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Designing mobility-as-a-service business models using morphological analysis

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ABSTRACT

Although Mobility-as-a-Service (MaaS) is a very prominent model for future passenger transport, ideas on how to offer it are still scarce. As MaaS platforms are currently mostly offered as field trials, they are highly use-case specific. One of the main reasons for seeing only few examples of 'real' MaaS as a commercial offer is the shortage of business models that could be applied when providing the service. To better understand potential business model configurations for MaaS, we propose a new conceptual framework to develop MaaS business models. We do so by integrating the Business Model Canvas with a morphological approach to compose all relevant factors in one framework. To populate the framework, we draw on a systematic literature review. We use this to generate morphological boxes for each of the nine building blocks of the Business Model Canvas. The framework helps to understand the features of MaaS and how to provide them from an operator's point of view. By discussing interdependencies of different configurations, we also provide a starting point to evaluate MaaS in a structured way and thereby generate implications for managerial practice, also for generating viable MaaS business models.

1. Introduction

Mobility-as-a-Service (MaaS) has become an important area of debate in transport studies, as it promises to deploy digital network technologies in a way that improves services to travellers while promoting sustainable transport systems (Catulli, Potter, & Cook, 2021; Cruz & Sarmento, 2020; Sochor, Arby, Karlsson, & Sarasini, 2018). Hensher et al. (2021, p. 153) define MaaS as "[…] a framework for delivering a portfolio of multi-modal mobility services that places the user at the centre of the offer." It is integrated in a digital platform providing "[…] information, booking, ticketing, [and] payment […]" (Hensher et al., 2021, p. 153). Specifically, it is considered to generate new possibilities for integrating transport modes to provide an effective alternative to private cars as primary mode (Smith, Sochor, & Karlsson, 2020). Concerning business organisation, it opens up transport systems to new business models (Cooper, Tryfonas, Crick, & Marsh, 2019; Hensher, 2017; Moura, 2018) that fulfil the needs of a respective user-base (Loubser, Marnewick, & Joseph, 2021). However, MaaS is still at the prototype stage and it is necessary to translate MaaS experiments into business models. This is crucial since for managers and society, business models are at least as important, if not more important than the technological innovation itself (Teece, 2010). Chesbrough (2007, p. 12) states: "A better business model often will beat a better idea or technology." Although MaaS apps have been downloaded millionfold, providers are still struggling to break even (van den Heuvel, Kao, & Matyas, 2020). Yet, as an innovation, MaaS has the potential to disrupt incumbent business models, which makes it a crucial driver for the transport industry (van den Heuvel et al., 2020). Hensher (2017) also identifies the increased importance of a broker role in MaaS to support a move away from private transport. Also, for creating viable shared services, a core to MaaS, the business model logic is important (Krauss, Krail, & Axhausen, 2022). Put simply, the development of business models is a critical requirement for the development of MaaS (Karlsson et al., 2020).

Despite its importance for the future transport industry, the analysis of MaaS business models is still limited. MaaS can cover a wide range of integrated mobility services (Reck, Hensher, & Ho, 2020) with an equally wide range of business model configurations. Approaches to MaaS business models are currently highly use-case specific, either regarding the type of mobility service (Chen & Qiu, 2019) or the location (Cooper et al., 2019; Cruz & Sarmento, 2020; Jokinen, Sihvola, & Mladenovic, 2019). Therefore, a framework to assess MaaS business models is needed to enable comparisons across applications. This allows

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to identify best practices and barriers to developing MaaS.

Developing this framework to design and assess MaaS business models is our main objective. We therefore use the Business Model Canvas (BMC) pioneered by Osterwalder, Pigneur, and Tucci (2005) to develop a structure for a MaaS provider. The BMC has been applied to MaaS in various approaches: König et al. (2016), Gilibert and Ribas (2019a), Gilibert and Ribas (2019b), Kukkamalla, Bikfalvi, and Arbussa (2021), Lygnerud and Nilsson (2021) or Polydoropoulou et al. (2020) describe single MaaS cases. The BMC incorporates nine building blocks characterising the business and its functioning (Osterwalder & Pigneur, 2013). The second objective is to combine the BMC approach with morphological analysis (Ritchey, 2011), i.e. morphological boxes (Zwicky, 1967), in order to populate the BMC building blocks. In previous work, Kley, Lerch, and Dallinger (2011) use the morphological box to assess business models for electric vehicles. We generate one morphological box for each of the nine building blocks. The morphological box positions potential solutions by defining features of a problem and the different possible configurations of the features (Günther, Jacobsen, Rehme, Götze, & Krems, 2020; Zwicky, 1967).

This original combined approach enables us to structure the BMC building blocks of MaaS business models and then structure the different configurations within these blocks. A consistent characterisation of business models is achieved and the results facilitate a precise definition of MaaS. It can also be used for a comparison of different MaaS providers. This enables the identification and development of successful business models. Since MaaS pilots or operations have been mostly in urban areas due to denser demand and origin-destination connections, we follow this scope and focus on the metropolitan context (Eckhardt, Nykänen, Aapaoja, & Niemi, 2018; Hensher et al., 2020; Jittrapirom, Marchau, van der Heijden, & Meurs, 2020). The applicability and transferability of this approach on rural MaaS operations is evaluated in the implication section. Doing so, our approach provides guidance to managers of public transport (PT), private mobility services or cities about which aspects to pay attention to when implementing it. Demonstrating the strengths of combining BMC and morphological analysis, we also provide a new method to better understand complex problems and how their decomposition and reassembling can help to solve these.

In the remainder of this paper, we first provide an overview about the literature drawing on a systematic review we conducted to later populate the BMC building blocks applying morphological analysis (Section 2). Second, we discuss the research questions and introduce the methodological approach applied to answer them (Section 3). Third, we present the proposed framework for MaaS business model configurations and apply it to four use cases (Section 4). Section 5 identifies the implications for managerial practice and states the contribution of this work for future research.

2. Literature review

As Hensher et al. (2021) state, digital integration is key to MaaS. Regarding the extent of integration of MaaS, Sochor et al. (2018) provide a topology ranging from "no integration" (level 0) to "integration of societal goals" (level 4). Each level integrates the preceding levels, such that level 4 integrates information (level 1), booking and payment (level 2), and the service offer (level 3). Eckhardt, Aapaoja, Nykänen, and Sochor (2017) propose three operator model categories for MaaS to realise this integration: commercial, public, and the combination, i.e. public-private partnerships. A commercial operator is either a reseller or an integrator. For integrators, MaaS can either be the main or a complementing business. Public operators can be municipality- or state-owned operators. For our approach, the commercial category is crucial and focuses on the integrator running MaaS as main business.

We review the literature about drivers and barriers for MaaS implementation to then outline previous work following the logic of the BMC. To enhance the understanding of interdependencies and receive a better overview, we divide the nine building blocks of the BMC into four categories: value proposition, infrastructure, customer structure, and revenue structure (see Fig. 1). The value proposition is an own building block (Osterwalder & Pigneur, 2013). Infrastructure contains *key resources*, *key partners*, and *key activities* (Osterwalder & Pigneur, 2013). The customer structure includes *customer relationships*, *customer segments*, and *communication channels* (Osterwalder & Pigneur, 2013). The revenue structure subsumes *cost structure* and *revenue streams* (Osterwalder & Pigneur, 2013).

2.1. Drivers and barriers for implementing MaaS

The challenge of adding suitable business models to the MaaS-concept is widely discussed. In their case study of Finland and Sweden, Karlsson et al. (2020) use qualitative data to identify crucial factors for developing MaaS. The work is based on institutional theory using the three analytical levels macro, meso, and micro. On macro-level, legislative barriers are one significant obstacle. Private actors name, amongst others, taxation laws as barrier since these have not integrated shared economy ideas yet (Karlsson et al., 2020). Public actors have to deal with the status quo definition of PT (Karlsson et al., 2020). However, as MaaS needs PT as backbone but questions its current understanding (Karlsson et al., 2020), public actors are torn between an old world that serves as basis for legislation and a new world that is hindered by the former. In public-private partnerships, new barriers emerge since public actors often must not interfere with market competition by restricting or distorting it (Karlsson et al., 2020, p. 289). On meso-level, the authors find the "[…] lack of appropriate business models […]" as one crucial factor. This is a focal topic for both public and private organisations. Interviewees describe the business model as "[…] Gordian knot […]" and it is concluded that benefits need to be created for all actors (Karlsson et al., 2020, p. 289). Habits and attitudes of people are found to be relevant on micro-level (Karlsson et al., 2020). Butler, Yigitcanlar, and Paz (2021) find that one supply-side barrier to adopt MaaS is business support as MaaS comes with high costs and low short-term return on investment. Hence, financial incentives are important although these could also lead to manipulation of the pricing process, threatening the economic sustainability of MaaS (Butler et al., 2021).

The drivers and barriers depicted underline the importance of disassembling the MaaS business model problem. Although Karlsson et al. (2020) state the business model explicitly on meso-level, its influences and consequences stemming from micro- and macro-level need to be incorporated. Costs play a crucial role on both levels, micro (return on investment and financial incentives) and macro (taxation). Hence, understanding the cost and revenue dimensions is crucial to overcome these barriers. For the legislative barriers (macro-level), knowing which key partners and regulatory bodies are involved and which change is required, is needed to make MaaS work. Also, MaaS providers need to understand the implications of respective legislation towards their service. For this, a systematic overview about ingredients and their dependencies is crucial to offer a service that provides a value proposition enabling new ways of transport (van den Heuvel et al., 2020) and is attractive enough for travellers to maybe even change habits (Catulli et al., 2021; Karlsson et al., 2020).

2.2. Value proposition

The value proposition is the product or service that solves a problem customers face or satisfies a certain need (Osterwalder & Pigneur, 2013). It is the sum of benefits the company provides (Osterwalder & Pigneur, 2013). The core of the MaaS value proposition is the integration of services and modes (Hensher et al., 2021; Sochor et al., 2018). Integration of information (König et al., 2016), booking (Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020), ticketing and payment (König et al., 2016; Polydoropoulou et al., 2020), fleet service (Gilibert & Ribas, 2019b), and freight service (Jittrapirom et al., 2017; König et al., 2016;

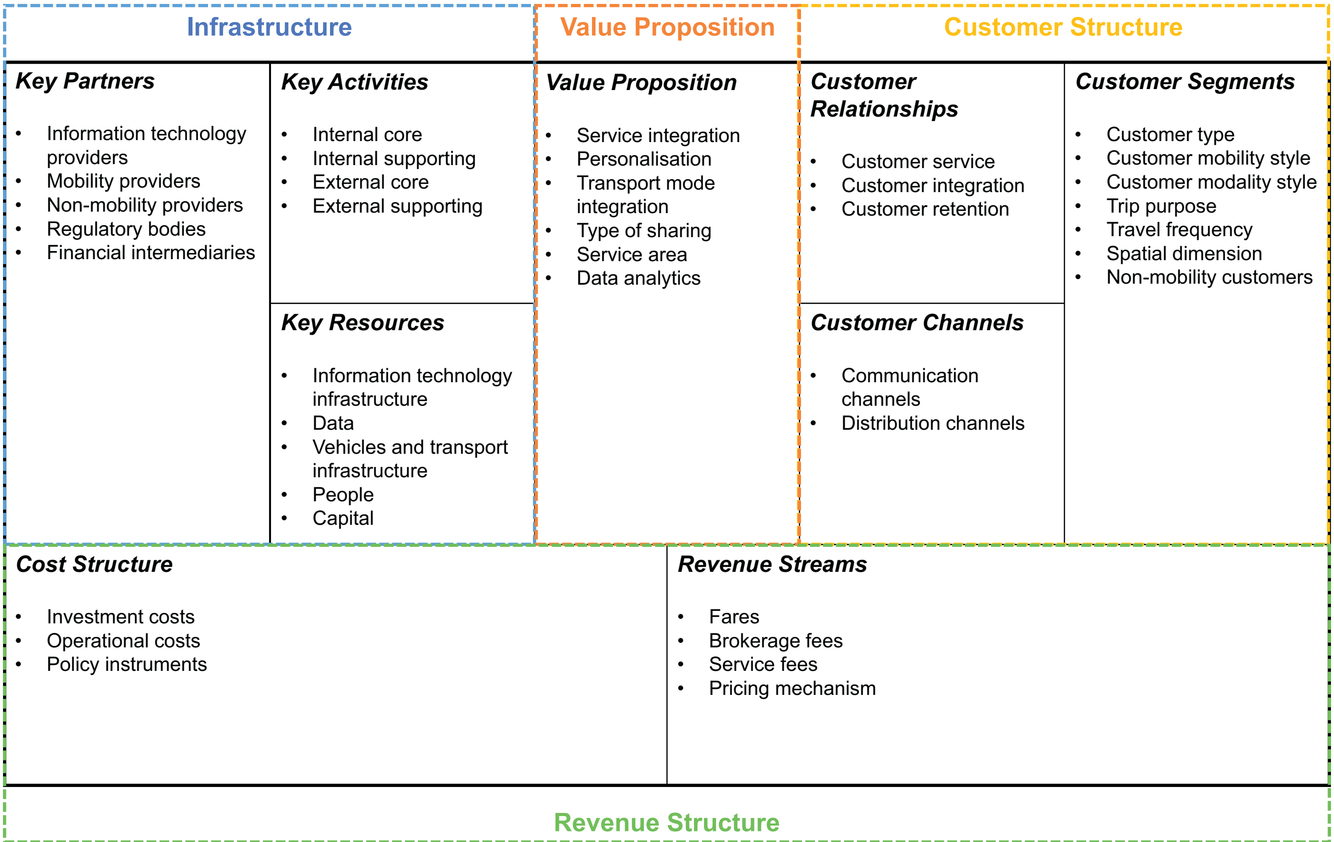

Fig. 1. Overview of BMC, its four categories, and nine building blocks including the respective characteristics.

Willing, Brandt, & Neumann, 2017) are possible parts of the service. MaaS provides customers with flexible mobility options (Polydoropoulou et al., 2020) that can be on-demand, low-cost, and available any time (Gilibert & Ribas, 2019b). MaaS is a fit-for-purpose solution or one-stop-shop incorporating individual preferences or constraints (König et al., 2016; Willing et al., 2017). This can include personalisation (Polydoropoulou et al., 2020) and ease of use (Günther et al., 2020), due to smart operations (Meng, Somenahalli, & Berry, 2020). The MaaS platform can range from local to international (Polydoropoulou et al., 2020). By generating large amounts of data, MaaS can supply big data to the domain of transport (Meng et al., 2020). By integrating public and private modes and generating data for town planning, MaaS can also support public-private partnerships (Meng et al., 2020; Polydoropoulou et al., 2020). Reduced travel times (Meng et al., 2020), reduced private car use (König et al., 2016; Meng et al., 2020), reduced emissions (König et al., 2016), transparent transport costs, and improved social equity (Gilibert & Ribas, 2019b; Meng et al., 2020) are further potential attributes delivered by MaaS.

2.3. Infrastructure

The infrastructure depicts the supply-side of the BMC. Key partners are the network of suppliers that are required for the business model to work (Osterwalder & Pigneur, 2013). Previous work emphasises the role of transport operators and information technology (IT) platform providers. The former includes PT and private mobility providers (Arias-Molinares & García-Palomares, 2020; Cruz & Sarmento, 2020;Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020). Private modes have not been in the focus of previous work, so do peer-to-peer (P2P) services such as carpooling (Polydoropoulou et al., 2020). The IT platform provider, the respective infrastructure, and data providers are identified as important ingredients to MaaS (Arias-Molinares & García-Palomares, 2020; Cruz & Sarmento, 2020; Gilibert & Ribas, 2019b; König et al., 2016). Non-mobility service providers can be included as well (König et al., 2016; Kukkamalla et al., 2021; Polydoropoulou et al., 2020). Regulatory bodies are named as policy framework (Gilibert & Ribas, 2019b; Karlsson et al., 2020; König et al., 2016; Polydoropoulou et al., 2020). Investors or funders are mentioned, too (Arias-Molinares & García-Palomares, 2020; Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020).

The key activities summarise the crucial activities to be executed by the firm to operate the business model (Osterwalder & Pigneur, 2013). Much of key activities related literature has emphasised data processing or data analytics (Chen & Qiu, 2019; Cruz & Sarmento, 2020; Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020; Sarasini, Sochor, & Arby, 2017). Service design, content development (König et al., 2016; Polydoropoulou et al., 2020), and customer service (Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020) are also key.

Key resources are assets the company needs to fulfil its business model (Osterwalder & Pigneur, 2013). Physical and technological resources (Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020) such as vehicles (Gilibert & Ribas, 2019b) are key resources. Software such as routing algorithms and the mobile application need to be provided (Gilibert & Ribas, 2019b). Further, human resources are required (Polydoropoulou et al., 2020).

2.4. Customer structure

In the customer structure category, the customer segments specify the relevant groups of persons or organisations that should purchase the services offered (Osterwalder & Pigneur, 2013). These groups can be defined based on common needs, behaviours or further characteristics relevant for the case (Osterwalder & Pigneur, 2013). For MaaS, private and business customers can be distinguished (Gilibert & Ribas, 2019b; König et al., 2016; Polydoropoulou et al., 2020). These customer types differ in their characterisation and required service foci. Nevertheless, parallels can be drawn: the frequency of interaction with the MaaS supplier (Gilibert & Ribas, 2019b), and the customer's profile such as commuters (Polydoropoulou et al., 2020), tech-savvy clients (Kukkamalla et al., 2021) or the general purpose of using MaaS (Gilibert & Ribas, 2019b; Polydoropoulou et al., 2020).

The customer channels building block represents the communication of the company and how the customer segments receive the value proposition (Osterwalder & Pigneur, 2013). The identified channels include information presentation (e.g. websites, media) and the supply of the service itself (e.g. website, smartphone application; Gilibert & Ribas, 2019b; König et al., 2016; Polydoropoulou et al., 2020).

The customer relationships define the type of relationship the company develops with the customer segments (Osterwalder & Pigneur, 2013). The type of assistance and service of the platform is key (Gilibert & Ribas, 2019b; König et al., 2016; Polydoropoulou et al., 2020). Additional characteristics are co-creation processes (Polydoropoulou et al., 2020), incentive programs (Polydoropoulou et al., 2020), and feedback systems (Gilibert & Ribas, 2019b; Kukkamalla et al., 2021).

2.5. Revenue structure

The revenue structure category comprises cost structure and revenue streams. Cost structure includes all costs that are incurred by the other building blocks (Osterwalder & Pigneur, 2013). For MaaS, developing and maintaining the software and the fleet are particularly important (Gilibert & Ribas, 2019b; König et al., 2016; Kukkamalla et al., 2021; Polydoropoulou et al., 2020). Personnel costs (Gilibert & Ribas, 2019b) and knowledge management (Kukkamalla et al., 2021) are also relevant. Revenue streams describe the income the business model generates from its customer segments (Osterwalder & Pigneur, 2013). This is the service fee for the traveller (Gilibert & Ribas, 2019b; Jittrapirom et al., 2017; König et al., 2016; Kukkamalla et al., 2021; Reck et al., 2020) and commissions or fixed contracts for the mobility providers (Gilibert & Ribas, 2019b; König et al., 2016; Polydoropoulou et al., 2020).

3. Research questions and methods

As the literature review emphasises, a systematic structure for MaaS business models integrating all essential ingredients is crucial to successfully implement MaaS. To do so, we use morphological analysis to decompose the overall problem and create compatible configurations. Thus, we aim to answer the following two research questions: How can a MaaS business model be characterised and structured from a provider's point of view? And, how can the BMC (Osterwalder et al., 2005) and the morphological box be combined in order to analyse and structure business models? While the first question focuses on the provider, it also refers to the customers for two reasons: first, the value proposition is defined as satisfying a certain need of customers (see Section 2.2). Second, the customer structure category integrates respective segments, their relationships, and channels used (see Section 2.4). Thus, taking the provider's point of view and using the business model perspective via the BMC, we include information about the demand-side, too. In Sections 4.1 (value proposition) and 4.3 (customer structure), the respective morphological boxes are developed, which integrate the demand-side perspective.

To address our research questions, we searched Scopus for journal, multi-volume reference works or reports since 2014, when the term was originally coined by Hietanen (2014). We searched the title, abstract, and keywords for "MaaS", "mobility as a service", "transport service", "mobility service","platform mobility", "mobility platform", or "mobility concept". The documents were required to include the term "business model" (see Appendix A.1 for the search string). Of the 95 publications identified, we extract quantitative and qualitative information about the understanding of MaaS relevant to business model configurations. We pay particular attention to work that uses approaches such as the BMC. We then classify this information into the relevant BMC building blocks.

We follow the understanding of business models primarily being conceptual and not financial models representing activities that are relevant for the company (Teece, 2010; Wirtz, Pistoia, Ullrich, & Göttel, 2016). The business model integrates value creation, characteristics of customers and markets, and strategic thinking to achieve a competitive advantage (Wirtz et al., 2016). We apply the definition of business models being formal conceptual representations of how a company works (Massa, Tucci, & Afuah, 2017). In combining MaaS and business models, we draw on the MaaS ecosystem proposed by Kamargianni and Matyas (2017). This integrates core business, extended enterprise, and the business ecosystem with respective stakeholders (Kamargianni & Matyas, 2017).

The BMC distinguishes nine building blocks that are relevant to make the business work (see Fig. 1; Osterwalder & Pigneur, 2013; Osterwalder et al., 2005). Each building block covers one dimension. Their combination results in a detailed description how the business functions. To populate these building blocks, we use morphological boxes (Zwicky, 1967). These are defined as a potential solution space to a specific problem that is decomposed in order to solve it. First, the characteristics of this problem are defined. Second, solutions for these problem characteristics are developed. Third, these characteristics are composed in possible configurations. Each characteristic has two or more elements that represent different approaches to solve it. Finally, the different elements of each characteristic are composed and generate different configurations to solve the problem. The problem dealt with here is the business model for a MaaS provider that we decompose into one morphological box per building block of the BMC.

Combining the BMC approach with morphological analysis allows us to decompose the challenges MaaS providers face. Due to this systematic disassembling into elements for each part of the business model, the chances and challenges of providing MaaS can be identified more explicitly. The reassembling of the single elements enables building logically sound and compatible characteristics for each BMC building block. As a result, we generate a structured framework for MaaS business models that integrates the relevant ingredients.

To test our framework, we apply it to four real-world use cases. We searched test cases in different countries with different providers and offers in order to receive a great amount of heterogeneity. The test cases are Regiomove in Karlsruhe, Germany (Regiomove, 2021), Mobil-Flat in Augsburg, Germany (Stadtwerke Augsburg, 2021), Whim in Vienna, Austria (MaaS Global, 2021), and yumuv in Zurich, Bern, and Basel, Switzerland (yumuv, 2021). In applying our framework to these cases, we identify interdependencies regarding two changes in the business models: whether bundling, i.e. the integration of different mobility services into packages (Reck et al., 2020), is offered, and the amount and type of modes integrated.

4. Developing the morphological boxes

Fig. 1 shows the BMC's four categories, nine building blocks, and characteristics identified. For each building block, we develop a morphological box outlining the characteristics and elements required to describe or develop a MaaS business model: value proposition; infrastructure including key partners, key activities, and key resources; customer structure including customer segments, customer relationships, and channels; and revenue structure including cost structure and revenue streams. To enhance readability, we refrain from citing the source of each element in the morphological boxes, instead listing all references used for the development of the morphological boxes per building block in Table A (Appendix A.2).

4.1. Value proposition of MaaS business models

Key areas for the value proposition of MaaS business models are service integration, personalisation, transport mode integration, type of sharing, service area, and data analytics. Fig. 2 shows the characteristics and elements.

As one-stop-shop, MaaS integrates services such as information provision on mobility options and prices, routing, planning, booking, ticketing, payment, bundling of modes, fleet services, and freight services. Bundling follows the idea of selling several products or services in one package (Stremersch & Tellis, 2002). Concerning MaaS, this means the integration of different mobility services (Reck et al., 2020). Reck et al. (2020) categorise MaaS bundles as mixed referring to Stremersch and Tellis (2002). Mixed bundling is the business selling the bundle and the separate products or services whereas pure bundling means only the bundle is sold (Stremersch & Tellis, 2002). Reck et al. (2020) argue that mixed bundling is accurate for the mobility services as these would be sold in the bundle and as standalone services separately. However, we argue that one needs to distinguish the two different points of view into the single mobility service and the MaaS platform provider. If the MaaS provider uses bundling as part of its value proposition and the single mobility service provider decides to provide its service as standalone and on the MaaS platform, the former can apply mixed or pure bundling. However, the mobility service provider outsources the bundling to the MaaS provider. Referring to Stremersch and Tellis (2002), this would not fulfil the definition of bundling since it needs to be one firm. Hence, true bundling can only take place in the MaaS provider's business model, making this a crucial unique selling point.

Personalisation is the generation of value by services that are changed to meet the requirements or preferences of each customer. These preferences will change, so the value proposition will include the facility for the user to define their own preference profile or recall standard profiles (e.g. commuting, leisure, long distance). The MaaS provider might include this personalisation option or not. If it is included, these characteristics are similar to customer segments (see Section 4.3.1), but here they are used to offer a different service to each customer. To do so, we apply the concept of mobility styles. Trip purpose and travel frequency are manifestations of personalisation. The former can have an impact on how the customer wants to spend the travel time: Commuting might require an internet connection whilst a leisure trip requires space for a suitcase.

Alternative transport modes may be integrated: PT, car, bike, walk, ridesourcing, taxi, e-scooter, and aircraft. Usually it can be assumed that more available modes increase the value for the customer (Guidon, Wicki, Bernauer, & Axhausen, 2020). Since MaaS is often linked to sharing, different types are specified: sharing of vehicles or pooling of rides. Whilst cars, bikes, and e-scooters can be shared, ridesourcing can be operated as pooled service. Furthermore, the value proposition can be characterised by its service area, which can be local (i.e. districts within the city), city-wide, regional, national or international. Besides serving travellers, MaaS can also include data analytics services. This might be used for demand management and can enhance town planning by, e.g. saving space by reducing the amount of parking vehicles. Service improvements regarding the MaaS provider or the integrated modes, commercial use (e.g. selling data) as well as fleet planning, operation, and maintenance can be further elements of applying the data generated.

4.2. Infrastructure for MaaS business models

Infrastructure includes the building blocks key partners, key activities and key resources. Fig. 3 shows the characteristics and respective elements.

4.2.1. Key partners

The key partners comprise IT, mobility, and non-mobility service providers, regulatory bodies, and financial intermediaries. IT infrastructure providers, data service providers, GPS service providers, telecommunication providers, and payment operators can be specified as IT providers. PT operators, private transport operators, transport infrastructure providers, original equipment manufacturers (OEMs) for all means of transportation, and other MaaS providers are elements for the mobility providers. Private transport operators include private persons offering P2P mobility services, e.g. P2P carsharing. Regarding the future development of MaaS as a potentially multi-service platform can make non-mobility service providers necessary. These are accommodation services, event and entertainment services, leisure services or research organisations. Since MaaS is integrated in a regulated (public) transportation system, regulatory bodies are key partners. Depending on the value proposition, public authorities can be customers (see Section 4.3). Local, regional, and (inter-) national governments as well as road authorities can be specified as regulatory bodies. Finally, financial intermediaries, i.e. investors and banks, venture capitalists, and insurance companies, are key.

4.2.2. Key activities

For key activities we differentiate internal core, internal supporting, external core, and external supporting activities. Distinguishing internal and external activities draws on the degree of integration of the multiple partners in the MaaS ecosystem. This integration varies from very close to rather loose (Senn, 2020). Internal core activities are IT platform development, application programming interface (API) development, service and content development, trip planning, booking, ticketing, routing, dynamic information provision, revenue sharing, and fleet

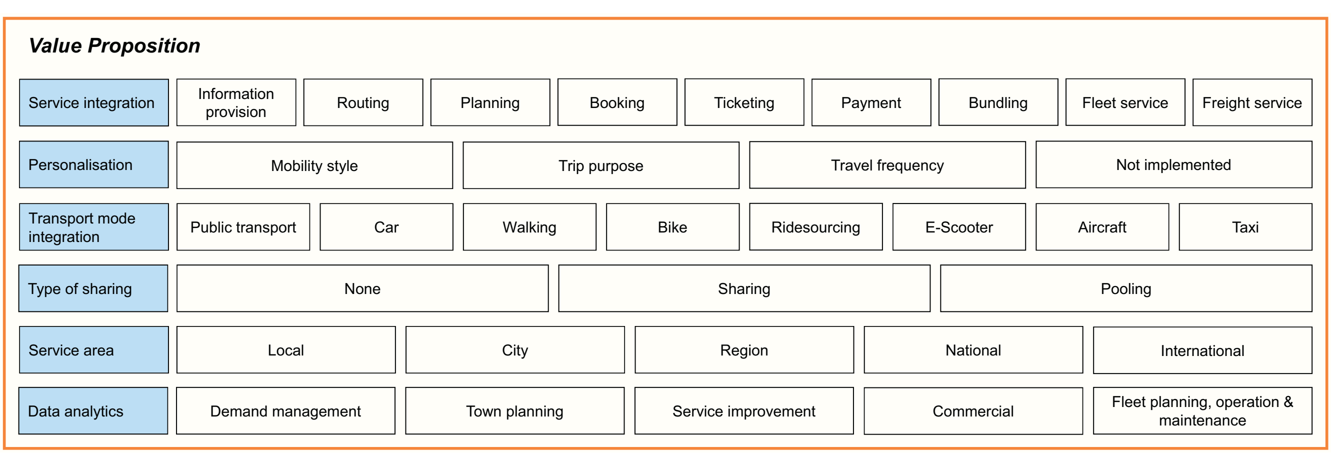

Fig. 2. Morphological box for the value proposition of MaaS business models.

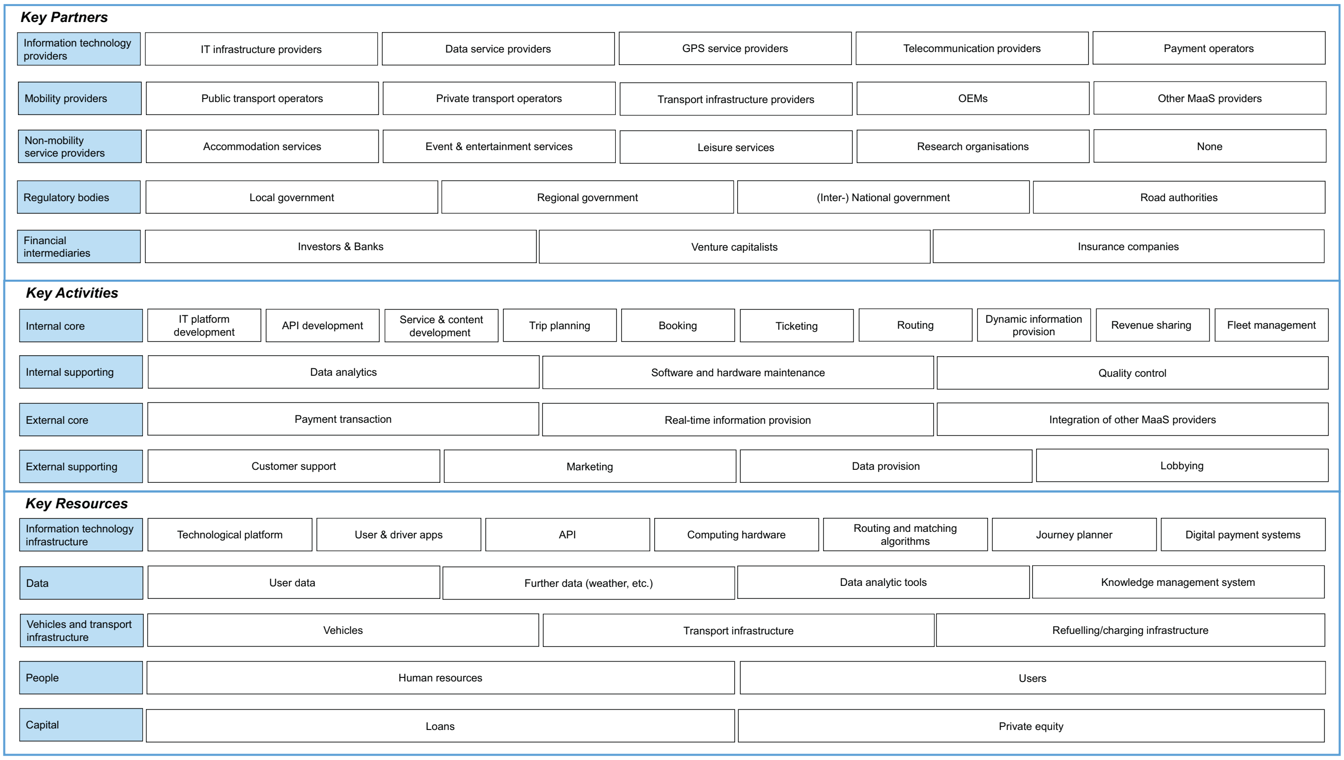

Fig. 3. Morphological boxes for the infrastructure category of MaaS business models, i.e. key partners, key activities, and key resources.

management. Internal supporting activities focus on data analytics, software and hardware maintenance, and quality control. External core activities, carried out by key partners, are processing (customer) payments, real-time information provision (e.g. external traffic data, weather data), and integration of other MaaS providers. Customer support, marketing, data provision, and lobbying are specified as external supporting activities.

4.2.3. Key resources

Key resources can be differentiated in IT infrastructure, data, vehicles and transport infrastructure, people, and capital. Technological platforms, APIs, user and driver apps, computing hardware, routing and matching algorithms, journey planner and digital payment systems are key IT infrastructure resources. Due to its criticality to MaaS, we consider data as a separate category. It comprises user data, further data (e.g. weather, event, social media data), data analytic tools, and a knowledge management system. Vehicle and transport infrastructure can be divided in vehicles, transport infrastructure, and refuelling or charging infrastructure. People involved in MaaS are either human resources within firms or users, while capital can be loans or private equity.

4.3. Customer structure for MaaS business models

The customer structure includes the building blocks customer segments, customer relationships, and customer channels. Fig. 4 depicts the respective characteristics and elements.

4.3.1. Customer segments

We consider customer types, customer mobility styles, customer modality styles, trip purpose, travel frequency, the spatial dimension, and non-mobility customers as characteristics. We distinguish private and business customer types. While customer mobility styles refer to long-term, modality styles refer to short-term transport decisions (Gehrke, Singleton, & Clifton, 2019; Vij, Carrel, & Walker, 2013). Both are affected by the traveller's lifestyle, i.e. orientations on a higher level such as attitudes and values (Vij et al., 2013). Mobility styles have been identified in various contexts: all across Europe (Haustein & Nielsen, 2016), specifically for leisure travel (Lanzendorf, 2002), concerning travel behaviour towards more sustainability (Prillwitz & Barr, 2011) or regarding shared mobility (Ramos, Bergstad, Chicco, & Diana, 2020). We follow the classification of Gehrke et al. (2019) due to their integrated analysis of lifestyle and lifecycle latent factors based on stated preference data. Thus, we distinguish three classes: the private car-oriented driver who holds a driver's license and no transit pass, the captive transit user class in which holding a driver's license and transit pass is mixed, and the multimodal traveller who holds a driver's license and rather less frequently a transit pass (Gehrke et al., 2019). Multimodal travellers can be differentiated further (Molin, Mokhtarian, & Kroesen, 2016), reflecting parts of the modality style characteristic. Modality styles have been analysed regarding their mode shift potential (Anable, 2005; Kroesen, 2014), for first−/last-mile trips (Lu, Prato, & Corcoran, 2021; Lu, Prato, Sipe, Kimpton, & Corcoran, 2022), concerning their carbon footprint (Keskisaari, Ottelin, & Heinonen, 2017), their development and shift over time (Vij, Gorripaty, & Walker, 2017), the relationship of daily and non-daily patterns (Große, Olafsson, Carstensen, & Fertner, 2018), the connection to normative beliefs (Krueger, Vij, & Rashidi, 2018), or the interdependence with life events (Janke, Thigpen, & Handy, 2021). Due to their contextualisation of modality styles and the detailed analysis of a six-week dataset, we follow the approach by Vij et al. (2013) who distinguish three styles: The habitual driver only considers car and walk with a ratio of four to one. Time sensitive multimodals consider every mode and show the highest elasticity regarding travel time. Time insensitive multimodals consider all modes but show an inelastic demand regarding travel time. We further specify the characteristics trip purpose (business, private, leisure, commuting/education), spatial dimension (intra-urban, inter-urban, international), and travel frequency (daily, weekly, monthly, occasionally). Additionally, Hensher et al. (2020) note that existing businesses need to rethink when it comes to their future customers. From the MaaS

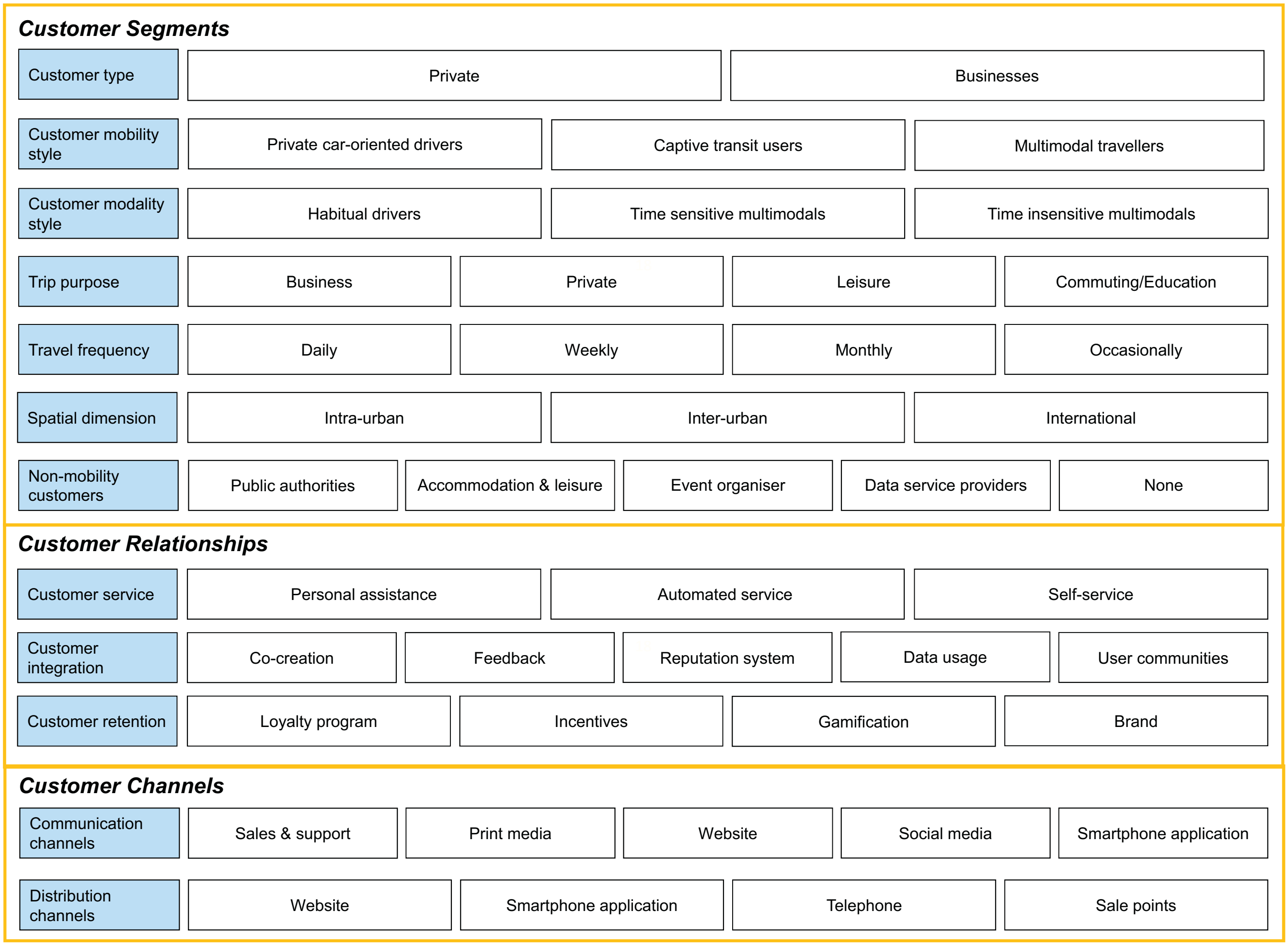

Fig. 4. Morphological boxes for the customer category of MaaS business models, i.e. customer segments, customer relationships, and customer channels.

provider's point of view, this relates to non-mobility customers: accommodation, leisure and event organisers, public authorities (e.g. town planning), and data service providers.

4.3.2. *Customer relationships*

Customer relationships include customer service, customer integration, and customer retention as characteristics. Personal assistance, automated service as well as self-service define MaaS customer services. Customer integration to improve existing and develop new services can be realised with co-creation in e.g. living labs, feedback or social media interaction, reputation systems, data usage (big data analyses of user data), and user communities. Customer retention can be achieved by loyalty programs, further incentives (e.g. discount coupons), gamification approaches, and strong brand images.

4.3.3. *Customer channels*

Customer channels can be divided into communication and distribution channels (Osterwalder & Pigneur, 2013). We identify

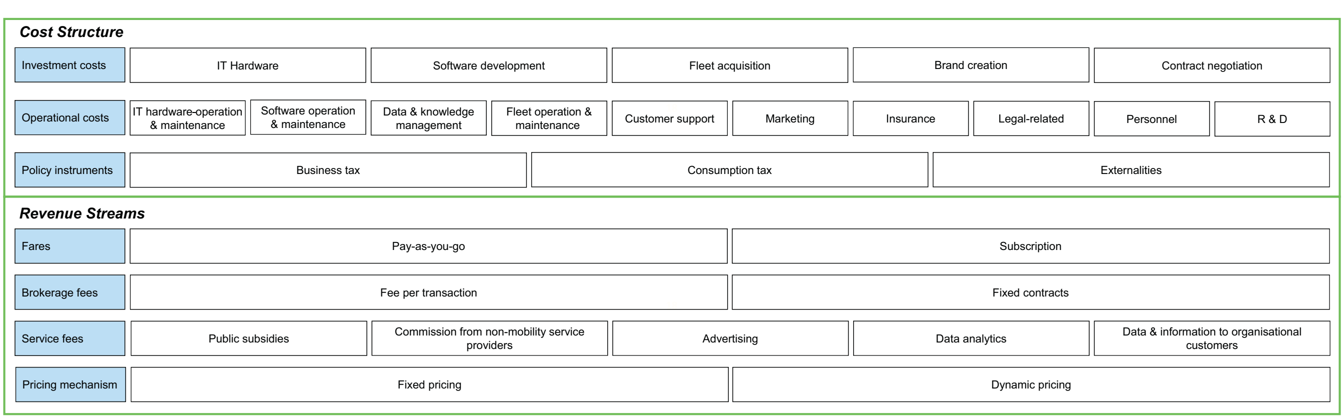

Fig. 5. Morphological boxes for the revenue structure category of MaaS business models, i.e. cost structure and revenue streams.

communication channels as sales and support teams, print media, and digital communication channels, i.e. websites, social media, and smart phone applications. Websites, smartphone applications, telephone, and regular sales points can be identified as most important distribution channels.

4.4. Revenue structure for MaaS business models

The revenue structure comprises the building blocks cost structure and revenue streams. Fig. 5 illustrates these morphological boxes with the respective characteristics and elements.

4.4.1. Cost structure

Investment and operational costs can be differentiated, which is supplemented by costs for policy instruments addressing ecological, social, political, and legal liabilities. Investment costs include costs for all resources required, i.e. IT hardware, software development, fleet acquisition, and establishing a strong brand. Since a MaaS provider integrates multiple stakeholders, contract negotiation is another important cost, especially during service development. Operational costs mainly relate to key activities and include IT hardware as well as software operation and maintenance, data and knowledge management as well as fleet operation and maintenance. Customer related operational costs are customer support and marketing costs. Insurance costs and legal-related costs are required to cover the liabilities of the MaaS provider. Salaries and research and development (R&D) are operational costs, too. Regarding policy instruments, the MaaS provider has to transfer business and consumption taxes. Integrating externalities might become more important due to mobility's high ecological and social impact.

4.4.2. Revenue streams

Revenue streams for the MaaS provider include fares, brokerage fees, service fees, and require a pricing mechanism. Fares describe revenues paid by travellers, brokerage fees are revenues paid by single service providers, and service fees are revenues paid for offering the service in the first place. Fares are distinguished in two elements: pay-as-you-go (time- and/or distance-dependent), or subscriptions on a daily, monthly or yearly basis combining diverse MaaS bundles. However, fares are not necessarily revenue streams for the MaaS provider since it might only pass these to the single service providers. Brokerage fees are the most important revenue stream, including fees per transaction or fees based on fixed contracts. Additional service fees can be relevant and their role might increase in future as current MaaS tends not to be economically viable. Thus, since MaaS provides (public) transport services, public subsidies can be an important service fee. Non-mobility customers (e.g. entertainment, catering, hospitality industry) using MaaS platforms as marketing instruments may pay commissions for brokerage or advertisements. With increasing importance and value of data, revenues for data analytics or selling data and information to organisational customers might be significant. All revenues can be operationalised as fixed or dynamic pricing with the latter relying on market conditions.

4.5. Application of framework to use cases

We test our framework by drawing on four real-world MaaS cases, i.e. Regiomove (2021), Mobil-Flat (Stadtwerke Augsburg, 2021), Whim (MaaS Global, 2021), and yumuv (2021), and compare these by focusing on whether bundling is offered (Fig. 2, 'service integration') and type and amount of transport modes integrated (Fig. 2, 'transport mode integration'). The selection criteria for the test cases are based on their value propositions and a preferably high heterogeneity between them to demonstrate the diverse consequences of different BMC configurations. In particular, the scope of service integration (information provision, routing, booking, payment, etc.), the amount and type of modes integrated (mode itself, type of sharing), and the service area (local, city- or region-wide) were relevant for selection. Further, the operator model (see Polydoropoulou et al. (2020)) and level of integration (see Sochor et al. (2018)) were assessed.

Table 1 gives a comparative overview about the test cases and relevant elements. Mobil-Flat is a city-wide service in Augsburg (Germany). It is an incorporation of public administration and private companies. Regiomove is based in Karlsruhe (Germany) and available in the middle Upper Rhine region (including the two administrative districts Karlsruhe and Rastatt and the urban district Baden-Baden), thus a region-wide service. It is operated by the PT carrier. Whim in Vienna offers a city-wide service and is operated by MaaS Global, a private company. Yumuv operated[1] in Zurich, Basel, and Bern (Switzerland), thus offered a multi-city service area and is operated by a private corporation of the PT carriers. Yumuv and Mobil-Flat offer bundling whilst Regiomove and Whim in Vienna do not. Regiomove integrates booking and payment for PT and carsharing. Private car, private bike, and walking are used for routing. Yumuv used PT, shared bikes, e-scooters, and cars (booking and payment for each), and walking. Mobil-Flat integrates PT, shared bikes and cars (booking and payment for each), and walking. Whim uses PT, shared e-scooters, taxi (booking and payment for each), and walking. According to Sochor et al. (2018), Mobil-Flat and yumuv are level 3 while Regiomove and Whim are level 2 MaaS. Regarding the BMC, integrating the element bundling as in yumuv and Mobil-Flat is an extension of the value proposition (Fig. 2) compared to Regiomove and Whim. The same holds for integrating more transport modes. The cases selected therefore incorporate different schemes of bundling and show how the framework can be applied across differing cases to enable a comparative analysis. This extends previous literature, which is mainly case-specific, since we first develop a structured framework to then systematically compare MaaS business models. Hence, the framework proposed here enables an assessment of best practices and may be used to develop more generalised insights on barriers to MaaS through the application of a consistent framework across multiple cases.

One measure to increase the number of users might be integrating more modes. Addressing more mobility styles (Vij et al., 2013) results in a larger potential customer base. Regarding customer segments, integrating the private car, as Regiomove does, includes different mobility styles: private car-oriented drivers can use the service as routing application, which might be a door opener to try income-generating services. The same holds for modality styles: previous work shows that carsharing members use PT more often (Göddeke, Krauss, & Gnann, 2021), thus integrating private and shared modes can open the services to all three modality styles. Given a certain retention rate, increasing traffic on the MaaS platform is one possibility to increase revenue. Integrating more modes, shared or not, means potential customers can use the MaaS platform for more trip purposes. This effect can be amplified by travel frequency that increases when more trip purposes are covered. By integrating more modes, customer relationships might need adaption as different modes can require different customer services or allow different types of customer retention. For new transport modes such as carsharing it might be helpful offering personal assistance as the driver's license has to be checked (as yumuv, Regiomove, and Mobil-Flat do). For integrated PT, self-service might be enough for check-in/-out or single-trip tickets. Integrating more modes also increases the possibility to use broader loyalty programs, incentives, and gamification approaches. In this sense, the MaaS provider could support a less carbon-intense transport footprint. A loyalty program could promote using PT by decreasing ticket prices after a certain number of trips. Incentives could

[1] Yumuv has terminated its pilot by 31.12.2021 but the partners continue their work and currently examine possibilities to prospectively offer MaaS in Switzerland. Due to the rich information available, its broad range of modes integrated for booking and payment, and its approach across multiple cities, we still judge this case as very insightful for our application.

Table 1
Characteristics of the four test cases.

Name	City (Country)	Operator model[a]	Bundling	Modes for booking and payment	Modes for routing	Level of integration[b]
Mobil-Flat	Augsburg (Germany)	Public-private partnership	yes	PT, carsharing, shared bikes	Walk	3
Regiomove	Karlsruhe (Germany)	PT operator	no	PT, carsharing	Private car, private bike, walk	2
Whim	Vienna (Austria)	Private company	no	PT, shared e-scooters, taxi	Walk	2
yumuv	Zurich, Basel, Bern (Switzerland)	Private company	yes	PT, carsharing, shared bikes, shared e-scooters	Walk	3

[a] According to Polydoropoulou et al. (2020)
[b] According to Sochor et al. (2018)

be embodied by showing the CO_2-impact the requested trip has (as Regiomove does). Gamification approaches could be applied in a way that customers earn points for using active modes (Harris & Crone, 2021) that can be redeemed in local shops. By this, habits, described as barriers for MaaS (Karlsson et al., 2020), could be overcome by making the trip cheaper. Reducing prices for shared modes and PT or increasing costs for private cars have been shown to increase the potential uptake of the former (Krauss et al., 2022). Further, the MaaS provider might add more customer channels to reach all potential customer segments.

Bundling might make MaaS more attractive to business customers as they could be given a mobility budget. This could change customer mobility and modality styles as well as trip purpose and travel frequency as described above. Customer relationships and channels are affected by integrating bundling. As bundling is still new, the customer service might be extended towards personal assistance (at sale points). Mobil-Flat (offering bundles) provides customer support via mail and phone, which is not for Regiomove or Whim. Since the bundles need to meet the travellers' needs (Ho, Hensher, & Reck, 2021), customer integration requires more information. This can be done using co-creation, feedback, and data. The same applies to customer retention where loyalty programs or incentives can be used to draw the customers towards buying MaaS bundles, generating fixed income for the provider.

Increasing the number of transport modes integrated and offering bundling leads to higher requirements regarding key partners, activities, and resources (Fig. 3). Regiomove currently does not offer bundling and does not integrate shared e-scooters or ridesourcing. Yumuv and Mobil-Flat, however, integrate bundling drawing on a different set of modes. PT is integrated in all MaaS platforms independent of whether the respective PT operator is the owner of the platform or not. While key partners might not change significantly in the case of bundling, this is different for increasing the number of modes. The MaaS provider has to pay attention to an increasing number of regulatory bodies. Key activities tend to change in complexity rather than configuration. This means that, for instance, ticketing or data analytics become more complex but the business model elements required are not expected to change. For key resources, the data as well as vehicles and transport infrastructure changes. Concerning user data, integrating carsharing as yumuv, Regiomove, and Mobil-Flat do, requires verification of the driver's license. With an increasing number of modes and higher complexity of generated data and analytics, the requirements for data analytic tools and knowledge management systems potentially increase.

When integrating more transport modes, costs are likely to increase due to a higher complexity of the processes, especially regarding contracting (Sochor et al., 2018). The opposite might be true for bundling. Integrating more modes requires IT hardware, software, and contract negotiation investments for a larger number of mobility providers. Yet, bundling might decrease costs since bundles require less payments to be processed, which results in less IT hardware required. Concerning operational costs, more marketing and R&D is required to identify the most important modes or bundles for the travellers. More modes also require more legal-related, customer support, IT hardware and software as well as fleet operation cost. As with the investment costs, the opposite for IT hardware and software might be true for bundling. However, customer support can be more cost intensive due to the more complex service structure. Covering more customer types and mobility or modality styles increases fares and brokerage fees. Mobil-Flat only offers subscription whilst yumuv offers both. Hence, Mobil-Flat might make use of reduced costs due to simpler processes whilst yumuv has to offer both ways of processing bookings and payments. Lastly, one could think of applying dynamic pricing with respect to integrating externalities or politically undesired effects such as ecologically negative mode shifts. Hence, the taxi might become more expensive for cases in which a comparable connection by PT exists (at Whim). Urban governance might apply a policy instrument that regulates additional charges in these cases.

5. Research implications

The framework presented has two main contributions: first, it facilitates the understanding of the nature of MaaS from the provider's perspective. Second, it serves as conceptual guideline to compare and design MaaS business models. As shown in Figs. 1-5, MaaS requires a complex structure of ingredients to enable the provider to offer the service. Thus, a provider needs to pay close attention to the characteristics within and interdependencies between the nine building blocks. This is why we first identify the implications of the proposed MaaS business model framework for managerial practice. Second, the contribution to scholarly knowledge is identified and we provide an agenda for future research to fill gaps that remain.

5.1. Implications for managerial practice

In the short-term, MaaS providers regularly face high investments but low returns (Butler et al., 2021). Thus, managers of MaaS projects should aim for the largest possible amount of users to increase potential revenue. To achieve this, integrating more transport modes might be one measure. This approach might be important for scaling the business to generate a critical customer mass. When integrating new transport modes, the MaaS provider should keep in mind that some customers might need assistance in their first usage of these modes or services (e.g. verifying the driver's license for carsharing).

Bundling can be another measure to increase the amount of potential customers. It can be an option for business customers. Offering bundles as mobility budgets might be an attractive alternative to offering company cars. This enables the MaaS provider to exploit a new market segment besides private customers. Business customers might even be a good starting-point as they offer access to a large group of potential customers. This can also be seen as a gateway for MaaS in more rural areas to make use of commuters who often have more predictable travel patterns regarding time and place.

While integrating more transport modes might increase costs due to more stakeholder negotiations and adaptation of internal key activities, bundling might lead to decreased (marginal) costs. Once the bundles are developed, the marginal costs of offering them are rather low as it reduces the number of transactions.

As can be seen from the application, slight changes to few elements result in significant changes for the MaaS provider's overall business model. Respecting changes or extensions of the business model (e.g. increasing the transport modes integrated), the MaaS provider should closely watch the relevant regulatory bodies. Further, key partners should be included from the beginning. Changes to the business model at later stages might be significantly more expensive as, for example, the IT hard- and software would be established. This also holds for data analytics and knowledge management. Consequently, MaaS providers should think thoroughly about how to build their knowledge platform and how to add new insights. It follows that a precise definition of the business model is crucial for all nine building blocks of the BMC. As it has become clear from the examples presented, differences in the customer category require different elements from the infrastructure. Vice versa, with an existing infrastructure, e.g. a PT authority developing a MaaS platform, not all customers and elements of the value proposition can be covered. It might be worthwhile for MaaS providers to define a minimum scenario of which elements should be covered with the service striving for viability and a maximum scenario of what is desired. Defining these helps identifying critical elements in the business model. Moreover, as the PT authority usually has a large number of customers, this might be the first mover. For a commercial supplier, it might be difficult to work around the bargaining power of the local PT authority - or to find niche applications.

The characteristic of each particular MaaS scheme differs from others in terms of its objectives which influence how this specific scheme is populated. While the precise objectives might be manifold, the topology by Sochor et al. (2018) helps to categorise these. As the authors note, the customers and their needs determine the selected level. In terms of value proposition, a MaaS scheme aiming for level 1 (”integration of information”) requires a defined service area and appropriate data analytics while it can decide on modes and respective types of sharing integrated. Regarding personalisation and service integration, however, this MaaS scheme would be very limited since it does not enable anything related to booking and payment. On the other hand, a MaaS scheme aiming for level 3 (”integration of the service offer”) enables customers to select from a broad range of services and respective bundles that are customised to their needs. As presented, these differences in value proposition, thus objectives, imply major differences in characteristic of the customer structure targeted, required infrastructure, and enabled revenue structure. Consequently, the value proposition of a specific MaaS scheme may vary regarding its objectives and respective organisation.

Regarding MaaS operations in peri-urban or rural areas with lower demand density but longer trip distances (Eckhardt et al., 2018), defining a minimum and maximum scenario might be even more crucial. This particularly holds for the customer segments as it might be worthwhile to first focus on specific groups such as commuters or tourists (Eckhardt, Lauhkonen, & Aapaoja, 2020). Depending on the specific group(s) selected, the number of modes required can be limited to keep costs low and bundling might be adapted to the customer types and styles (e.g. specific commuter bundles or tourist bundles with access to all modes for just one week).

5.2. Contribution to scholarly knowledge

Although MaaS has become widely discussed in transport studies, the analysis of respective business models has still been limited. MaaS can cover a wide range of bundles of mobility services (Reck et al., 2020) with an equally wide range of business model configurations. Therefore, MaaS has the potential to offer many differing new opportunities for value creation. The developing literature on business models for MaaS is mainly case-specific and a framework for reviewing and comparing MaaS business models is not yet established. This makes it difficult to assess their development, identify requirements, and unlock potential benefits.

To address this limitation, we use the BMC approach (Osterwalder et al., 2005) to develop a structure for MaaS and apply morphological analysis (Ritchey, 2011) to populate the BMC building blocks. For each of the building blocks, i.e. value proposition, key resources, key partners, key activities, customer relationships, customer segments, communication channels, cost structure, and revenue streams, a morphological box is developed. Thus, we provide the first comprehensive business model approach to MaaS. Further, this framework provides a more thorough and detailed definition for MaaS regarding the ongoing discussion about what MaaS actually is. By combining the BMC and morphological analysis, we also provide a new method to disassemble complex business problems. This original combination allows an in-depth understanding of the overall problem and the elements required to solve it.

This approach enables the detailed identification of different features of MaaS and the assessment of the potential for new business models. It provides a conceptual framework for characterising and describing MaaS business models in a general and comparable way. The application to four cases and the managerial implications show how the proposed framework can be used by new businesses to assess market potentials and requirements for new business models. These can also be applied to other markets which are being restructured through the use of IT. This framework provides a starting-point for analysing the potential performance and sustainability of new mobility services in the MaaS environment and can help to identify where barriers to development might be. The assessment of MaaS customers can indicate social benefits that can be realised by new governance mechanisms within the transport sector in order to climb to level 4 of MaaS (Sochor et al., 2018).

The development of the framework is also a starting-point for future research. Due to this work's focus on the urban context of MaaS, it would be interesting to apply the developed BMC to (one of the few) explicitly rural operations to identify crucial differences. While the proposed framework shows which costs need to be focused on, it cannot reveal information about their magnitude. Hence, further work about the cost elements of providing a MaaS platform is required. Combining this with potential revenues via (public) transport data for the MaaS provider, the financial business case of the service can be estimated. From the key partners it can be seen that we also need to better understand the dynamics and potential solution spaces amongst the very different types of stakeholders required.

CRediT authorship contribution statement

Konstantin Krauss: Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Cornelius Moll:** Conceptualization, Methodology, Investigation, Writing – original draft, Funding acquisition. **Jonathan Köhler:** Conceptualization, Methodology, Investigation, Writing – original draft, Funding acquisition. **Kay W. Axhausen:** Validation, Supervision.

Declaration of Competing Interest

none.

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Appendices

A.1. Literature search string

PUBYEAR >2013 SRCTYPE(j OR m OR r) TITLE-ABS-KEY ((maas OR"mobility as a service" OR"mobility?as?a?service" OR"transport service*" OR"mobility service*" OR"platform mobility" OR"mobility platform" OR"mobility concept*" OR (mobility W/3 concept)) AND ("business model*" OR ("business model*" W/3 design)) AND (transport OR mobility OR travel*)).

A.2. References for elements of morphological boxes

Table A
References for characteristics of each morphological box, i.e. BMC building block.

Characteristic	References
	Value proposition
Service integration	Ambrosino, Nelson, Boero, and Pettinelli (2016); Esztergár-Kiss, Kerényi, Mátrai, and Aba (2020); Gilibert and Ribas (2019b); Jittrapirom et al. (2017); König et al. (2016); Merkert and Wong (2020); Polydoropoulou et al. (2020); Willing et al. (2017)
Personalisation	Gehrke et al. (2019); Willing et al. (2017)
Transport mode integration	Esztergár-Kiss et al. (2020); Goehlich, Fournier, & Richter, 2020; Günther et al. (2020); Jittrapirom et al. (2017)
Type of sharing	Bösch, Becker, Becker, and Axhausen (2018); Wells, Wang, Wang, Liu, and Orsato (2020)
Service area	Merkert and Wong (2020)
Data analytics	Ambrosino et al. (2016); König et al. (2016); Meng et al. (2020); Polydoropoulou et al. (2020)
	Infrastructure category
Key partners	
Information technology providers	Ambrosino et al. (2016); Arias-Molinares and García-Palomares (2020); Cruz and Sarmento (2020); Gilibert and Ribas (2019b); König et al. (2016); Kukkamalla et al. (2021)
Mobility providers	Ambrosino et al. (2016); Arias-Molinares and García-Palomares (2020); Cruz and Sarmento (2020); Esztergár-Kiss et al. (2020); Jittrapirom et al. (2017); König et al. (2016); Reis and Macário (2015)
Non-mobility providers	König et al. (2016); Kukkamalla et al. (2021); Polydoropoulou et al. (2020)
Regulatory bodies	Gilibert and Ribas (2019b); Karlsson et al. (2020); König et al. (2016); Polydoropoulou et al. (2020)
Financial intermediaries	Arias-Molinares and García-Palomares (2020); Gilibert and Ribas (2019b); Polydoropoulou et al. (2020)
Key activities	
Internal core	Cruz and Sarmento (2020); Esztergár-Kiss et al. (2020); Gilibert and Ribas (2019b); König et al. (2016); Kukkamalla et al. (2021); Polydoropoulou et al. (2020); Reis and Macário (2015)
Internal supporting	Chen and Qiu (2019); Polydoropoulou et al. (2020); Sarasini et al. (2017)
External core	König et al. (2016); Polydoropoulou et al. (2020)
External supporting	Gilibert and Ribas (2019b); Polydoropoulou et al. (2020)
Key resources	
Information technology infrastructure	Gilibert and Ribas (2019b); Reis and Macário (2015)
Data	Gilibert and Ribas (2019b); König et al. (2016)
Vehicles and transport infrastructure	Gilibert and Ribas (2019b); Polydoropoulou et al. (2020)
People	Gilibert and Ribas (2019a, 2019b); Polydoropoulou et al. (2020)
Capital	Gilibert and Ribas (2019b); Pangbourne, Mladenović, Stead, and Milakis (2020); Polydoropoulou et al. (2020)
	Customer structure
Customer segments	
Customer type	Gilibert and Ribas (2019b); Polydoropoulou et al. (2020)
Customer mobility style	Gehrke et al. (2019)
Customer modality style	Vij et al. (2013)
Trip purpose	Günther et al. (2020); Hensher et al. (2020); König et al. (2016); Polydoropoulou et al. (2020)
Travel frequency	Günther et al. (2020); König et al. (2016); Polydoropoulou et al. (2020)
Spatial dimension	Gilibert and Ribas (2019b); Günther et al. (2020); Júnior, Gandia, Sugano, Souza, and Rodriguez (2019); König et al. (2016); Polydoropoulou et al. (2020)
Non-mobility customers	Gilibert and Ribas (2019b); König et al. (2016); Polydoropoulou et al. (2020)
Customer relationships	
Customer services	König et al. (2016); Polydoropoulou et al. (2020)
Customer integration	Ambrosino et al. (2016); Gilibert and Ribas (2019b); Kukkamalla et al. (2021); Polydoropoulou et al. (2020)
Customer retention	König et al. (2016); Polydoropoulou et al. (2020); Reis and Macário (2015)
Customer channels	
Communication channels	König et al. (2016); Polydoropoulou et al. (2020); Reis and Macário (2015)
Distribution channels	Gilibert and Ribas (2019b); König et al. (2016); Kukkamalla et al. (2021); Polydoropoulou et al. (2020); Reis and Macário (2015)
	Revenue structure

(continued on next page)

Table A (*continued*)

Characteristic	References
Cost structure	
Investment costs	Gilibert and Ribas (2019b); König et al. (2016); Kukkamalla et al. (2021); Polydoropoulou et al. (2020)
Operational costs	Gilibert and Ribas (2019b); König et al. (2016); Kukkamalla et al. (2021); Polydoropoulou et al. (2020)
Policy instruments	König et al. (2016); Polydoropoulou et al. (2020)
Revenue structure	
Fares	Gilibert and Ribas (2019b); Jittrapirom et al. (2017); König et al. (2016); Kukkamalla et al. (2021); Reck et al. (2020); Reis and Macário (2015)
Brokerage fees	Gilibert and Ribas (2019b); König et al. (2016); Polydoropoulou et al. (2020); Willing et al. (2017)
Service fees	Cooper et al. (2019); Polydoropoulou et al. (2020); Reis and Macário (2015); Willing et al. (2017)
Pricing mechanism	Osterwalder and Pigneur (2013)

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