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ORIGINAL ARTICLE

Product-service system-oriented business models: a taxonomy of startups in the mobility sector

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Abstract

Startups are becoming increasingly important in the mobility sector and are putting established companies under pressure to adapt their business models. Especially, the automotive industry faces a significant change from an automotive manufacturer towards a mobility provider. However, literature does not provide a comprehensive understanding of the elements and archetypes of product-service system-oriented business models of startups in the mobility sector. This paper provides a taxonomy with six dimensions and 55 characteristics based on the analysis of 34 startups' business models. Four clusters can be described as the result of a cluster analysis. Thus, a deeper understanding of the business models and a starting point for future research and practical application is provided. Furthermore, based on the results, implications for research and practice like dominated characteristics of product-service system-oriented business models as well as future research directions are pointed out.

Keywords Taxonomy · Archetypes · Product-service systems · Business model · Mobility sector

1 Introduction

Smart, connected products have been pushing the markets in recent years and promise sustainable competitive advantage. At the same time, they are shifting the ecosystem of companies (Porter and Heppelmann 2014). Especially present is the current change of the automotive industry towards a business model of a mobility provider

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with concepts like cars and software as upgradable devices supplemented by services and an increased focus on lifecycle management (Kuhnert et al. 2017–2018; Khan and Wuest 2019; Zhang et al. 2019). The literature also refers to the so-called servitization (Kamal et al. 2020; Baines et al. 2017) and the offering of Product-Service Systems (PSS) which "are defined as an integrated bundle of products and services which aims at creating customer utility and generating value" (Boehm and Thomas 2013). At the same time, investments in startups are increasing. According to studies, an increase of around 30% to around 27.5 billion USD worldwide can be observed between 2017 and 2018. Thereby, especially startups focusing on mobility services receive high funding (Oliver Wyman 2019). Furthermore, the sector is forecasted to grow by around $230 billion worldwide between 2019 and 2027 (Reports and Data 2020). This transition from product-oriented towards service-oriented business models is a challenging task for companies. The complexity and uncertainty increase the importance and at the same time the requirements for the strategic planning and evaluation of PSS (Mourtzis et al. 2016; Tenucci and Supino 2019).

Against this background, it can be observed that many researchers examine the new business models in the mobility sector and therefore primarily apply the classification according to Tukker (2004). Thereby, the classification of Tukker (2004) is based on a shift of the ownership and distinguishes the dimensions product-oriented, use-oriented, and result-oriented (see e.g. (Mahut et al. 2015). However, it can be assumed that there have been further evolutions in the business models of the mobility sector since the publication of the classification according to Tukker (2004). Hence, for example, Kohtamäki et al. (2019) and Aas et al. (2020) have derived dimensions of PSS-oriented business models that consider the advancing digitalization. However, these classifications still only consider the influences of the above-described developments towards an ecosystem-oriented business model to a limited extent. Furthermore, Kohtamäki et al. (2019) and Aas et al. (2020) focus on the classification of business models of established companies. For this reason, we see a need to investigate the applicability of the dimensions based on a specific business sector and thus contribute to the advancement of a generally valid classification of PSS.

By analyzing the PSS-business models of startups in the context of the mobility sector, we aim to close the identified research gap. We thereby specifically focus on startups because they indicate and shape the future business models. Furthermore, as described above, the mobility sector is a suitable subject for this investigation because the sector increasingly transforms towards PSS-oriented business models and a mobility ecosystem which is influenced by startups. In order to analyze the business models, we follow the methodical approach of the taxonomy development according to Nickerson et al. (2013). The development of taxonomies has proven to be very useful in information systems research to structure results as well as handle and compare individual cases and objects (Doty and Glick 1994; Glass and Vessey 1995; Nickerson et al. 2013). Consequently, we additionally provide a taxonomy and archetypes in order to reduce the complexity of the business models especially in the mobility sector and support traditional companies by providing a comprehensive overview of the current developments of the startups of the mobility sector.

Furthermore, our results should serve as a conceptual framework and starting point for future research and practical application. Against this background, the following research questions arise:

RQ1 What are the elements of PSS-oriented business models of startups in the mobility sector?

RQ2 What business model archetypes can be identified based on an empirical examination of the elements?

To answer these research questions, our paper is structured as follows. The following Sect. 2 provides an overview of the related research. Furthermore, after describing the research method of taxonomy development in Sect. 3, the taxonomy of startups of the mobility sector is described in Sect. 4 in order to answer the first research question. In this context, at first the related research is shortly illustrated following the development of the database of the taxonomy and finally the taxonomy development itself. Based on the taxonomy, Sect. 5 describes the performed cluster analysis in order to answer the second research question. At last, the results are discussed in Sect. 6.

2 Related research

To the best of our knowledge, current research contains four publications focusing on taxonomies regarding PSS-oriented business models (see Remané et al. (2017a, b), Kohtamäki et al. (2019), Lembcke et al. (2020) and Aas et al. (2020)). Remané et al. (2017a, b) for example, provide a taxonomy for digital business models in the mobility sector for a specific use-case of personal mobility and the transportation from one location to another. As well, Lembcke et al. (2020) focus on the specific use-case of ridesharing business models. Hence, Remané et al. (2017a, b) and Lembcke et al. (2020) provide multiple dimensions and characteristics like for example the travel distance and range coverage which are primarily applicable for specific use-cases. In contrast to this, Kohtamäki et al. (2019) and Aas et al. (2020) provide as part of their work more general applicable models. Thereby, the authors focus on the solution and the value in order to support the configuration of digital business models. Furthermore, from a broader focus, additional publications can be identified that describe taxonomies respectively dimensions for the classification of business models in general and with a different focus than on the mobility sector. For example, Eickhoff et al. (2017), Beinke et al. (2018), Gimpel et al. (2018), Tönnissen et al. (2020) and Weking et al. (2020a, b) focus on the financial sector and on blockchain technology. Furthermore, Chesbrough and Rosenbloom (2002), Hedman and Kalling (2003), Osterwalder et al. (2005), Remané et al. (2017b), Urbinati et al. (2017), Täuscher and Laudien (2018), Mengelkamp et al. (2019), Perboli and Rosano (2020) and Weking et al. (2020b) focus on providing taxonomies of business

models on a generally valid level without focusing for example on specific industries or use-cases.

In summary, the related research lacks a taxonomy and classification of PSS-oriented business models of startups in the mobility sector which neither focuses on a specific business model of the mobility sector nor provides general dimensions. Although advances have already been made to update taxonomies by considering the digitalization, the shift of business models towards ecosystems and specifically mobility ecosystems have not been considered. Furthermore, primarily established companies and business models have been considered by the related research.

3 Methodical approach of taxonomy development

To answer the research questions, we followed the iterative method of taxonomy development by Nickerson et al. (2013) as illustrated in Fig. 1. Based on this method, a cluster analysis was performed in the second step. The objective of the taxonomy development is the classification of objects in order to better understand a complex domain (Nickerson et al. 2013).

From this background, in a first step, Nickerson et al. (2013) suggest defining a meta-criterion as basis for the identification of the characteristics of the taxonomy. Because our work focuses on startups in the mobility sector that offer PSSs,

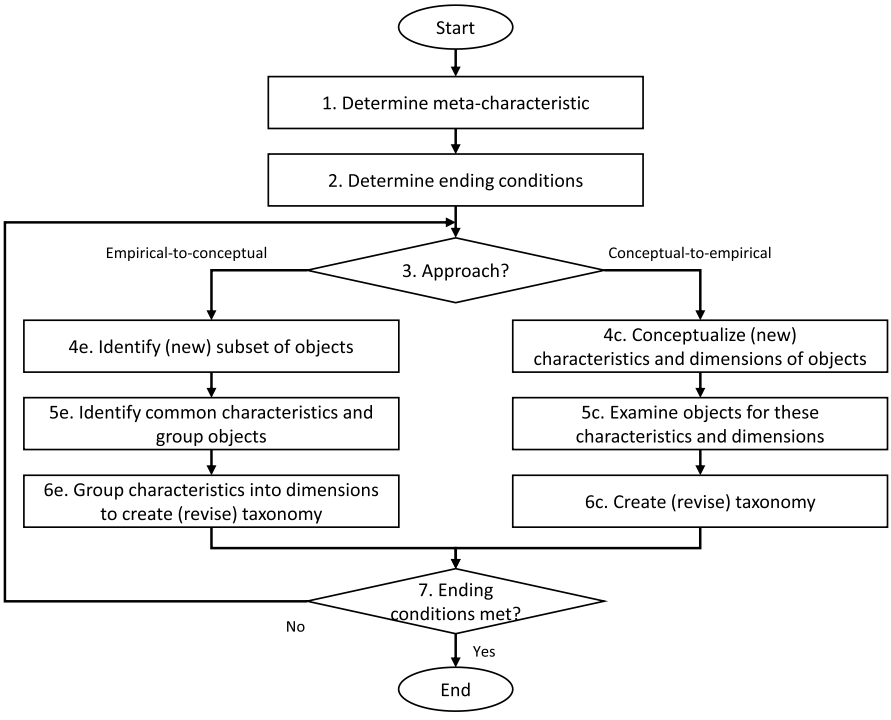

Fig. 1 Taxonomy development process based on Nickerson et al. (2013, p. 435)

we define the meta-criteria as "PSS-oriented business model components of startup companies in the mobility sector". In a second step, ending conditions in order to determine when to terminate the iterative taxonomy development process should be defined. We therefore apply the objective and subjective ending conditions presented in Table 1. At the beginning of every iteration, either an "empirical-to-conceptual" or "conceptual-to-empirical" approach can be followed. The deductive conceptual-to-empirical approach follows the abstraction of elements based on the existing theoretical knowledge and their evaluation by empirical data, whereas the inductive empirical-to-conceptual approach means the opposite.

The dimensions and characteristics are developed by iteratively examine PSS-oriented business models of startups in the mobility sector based on the information on the firms' websites considering the previously defined meta-criterion. After an iteration is finished and a dimension or characteristic was added to the taxonomy, the ending conditions are checked. Either the ending conditions are satisfied and the development process end or a new iteration starts (Nickerson et al. 2013).

4 Taxonomy development

4.1 Data set

Our taxonomy development starts with the identification of related research, which primarily serves as the data basis for the first iteration. We therefore have performed a literature review following the guidelines of Webster and Watson (2002). The databases Elsevier's Scopus, EBSCO Business Source Complete and Thomson Reuters Web of Science (WOS) were searched in April 2021 by the terms "Taxonomy and ("Product-service system*" OR PSS OR Startup* OR Mobility OR Automotive OR "Digital business*" OR "Business model")". Furthermore, we searched for

Table 1 Objective and subjective ending conditions based on Nickerson et al. (2013)

Objective ending conditions	Subjective ending conditions
All objects or a representative sample of objects have been examined	Concise—level of detail of the taxonomy
No object was merged with a similar object or split into multiple objects in the last iteration	Robust—differentiation among objects
At least one object is classified under every characteristic of every dimension	Comprehensive—assignability of all objects
No new dimensions or characteristics were added in the last iteration	Extendible—extension of characteristics
No dimensions or characteristics were merged or split in the last iteration	Explanatory—explanation of dimensions and characteristics
Every dimension is unique and not repeated	
Every characteristic is unique within its dimension	
Each cell (combination of characteristics) is unique and is not repeated	

publications in English and do not limit our search to any year or document type. Excluding the duplicates, 276 papers remain relevant from the database search. After screening the title, abstract and whole text by excluding publications not directly aimed at taxonomy or clustering of the topics product-service systems, start-ups, mobility, automotive, digital business or business models as well as a backward and forward search, 18 related publications remain (see Table 2). Thereby, we explicitly included publications providing a taxonomy or clustering of screening the title, abstract and whole text by excluding publications not directly aimed at taxonomy or clustering of the topics product-service systems, startups, mobility, automotive, digital business, or business models. The dimensions taken from the related research (see Table 2) are used for the first iteration of the taxonomy development as described above.

Next to the related research and as basis for the empirical-to-conceptual iterations of our taxonomy development, we made use of the company information of start-ups provided by the Crunchbase database (Crunchbase Inc. 2021) in order to identify companies and relevant PSS oriented business models in the mobility sector. At first, we filtered for companies associated to the keywords "Automotive", "Vehicle", "Car" and "Mobility". Accordingly, the industries "Autonomous Vehicles", "Automotive", "Car Sharing", "Electric Vehicle", "Fleet Management", "Last Mile Transportation", "Parking", "Procurement", "Public Transportation", "Ride Sharing", "Leasing", "Auto Insurance", "Financial Services" and "Payments" were selected. Furthermore, as China, the United States, Japan and Europe are the most important regions for the automotive industry (OICA 2021; VDA 2021), we have restricted the location of the headquarters to these regions. At last, we excluded companies with less than 251 employees and a last funding before 2020 in order to consider the most relevant startups. In doing so, we perceived an initial list of 78 companies which are subsequently used for the collection of PSS offered by the startups and elaboration of the taxonomy.

The database search with Crunchbase was performed on 03/06/2021. Since Crunchbase does not provide detailed information about the company's business models, we used the listed companies as database for a subsequent detailed analysis of the information provided on the company's website until 07/30/2021. The following analysis of the websites of the company list results in 49 PSS-oriented business models which were analyzed in multiple iterations following the guidelines by Nickerson et al. (2013) as described in Sect. 2. Thereby, we excluded 44 companies due to unavailability of data because the website was not available or in other languages than English or German, the company was founded more than 15 years ago, the company focuses on the development of automotive parts, cars, or vehicles itself, components, only on sale of products or the company's business models is not essentially mobility oriented. The remaining 34 companies are primarily located in the United States of America (20 companies) followed by Europe (ten companies) and finally China (four companies). The results are illustrated in Table 3.

Furthermore, we used the three common clusters "product-oriented", "use-oriented" and "result-oriented" of PSS provided by Tukker (2004) in order to structure the objects during the iterations and for analysis of our results. As described by Tukker (2004), product-oriented services are services, advice or consultancy offered in

Table 2 Data set of the first literature review

Source	Provided taxonomy	Dimension
Chesbrough and Rosenbloom (2002)	Business model	Market Segment, Value Proposition, Value Chain, Cost and Profit, Value Network, Competitive Strategy
Hedman and Kalling (2003)	e-Business models	Market, Offering, Activities and Organization, Resources, Factor Market, Causality and Longitudinal Process
Osterwalder et al. (2005)	Business model	Value Proposition, Target Customer, Distribution Channel, Relationship, Value Configuration, Capability, Partnership, Cost Structure, Revenue Mode
Eickhoff et al. (2017)	FinTech business model	Dominant Technology Component, Value Proposition, Delivery Channel, Customers, Revenue Stream, Product/Service Offering
Remané et al. (2017a, b)	Business models in mobility sector	Value Proposition, Interface, Service platforms, Org.model, Revenue model
Remané et al. (2017b)	Business model innovation	Hierarchical Impact, Degree of Digitization, Product Type, Strategy for Differentiation, Target Customers, Value-Delivery Process, Sourcing, Third Parties Involved, Value-Creation Process, Revenue Model, Pricing Strategy, Direct Profit Effect
Urbinati et al. (2017)	Business model	Value Proposition, Target Customer, Distribution Channel, Relationship, Value Configuration, Capability, Partnership, Cost Structure, Revenue Model
Beinke et al. (2018)	Blockchain business models	Value Proposition, Delivery Channel, Market Segment, Revenue Stream, Product Offering
Gimpel et al. (2018)	FinTech start-up service offerings	Personalization, Information Exchange, Interaction Type, User Network, Role of IT, Hybridization, Channel Strategy, Data Source, Time Horizon, Data Usage, Data Type, Payment Schedule, User´s Currency, Partner´s Currency, Business Cooperation
Täuscher and Laudien (2018)	Marketplace business models	Value Creation Dimension, Value Delivery Dimension, Value Capture Dimension
Kohtamäki et al. (2019)	Digital servitization business models	1. Solution Customization, Solution Pricing, Solution Digitalization
		2. Description of the business model, The role of digitalization, Resource-based view, Power approach, Organizational identity, Transaction cost approach
Mengelkamp et al. (2019)	Business models in local energy markets	Value Proposition, Understanding of LEM, Exchange Partners, Product/Service Offering, Cost-/Revenue Model, Role, Legal Issues, Success Factors, Transactional Object
Aas et al. (2020)	PSS business models	Value Creation, Value Capture, Value Deliver
Lembcke et al. (2020)	Ridesharing business models	Value Proposition, Interface, Service Platform, Organizing Model, Revenue Model

Table 2 (continued)

Source	Provided taxonomy	Dimension
Perboli and Rosano (2020)	Smart city projects	Description, Business Model, Purpose
Tönnissen et al. (2020)	Blockchain-based business models	Customer Segment, Types of Decentralized Business Models, Associate, Market Types, Stage of Business Ecosystem, Level of Control, Collaboration, Increase Network Effects, Network Effect, Token Incentive, Token Purpose/-type
Weking et al. (2020a, b)	Blockchain business models	Value Proposition, Value Creation & Delivery, Value Capture
Weking et al. (2020b)	Business model patterns	Value Proposition, Revenue Streams, Customer Segments, Cost Structure, Customer Relationship, Partners, Resources, Activities, Distribution Channels

Table 3 Clustered PSS-oriented business models per company

Company	Product-oriented	Use-oriented	Result-oriented
Arrive		Parking services	
Aurora	Self-driving technology (Aurora Driver)		
AUTO1 Group	Car retail platform		
Bird	Vehicle sharing platform	Vehicle sharing (E-scooter, E-Moped, E-Bike)	
Bolt	Vehicle sharing platform	E-Scooter sharing	Ride-hailing service
CAR Inc		Short- and long-term rental, finance leasing	
ChargePoint	Charging services (Software/Cloud-Services)	Charging service (ChargePoint as a Service)	
Cityscoot		Vehicle sharing (electric mopets)	
CollisionRight	Car body repair service		
Cruise			Ride-hailing with self-driving vehicles
Getaround		Peer-to-peer car sharing platform	
Go Insurance	Car insurance		
Helbiz	Vehicle sharing platform	Vehicle sharing (E-scooter, E-Moped, E-Bike)	
Joby Aviation			Air taxi service
Lilium			Air taxi service
Lime		Vehicle sharing (E-scooter, E-Moped, E-Bike)	
Local Motors			Self-driving electric shuttle (Olli)
Mapbox		Customizable online maps	
MotorK	Car retail platform		
NIO	-Basic/maintenance service (Nio Service)- Charging services (Power Swap, mobile charging vans, charger stations etc.)		Battery as a service
Nuro			Autonomous delivery of goods
Pony.ai			Robotaxi service

Table 3 (continued)

Company	Product-oriented	Use-oriented	Result-oriented
Surve Mobility		Fleet management service	
Tekion	Car retail platform		
Tesla	Over-the-air software updates	Long term leasing (24–36 months)	
	Extended service agreement-		
	Autopilot		
	Connectivity		
TIER Mobility		Vehicle sharing (E-scooter, E-Moped)	
Turo		Peer-to-peer car sharing platform	
Urent		Peer-to-peer renting platform for vehicles	
Via			Services for on-demand mobility solutions
VOI Technology		E-Scooter sharing	
Wallbox	Charging platform & App (myWallbox)		
Waymo			Ride-hailing service („Waymo One)
			Autonomous transportation of goods (Waymo Via)
WM Motor		Charging- and rental services (GETnGO)	
Xpeng Motors	Vehicle charging services	Vehicle leasing (Ypeng Auto Finance)	
	Finance and insurance		
	Vehicle post-sales service		

addition to a product like maintenance contracts. The business model focuses primarily on the sale of the product, which therefore changes the owner (Mahut et al. 2015, p. 843). Use-oriented services are characterized by the fact, that the ownership does not shift to the customer. In general, the provider is responsible for maintenance, repair and control and the customer pays a fee. However, it can be distinguished between product lease with usually unlimited access, renting/sharing with limited access and pooling with simultaneous use of the product. At last, in case of result-oriented services, the customer and provider generally agree on a defined result without a defined product. This could be for example the outsourcing of activities like catering or pay per service units, where the customer buys the output (Tukker 2004).

4.2 Iterations

In order to define the dimensions of the taxonomy, our first iteration follows the conceptual-to-empirical approach, building up on the identified related research and the literature on business models. We aimed to select dimensions for which information on the business models of the considered companies are accessible on their websites. Since Eickhoff et al. (2017) and Beinke et al. (2018) as well-developed a taxonomy based on information from companies' websites, we used the dimensions focused by the authors as orientation for our first iteration (see Table 2). On closer observation, it can be noted that the dimensions derived by Eickhoff et al. (2017) and Beinke et al. (2018) are also based on further related research of Table 2 such as Chesbrough and Rosenbloom (2002) and Osterwalder et al. (2005). Furthermore, the dimensions can be found primarily in the close related research of Remané et al. (2017a, b) and Lembcke et al. (2020) with focus on carsharing business models. Their taxonomy as well contain the dimension "value proposition" and "revenue model". In further detail, several intersections can be recognized. For example, Remané et al. (2017a, b) list the dimension "sales channels" and Lembcke et al. (2020) the dimension "payment options" under the main dimension "interface" with which intersections can be drawn with the dimension sales channel in this paper. A further example is the main dimension "service platform" of Lembcke et al. (2020) and the corresponding dimension "service scope" which is similar to the dimension "product/service offering". Nevertheless, as mentioned above, a dimension like "organization model" (see Lembcke et al. (2020)) does not fit for the research aim and method of this paper since the authors focus on carsharing business models in particular and also pursue a different research approach. At the same time, the dimensions are comparable with the dimensions applied in more general valid taxonomies like, e.g., by Kohtamäki et al. (2019).

This paper does not aim to build on this work, but to give a new view for PSS in the automotive industry. Finally, we selected six dimensions which can be defined after Eickhoff et al. (2017, p. 10) as follows:

- D_1 Value Proposition = Describes the value the company creates for its ecosystem (customers, partners etc.)

- D_2 Sales Channel = Describes how the products and services are ordered by the customers
- D_3 Market Segment = Describes to whom the company intends to offer its products and services
- D_4 Revenue Stream = Describes how the company generates revenue from its products or services
- D_5 Product/Service Offering = Describes what the company offers to its customers
- D_6 Technology = Dominant IT artifact that is the driver for the IT-based business model

Since these rough dimensions do not yet satisfy the ending conditions, the second iteration followed an empirical-to-conceptual approach based on the 20 business models that are assigned to the product-oriented cluster. Thus, we were able to identify 33 characteristics according to the dimensions of the first iteration. Since we added several characteristics and considered only a part of the objects, the taxonomy has not yet reached all ending conditions. The third iteration as well follows an empirical-to-conceptual approach. Thereby, the 18 use-oriented business models were added to the iteration. We identified the eleven characteristics $C_{1,13}$ = Integrate mobility in daily routine, $C_{1,14}$ = Earnings $C_{3,3}$ = P2P, $C_{4,4}$ = Abonnement, $C_{4,5}$ = Leasing, $C_{5,13}$ = Vehicle sharing, $C_{5,14}$ = Vehicle renting, $C_{5,15}$ = Parking, $C_{5,16}$ = Autonomous Driving, $C_{5,18}$ = Logistics and $C_{6,11}$ = Augmented Reality. Furthermore, three characteristics were specified $_{C2,1}$ = Product as Embedded device, $C_{4,2}$ = Fee as Fee per use and $C_{5,1}$ = Charging as Power. Similar to the second iteration, the taxonomy is still changing significantly and does not meet all ending conditions. In the fourth iteration, we add the remaining 11 result-oriented business models to the scope. Thereby, one characteristic $C_{5,18}$ = Ride-hailing is added as well as $C_{1,2}$ = Cost reduction and $C_{1,14}$ = Earning is combined to $C_{1,15}$ = Monetary and $C_{1,9}$ = Lower entry barrier to electrification and $C_{1,13}$ = Integrate mobility in daily routine to $C_{1,16}$ = Integration of sustainable mobility. Furthermore, we specify $C_{1,7}$ = Vehicle availability as PSS availability. After this iteration, all identified PSS-oriented business models are considered. Because of the minor changes in this iteration, we consider all ending conditions as met. The resulting final taxonomy, illustrated in Table 4, contains six dimensions and 52 characteristics. The corresponding crosstab analysis is illustrated in Table 5.

5 Cluster analysis

Based on the previously developed taxonomy, we have performed a cluster analysis following the approaches of Beinke et al. (2018, p. 5) and Tönnissen et al. (2020, p. 313) with support of SPSS (version 26) in order to review and identify clusters respectively archetypes of the business models in the mobility sector. Therefore, the assignment of the PSS-oriented business models to the characteristics of the previously developed taxonomy served as the data basis for the cluster analysis.

Table 4 Taxonomy of mobility-oriented PSS

Dimensions											
D_1	Value proposition	D_2	Sales channel	D_3	Market segment	D_4	Revenue stream	D_5	Product/service offering	D_6	Technology
Characteristics											
$C_{1,1}$	Flexibility	$C_{2,1}$	Embedded device	$C_{3,1}$	B2B	$C_{4,1}$	Sales	$C_{5,1}$	Maintenance, Warranty	$C_{6,1}$	Cloud
$C_{1,3}$	Efficiency	$C_{2,2}$	Website	$C_{3,2}$	B2C	$C_{4,2}$	Fee per use	$C_{5,2}$	Driver assistance system	$C_{6,2}$	IOT
$C_{1,4}$	Customer experience	$C_{2,3}$	App	$C_{3,3}$	P2P	$C_{4,3}$	Freemium	$C_{5,3}$	Connectivity	$C_{6,3}$	Machine learning
$C_{1,5}$	Customer satisfaction	$C_{2,4}$	Physical			$C_{4,4}$	Leasing	$C_{5,4}$	Retail Platform	$C_{6,4}$	Analytics
$C_{1,6}$	Customizable					$C_{4,5}$	Abonnement	$C_{5,5}$	Product upgrading	$C_{6,5}$	Digital platform
$C_{1,7}$	PSS availability							$C_{5,6}$	Finance	$C_{6,6}$	Wifi
$C_{1,8}$	Safety & Security							$C_{5,7}$	Insurance	$C_{6,7}$	5G
$C_{1,16}$	Integration of sustainable mobility							$C_{5,9}$	Payment	$C_{6,8}$	GPS
$C_{1,10}$	Time efficiency and effectivity							$C_{5,10}$	Fleet management	$C_{6,9}$	API
$C_{1,11}$	All in one solution							$C_{5,11}$	Power	$C_{6,10}$	System-/ Application Software
$C_{1,12}$	Environmental sustainability							$C_{5,12}$	Information	$C_{6,11}$	Augmented reality
$C_{1,15}$	Monetary							$C_{5,13}$	Vehicle sharing/ Sharing platform		
								$C_{5,14}$	Vehicle renting		
								$C_{5,15}$	Parking		
								$C_{5,16}$	Autonomous driving		
								$C_{5,17}$	Logistics		
								$C_{5,18}$	Ride-hailing		

Table 5 Results of Crosstab Analysis based on Ward's method

		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Total
	Product-oriented	14	6	0	0	20
	Use-oriented	6	2	10	0	11
	Result-oriented	3	1	2	5	18
	Total objects	23	9	12	5	49
	Percent of total objects	47%	18%	24%	10%	
Dimension	**Characteristic**	**Average expression of the characteristics per cluster**				
Value Proposition	Flexibility	13%	22%	64%	50%	31%
	Environmental sustainability	9%	0%	91%	50%	31%
	Monetary	9%	56%	45%	33%	29%
	Efficiency	4%	56%	27%	17%	20%
	Customer experience	57%	44%	91%	67%	63%
	Customer satisfaction	22%	44%	0%	33%	22%
	Customizable	26%	33%	18%	0%	22%
	Time efficiency and effectivity	22%	11%	18%	67%	24%
	All in one Solution	4%	44%	0%	0%	10%
	Integration of sustainable mobility	13%	0%	45%	0%	16%
	PSS availability	13%	11%	18%	33%	16%
	Transparency & Information	17%	78%	27%	17%	31%
	Safety & Security	30%	11%	55%	83%	39%
Sales channel	Embedded device	17%	0%	36%	0%	16%
	Website	22%	67%	27%	0%	29%
	App	39%	22%	100%	33%	49%
	Physical	30%	0%	0%	0%	14%
Market segment	B2B	30%	100%	45%	50%	49%
	P2P	0%	0%	36%	0%	8%
	B2C	43%	11%	55%	83%	45%
Revenue stream	Sales	9%	22%	0%	0%	8%
	Fee per use	9%	11%	100%	33%	33%
	Abonnement	22%	11%	18%	0%	16%
	Freemium	17%	0%	0%	0%	8%
	Leasing	9%	0%	0%	0%	4%

Table 5 (continued)

Dimension	Characteristic	Average expression of the characteristics per cluster				
Product/service offering	Maintenance/Warranty	22%	0%	0%	0%	10%
	Driver assistance system	22%	0%	0%	0%	10%
	Connectivity	13%	0%	0%	0%	6%
	Vehicle sharing	0%	0%	91%	0%	20%
	Vehicle renting	9%	0%	9%	0%	6%
	Ride-hailing	9%	11%	9%	67%	16%
	Parking	0%	11%	0%	0%	2%
	Autonomous driving	4%	0%	0%	83%	12%
	Retail platform	0%	33%	0%	0%	6%
	Product upgrading	13%	0%	0%	0%	6%
	Finance	13%	0%	0%	0%	6%
	Logistics	0%	11%	0%	33%	6%
	Insurance	13%	0%	0%	0%	6%
	Digital service platform	0%	56%	27%	0%	16%
	Payment	4%	11%	0%	0%	4%
	Fleet management	0%	56%	0%	0%	10%
	Power	30%	0%	0%	0%	14%
	Information	4%	22%	18%	0%	10%
Technology	Cloud	13%	22%	0%	0%	10%
	IOT	13%	0%	0%	100%	18%
	Machine learning	9%	11%	9%	100%	20%
	Augmented reality	4%	0%	0%	0%	2%
	Analytics	0%	44%	0%	0%	8%
	Digital platform	0%	44%	27%	0%	14%
	Wifi	9%	0%	0%	0%	4%
	5G	13%	0%	0%	0%	6%
	GPS	0%	11%	0%	33%	6%
	API	4%	22%	0%	0%	6%
	System-/Application Software	35%	100%	100%	50%	63%

We also followed the two-step method of Punj and Stewart (1983) to identify the appropriate number of clusters. In a first step, Ward´s method is applied with support of SPSS (version 26). Thereby, the most similar objects, according to the number of identical characteristics, are grouped iteratively until all objects belong to the same group. Based on the agglomeration schedule as one output of clustering with

Ward's method which also represents the increase in heterogeneity in each stage through a coefficient and the "squared Euclidean distance", we were able to select a suitable number of clusters. The scree plot of the coefficient indicates that a three- respectively four-cluster solution is suitable.

In a second step, these possible cluster solutions were compared using the K-Means method. "In a nutshell, K-means is a prototype-based, simple partitional clustering algorithm that attempts to find K non-overlapping clusters. These clusters are represented by their centroids (a cluster centroid is typically the mean of the points in that cluster)." Wu (2012) As a result, the three-cluster solution required five iterations and the four-cluster solution three iterations until the sum of the squared deviations from the cluster focal points is zero. Against this background, we select a four-cluster solution.

Based on the resulting crosstab analysis (see Table 5), the clusters are visualized in Fig. 2. In order to develop Fig. 2 one characteristic was assigned to a maximum

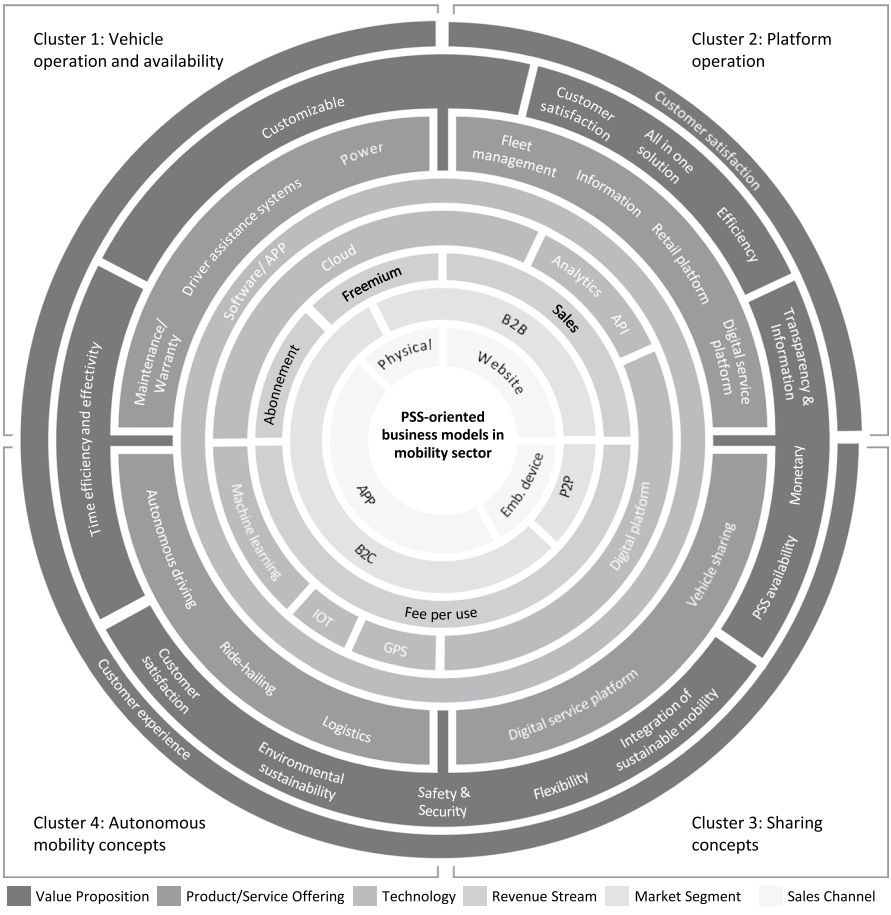

Fig. 2 Clusters of PSS-oriented business models of startups in the mobility sector

of two clusters in which the dominance of this characteristic is highest. An exception was made for the characteristics System-/Application Software and customer experience, due to the high dominance in all clusters. At last, characteristics with a low dominance in any cluster (< 15%), are not considered in Fig. 2. By the following description of each cluster and its typical characteristics, archetypes of PSS-oriented business models and the answer to the second research question are provided.

5.1 Cluster 1: vehicle operation and availability

The first cluster contains companies that support the operation and availability of a vehicle by services like maintenance, warranty, driver assistance systems and power. Since maintenance and warranty are long-established services, the technological shift of the mobility sector towards electrification and autonomous driving are supported by providing driver assistance systems and power (currently especially electric power) to the customer. Against this background, the revenue is not generated through fees per use, but through subscription and freemium services in a B2C (Business-to-Customer) and B2B (Business-to-Business) market segment. Customers can order the products and services traditionally by physical contact or via App, whereby in general IT-technologies are not very dominant in this cluster. Only the share of the system—and application software is significant but still below the values in the other clusters. The companies assigned to this cluster promise to place a high value on customer experience, time efficiency and effectivity, as well as customizability. This is expressed for example by the ease of use of vehicle charging and customer specific solutions in B2B environment. The following companies are assigned to cluster 1: Aurora, CAR Inc., ChargePoint, CollisionRight, Go Insurance, Joby Aviation, Lilium, Mapbox, NIO, Tesla, Wallbox, WM Motor and Xpeng Motors. Cluster 2: Platform operation.

5.2 Cluster 2: platform operation

The PSS-oriented business models of the second cluster focus on the B2B market segment by supporting fleet management and providing digital service—and retail platforms to the customers. As well as in cluster 3 and 4, system—and application software are very dominant IT-technologies. Furthermore, companies use digital platforms, analytics, and application programming interfaces (APIs) which support the business management of the customer in a B2B environment by providing information. The primarily sales channel is the website, respectively the contact through the website. Since the objective of the companies of this cluster is to support the business of other companies, it stands to reason that the value propositions are efficiency, transparency, and information, customizable as well as monetary like the reduction of cost and increase of earnings. Furthermore, it is characterized by patterning and taking over activities of the other company to provide customer satisfaction and all in one solution. The following companies are assigned to cluster 2: Arrive, Auto1 Group, Bird, Bolt, Helbiz, MotorK, Surve Mobility, Tekion and Via.

5.3 Cluster 3: sharing concepts

Companies of the third cluster contain companies with vehicle sharing business models and digital service platforms to support vehicle sharing with focus on B2C, B2B but as well P2P (Peer-to-Peer) market segment. The customer can acquire the service via App or the embedded device. The revenue is generated through fees per use or subscription. In contrast to cluster 1 and 2, the companies of this cluster promise environmentally sustainable PSS as well as the integration of sustainable mobility in the society through a low entry barrier. Furthermore, the customer experience and satisfaction, flexibility as well as safety and security of the PSS are key value propositions of this cluster. The following companies are assigned to cluster 3: Bird, Bolt, Cityscoot, Getaround, Helbiz, Lime, TIER Mobility, Turo, Urent and VOI Technology.

5.4 Cluster 4: autonomous mobility concepts

The fourth cluster contains PSS-oriented business models focusing on autonomous driving and ride-hailing, as well as logistics (transportation of goods). Customers of primarily the B2C environment pay a fee per use and can acquire the service via App. In contrast to the other clusters, machine learning, GPS, and Internet of Things (IOT) are, next to the system—and application software, the dominant IT-technologies. Since this cluster focuses on autonomous driving, safety and security is a central characteristic of the value propositions. Like in cluster three, the environmental sustainability, customer experience and flexibility of the PSS are as well addressed. But since the customer must not drive by himself, time efficiency and effectivity are a key value of the companies of this cluster. The following companies are assigned to cluster 4: Cruise, Local Motors, Nuro, Pony.ai and Waymo.

6 Discussion

Based on the developed taxonomy, the results of the cluster analysis show clear differences between the PSS-oriented business models of startups in the mobility sector, with several theoretical and practical implications. From a theoretical perspective, to a certain extent, correlations between the resulting archetypes of our analysis and the cluster provided by Tukker (2004) can be drawn. Our results show that the majority of the investigated PSS-oriented business models of our first cluster were assigned to product-oriented services of Tukker (2004) like maintenance, warranty, and power services. Nevertheless, in the context of the mobility sector, our analysis indicates, that regardless of whether the ownership is held by the provider or the customer, the operation and availability of the vehicle and mobility is a relevant topic of startups. Hence, our results from the perspective of the mobility sector indicate that the distinction based on the ownership of Tukker (2004) is not a standalone characteristic for differentiating product-oriented business models. Thus, our

results support the approaches of the enhancement and combination of the dimensions of PSS of Aas et al. (2020) and Kohtamäki et al. (2019). Against this background, our results show first of all similarities between the product-oriented and performance-oriented contracts of the value capture dimension of Aas et al. (2020) and the revenue streams of fee per use and subscription of the taxonomy provided in this work. However, our results contribute to the literature by pointing out, that as well freemium offers should be considered, especially in the growing mobility ecosystem. Furthermore, in addition to the dimensions of Aas et al. (2020), traditional sales or leasing offers are as well dominant in the second cluster. Second, in line with the differentiation of value delivery by Aas et al. (2020) into smart digital services and non-smart services, our results confirm the distinction of an embedded device, website, APP and physical of the dimension sales channel. However, our results show the need to distinguish between applications and physical contact since business models in the B2C environment are primarily based on APPs, which require a corresponding end device, whereas the B2B business relies on websites and physical contact.

In addition to the dimensions of Aas et al. (2020), further correlations between the results of this work and the dimensions provided by Kohtamäki et al. (2019) can be noticed. First, similarities can be identified between the first cluster of vehicle operation and availability as well as the business models product-oriented service and integrated solution provider of Kohtamäki et al. (2019). Furthermore, the second cluster of platform operation and the business model of the platform provider of Kohtamäki et al. (2019) are very similar. However, for example it can be recognized that Kohtamäki et al. (2019) assign the business model of platform provider to the outcome-oriented solution pricing whereby the results of this paper show that the platform operation primarily takes place in a B2B environment and the services are usually sold to the partner instead of concluding outcome-oriented agreements. For example, companies like Bird and Bolt offer a vehicle sharing platform and their vehicles like e-scooters to a local sharing provider for a fee, enabling the provider to develop a business on its own. Furthermore, regarding the dimension of solution customization of Kohtamäki et al. (2019), for example, the products and services related to charging of vehicles of the first cluster of our results show that customizable solutions are required in the B2B environment. Against this background, our results indicate correlations between the first cluster in this paper and the business model of an integrated solution provider of Kohtamäki et al. (2019). Additionally, from the perspective of the dimension of the solution digitalization of Kohtamäki et al. (2019), for example, the autonomous function is described as a characteristic of an outcome provider. This description is consistent with the business models of a robotaxi service of the fourth cluster of our results. However, considering for example the PSS-oriented business model of the autopilot of Tesla assigned to the first cluster, our results show business models characterized by autonomous function which are not assigned to the business model of an outcome provider of Kohtamäki et al. (2019). Moreover, the characteristic of the autonomous function of the first cluster, which has as previously described correlations to the product-oriented service provider of Kohtamäki et al. (2019), is a differentiation to the description of the level of digitalization of a product-oriented service provider of Kohtamäki et al.

(2019), which is described by Kohtamäki et al. (2019, p. 388) as "some smart features based on remote diagnostics". Furthermore, parallels can be identified between third and fourth cluster of this paper and the characteristics of the outcome provider according to Kohtamäki et al. (2019). These include, for example, the revenue stream of fee per use, which, as described by Gebauer et al. (2017), is similar to the outcome respectively performance pricing model described by Kohtamäki et al. (2019). However, the characteristics of third and fourth cluster, for example, suggest that, in contrast to the description of Kohtamäki et al. (2019, p. 388) on outcome providers, it is not necessarily the manufacturer of the product that offers the PSS-oriented business model but as well other companies.

In summary, the characteristics of the business models of a product-oriented service provider and industrializer according to Kohtamäki et al. (2019) are minorly represented in the startups of the mobility sector. Rather, the results of the cluster analysis in this paper show correlations to the characteristics of the business models of an integrated solution, platform, and outcome provider according to Kohtamäki et al. (2019). This is as well indicated by the advanced level of digitalization of the startups in the mobility sector. Especially against the background of the ecosystem concept, which is as well focused by Kohtamäki et al. (2019), it can be discussed if the distinction between a product-oriented, industrializer and integrate solution provider will support research and practice in the future. We rather note that these business models are similar to the degrees of servitization rather than business models in an ecosystem (Weiller and Neely 2013, p. 19; Zheng et al. 2017). As the results of this paper show, the product-oriented, industrializer, and integrate solution provider could be named product operation and availability provider. In this way, it is expressed that the business model is part of the value creation of an ecosystem. Furthermore, the discussion above indicates on the one hand that the distinction between B2C, B2B and P2P is another characteristic between the business models such as platform provider and outcome provider respectively sharing concepts. On the other hand, it shows that due to the advances in the digitalization, a distinction of third and fourth cluster, which can be assigned to the outcome providers according to Kohtamäki et al. (2019), is reasonable. The distinction of autonomous and sharing concepts is also shown by other industries respectively products like the sharing of tools, apartments, and parking spaces as well as autonomous robots. Additionally and in contrast to Kohtamäki et al. (2019) and Aas et al. (2020), the characteristics of the third and fourth cluster show that the environmental sustainability and customer experience in particular should be taken into account when characterizing PSS-oriented business models. Hence, the results and discussion contribute to the theory by indicating that in total, one model is not sufficient in order to characterize PSS-oriented business models. Rather, it can be derived, that several models should be built.

Nevertheless, since previous research either focus on the specific use-case of ride-sharing respectively personal transportation or in general on PSS-oriented business models without a specific focus on the mobility sector, our study addresses this gap and provides a taxonomy focusing on PSS-oriented business models of the mobility sector. Furthermore, in the context of PSS in the mobility sector, our study is, to the best of our knowledge, the first which bases on a comprehensive database of companies. Like

all taxonomies, our taxonomy contributes to the theory by providing a comprehensive overview and clustering of existing PSS-oriented business models in the mobility sector and a starting point for future research.

In addition to these theoretical implications, our study also reveals implications for practice. First, by focusing on startups, our study shows the current state of startups and new PSS-oriented business models in the mobility sector, which is changing rapidly. Based on this initial analysis, practitioners can draw first conclusions like for example that round about 50% of our initial identified startups of the mobility sector show a PSS-oriented business model.

Second, our developed taxonomy and archetypes can be used by practitioners to a certain extent as guidance for business model innovations in order to manage and expand their business model portfolio, the classification of competitors, potential business partners or business models. For example, like identified by Lembcke et al. (2020, p. 13), who examined ridesharing business models, companies also offer their ridesharing platform to other companies instead of operating them by their own since this business model should be more efficient. As well, the second cluster of our analysis contains business models offering ridesharing platforms. In this context, like pointed out by for example Moazed and Johnson (2016) and Weiß et al. (2018), that digital platforms and their proper marketing will play a central role in the business models of the automotive industry. Furthermore, innovative charging solutions like Battery as a service or battery swap by NIO to support the integration of electro mobility and to increase the availability of the vehicle of the customer and the company's own fleet for sharing models are entering the market and increase the pressure on established companies.

Third, the results of our work could support strategic planning and evaluation of PSS-oriented business models, since the different clusters could have individual requirements regarding evaluation methods and KPI. For example, it could be discussed if on the one hand sharing and ride-hailing models (see cluster 3 and 4) require the evaluation of for example active users and operation costs while on the other hand cluster 1 and 2 require the evaluation of running contracts as one measure for the performance. Furthermore, a closer look at the individual clusters of our analysis reveals that business models focusing on the transportation of people and goods (see cluster 3 and 4) are, as well like the results of Lembcke et al. (2020, p. 13) reveal, characterized by the value propositions flexibility, safety and environmental sustainability as well as monetary factors. In addition, we found that especially our fourth cluster is characterized by IT-technologies like IOT, machine learning and that the system—and application software are of central significance in all clusters. In general, the taxonomy and clusters can serve as a basis for practitioners for further additions and adjustments according to their individual needs and processes as well to better meet the interest of the customer. The main findings and implications are illustrated in Table 6.

Table 6 Main findings and implications

Main findings	Implications
RQ1: What are the elements of PSS-oriented business models of startups in the mobility sector?	
MF1.1: Six dimensions and 53 characteristics could be identified in order to describe elements of PSS-oriented business models of startups in the mobility sector which also enable clear differences in cluster analysis	I1.1: Apply the provided elements and archetypes of PSS-oriented business models in the mobility sector for classification of for example competitors and potential business partners and the identification, comparison, and analysis of innovative business models
MF1.2: First research based on a comprehensive database of companies in the mobility sector and focus on startups that shows current trends and basis for future business models a) Majority of startups (approx. 50%) show PSS-oriented business models b) Business models are often built on digital platforms c) Vehicle sharing and ride-hailing services, autonomous driving and charging services dominate the market	I1.2: Focus on the integration and management of digital platforms and innovative business models to support availability of electric vehicles as well as sharing and ride-hailing models to remain competitive
RQ2: What business model archetypes can be identified based on an empirical examination of these elements?	
MF2.1: PSS-oriented business models of startups in the mobility sector can be differentiated by four clusters: a) Vehicle operation and availability (Maintenance, warranty, and power) b) Platform operation (Fleet management, digital service- and retail platforms) c) Sharing concepts (Vehicle sharing and digital service platforms) d) Autonomous mobility concepts (Autonomous driving and ride-hailing)	I2.1: Use the provided archetypes as… a) Guidance for business model innovations in order to manage and expand business model portfolios of companies b) Support of strategic planning and evaluation of PSS-oriented business models by deriving individual requirements as well as methods and KPIs from the identified clusters c) Clusters to support the distinction between research results
MF2.2: Dimensions in the current literature only partially meet the future requirements of the classification of business models in ecosystems	I2.2: Consider… a) Ownership as not necessarily key characteristic in order to differentiate PSS-oriented business models b) Product operation and availability provider within the framework of an ecosystem as a designation of business models similar to product-oriented, industrializer, and integrate solution provider c) For example, B2C, B2B and P2P as well as the environmental sustainability and customer experience as further characteristics between the business models

7 Conclusion

Motivated by the increasing importance of startups in the mobility sector, we developed a taxonomy from their PSS-oriented business models for, based on data from the companies' websites. Furthermore, the provided taxonomy was used to identify archetypes of these business models. Both, the taxonomy, and the archetypes offer researchers and

practitioners insights into the business models of startups and provide a starting point for further investigations and applications. In combination with the established theoretical dimension of business models, our research is robust and at the same time not as generic as other taxonomies and clusters. Nevertheless, as any research, limitations must be taken into account and future research should be pointed out. Our database for the development of the taxonomy is based on the data provided by Crunchbase. Furthermore, we analysed the companies only based on the data of their websites, which are available in English and German. In this context, it should be noted that these data and business models of startups in particular are constantly and dynamically changing. Furthermore, as with the use of other data sources, information may therefore be disregarded. Hence, future research could take into account these changes over time and review the provided taxonomy and clusters. In this context, information from additional data sources like information provided for investors would support the analysis. Since we initially analysed 78 companies and finally focused on 34, an extension of the database and an investigation beyond that of the websites (for example qualitative research such as mixed-method cross-case studies) would lead to further interesting results. Also, due to the sole availability of information for example in the Chinese languages, individual companies could not be considered so that a consideration of these in future research would be meaningful. Considering and pointing out local differences in the taxonomy and clusters could also provide further interesting insights. As for all taxonomy developments, it also applies for this paper that subjective perceptions and errors in the analysis could influence the results. Furthermore, the detailing of the taxonomy and clusters is challenging. Against this background, future research may apply and expand the results of this paper as well as focus on a single dimension like for example the technology dimension, which could only be analysed superficially but could lead to interesting insights. At last, our research can serve future research to analyse and compare companies and business models both internally and externally, as well as to structure and compare research results.

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Declarations

Conflict of interest The results, opinions and conclusions expressed in this paper are not necessarily those of Volkswagen Aktiengesellschaft.

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