well as increase the complexity of commercial negotiations with mobility service providers due to the competition of potentially multiple providers of the same mode. Indeed, we currently have limited information on how individuals might process the model offerings, with the risk that some modes might not be of interest but their presence causes concern about the value of the subscription fee (‘why pay for something I will not use’).

After deciding which modes to include, one has to decide how. This is a question of ‘metrics’ (i.e., the way in which a mobility budget/entitlement to each mode is measured). Metrics can be time-based (minutes, hours, days), distance-based (kilometers, miles), trip-based (number of trips), combinations of these (i.e., a cost per minute plus a trip-based fee to unlock a shared e-scooter) or simply flat rates (note that flat rates might be constrained using caps). Different metrics have different advantages, need to be considered together with caps and discounts and should be chosen in alignment with the overall objective for offering the MaaS bundle (i.e., profit maximization, sustainability, customer retention). As time-based or distance-based metrics measure the amount of consumption, they are generally more suitable to modes that incur higher marginal costs of production (e.g., taxi, ridehailing, car rental, carsharing). Flat rates are more suitable for other modes such as bikesharing or public transportation and are particularly useful to encourage sustainable changes in travel behavior as marginal (monetary) costs of use drop to 0. Trip-based metrics can be used in conjunction with caps to nudge customers to try new modes (e.g., by allowing few heavily subsidized rides for specific modes). Finally, choosing similar metrics for multiple modes allows caps to be shared (i.e., a certain number of minutes to be used both for shared e-scooters and bikesharing).

The area of validity (geography) is usually bounded to the service areas of the different operators within a single city. However, expanding this area to multiple cities or even a whole country (always bounded by each operator’s service area, of course) adds value for long-distance commuters and travelers – arguably one main use-case for shared transportation modes – and levels the service area of the MaaS bundle with the service areas of individual operators which often operate in multiple cities anyways.

The market segment the bundle is designed for can be individuals (e.g., residents, commuters, tourists, senior citizens), households or any other grouping (e.g., employee groups). Offering bundles to households (and offering members to share allowances) might be a way to decrease monthly variability of demand for certain modes with high marginal costs (e.g., carsharing, car rental) and thus increase the willingness to subscribe (Reck and Axhausen, 2020). Also, if reducing car use/ownership is an objective, households might be the right market segment as cars often serve multiple members of a household. Yet, this might be difficult to implement as certain operators restrain simultaneous rentals of vehicles (e.g., bikesharing or e-scooters) or impose age restrictions (e.g., carsharing). Employees can be another target group for corporations aiming to subsidize more sustainable transportation compared to conventional car lease arrangements. Finally, travel packages are most established in tourism, where, for example, multi-day public transport passes
| Study | Necessary design dimensions | Complementary design dimensions | Customizability | Roll-over option |
|-------|-----------------------------|--------------------------------|----------------|-----------------|
|        | **Modes** | **Metrics** | **Geography** | **Market segment** | **Subscription cycle** | **Discounts** | **Caps** | **Add-ons** | **Service levels guarantees, additional information and payment integration services** |
|        | **and** | **Subscription cycle** | **Discounts** | **Roll-over option** |
| **Academic studies** | | | | |
| Caiati et al. (2020) | PT | trips/flat rate, hours, minutes, km | Regional (Amstermad/Eindhoven) or national | Individual | Month | Subscription fee + optional per trip (%) discounts | no | no | no | yes | no |
| Feneri et al. (2020) | PT | trips/flat rate, trips, hours, minutes | Rotterdam, Amsterdam, Utrecht | individual | month | subscription fee + varying per trip (%) discounts | no | no | no | no |
| Guidon et al. (2020) | PT | NA (flat rate), km, hours, minutes | Zurich | individual | month | subscription fee | yes | no | no |
| Ho et al. (2018) | PT | Carshare, Taxi, e-Bikeshare | Sydney | individual | fortnight | subscription fee | yes | no | no | yes |
| Ho et al. (2020a,b) | PT | Carshare, Taxi, Uber | Tyneside | individual | month | subscription fee per trip (%) | yes | no | no | yes |
| Matyas and Kamargianni (2019a) | PT | Taxi, Carshare, Bikeashare | London | individual | month | subscription fee | yes | no | no | yes |
| Mulley et al. (2020) | Shopping bus, Social outings, Medical transport, Emergency taxi service | Trips | New South Wales, Queensland | individual | month | subscription fee | yes | no | no |
| **Commercial trials & products** | WHIM | PT | Helsinki | individual | 30 days | subscription fee | no | no | no | no | no |

(continued on next page)
| Study   | Modes       | Metrics               | Geography    | Market segment | Subscription cycle | Discounts     | Caps   | Add-ons | Customizability | Roll-over option |
|---------|-------------|-----------------------|--------------|----------------|--------------------|---------------|--------|---------|-----------------|-------------------|
| Mobil Flat | Rental car  | days\(^4\) km         | Augsburg     | individual     | month              | pre trip (%/€\(^3\)) | no     | yes     | no              | no                |
|          | Taxi PT     |                       |              |                |                    | subscription fee | no     | no      | no              | no                |
|          | Bikeshare   |                       |              |                |                    | (no)\(^2\)     | yes     | no      | yes             | yes               |
|          | Carshare PT |                       |              |                |                    | volume and flexibility\(^5\) | no     | yes     | yes             | yes               |
|          | Carshare    |                       | Stockholm    | household       | month              | none          | yes     | no      | no              | ?                 |
|          | Carshare    |                       |              |                |                    | subscription fee | no     | no      | no              | ?                 |
| zengo    | PT          |                       | Geneva       | individual     | month              | none          | yes     | no      | no              | ?                 |
|          | Carshare    |                       |              |                |                    | (token)       | yes     | no      | no              | ?                 |
|          | Carshare    | membership hours      |              |                |                    |               |         |         |                 |                   |
|          | Taxi PT     |                       |              |                |                    |               |         |         |                 |                   |
|          | Carshare    | membership hours trips |              |                |                    |               |         |         |                 |                   |
|          | Carshare    |                       |              |                |                    |               |         |         |                 |                   |

\(^1\)Caliati et al. (2020) conducted a portfolio-choice experiment with various metrics per mode, offering pay per ride and trip-based discounts next to mode-specific metrics, discounts & caps.

\(^2\)Unlimited up to 30 min/1 h.

\(^3\)Whim Urban 30: 10€ max charge, Whim Weekend: 15% discount.

\(^4\)Whim Urban 30: 49€/day, Whim Weekend: free on weekends, Whim Unlimited: flat rate.

\(^5\)Discount for higher purchased volumes but additional price for flexibility (PT day passes vs individuum-bound monthly tickets).
are often combined with entries to museums.

Last but not least, the subscription cycle (e.g., weekly, fortnightly, monthly) has to be decided upon. Local customs arguably are most important here and cycles can be by calendar or rolling.

3.2. Complementary design dimensions

Discounts can be trip-based or budget-based. Trip-based discounts can be differentiated by mode and range from percentage-based discounts (i.e., 20% off each trip) to absolute discounts (i.e., $5 off each trip) and maximum charges per trip (i.e., $15). Absolute discounts per trip favor short rides. Budget-based discounts are more general and can be implemented through a subscription fee or a ‘mobility wallet’ (i.e., top up $50, pay $45). The choice of the discounts is deeply intertwined with their overall goal, i.e., if more sustainable travel is desired, higher discounts should be given to more sustainable modes. At the same time, discounts on less sustainable modes (in the short-term) may have more potential to replace private car trips (i.e., taxi, ridehailing, car rental, carsharing) and thus encourage less car ownership in the long-term, although this has to be carefully considered if it risks in the long term reducing public transport use and add car-based kilometers to the system. The design of discounts can, but does not need to be, decoupled from their source of funding. Funding sources depend on the overall business model of the MaaS broker (see Hensher et al., 2020a, Chapter 8 for details) and can stem from government subsidies for reduced emissions (‘reversed emission taxing’) and car ownership or bulk contracts between the MaaS broker and the mobility service providers. Corporations can be another sponsor if they are willing to expend for providing greener mobility options for their employees. Finally, individual customers can play a role by spending more than they would under a pay-per-use regime due to the flat rate bias.

Discounts are closely related to caps (also referred to as budgets). Caps depend on the metric used to measure the consumption of each mode and thus also vary from trip-base (i.e., 10 free trips) to time-based (i.e., 30 included hours of carsharing) and distance-based (i.e., 300 included kms of carsharing). Flat rates can also be capped (i.e., commonly bikeshare flat rates only include unlimited rides up to 30 min). Caps are handy to calculate subscription fees (i.e., the fee a user pays to receive the discounts) and limit expenses of the MaaS broker. As such, they are often applied to modes where the marginal cost of production is relatively high (e.g., taxi, ridehailing, car rental, carsharing). Including a number of free carsharing/ridehailing/taxi trips might also encourage customers to try out new modes (some potentially being alternatives to the private car) and thus contribute to long-term sustainability objectives should they be important in the overall design.

MaaS bundles can be complemented with various add-ons. Different add-ons appeal to different customers, might be more or less related to the main purpose of the bundle (passenger transportation) and might depend on local customs. In Japan for example, rail tickets are often bundled with vouchers for restaurants, supermarkets or accommodation. Matyas and Kamargianni (2019a) have analyzed add-ons such as a dinner or food delivery vouchers in the UK (which, however, turned out to be insignificant regressors for bundle uptake in their models). Guidon et al. (2020) included parking (park-and-ride) in their study in Switzerland, which turned out to be significant for bundle uptake and customers exhibited a higher willingness to pay (on average) for park and ride in bundles than

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Note that some countries require MaaS brokers to hold a bank license to store credit. Conversion to tokens can be a potential way to circumvent this.
as a stand-alone service. Caiati et al. (2020) include service level guarantees (e.g., maximum pick-up time for taxis) and additional payment and information integration services in their add-ons.

Bundles can be fixed or customizable. The latter requires more sophisticated software front-ends but allows customers to co-create their own bundle based on their needs. A customization option can be one-off or recurring (every subscription cycle). Budgets can further include a roll-over option which automatically transfers unused credit to the subsequent cycle. This is preferable from a customer perspective but reduces profit for the MaaS provider all else held constant.

### Table 3
Systematic comparison of MaaS bundle design study designs and outcomes focusing on carshare.

| Statistical design | Guidon et al. (2020) | Ho et al. (2018) | Ho et al. (2020) | Matyas and Kamargianni (2019a) | Caiati et al. (2020) |
|--------------------|----------------------|-----------------|-----------------|-------------------------------|---------------------|
| Choice sets        | 18                   | 12              | 12              | 4                             | 8                   |
| Alternatives       | 2                    | 3               | 3               | 3                             | 2                   |
| Attributes per choice set | 8           | 6               | 6               | 6                             | 14                  |
| Levels per alternative | 2           | 6               | 6               | 6                             | 4                   |

| Experimental design | | | | | |
|--------------------|-----------------|-----------------|-----------------|-------------------------------|---------------------|
| Modes              | carshare        | carshare        | carshare        | carshare                      | carshare            |
| Metrics            | km               | hours           | hours           | hours                         | min / pay per ride  |
| Geography          | Zurich           | Sydney          | Tyneside        | London                        | Amsterdam            |
| Market segment     | individual       | individual      | individual      | individual                    | individual          |
| Subscription cycle | month            | month           | month           | month                         | month               |
| Discounts          | overall subscription fee | overall subscription fee | overall subscription fee | overall subscription fee | overall subscription fee |
| Cap                | yes              | yes             | yes             | yes                           | yes                 |
| Add-ons            | park and ride    | no              | no              | various (see Table 2)         | various (see Table 2) |
| Customizability    | no               | no              | no              | yes                           | yes                 |
| Roll-over option   | no               | yes             | yes             | no                            | no                  |

| Data elicitation and modeling | | | | | |
|-------------------------------|-----------------|-----------------|-----------------|-------------------------------|---------------------|
| Data elicitation             | Sample size     | 998             | 252             | 290                           | 1,068               |
| Choice observations          | 17,879          | 1,260           | 1,450           | 3,769                         | 8,624               |
| Choice scenario design       | D-optimal design | Pivot design   | Pivot design | Random design               | Orthogonal fractional factorial design |
| Modeling Type                | Mixed MNL       | Heteroscedastic non-linear random parameter MNL | Mixed MNL | Mixed MNL |

| Co-efficients | | | | | |
| Carshare (one-way) | 1h | 0.464*** | 0.01*** |
| Carshare (round-trip) | 1h | 0.411*** | 0.379*** |
| Day                | -0.437*** | 0.03 |
| 2h                 | 0.17***      |
| 1h                 | -0.022***   |

| Outcome | | | | | |
| WTP     | | | | | |
| Carshare (one-way) | day | £ 36.96 |
| Carshare (round-trip) | day | AUD 63.85 | £ 30.24 |
| AUD 6.39 | £ 4.32 |

*** p < 0.01, ** p < 0.05, * p < 0.1.
3.3. Mapping and comparing bundle designs along design dimensions

Table 2 maps existing MaaS bundle designs from peer-reviewed academic stated choice studies (2.3.1.) and commercial trials (2.3.2.) to the ten design dimensions introduced previously. It is intended as a summary and synthesis of the previous two sections. As all elements (academic studies, commercial trials and design dimensions) have been introduced in detail, Table 2 is thus not further described here.

4. Disentangling differences in design from differences in outcome

Reviewing the literature on stated choice studies exploring consumer preferences for MaaS bundles (Section 2.3.1), we noted that outcomes are partially contradictory. For example, Guidon et al. (2020) find a positive willingness to pay for carshare in bundles, whereas Matyas and Kamargianni (2019) find negative coefficients for carshare in their bundles. Another example is the willingness to pay for an integrated smartphone app, which is highly positive in one study (Guidon et al., 2020), and negative in another (Ho et al., 2020a). While differences might be due to location or methodological differences in data elicitation and analysis, could they also be due to more subtle differences in bundles design? One example is the ‘metric’ used to measure the ‘consumption’ of mobility services and the mobility allowance (‘budget’, cf. Hensher, 2017). While Guidon et al. (2020) use a distance-based metric (number of km) to define the allowance of carshare trips, Matyas and Kamargianni (2019) use a time-based metric (number of hours), while others used trip-based metrics (number of trips). While our hypothesis of a relationship between the design dimensions of a MaaS bundle in a stated choice study and study outcome (e.g., willingness to pay) remains to be tested empirically, a recent study by Caiati et al. (2020) suggests such a relationship.

4.1. Exploring the conceptual link between design and outcome

Hensher (2004) asked a similar question in a different context in his seminal paper titled: “Identifying the Influence of Stated Choice Design Dimensionality on Willingness to Pay for Travel Time Savings”. He conducted a stated choice experiment in which only design dimensions (i.e., number of choice sets, number of alternatives in each choice set, number of attributes per alternative, number of levels of each attribute and range of attribute levels) - in their entirety of combinations referred to as the Design of Designs (or then ‘master design’) - were systematically varied. Subsequently, he estimated a mixed logit model in which design dimensions were interacted with the attribute parameters to explore differences in willingness to pay for travel time savings. He found that design dimensionality does indeed influence variations in willingness to pay for respondents in Sydney (Hensher, 2004, 2006a, 2006b). Caussade et al. (2005) later used Hensher’s (2004) design for a repeat study in Santiago de Chile. They estimated a heteroskedastic logit model with the scale parameter specified as a function of design dimensionality. Their results showed that all design dimensions affect choice variance (and consistency), yet no systematic effects on willingness to pay estimates were found.

The ‘Design of Designs’ stream of research helps to differentiate between and examine the impact of what we call ‘statistical design dimensions’. Identifying the impact of statistical design dimensionality on choices and ultimate study outcome (here: willingness to pay) clearly contributes to disentangling differences in design from differences in outcome. Yet, we argue that this picture is incomplete. Not only the number of choice situations, alternatives, attributes and levels, but also their selection (i.e., which attributes and levels) could impact study outcome.

4.1.1. Introducing behavioral design dimensions

Extending the Design of Designs literature on statistical design dimensions (number of choice situations, alternatives, attributes and levels), we introduce the concept of behavioral design dimensions (selection of attributes, levels and metrics by which attribute levels are measured) to describe sources of differences in the design of stated choice experiments comprehensively. While it is obvious that different attributes and levels should be chosen for different areas of application of stated choice experiments (i.e., transportation mode choice vs mobile phone contract choice), it is less obvious why different attributes, levels and metrics are chosen for stated choice experiments within a certain area of application (if testing them is not the specific motivation for the study, of course).

Consider our example of MaaS bundles. Several authors have conducted stated choice studies to examine the willingness to pay for MaaS bundles as a whole and each component individually. Despite this very same area of application and study objectives, the attributes, levels and metrics chosen to define the bundles vary substantially (cf. Table 2). While all studies display the modes that are included in each bundle, the price for each bundle and the subscription cycle, some include additional attributes such as roll-over options or customizability. The greatest variance, however, lies in ways in which the budget is measured (‘metric’ – see example above). In general, attributes (e.g., modes, price, roll-over option, customizability), metrics (time-based, trip-based, distance-based) and levels for each attribute (e.g., range of modes and prices) vary in the design of stated choice experiments.

Some amount of variation of these behavioral design dimensions from one study to the next is preferable to learn about their (relative) influence. However, we argue that varying too many statistical design dimensions simultaneously compromises comparability amongst studies, especially if the context of the study (e.g., geographical, environmental and institutional settings) is also varied. This is due to multiple confounding effects.

An example in our area of application is the preference of consumers for shared modes in MaaS bundles. Guidon et al. (2020) find a positive willingness to pay for carshare in bundles, whereas Matyas and Kamargianni (2019a) find negative coefficients for carshare in their bundles. Another example is the willingness to pay for an integrated smartphone app, which is highly positive in one study (Guidon et al., 2020), and negative in another (Ho et al., 2020a). Due to many differences in study design (and indeed a missing
overarching framework to even compare the design of MaaS bundles before this paper), to date it remains unclear what the influence of specific design variations on outcome is, how to compare these studies systematically and how to design new studies with ‘informed’ variations.

4.1.2. Towards a holistic Design of Designs

It is here that the potential of a holistic Design of Designs, comprising both statistical and behavioral design dimensions, becomes apparent. In their entirety, the statistical and behavioral design dimensions (‘master designs’) describe all potential structural variation in experimental designs. Thus, they define a grid in which researchers can systematically compare stated choice studies, identify empirical research gaps and design new experiments accordingly (Fig. 4). If subsequent contextual variation (e.g., attribute ranges and values, place, sampling) and modeling methods are comparable (note that aspects such as respondent socio-demographics, the recruitment process, and the framing of MaaS can have a substantial impact on the results), this is a structured way to describe and disentangle differences in design from differences in outcome.

4.2. Application to MaaS bundle design

In the outset of this section, we identified partially contradictory findings of several studies with respect to preferences regarding carshare in a bundle. We can now use the analysis scheme described above (Fig. 4) to systematically compare studies to develop

Table 4
Systematic comparison of MaaS bundle design study designs to identify research gaps.

|                | Guidon et al. (2020) | Ho et al. (2018) | Ho et al. (2020) | Matyas and Kamargianni (2018) | Caati et al. (2020) | Feneri et al. (2020) | Mulley et al. (2020) |
|----------------|----------------------|-----------------|-----------------|-----------------------------|---------------------|---------------------|---------------------|
| **PT**        | X                    | X               | X               | X                           | X                   | X                   | NA / different     |
| **Carshare**  |                      |                 |                 |                             |                     |                     | structure (by     |
| **Bikeshare** |                      |                 |                 |                             |                     |                     | trip purpose)      |
| **e-Bikeshare** |                    |                 |                 |                             |                     |                     |                     |
| **Modes**     |                      |                 |                 |                             |                     |                     |                     |
| **Taxi**      | X                    | X               | X               | X                           | X                   | X                   |                     |
| **Ridehail**  |                      |                 |                 |                             |                     |                     |                     |
| **Car rental**|                      |                 |                 |                             |                     |                     |                     |
| **On demand bus** |                |                 |                 |                             |                     |                     |                     |
| **e-Scooter** |                      |                 |                 |                             |                     |                     |                     |
| **Metrics**   |                      |                 |                 |                             |                     |                     |                     |
| **Distance-based** |              |                 |                 |                             |                     |                     | mode-specific (cf. Table 2) |
| **Trip-based** |                      |                 |                 |                             |                     |                     |                     |
| **Flat rate** |                      |                 |                 |                             |                     |                     |                     |
| **Geography** |                      |                 |                 |                             |                     |                     |                     |
| **Single city** |                    |                 |                 |                             |                     |                     | X                   |
| **Multiple cities** |                |                 |                 |                             |                     |                     | X                   |
| **Market segment** |              |                 |                 |                             |                     |                     | X                   |
| **Individuals** |                      |                 |                 |                             |                     |                     | X                   |
| **Households** |                      |                 |                 |                             |                     |                     | X                   |
| **Subscription cycle** |             |                 |                 |                             |                     |                     | X                   |
| **Monthly**   |                      |                 |                 |                             |                     |                     | X                   |
| **Bi-weekly** |                      |                 |                 |                             |                     |                     | X                   |
| **Discounts** |                      |                 |                 |                             |                     |                     | X                   |
| **Trip-based** |                      |                 |                 |                             |                     |                     | X                   |
| **Budget-based** |                  |                 |                 |                             |                     |                     | X                   |
| **Caps**      |                      |                 |                 |                             |                     |                     | X                   |
| **Distance-based** |              |                 |                 |                             |                     |                     | mode-specific (cf. Table 2) |
| **Trip-based** |                      |                 |                 |                             |                     |                     |                     |
| **Add-ons**   |                      |                 |                 |                             |                     |                     |                     |
| **Parking**   |                      |                 |                 |                             |                     |                     | X                   |
| **Restaurant** |                      |                 |                 |                             |                     |                     |                     |
| **Food delivery** |                  |                 |                 |                             |                     |                     | X                   |
| **Service level guarantees** |          |                 |                 |                             |                     |                     | X                   |
| **Add. Inf. & paym. integration** |     |                 |                 |                             |                     |                     | X                   |
| **Shopping**  |                      |                 |                 |                             |                     |                     |                     |
| **Accommodation** |                |                 |                 |                             |                     |                     |                     |
| **Customizability** |               |                 |                 |                             |                     |                     | X                   |
| **Roll-over option** |              |                 |                 |                             |                     |                     | X                   |
| **X**         | X                    | X               | X               | X                           | X                   | X                   |                     |
hypotheses as to the origin of the differences. Table 3 displays the resulting comparison (for readability, we focus on carshare only, and further exclude two studies that either do not include carshare, or do not estimate coefficients/WTP for carshare per se and are thus not comparable in outcome). Our interest lies in identifying reasons for the negative coefficients of carshare in the study by Matyas and Kamargianni (2019a). It is important to note that this table only serves as an illustrative example. Similar tables can be created for any mode or indeed any attribute of any set of stated choice studies as long as the underlying behavioral design dimensions are known.

We recapitulate that the study by Matyas and Kamargianni (2019a) is the only study that exhibits negative coefficients for carshare in a MaaS bundle (−0.437 for a daily pass and −0.022 for an hourly allowance). While differences comparing any two studies are manifold (e.g., metric, add-ons, roll-over option, customizability), there are only two systematic differences when comparing Matyas and Kamargianni (2019a) to all others. First, they conduct their study in a different place (London). Second, they use a random design while others used pivot or efficient designs. For random designs, attribute levels are selected for all choice tasks in a random manner, without recognizing previous patterns of demand (i.e., carsharing usage) or socio-demographics (i.e., driving license ownership). This might result in a situation where many participants might not prefer carsharing in their bundles where in other studies they might not have been asked due to previous patterns of demand or socio-demographics. Hence, on average, the parameter associated with carsharing is negative.

4.3. A research agenda for stated choice studies on MaaS bundle design

As argued in Section 4.1, the knowledge of behavioral and statistical design dimensions enables researchers to systematically compare previous stated choice studies, but also to identify empirical research gaps and design new experiments accordingly. Table 4 exhibits a comparison of all peer-reviewed academic stated choice studies on MaaS bundle design that we discussed in our literature review and highlights commonalities in their behavioral design. It also allows the identification of empirical research gaps (highlighted in italic). These include the impact of emerging modes (e.g., e-scooters), households or specific groups of individuals (i.e., tourists, senior residents) as the subscribing unit of MaaS bundles (cf. UbiGo) effectively sharing the allowances of a bundle, and certain add-ons (shopping, accommodation). Subsequent studies can thus be designed in a more ‘informed’ way to replicate existing studies in a different context, or complement studies and test new aspects of MaaS bundle design.

The next steps in the evolution of our understanding of the influence of statistical and behavioral design dimensions should further include a Design of Design stated choice study, enabling us to identify in a more holistic way, the role that specific (configurations of) statistical and behavioral designs play in study outcome. Applied to MaaS bundles, the study would investigate the role that specific (configurations of) modal offerings play in individuals’ choices of MaaS bundles, revealing preferences and willingness to pay (or not) for specific service constructs. In addition to the influence of statistical and behavioral design dimensionality, local context will also have to play a role.

5. Conclusion

The question of how to design MaaS bundles for a particular purpose has motivated us to conduct a thorough review of the existing literature. We found that previous stated choice studies on MaaS bundles exhibit great variation in experimental design, which - without an overarching framework - hampers systematic comparison to explain the partially contradictory findings and design new studies with well-informed variations in design. Previous literature (the Design of Designs stream) only helps to identify differences in statistical design (e.g., how many choice sets, attributes and levels) but not in the specific selection of attributes, levels and metrics. In response, we develop the concept of the behavioral design for stated choice experiments. A behavioral master design lists all relevant attributes, levels, metrics and configurations thereof for stated choice studies in a specific field of application and thus conceptualizes the so-far uncaptured part of variation in experimental designs. As a result, experimental designs can be described as permutations in a grid of a statistical and a behavioral master design. This enables systematic comparison of experimental designs, the identification of empirical research gaps and informed design of new studies. We show the practical value of this conceptual contribution by developing a behavioral master design for MaaS bundles, comparing previous experimental designs of stated choice studies and identifying empirical research gaps accordingly.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Research leading to this paper was partially funded by the iMOVE Cooperative Research Centre, the ETH Mobility Initiative, the Erich Degen-Stiftung and the Volvo Research Education Foundation Bus Rapid Transit (BRT+) Centre. The authors are very thankful to Sam Lorimer and colleagues in Insurance Australia Group (IAG) for ongoing discussions on bundle design in the Sydney MaaS trial, and Kay W. Axhausen and three anonymous reviewers for their constructive comments which have substantially improved this paper.
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