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Estimation of joint value in mobility as a service ecosystems under different orchestrator settings

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Abstract

Background Ecosystems aim to create joint value that is higher than the sum of the value added of the single companies combined. However, for Mobility as a Service (MaaS) ecosystems, the economic potential is not yet proven. This concurs with the definition of MaaS ecosystems and the debate about who should be the orchestrator – a private or a public entity.

Purpose This article therefore delivers a first approach to quantify the joint value of publicly and privately orchestrated MaaS ecosystems.

Methodology The value estimationations are based on potential user preference analysis combined with market simulation and different volume discounts granted to a private orchestrator in the agency.

Findings The results show that due to the high costs of all ecosystem actors in this asset-heavy industry, no profits are made in all constellations. The least value is destroyed when a private orchestrator receives 2% discount. Thus, added value must be created, for example through data analysis and advertising. Cities and governments must hence reallocate subsidies and support all MaaS actors to build a viable ecosystem.

Keywords Conjoint analysis, Mobility as a Service (MaaS), Ecosystems, Joint value creation, Orchestrator

1 Introduction

Mobility as a service (MaaS) is said to foster the mobility transition in travel behavior from automobility dependence towards more sustainable transportation modes [1]. It is a well-established concept in transportation science that combines multiple publicly or privately owned transportation modes [2], taking a user-centric perspective in integrating data from transportation services and user preferences to provide information and transportation bundles [3].

To date, the economic feasibility of MaaS is still not proven [4–7]. However, in the automotive sector, a shift from selling cars to offering mobility services is increasingly seen [8]. In this context, the concept of ecosystems, a novel form of value network in strategy science, has gained increasing attention from both industry and academia [9]. A starting point for companies to cooperate in such an ecosystem is the estimation of joint value created [10]. Hence, it is important to show the surging new ways of joint value creation to convince firms in participating in the ecosystem design [11]. Until now, MaaS ecosystems are created and discussed mainly for their environmental and social benefits (see e.g. [1, 2, 12–16]). While economic outcomes of MaaS are still absent in research [8, 17], the financial impact of an ecosystem perspective in other markets is proven, especially for big platform businesses [18]. Taking on an ecosystem perspective implies

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creating more value jointly through synergies with partners of which each partner captures a share through offering an overarching value proposition to the customers [9]. Since MaaS has failed to generate this overarching value an absent ecosystem perspective is perceivable.

The need for an ecosystem perspective in MaaS is formulated in academia [19]. As no universally accepted definition of the MaaS ecosystem exists, it has been researched regarding the necessary stakeholders [20] and the business model of the orchestrator [21] but with different conceptual boundaries. The fuzziness of the term is also reflected in the fact that in strategy research not all stakeholders are ecosystem partners, contrary to Kamargianni and Matyas [20] for MaaS, as only those with multilateral dependencies and non-generic complementarities [9] are. This also explains the ambiguous estimations of the market potential of MaaS (see e.g. [22–24]). It is therefore essential to define the MaaS ecosystem, in accordance with strategy research, unambiguously in a first step in order to derive value elements and partners necessary for value creation calculations.

The possible joint value created furthermore depends on whether the ecosystem orchestrator is a public or a private institution. Public ecosystem orchestrators want to create value for the ecosystem stakeholders instead of capturing the value mainly for themselves: They create a public good (without profit) through the ecosystem [25]. Contrary to that, private orchestrators create value to internalize it. The amount of value depends on the prices paid to the other ecosystem actors offering their services. Price-based scenarios regarding the mobility transition represent a research gap [16]. The following research questions result:

1. How is the MaaS ecosystem unambiguously defined?
2. What value elements does the MaaS ecosystem comprise?
3. How does the joint value creation differ in private-driven MaaS ecosystems from a public-driven ecosystem?

To answer these questions, user preference analysis and market simulations to calculate the joint value created are applied, using the example of an academic MaaS offer. Universities are of particular interest because young people and academics are more receptive to adopting new sustainable and app-based mobility services such as MaaS [3, 8, 26–28].

The paper is structured as follows. The theoretical and conceptual background to answer the research questions is provided in Sect. 2, including a definition of the value elements of the MaaS ecosystem and the design of an operating model. Section 3 describes the methodology used. Section 4 presents the analysis and results. A subsequent discussion of the results is provided in Sect. 5. The study terminates with conclusions in Sect. 6.

2 Background

2.1 Joint value creation in transaction ecosystems

Ecosystems are understood in strategy science as partnership networks in which an overarching value proposition as a joint customer solution is tailored by the companies' individual value streams (e.g. [10, 29]). Jacobides et al. [9] define ecosystems as "a set of actors with varying degrees of multilateral, non-generic complementarities that are not fully hierarchically controlled" (p. 2264). A focus lies on modularization, and complementarity must be given both in consumption and production due to complementary resources (economies of scope). Adner [11] defines these specific 'ecosystems as structure' as "the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize" (p. 42). The binding alignment structure, multilateral relationships between partners, the defined set of partners, and the joint focal value proposition from this definition can be translated into building blocks of ecosystem design according to Lewrick et al. [30] and Dattée et al. [10] (see Fig. 1). Resulting from customer information, the focal value proposition of the ecosystem is formulated [31]. It is the goal of the platform [21] to deliver the proposed value by arranging the necessary value elements in a certain manner for the value to be delivered ("operating model"; [30]). Certain value drivers such as network effects and economies of scope are leveraged through the platform. Control and access to the platform are ensured ("governance"; [11]). Then, the expected joint value created via the platform can be calculated [31].

The joint value created by the company, the buyer and the supplier in a vertical chain is determined by the customer's willingness to pay [32] and the opportunity cost, i.e., the minimum monetary value a supplier accepts in exchange for his/her resources [33]. The amount of value appropriated ("economic rent") by each actor is determined as follows [34]:

- The difference between willingness to pay and the price is a buyer's appropriated value.
- The difference between the price and the cost is the company's appropriated value.
- The difference between the opportunity cost and the company's cost for the acquired services is the supplier's appropriated value [35].

When shifting the perspective from a vertical chain to an ecosystem, the joint value created increases as added

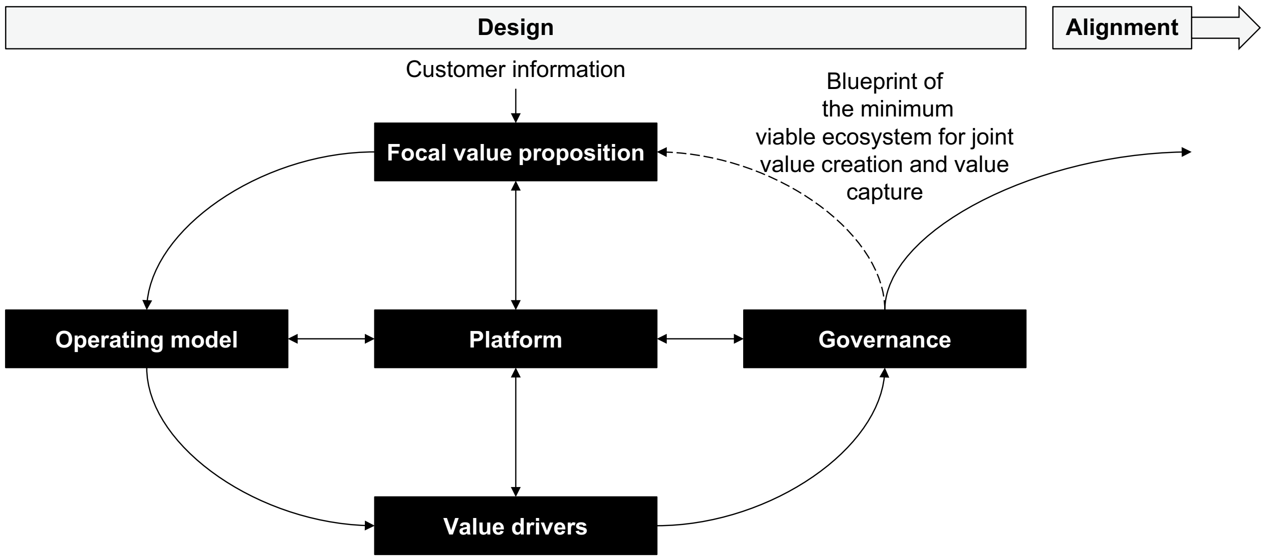

Fig. 1 Joint value creation as outcome of a minimum viable ecosystem (based on [30, 31])

value is built (economies of scope) [36, 37]. This added value is only achieved when companies integrate external competencies jointly [38], thereby shifting the focus to an external perspective [39].

2.2 Ecosystem orchestrator

The ecosystem orchestrator provides financial resources and/or labor and the rules for value creation, which determine the financial outcome for all participating actors [40]. The orchestrator also aligns all ecosystem members to the focal value proposition and is responsible for the coordination of activities and for providing resources and infrastructures [41]. It is the main decision-maker on frameworks, rules and principles for growth, thereby being responsible for the governance mechanisms [42]. To increase the attractiveness of participation, the orchestrator must ensure that all partners benefit and appropriate value [43]. There are three types of orchestrators: (a) the "player orchestrator" with a commercial interest, using the coordination for its own advantage, (b) the "facilitator orchestrator" with a non-commercial interest in ecosystem development and (c) the "sponsor orchestrator" as a venture capitalist with a commercial interest as an outsider [44], whereas the latter is outside the ecosystem.

2.3 Research on MaaS ecosystems

The ecosystem perspective is inherently included in the MaaS concept, which has been defined as an ecosystem since its emergence [45, 46]. MaaS is generally defined as the "3B's": the brokers, the budgets and the bundles [47]. MaaS can further be defined as a service ecosystem, in which value creation between the app (platform) provider (i.e. the orchestrator) and the transportation service providers (TSPS) takes place [8].

The MaaS ecosystem orchestrator is either a private company or a state- or municipality-owned public entity [48]. Public orchestrators search for efficiency and utilization benefits, thereby increasing the number of users. The advantage is easier approval and maximized social surplus, as prices are equal to the marginal costs [49]. Disadvantages include difficulties in innovation, scaling and bureaucracy [20] and scarce development resources [21]. These disadvantages are the advantages of private orchestrators. Although public authorities may have only limited influence to orchestrate [50], private orchestrators might promote unsustainable technologies [20]. In contrast, Wong et al. [51] assumed that governments might not be keen to be orchestrators. The private and public actors in the MaaS ecosystem simultaneously compete and cooperate to create, deliver and capture value [21], i.e., they are in "co-opetition" (e.g. [52]). A further option are public private partnerships for MaaS [53] but since the type of collaboration is not unambiguously defined it is out of scope of this research.

Transferring ecosystem definitions (Sect. 2.1) to MaaS, the joint focal value proposition is to create seamless mobility through a unique service combination [54]. The defined set of partners comprises the customers, the MaaS orchestrator, the data provider, the transport operator, and occasionally the government [8, 19]. Multilateral relationships are given if the TSPs also interact between themselves to increase resource complementarity. A binding alignment structure only exists if all parties adhere to a standard on the platform. Combining ecosystem complementarities with MaaS integration levels (see [19, 55]) ranging from 0 to 4, only level 3-MaaS offers (i.e. offers in which not only generic information is provided, but also booking and payment options are included [56, 57] as well as transportation service bundling [58, 59] can be classified as ecosystems, which are few [55], showing that transportation service bundling is necessary for complementarity in consumption [58, 59]. One reason is that the possible joint value creation, necessary for a minimum viable ecosystem to survive and grow is still not analyzed [60]. As for RQ1, the fact that numerous studies needed to be analyzed together to create this transparent definition of the MaaS ecosystem proves the previous gap in the literature regarding its definition.

2.4 Value elements and operating model in the MaaS ecosystem

To calculate the joint value created in the MaaS ecosystem, the value elements as inflow (revenue) and outflow (costs) must be gathered (see Fig. 2). The value inflow elements are:

- Ecosystem revenue as the number of MaaS adopters times the prices paid by them;
- Value appropriation by the orchestrator, consisting of
  - Price discounts for the transportation service (price paid by the customer minus the discounted price for the transportation service) as the basic value and
  - Additional value as revenue for data analysis and advertisements for private orchestrators; and
- Value appropriation by the TSPs as new profits/losses made by each TSP for the additional subscriptions as their value appropriated.

The ecosystem revenue from the customers is determined by the willingness to pay and preference for pay-as-you-go (PAYG) or subscription models. Subscriptions of package options of complementary products are superior [61] because they can lead to higher social welfare, consumer surplus and company benefit [62]. The price should not be higher than individual sales/cost of transportation offers [63]. The second element is the discount from the TSPs depending on the underlying MaaS model: an “agency model” or a “merchant model” [48, 63]. In the agency model, transportation capacities [20] are bought by the orchestrator from the TSPs for wholesale prices [49]. In the merchant model, commissions are paid by the TSPs to the orchestrator for reselling [64]. In a private MaaS offer the orchestrator also gets revenue from other value-adding services [20, 65, 66], e.g. advertisements, cross-selling commissions and subsidies [63]. The state has an important role as facilitator, providing funding for the initial uptake of the MaaS ecosystem [67, 68]. Data analytics should be provided for the public sector [69].

Value outflow elements for providing the MaaS solutions found in the literature concern the expense for the transportation service (for the orchestrator and the TSPs made by new trips generated) [63] and for the platform, including variable costs for payment integration [49, 55]

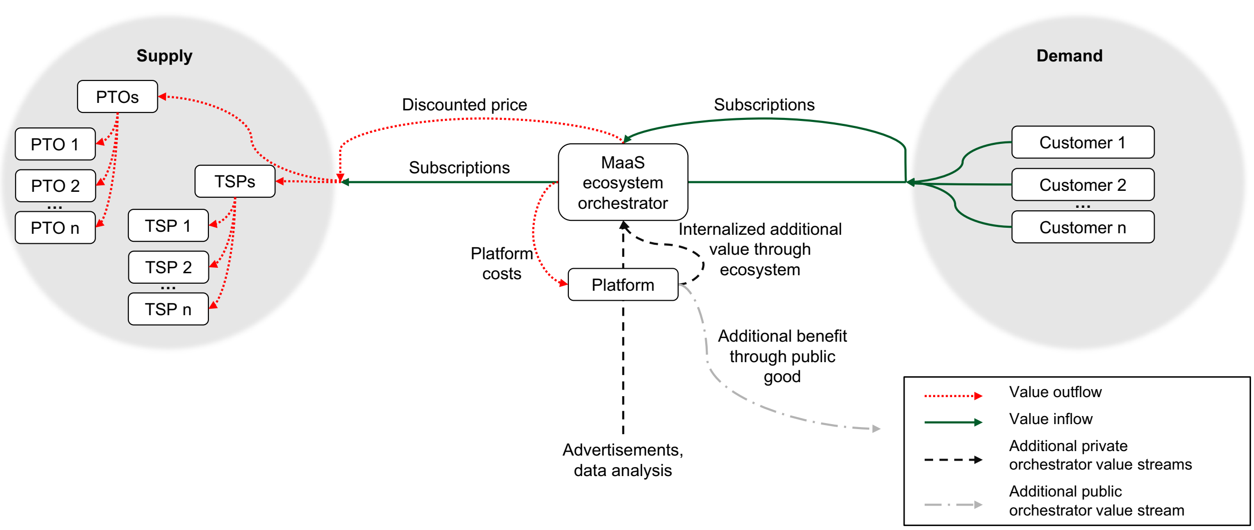

Fig. 2 Agency operating model of a public or private MaaS orchestrator (adopted from [20] and [65])

and insurance [20, 21] and fixed costs for the service (customer support) [48], and platform development (personnel) and infrastructure [48].

From a sustainability perspective, impact assessment could comprise even further indicators, such as modal shift (to know whether the customers are new for the TSPs), total travel costs per individual, and the number of new customers [70] which lie outside of this scope due to the ecosystem perspective from strategy research.

These value elements had to be collected from different sources, proving the research gap for RQ2. Hence, one all-encompassing study quantifying the joint value created in such an ecosystem (RQ3) is also still missing. Therefore, Fig. 2 shows an operating model of the MaaS ecosystem based on the agency model which the most integrated MaaS operators use [48, 63]. The model comprises the above-mentioned value elements with a public ("facilitator orchestrator") and a private ("player orchestrator") MaaS ecosystem orchestrator. Several public transportation operators (PTOs) from several cities and TSPs for other private providers are on the supply side. The additional value stream of public entities is created by providing a public good whereas private orchestrators internalize it. Subsidies and cross-selling are not considered since the existence and quantity are less discussed in the literature. Multilateral relationships for increased resource complementarity are not included due to the difficult monetary valuation.

3 Methodology

To calculate the value elements previously mentioned, market simulations based on market data and choice experiments were used. Different competitive scenarios were simulated, especially for services that lack historical data [71], such as highly integrated MaaS ecosystems [55]. An approach combining previous studies by Tseng et al. [72], Jeon et al. [73] and Eggers and Eggers [71] adjusted for the aim of this research was used.

The basis for this study is conjoint analysis, a method to find the product attributes that maximize the consumers' preference [73] for new services [74]. Conjoint analysis follows random utility theory [75], stating that a consumers' utilities U for product attributes are unobservable latent constructs with a systematic component V and a random component ε, representing all unsystematic effects. V links product attributes (X) to preference estimates β in choice-based conjoint analysis. Often, a multinomial logit model (MNL) is used to estimate preferences [71, 76], for instance in MaaS [77]. Especially the choice-based approach is useful because the discrete choice behaviour provides the best representation of real market decisions and actual demand patterns [71, 78]. The steps in conjoint analysis are the determination of sample and procedure, the definition of the conjoint settings and the examination of results [71].

The second methodological step is choice simulation. The preferences calculated via conjoint analysis can be used to estimate adoption behavior and purchase probabilities can be estimated in prediction models [71, 79] with competitive market scenarios [73] using market data. Hence, market share based on customers' choice simulation is predicted to determine the best product composition [73]. The simulation consists of the identification of the research focus, sensitivity analysis to estimate demand curves [80] and product price optimization to calculate the market share (adopted from [71] and [72]).

The third step estimates the joint value created: The predicted market share from the choice simulation is used in combination with real market data [72] to quantify the required value elements from Sect. 3. This allows the estimation of the value elements and the joint value created. The steps are visualized in Fig. 3.

4 Analysis and results

4.1 Conjoint analysis

4.1.1 Sample and procedure

This study is part of the research project "InnaMoRuhr" (integrated sustainable mobility for the University Alliance Ruhr), involving the universities Duisburg-Essen, Bochum and Dortmund in Germany, members of the University Alliance Ruhr. It aims to examine whether a MaaS ecosystem for the concerned customer segments of approximately 119,000 students and 16,000 university employees could enhance the modal shift and lead to a more sustainable travel. The University Alliance Ruhr is of particular interest because (a) the Ruhr Area is one of the biggest metropolitan regions in Europe with high traffic density [81], (b) two of the three universities involved belong to the ten biggest in Germany [82] and (c) joint research and study programs induce interregional travel between the universities [83].

As part of the project, a survey about mobility behavior and mobility demand was answered by 10,782 students and employees of the universities in April and May 2021. In the last survey section, the respondents could opt to participate in a conjoint study consisting of two different surveys, one for employees and one for students, using Sawtooth Software. Students have a compulsory public transportation (PT) subscription, hence, a stated choice experiment with this attribute was not necessary as the revealed choice is provided. Furthermore, attributes and levels were modified to the lower income of students. The surveys consisted of a build-your-own task and eight choice tasks. After data cleaning, the data basis

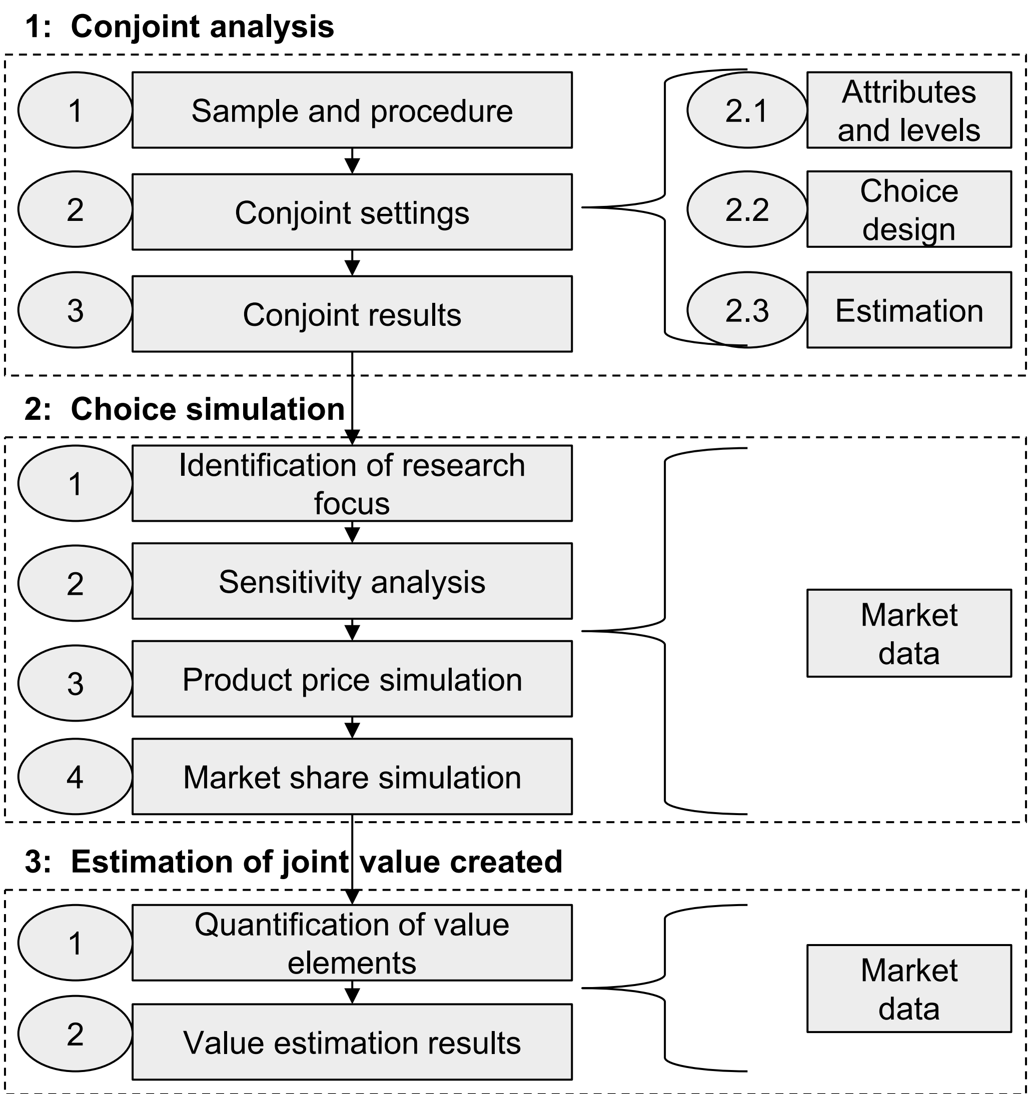

Fig. 3 Methodology combining conjoint analysis and choice simulation (own elaboration based on [71, 72] and [73])

for conjoint analysis consisted of 503 employees and 1165 students.

4.1.2 Conjoint settings

Only transportation modes available in the four university cities and offered by one operator/ one association were included in the conjoint analyses as attributes, each with three monthly attribute levels: PAYG (for students and employees), one intermediate and one high level of service inclusion (following e.g. [12]):

- PT (for employees only): (1) PAYG, (2) monthly subscription for one city or (3) monthly subscription for the tariff association (local representatives of PTOs [8] comprising defined areas of operation),
- Car sharing (CS): (1) PAYG, (2) 3 h/100 km contingent (students and employees) or (3) 6 h/200 km contingent (students) or 9 h/300 km (employees) respectively,
- Bike sharing (BS): (1) PAYG, (2) 30 min contingent per trip on a normal bike, or (3) 30 min contingent per trip on an e-bike (both students and employees) and
- E-scooter sharing (ES): (1) PAYG, (2) 10 trips/50 min or (3) 20 trips/100 min contingent (both students and employees).

On-demand e-shuttles were originally included but then deleted for joint value creation as no real market data was available. Furthermore, the price was included as a summed pricing attribute. The hierarchical Bayes algorithm was used to model the part-worth utilities of all attribute levels as direct input for market simulation.

4.1.3 Conjoint results
McFadden's *pseudo* R^2, a measure for the goodness of fit of hierarchical Bayes was 0.617 for the student conjoint analysis and 0.618 for employees, proofing model validity [84]. The calculated relative importance in both samples shows a high price sensitivity in both analyses and a valuation of PT by employees higher than all other sharing attributes combined.

4.2 Choice simulation
4.2.1 Identification of research focus
As for the private orchestrator setting, based on the agency operating model, the value created depends heavily on the discounts provided by the TSPs. The joint value created was calculated using three different amounts as discussed in the literature: 2% [49], 5% [63] and 10% [85]. In the real case, PT provides a 2% discount as a maximum. Hence, this value was not altered. For the publicly orchestrated MaaS ecosystem all discounts from cooperations are passed to the customers to maximize the social surplus (see Appendix A; for all additional data see Additional file 1). Therefore, four orchestration settings are distinguished:

1. a public one,
2. a 2% discount private setting,
3. a 5% discount private setting and
4. a 10% discount private setting.

As a basis for all further calculations, the market size for MaaS was determined based on the percentage of students and employees indicating the perceived usefulness of mobility apps with either "rather applies" or "fully applies" in a survey about mobility behavior and mobility demand (7333 students and 3449 employees). The market size for students was extrapolated as $N_{Stud} = 103{,}210$ (86.77%) and $N_{Emp} = 12{,}988$ (79.25%) for employees for the three universities. The competing products were the unimodal offers for full prices (see Additional file 1: Appendix A).

4.2.2 Sensitivity analysis
MaaS packages for students (Table 1) and employees (Table 2) were composed with at least two transportation modes included with a level different than PAYG were composed [12]. Table 1 shows that students value multimodal packages as apart from $P4_{Stud}$ all packages include three modes with a service level higher than PAYG. As for the employee packages in Table 2, ES is not integrated in the MaaS packages with a service level higher than PAYG.

To determine these MaaS packages potentially offered, sensitivity analyses based on the respondents' preferences were performed. Because mobility users are heterogeneous [86], a scientifically reasonable reduction to the most important package offers is benefit segmentation (see [87]) based on cluster analyses [71, 74]. The Ward algorithm was implemented in k-means to group the respondents into clusters. For both student and employee data, the three-cluster solution provided the best results. The most preferred transportation attribute levels were included. Whenever the difference to the next lower attribute level was lower than one percent, an additional level was included. The sensitivity analysis was applied to the resulting clusters and the total sample. Regarding the students, the clusters did not differentiate in their preference of CS (6 h/200 km), only Cluster 2 had less than 1% difference to the 3 h/100 km level. The total and Cluster 2 preferred e-bike sharing, Clusters 1 and 3 normal bike sharing. Only Cluster 3 preferred ES as a PAYG option, all other clusters and the total preferred 20 trips/100 min inclusion, although this preference was less than 1% to the 10 trips/50 min level. Regarding the employees, only Cluster 1 prioritized the inclusion of PT in one city. All other clusters and the

Table 1 MaaS packages for students resulting from segment-specific sensitivity analysis

Package name	CS	BS	ES
$P1_{Stud}$	6 h/200 km	e-bike	10 trips/50 min
$P2_{Stud}$	6 h/200 km	Normal bike	20 trips/100 min
$P3_{Stud}$	6 h/200 km	e-bike	20 trips/100 min
$P4_{Stud}$	6 h/200 km	Normal bike	PAYG
$P5_{Stud}$	6 h/200 km	Normal bike	10 trips/50 min
$P6_{Stud}$	3 h/100 km	e-bike	20 trips/100 min
$P7_{Stud}$	3 h/100 km	e-bike	10 trips/50 min

Table 2 MaaS packages for employees resulting from segment-specific sensitivity analysis

Package name	PT	CS	BS	ES
$P1_{Emp}$	Tariff association	9 h/300 km	e-bike	PAYG
$P2_{Emp}$	One city	9 h/300 km	e-bike	PAYG
$P3_{Emp}$	Tariff association	PAYG	e-bike	PAYG
$P4_{Emp}$	Tariff association	9 h/300 km	PAYG	PAYG

total preferred PT as a subscription for the tariff association. CS was preferred as a 9 h/300 km level for the total and Cluster 1 and as a PAYG option for Clusters 2 and 3, although the latter had less than a 1% preference difference to the 9 h/300 km level. Apart from Cluster 3 (PAYG preference), all other clusters and the total preferred e-bike sharing inclusion.

4.2.3 Product price simulation

Starting with the presentation of the calculations, results for the 5% discount private setting will be exemplarily shown. All remaining calculations are listed in the Additional file 1: Appendix C. The prices in the publicly orchestrated MaaS setting were the summed discounted prices for the transportation service according to market analysis (see Additional file 1: Appendix A) due to subsidized services by the cities and the higher negotiation power. For each privately orchestrated setting, market simulation with profit and number of MaaS adopters (share of preference) as two simultaneous optimization goals was performed, following Eisenmann et al. [88]. Price ranges between the summed prices with and without the discounts provided by the TSPs were simulated for the packages created with inclusion of the competing offers. For instance, in the 5% discount private setting, the price range for $P1_{Emp}$ (PT in the tariff association, 9 h/300 km car sharing and e-bike sharing) was between the full price (standalone) as upper bound:

$$\mathrm{P_{upper}} = 155.17€(\mathrm{PT}) + 53.63€(\mathrm{CS}) + 15.00€(\mathrm{BS}) = \underline{223.80€}$$

and the passing of all possible price discounts to the customer as lower bound (see 5% discount in Additional file 1: Appendix A):

$$\begin{aligned}\mathrm{P_{lower}} &= 152.07€(2\%\ \text{discount PT}) \\ &\quad + 50.95€(5\%\ \text{discount PT}) \\ &\quad + 14.25€(5\%\ \text{discount BS}) = \underline{217.27€}\end{aligned}$$

Within this price range all packages were simulated with variations of 0.05€ to simultaneously optimize profit and market share, respectively. Graphical determination of elbow points in the market simulation was used to select the prices: Starting with the highest adoption rate possible, whenever the subsequent decrease of profit was significantly higher than the increase in MaaS adoption rate, the solution and its underlying package prices were chosen (see Additional file 1: Appendix B).

4.2.4 Market share simulation

Market simulations were performed to determine the MaaS adoption rate for the packages with the resulting prices. Percentages from the conjoint analysis sample were extrapolated to the market size determined in Sect. 5.2.1 using Eq. (1):

$$N_{adopters_{i,j}} = \frac{n_{i,j\ choosing_{PK_{i,j}}}}{n_{i,j\ survey\ participants}} * N_{i,j} \tag{1}$$

with n = number of survey participants, N = market size, i = students, j = employees, PK = MaaS package P number K.

In the 5% discount private setting, 6466 students (6.26%, N_{Stud} = 103,210) and 3529 employees (27.17%, N_{Emp} = 12,988) adopted the MaaS offers (see Additional file 1: Table C.1 for remaining results). This was the basis for the estimation of joint value creation from these MaaS packages.

4.3 Estimation of joint value created

4.3.1 Quantification of value elements

Following Sect. 3 based on the explanations in Sect. 2.1, the overarching key decision factors are elements for the value estimation: (a) value appropriation by the orchestrator, and (b) value appropriation by the TSPs.

(a) Value appropriation orchestrator (VA_O)

The first part of the VA_O calculation is the value inflow as the basic value for the orchestrator (BVO) calculated as shown in Eq. (2). The BV_O for the private orchestrator in the 5% discount private setting was (all settings see Additional file 1: Table C.2; price differences as input data see Additional file 1: Table C.3).

$$BV_O = \sum N_{adopters_{i,j}} * (Price_{PK_{i,j}} - discounted\ Price\ TSP \in PK_{i,j}) \tag{2}$$

$$\begin{aligned}\mathrm{BV_{Opriv5\%}} &= (6378 * 1.55€ + 88 * 0.0025€) \\ &\quad + (51 * 6.53€ + 51 * 1.50€ \\ &\quad + 3118 * -0.02€ + 309 * 5.78€) \\ &= 9886.12€ + 2145.36€ = \underline{12{,}031.48€}.\end{aligned}$$

Following Eq. (3), the additional value for private orchestrators (AV_O) was calculated as follows:

$$\begin{aligned}AV_O &= AV_{O_{Ads}} + AV_{O_{Data}} \\ &= \sum N_{adopters_{i,j}} * \frac{\frac{views}{month}}{customer} * \frac{revenue\ rate}{view}\Bigg) \Bigg/ 12 + \frac{data\ selling\ revenue\ per\ year}{12}\end{aligned} \tag{3}$$

Starting with the revenue from advertisements, it was assumed that based on the average trips made before the pandemic and the scope of performances, each user viewed the MaaS app on average 20 times per month. In the topic area of work and education in Europe, 0.0586€ revenue per view and year could be generated [89]. The value was calculated for the 5% discount private setting as:

$$AVO_{Ads_{priv5\%}} = \frac{(6378+88)+(51+51+3118+309) * 20\frac{\frac{views}{month}}{customer} * 0.0586€\frac{revenue\ rate}{view}}{12} = \underline{976.18€}.$$

According to interviews with fellow researchers, cities and municipalities pay around 10,000€ per year per data set received. Because data from four different cities could be received, the monthly added value was:

$$AVO_{Data} = \frac{4 * 10{,}000€/year}{12} = \underline{3333.33€}.$$

Hence, the monthly additional value for the orchestrator in the 5% discount private setting was:

$$AV_{Opriv5\%} = 976.18€ + 3333.33€ = \underline{4309.51€}.$$

The remaining AV_O calculations are listed in Additional file 1: Table C.4. Following Eq. (4), the value outflow of the orchestrator (VO_O) consists of the variable and fixed costs as follows:

$$VO_O = C\ var_{pay} + C\ var_{ins} + C\ fixed_{computer\ scientist} + C\ fixed_{service} + C\ fixed_{IT} \quad (4)$$

$$VO_{Opriv5\%} = 16{,}082.65€ + 16{,}082.65€ + 5000€ + 2500€ + 696.67€ = \underline{40{,}361.97€}.$$

The remaining calculations can be found in Additional file 1: Table C.5 and additional information regarding the data used in Additional file 1: Tables C.6 and C.7. The value appropriated by the orchestrator (VA_O) was calculated using Eq. (5). In the 5% discount private setting, the orchestrator appropriated the following amount (all settings see Additional file 1: Table C.8):

$$VA_O = BV_O + AV_O - VO_O \quad (5)$$

$$VA_{Opriv5\%} = 12{,}031.48€ + 4309.51€ - 40{,}361.97€ = -\underline{24{,}020.98€}.$$

(b) Value appropriation TSPs (VA_{TSP})

First, we analyzed whether the MaaS adopters already had a subscription with a TSP to calculate the new revenues from MaaS (NRM) to the TSPs by using Eq. (6). For the 5% discount private setting, this value was calculated as follows (all settings see C.9 and C.10 for input data).

$$NRM_{TSP} = \sum New\ subscriptions_{TSP_{PK_{i,j}}} * discounted\ Price\ TSP \in PK_{i,j} \quad (6)$$

$$NRM_{PT_{priv5\%}} = 0€ + 0€ + 157{,}997.20€ + 23{,}418.26€ = \underline{181{,}415.45€}.$$
$$NRM_{CS_{priv5\%}} = 179{,}998.40€ + 1107.70€ + 2598.37€ + 2598.37€ + 13{,}756.10€ = \underline{200{,}058.94€}.$$
$$NRM_{BS_{priv5\%}} = 1003.20€ + 726.75€ + 726.75€ + 42{,}099.25€ = \underline{44{,}555.95€}.$$
$$NRM_{ES_{priv5\%}} = \underline{3260.40€}.$$

Especially PT and CS gained new revenue. Multiplied with each TSP's ratio of overall profits/losses (EBIT) to revenue (Eq. 7), the value appropriated per TSP (VA_{TSP}) was as follows (see Additional file 1: Tables C.11 and C.12 for all settings and additional data):

$$VA_{TSP} = NRM_{TSP} * \frac{EBIT}{Revenue\ \frac{TSP}{year}} \quad (7)$$

$$VA_{PT_{priv5\%}} = 181{,}415.45€ * (-0.57) = -\underline{103{,}129.64€}.$$
$$VA_{CS_{priv5\%}} = 200{,}058.94€ * 0.11 = \underline{22{,}391.91€}.$$
$$VA_{BS_{priv5\%}} = 44{,}555.95€ * (-1.33) = \underline{59{,}185.15€}.$$
$$VA_{ES_{priv5\%}} = 3260.40€ * (-1.33) = \underline{4330.90€}.$$

Only CS was profitable and can therefore appropriate value.

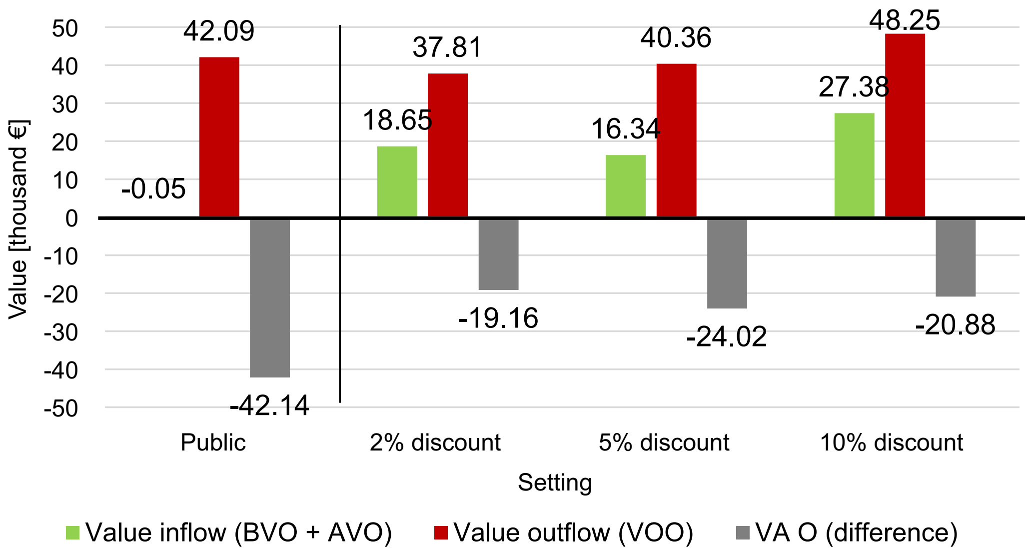

Fig. 4 Value inflow, value outflow, and value appropriated by orchestrator in different operator settings per month

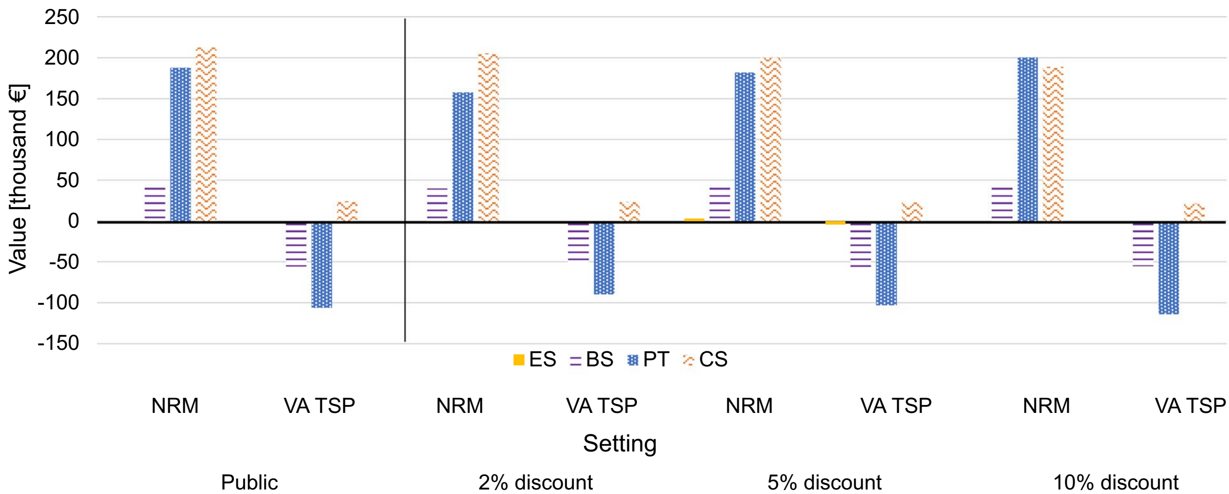

Fig. 5 New MaaS revenue and value appropriated by the TSPs in different operator settings per month

4.3.2 Value estimation results

As presented previously, the value inflows and outflows were also calculated for the three remaining settings (see Additional file 1: Appendix C also for assumptions). Both the value inflow (BV_O and AV_O) and the value outflow (VO_O) were the highest for the 10% discount private setting (27,376€ and 48,254€ respectively). Regarding the VA_O (net value), the 2% discount private setting led to the least loss made by the orchestrator (−19,158€) (see Fig. 4).

The value appropriated per TSP and setting was only positive for CS in all settings since this was the only company already making profits, as shown in Fig. 5. All other TPSs did not make profits (yet) from transportation and PT relies intrinsically on subsidies and cannot make any profit. Nonetheless, PT provides social benefits such as accessibility and equality. Although revenue could be increased, the costs per trip exceeded the earnings.

A graphical representation of the joint value created by the ecosystem actors (orchestrator and TSPs) is provided in Fig. 6. The 2% discount private setting was the one destroying the least value (−138,264€), which was appropriated to more than half by PT (−89,557€).

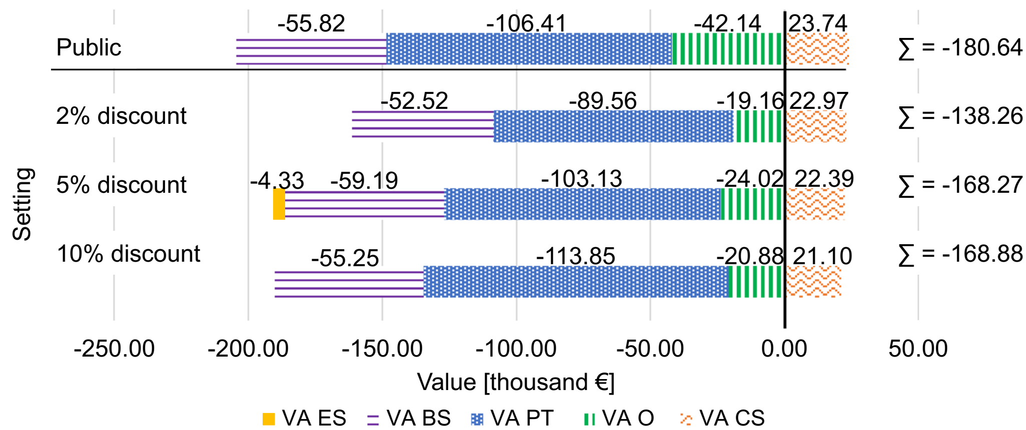

Fig. 6 Comparison of joint value destroyed in different operator settings per month

5 Discussion

To answer the question: "[…] what sort of financial return might prospective MaaS businesses expect?" by Hensher et al. [19], we discuss the results as follows. In no setting, neither public nor private orchestration, value could be created. Moreover, trade-offs are visible between profit and adoption rate (see Additional file 1: Table C.1) and between value inflow and VA_O (see Fig. 4): The 10% discount private setting provided the highest value inflow, but the least joint value was destroyed in the 2% discount private setting. Hence, although gaining new customers, which is especially important because the mobility budget is price sensitive [90] and customer data is a highly valued good [91], this paper contributes to the increasing research stream on joint value destruction instead of value creation because the net outcome of resource integration and service exchange is negative, especially due to a loss of financial resources [8]. The main reason is that joint value creation is not possible by economies of scale (platform effects) alone due to fixed-step costs in the asset-heavy transportation industry. Hence, increasing the market share increases the loss because the net joint value is negative. We showed that regarding research in surging ecosystems, the term "value formation" might be more appropriate since only few (mobility) ecosystems are able to actually create value [8]. Explanations for the negative value appropriation are provided as follows.

Regarding the negative VA_O, the variable costs for the MaaS platform listed in Sect. 3 (payment integration and insurance) directly depend on the market share and exceed the contribution margins of almost all TSPs, especially because no additional willingness to pay for service bundling is given [92]. Regarding the negative VA_{TSP}, the reasons for their losses are among others, Covid-induced travel restrictions. The private TSPs only recently entered the new mobilities market in Germany, which is still volatile, causing insecurity and (initial) losses. Regarding the PTOs, since they are non-profit organizations in Germany, they must not make profits and are hence subsidized by the federal states [93]. It is feasible because PT drives the customers' utility of MaaS [8], which is also visible in our study.

Four suggestions to solve the trade-offs result from this analysis. First, in the initial stage, subsidies are necessary, not only for the TSPs but also for the integration of the MaaS platform [67, 68]. Subsidizing PT discounts during high air pollution levels is one possibility to increase the market share [8]. Nonetheless, the customers' willingness to pay must be increased. Thus, second, an added value for the customers by the MaaS platform must be provided, for instance through artificial intelligence to dynamically adjust route planning on behavior, preferences, or environmental factors such as vehicle capacity utilization [8]. Third, further revenue streams, e.g., for cross-selling, need to be realized, which goes in line with current debates about the transformation from MaaS to MaaF (Mobility as a Feature), stressing the importance of further services apart from mobility [6]. Fourth, since profit margins per package are quite low for our researched customer groups, expansion to other customer groups or other regions should succeed. However, this might pose a problem for PT: Although the transport association has some authority in the price setting, it is the cities that provide concessions and special negotiations for each corresponding PTO. As for the private offer, scaling up is easier because no city boundaries are given. Through the platform, transaction costs of complementarily produced products, especially for the coordination of activities and resources (competencies) of the partners are reduced [94].

Although MaaS ecosystems are currently not profitable, by attracting more users, especially for value-added services, sticking with the ecosystem can pay off in the long run. By scaling and diversifying the offer, from a mid- and long-term perspective, ecosystems can create joint value because more partners are attracted to participate, the so-called platform effect [95]. Subsidizing the more price-sensitive market side on platforms for this aim is a common practice [88]. Because in our research, apart from car sharing, all TSPs need subsidies to be able to operate, it is of the utmost importance to fundamentally reallocate subsidies paid following the efficiency and service level provided and to thus change the market settings for the whole transportation system [8].

Some calculations are beyond the scope of this study. Initial investment costs for the platform setup are not considered. Because transportation has fixed-step costs, a reliable calculation of the TSPs' costs was not possible. We used publicly available data instead to calculate approximations. Secondary value streams could be reached as higher utilization of vehicles increases efficiency and decreases operating costs [20, 65], which could not be calculated due to missing data availability. For the same reason, neither the cross-selling potential nor the subsidies are included in the calculations, although proven to be important. Furthermore, the quantification of the buyers' value appropriated as described in Sect. 2.1 also lies outside this scope. The results are calculated with data collected in our research area and probably differ in another study area due to different regulatory and economic conditions [21]. Future research can build on this outcome and should focus on the following aspects:

- The joint value creation should be estimated for other settings, for other customer segments and for income levels different from university students' and including further diversified services (e.g. including ride hailing operators).
- A longitudinal study on existing MaaS ecosystems can discover the development of joint value creation over time in different ecosystem phases.
- A shift in subsidy grants in urban transportation away from private car privileges should be discussed and simulated regarding its effect on joint value creation in MaaS ecosystems.
- Governance aspects and their influence on joint value creation should be investigated, especially regarding data and access to customer information [8, 96].
- Also, a business model for the MaaS orchestrator must be designed that specifies the profit model but also defines the resource allocation, competitive advantage, and value architecture [97].
- The definition of value should be broadened to include also non-monetary aspects (see e.g. [98]), for instance using multi-criteria decision analysis when comparing privately and publicly orchestrated MaaS ecosystems [8].

6 Conclusions

This research is the first to quantify the actual value created in a MaaS ecosystem, following the more restrictive ecosystem definitions from business strategy research. It complements existing studies on MaaS by taking on the economic perspective [60].

To answer the first research question regarding the definition of a MaaS ecosystem, a MaaS offer is an ecosystem where functions such as ticketing and payment are integrated, and seamless mobility is provided through mobility packages, thereby creating value superior to unintegrated value chains. Regarding the second research question about the value elements the MaaS ecosystem comprises, we answer as follows: Apart from the subscriptions sold, the commissions or bulk discounts from TSPs must be considered, as well as the new customers and revenue for the TSPs, in relation to their ratios of EBIT to revenue. Fixed and variable costs for IT infrastructure, personnel, payment integration and insurance are paid. Private MaaS ecosystem operators must furthermore create additional value via advertisements or data analysis to sell to municipalities. Regarding the third research question, the superiority of private MaaS is dependent on the discount provided by the TSPs in the agency operating model. None of the settings creates joint value under the current circumstances, but for the 2% discount private setting, the least joint value is the destructed.

Our study shows that under the current circumstances, joint value can neither be created in public- nor private-driven MaaS ecosystems. Additional revenue from data and added services is essential for MaaS to thrive. This goes in line with recent discussions about the transition from mobility as a service to mobility as a feature [7].

Supplementary Information

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Additional file 1. Detailed calculations and assumptions for all settings.

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Availability of data and materials
The calculations are gathered in the Additional file 1.

Declarations

Competing interests
The authors ensure that, although they could have also been the subject of the study, they conducted the data analysis without interference and possible bias.

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