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MaaS Bundle Design

By
Daniel J. Reck[ab], David A. Hensher[b], Chinh Q. Ho[b]

[a] Institute for Transport Planning and Systems (IVT), ETH Zürich, Stefano-Franscini-Platz 5, 8093 Zürich, Switzerland.
[b] Institute of Transport and Logistic Studies (ITLS), The University of Sydney Business School, Sydney Australia

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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 extending the Design of Designs literature to distinguish between two categories of design dimensions for stated choice experiments: statistical and behavioral. We argue that not only statistical design (how many alternatives, attributes and levels) but also behavioral design (i.e., which attributes and levels) influences outcome. Behavioral 'master designs' are seldomly made explicit, yet precisely this situation leads to seemingly disjointed landscapes of stated choice studies in specific areas of application, limiting scientific advances, relevant policy-making and commercial realization. We demonstrate the practical value of our conceptual contribution by developing a behavioral master design for MaaS bundles. We show that every MaaS bundle is a permutation along ten design dimensions and every stated choice study is a permutation in a statistical and behavioral master design. Using the resulting grid, researchers can systematically compare studies, identify empirical research gaps and design new experiments accordingly and practitioners can obtain practical guidance for the design of new bundles.

KEY WORDS: ***Mobility as a Service, MaaS, Bundling, Design of Design, DoD, Choice Experiment***

AUTHORS: **Reck, Hensher and Ho**

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CONTACT: INSTITUTE OF TRANSPORT AND LOGISTICS STUDIES (H73)

The Australian Key Centre in Transport and Logistics Management

The University of Sydney NSW 2006 Australia

Telephone: +612 9114 1824

E-mail: business.itlsinfo@sydney.edu.au

Internet: http://sydney.edu.au/business/itls

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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., is more discount 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 (e.g., Guidon et al., 2020; Ho et al., 2018; Ho et al., 2020; Matyas and Kamargianni, 2018) and the increasing number of commercial trials (e.g., UbiGo, 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 meaningful 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, 2018) 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 address this question by making a conceptual and an applied contribution. Conceptually, we scrutinize sources of design differences in stated choice experiments. We find that they can be statistical (*how many* alternatives, attributes, levels) or behavioral (*which* attributes and levels in which configuration). Statistical designs and their influence on outcome have been researched thoroughly under the label Design of Designs (DoDs) (Hensher, 2004; Caussade et al., 2005; Hensher, 2006a; Hensher, 2006b). Behavioral designs, on the other hand, are often based on researchers' experience or intuition and seldomly made explicit. Yet precisely the lack of established behavioral 'master designs' for specific areas of application (here: MaaS bundles), outlining all relevant attributes and levels, leads to the seemingly disjointed landscape of stated choice studies, especially when it comes to determining if the evidence is transferable. The distinction between statistical and behavioral designs allows us to classify every stated choice experiment in a grid and thus enables not only the systematic comparison of studies in terms of design and outcome, but also the systematic identification of empirical research gaps and the subsequent design of meaningful studies. The systematic capture of differences in design is also a necessary first step to disentangle differences in design and differences in outcome. We demonstrate the practical value of our conceptual contribution by developing a behavioral 'master design' for MaaS bundles. We show that each MaaS bundle is a permutation along ten design dimensions and each stated choice experiment is a permutation along this behavioral and a statistical master design.

The remainder of this paper is structured as follows. We first review the literature on *MaaS,* revisit the origins of *bundling* in Marketing and discuss most recent developments in *MaaS bundling* to substantiate the 'applied research gap'. We then review the *Design of Designs* literature and argue that it only helps to identify one part of the design differences of stated choice studies ('conceptual research gap'). In response, we introduce the concept of behavioral designs, apply it to develop a behavioral 'master design' for MaaS bundles and use it to compare previous stated choice studies and identify empirical research gaps. We close with a summary and discussion of the implications for research and policy.

2. Literature review

2.1. MaaS

Though the *term* MaaS was only conceived in 2014 (Heikkilä, 2014), 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 transportation authorities were predecessors of Mobility Management, integrating planning, booking and payment across various public transportation providers as early as 1965 in Germany. Technological progress, often summarized by the term 'Internet of Things', arguably led to 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., 2020) ranging from demand-side research on the willingness to pay for MaaS bundles (e.g., Guidon et al., 2020; Ho et al., 2018, 2020; Matyas and Kamargianni, 2018) 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[1].

[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).

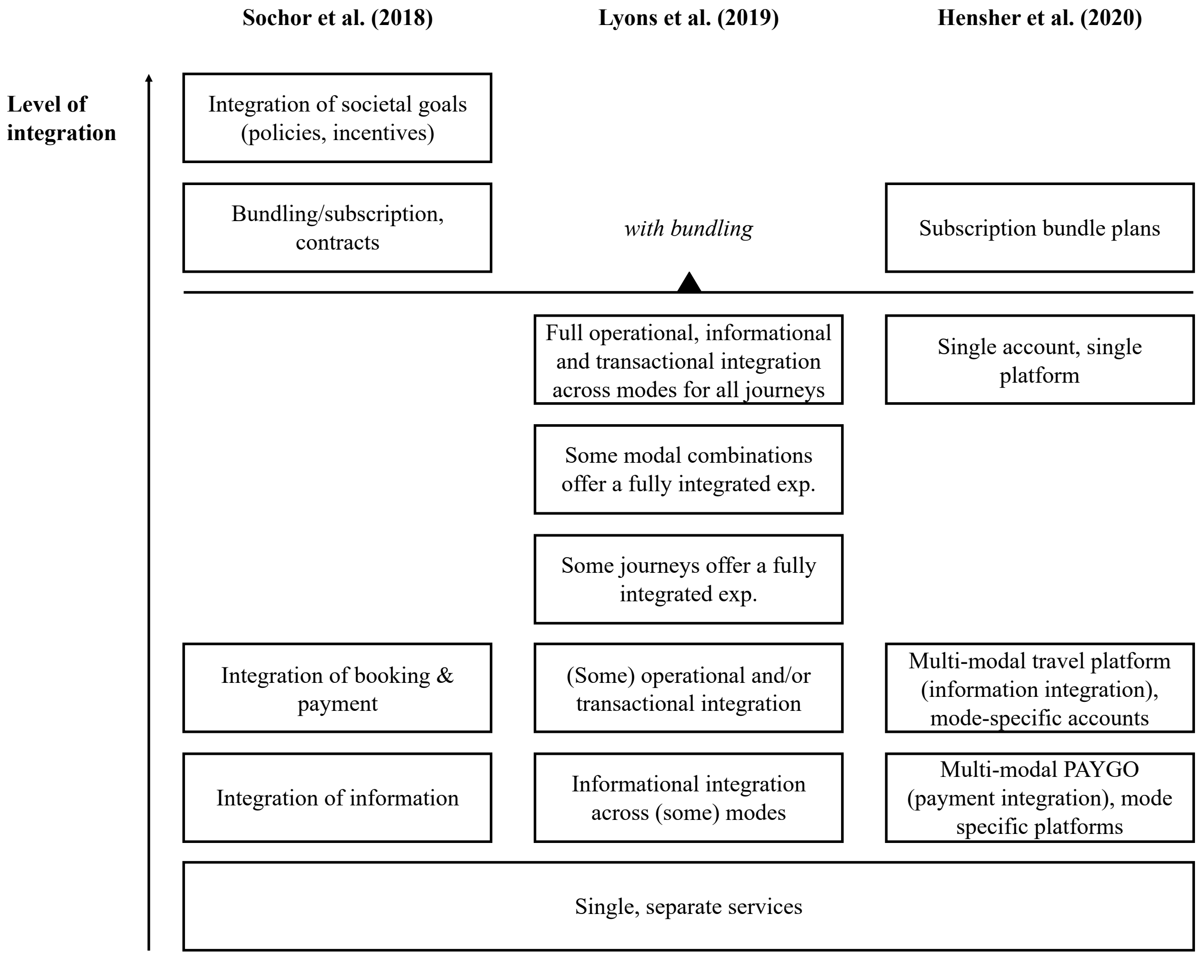

Fig. 1. MaaS topologies with and without bundling.

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[2]. 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).

[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).

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).

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[3]. 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 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 in transportation. Historically, public transportation season tickets have been heavily subsidized to address market failure (tragedy of the commons) and incentivize sustainable travel. From a societal perspective, one hope is that MaaS might increase the share of intermodal alternatives compared to private car use and ultimately reduce car ownership.

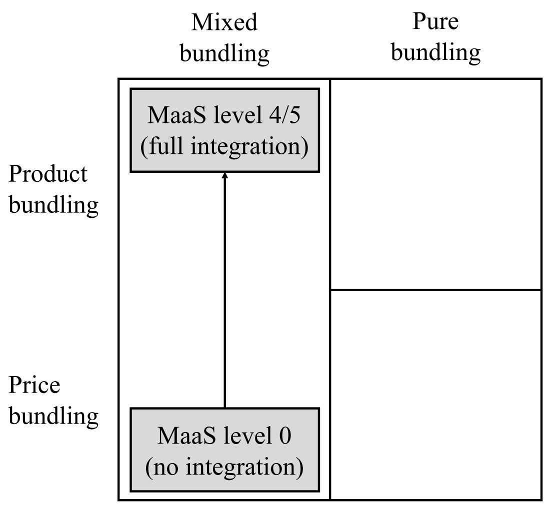

Fig. 2. MaaS topologies integrated into Stremersch and Tellis' (2002) bundling framework.

[3] We use this term subsequently to remain consistent with the Marketing literature.

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).

Thus-far, research has focused on eliciting consumer preferences for MaaS bundles using stated choice surveys (e.g., Guidon et al., 2020; Ho et al., 2018; Ho et al., 2020; Matyas and Kamargianni, 2018). Methodologically, the authors of all studies show varying bundle configurations to participants and subsequently model the willingness to subscribe or the willingness to pay for bundles as a whole and individual components. Interestingly, the designs of bundles, regardless of their academic or commercial origin, greatly differ in several dimensions (e.g., included modes, 'metrics' to measure the consumption of mobility services, discount schemes), which makes study outcomes (e.g., willingness to pay) difficult to compare as they might be attributed to design differences. One example for differences in study design is the way in which the 'budget' (cf. Hensher, 2017) is measured (we call this the 'metric'). While taxis are included in most studies, metrics differ widely from time-based (minutes, hours) to trips-based (number of trips per month) to distance-based (km, miles) to a combination of these (e.g., number of trips up to 5 kms). Roll-over options (i.e., unused budget transfers to the next month) are offered only in some bundle designs and one study even allows full customization of bundles (Matyas and Kamargianni, 2018). Several other examples of variations in bundle design can be found in Table 1 (cf. Section 4 for detailed explanations of each design dimension).

Table 1
Exemplary differences in MaaS bundle designs.

		Necessary design dimensions					Complementary design dimensions				
		Modes	Metrics	Geography	Market segment	Subscription cycle	Discounts	Caps	Add-ons	Customize-ability	Roll-over option
Academic studies	Guidon et al. (2020)	PT	NA (flat rate)	Zurich	individual	month	subscription fee	no	Park and ride	no	no
		Carshare	km					yes			
		Bikeshare	hours					yes			
		e-Bikeshare	hours					yes			
		Taxi	minutes					yes			
	Ho et al. (2018)	PT	days	Sydney	individual	fortnight	subscription fee	yes	no	no	yes
		Carshare	hours					yes			
		Taxi	trips				per trip (%)	no			
		Uber	trips				per trip (%)	no			
	Ho et al. (2020)	PT	days	Tyneside	individual	month	subscription fee	yes	no	no	yes
		Carshare	hours					yes			
		Bikeshare	hours					yes			
		Taxi	trips				per trip (%)	no			
	Matyas and Kamar-gianni (2018)	PT	NA (flat rate)	London	individual	month	subscription fee	no	Dinner and food delivery vouchers	no	no
		Taxi	miles					yes			
		Carshare	hours					yes			
		Bikeshare	hours					(no)[1]			
Commercial trials & products	WHIM	PT	NA (flat rate)	Helsinki	individual	30 days	subscription fee	no	no	no	no
		Bikeshare	minutes					(no)[1]			
		Rental car	days[3]					no			
		Taxi	km				pre trip (%/€[2])	yes			
	Mobil Flat	PT	NA (flat rate)	Augsburg	individual	month	subscription fee	no	no	no	no
		Bikeshare	minutes					(no)[1]			
		Carshare	hours & km					yes			
	UbiGo	PT	days	Stockholm	household	month	volume and flexibility[4]	yes	no	yes	yes
		Carshare	hours					yes			
		Rental car	days					yes			
		Taxi	hours & km				none	NA			
	zengo	PT	NA (flat rate)	Geneva	individual	month	subscription fee	no	no	no	?
		Carshare	membership					yes (token)			
		Rental car	hours								
		Taxi	trips								

[1] Unlimited up to 30 min.

[2] Whim Urban 30: 10€ max charge, Whim Weekend: 15% discount

[3] Whim Urban 30: 49€/day, Whim Weekend: free on weekends, Whim Unlimited: flat rate

[4] Discount for higher purchased volumes but additional price for flexibility (PT day passes vs individuum-bound monthly tickets)

It is evident from Table 1 that the designs of bundles in stated choice experiments and commercial trials differ widely. This hampers comparative learning (and the meaningful 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. The latter include contradictory findings such as some authors arguing that customers do not prefer shared modes (carsharing, bikesharing, taxi) in their plans (Matyas and Kamargianni, 2018) while other authors have found a higher willingness to pay for carsharing in bundles (vs stand-alone) suggesting that respondents do prefer some shared modes in their bundles (Guidon et al., 2020; Ho et al., 2018).

2.4. Design of Designs

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 '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; Hensher, 2006a; Hensher, 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 our conceptual research question (how to disentangle 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.

3. 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 (Guidon et al., 2020; Ho et al., 2018; Ho et al., 2020; Matyas and Kamargianni, 2018) 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 1). 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 taxi 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 on MaaS bundles.

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 multiple *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. Thus, meaningful discussion of results is hampered if these differences in design in comparison to previous studies are not made explicit.

An example in our area of application (MaaS bundles) is the preference of consumers for shared modes. Some authors have found that respondents generally do not prefer shared modes (carsharing, bikesharing, taxi) in their plans (Matyas and Kamargianni, 2018) while other authors have found a higher willingness to pay for carsharing in bundles, suggesting that respondents do prefer some shared modes in their bundles (Guidon et al., 2020; Ho et al., 2018). To date it remains unclear what the influence of specific design variations on outcome (here: willingness to pay for individual components of bundles) is, how to compare these studies systematically, or indeed how to design new studies with meaningful variations. The need to be able to identify the role of design and to control for it in comparing MaaS studies is clearly needed.

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 meaningful variation in experimental design. Thus, they define a grid in which researchers can systematically compare stated choice studies, identify empirical research gaps and design new experiments accordingly (Fig. 3). If subsequent contextual variation (e.g., place, sampling) and modeling methods are held constant, this is a structured way to describe and disentangle differences in design from differences in outcome.

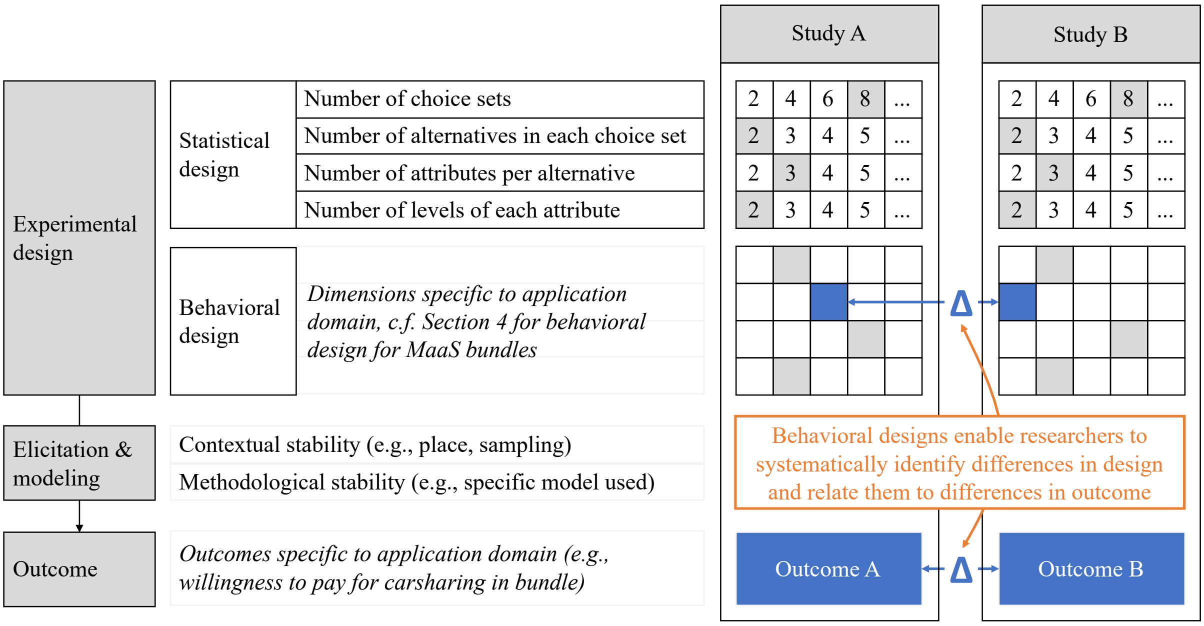

Fig. 3. Schematic classification of stated choice experiments along statistical and behavioral design dimensions to systematically relate differences in (behavioral) design to differences in outcome

We continue by developing a behavioral master design for MaaS bundles. We then demonstrate the practical value of our conceptual contribution by showing that each MaaS bundle is a permutation along ten behavioral design dimensions and each stated choice study is a permutation along this behavioral and a statistical master design.

4. Towards a behavioral master design for MaaS bundles

Our analysis of existing stated choice studies and commercial trials has yielded ten behavioral design dimensions along which MaaS bundles systematically vary (Table 2). In their entity, we call them a first behavioral master design for MaaS bundles. This section aims to complement the conceptual discussion thus-far in that it outlines the main design dimensions for MaaS bundles in a practice-oriented way and thus includes practical advice on bundle design.

In principle, we distinguish between *necessary design dimensions* and *complementary design dimensions*. 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.

Table 2
A first behavioral master design for MaaS bundles

	Term	Definition	Examples
Necessary design dimensions	Modes	Modes of transportation included in the bundle	Public transportation, carshare, (e-)bikeshare, e-scooters, taxi, car rental, ridehail
	Metrics	Way in which the mobility budget / entitlement and consumption of a mode is measured	Time-based (minutes, hours, days), distance-based (km, miles), trip-based (number of trips)
	Geography	Area of validity	Single city, multiple cities, country
	Market segment	Entity the bundle is designed for	Individuals (residents, tourists, commuters, seniors), households, employee groups
	Subscription cycle	Period of single recurrence of a subscription	Weekly, fortnightly, monthly; Calendar or rolling
Complementary design dimensions	Discounts	Type and granularity of rebate	Trip-based (20% / $5 off each trip), budget-based (subsription fee or top up $50, pay $45)
	Caps	Limit to discounted trips / entitlements depending on the metric, also referred to as budgets	Time-based (30 hours / trips up to 30 min), distance-based (30 km), trip-based (10 trips)
	Add-ons	Non-transportation services included in the bundle	Parking, coupons (e.g., shopping, accommodation, restaurants, food delivery)
	Customizability	Bundles can be pre-defined by the mobility broker or personalized by the users	NA
	Roll-over option	Transfers unused credit to the subsequent time period	NA

4.1. 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 be applied 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 might be a way to decrease monthly variability of demand for certain modes (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 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.

4.2. 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'[4] (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

[4] 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.

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., 2020, 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 (2018) 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 as a stand-along service.

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.

5. Comparing previous stated choice experiments on MaaS bundles along behavioral and statistical design dimensions

As argued in Section 3, the knowledge of behavioral and statistical design dimensions enables researchers to systematically compare previous stated choice studies, identify empirical research gaps and design new experiments accordingly. Table 3 presents a first such comparison of all four stated choice experiments on MaaS bundles.

It becomes evident that MaaS bundles can be described as permutations along behavioral design dimensions and that stated choice experiments as permutations in a behavioral and statistical master design. This classification enables researchers to compare study design systematically to develop hypotheses for differences in outcome. In our example, we noted that Matyas and Kamargianni (2018) found that respondents do not prefer carsharing in their bundles while Guidon et al. (2020) and Ho et al. (2018) have found the opposite. Our comparison shows that behavioral designs vary and thus might be an explanation for the difference in outcome: Ho et al. (2018) include a roll-over option allowing participants to use unused credit for carsharing in the subsequent billing cycle while Matyas and

Kamargianni (2018) do not include this option. Losing all unused credit arguably makes the carsharing component in the package substantially less attractive as timing of need is relatively uncertain. Guidon et al. (2020) use a distance-based metric (km) to define the carsharing budget while Matyas and Kamargianni (2018) use a time-based metric (hour). This difference might be more subtle but could be important for some participants in deciding against or for one or the other bundle. Additionally, Guidon et al. (2020) include an attribute "integrated smartphone app" which could influence the WTP for other components in the bundle (i.e., some participants might prefer bundles with more modes if an integrated smartphone app is also offered) while Matyas and Kamargianni (2018) solely offer bundles.

Besides comparing previous studies and identifying explanations for differences in outcome, our comparison also serves to design new stated choice studies with targeted variation to analyze the impact of individual design dimensions. It also allows the identification of empirical research gaps (highlighted in Table 3 in *italic*). These include the impact of emerging modes (e.g., e-scooters), bundles that allow travelling in multiple cities, households or specific groups of individuals (i.e., tourists, senior residents) as the subscribing unit of MaaS bundles (cf. UbiGo), certain add-ons (shopping, accommodation), trip-based caps and customizability (ibid.). Subsequent studies can thus be designed in a meaningful way, complementing existing studies and testing new aspects of MaaS bundle design.

Table 3
Structured comparison of stated choice experiments along behavioral and statistical design dimensions enables the systematic identification of research gaps and design of meaningful new experiments.

			Guidon et al. (2020)	Ho et al. (2018)	Ho et al. (2020)	Matyas and Kamargianni (2018)
Behavioral design	Modes	PT	X	X	X	X
		Carshare	X	X	X	X
		Bikeshare	X			X
		e-Bikeshare	X			
		Taxi	X	X	X	X
		Ridehail		X	X	
		e-Scooter		*Research gap*		
	Metrics	Time-based	X	X	X	X
		Distance-based	X			
		Trip-based		X	X	
	Geography	Single city	X	X	X	X
		Multiple cities		*Research gap*		
	Market segment	Individuals	X	X	X	X
		Households		*Research gap*		
	Subscription cycle	Fortnightly		X		
		Monthly	X		X	X
	Discounts	Trip-based		X	X	
		Budget-based	X	X	X	X
	Caps	Time-based	X	X	X	X
		Distance-based	X			
		Trip-based		*Research gap*		
	Add-ons	Parking	X			
		Restaurant				X
		Food delivery				X
		Shopping		*Research gap*		
		Accommodation		*Research gap*		
	Customizability			*Research gap*		
	Roll-over option			X	X	
Statistical design	Number of choice sets		18	12	12	4
	Number of alternatives per choice set		2	3	3	3
	Number of attributes per alternative		8	6	6	6
	Number of levels per alternative		2-6	2-4	2-4	2-6

6. Concluding discussion

The question of how to design MaaS bundles for a particular purpose has motivated us to conduct a thorough review of the extant 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 meaningful new studies. 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 meaningful 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.

The next steps in the evolution of our understanding of the influence of statistical and behavioral design dimensions should 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. The Design of Designs approach enables us to separate the two classes of influence, which to date has not been possible. The ultimate role of such a study in the context of MaaS is to guide the structural design of MaaS trials and products, and to identify suitable levers to foster sustainable MaaS adoption as input for evidence-based policy-making.

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