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Understanding Car Data Monetization: A Taxonomy of Data-Driven Business Models in the Connected Car Domain

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Abstract. Data monetization has proven to be one of the most viable profit pools across industries. As vehicles become increasingly connected, leveraging their collected data through novel business models is the most promising value driver for automotive enterprises. Despite the increasing practical relevance, theoretical and conceptual insights on connected cars and their associated business models are still scarce. Thus, we develop a taxonomy of data-driven business models in the connected car domain according to four perspectives—value proposition, value architecture, value network, and value finance. Further, we apply the taxonomy to analyze the business model of 70 companies acting under the realm of connected cars. A subsequent evaluation indicates both the robustness and general feasibility of our taxonomy. Our taxonomy contributes to descriptive knowledge in this emerging field and enables researchers and practitioners to analyze, design, and configure data-driven business models for connected cars.

Keywords: Business Models, Connected Cars, Data Monetization, Taxonomy.

1 Introduction

The connected car has become the next big thing for the automotive industry [1]. There is no doubt that this megatrend will shape future mobility shifting to high-value services for drivers and fleet owners [2]. As of 2025, Accenture [3] expects all newly sold passenger cars to be connected, capturing and sharing a tremendously growing amount of data (e.g., fuel consumption, vehicle health, and driver condition) with their embedded sensors. This valuable car data eventually paves the way for novel types of data-driven business models (DDBMs), forcing original equipment manufacturers (OEMs) to wade more deeply into connectivity [4, 5]. However, although the opportunity is vast, most legacy companies still struggle to harness connected cars' potential and fully monetize the captured data [6–8]. Ultimately, the transition to DDBMs will be crucial to achieving connected car profitability and making software-driven services the primary revenue driver in the long term.

Despite the increasing importance of vehicle connectivity, there is little theoretical knowledge of connected cars and their associated business models. Broadly speaking, the issue of directly selling and monetizing data assets has been little discussed in the literature so far [9]. As a result, we do not know in detail how to use the valuable data

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generated by these "computers on wheels" [10, p.11] to create a data-driven service ecosystem [8, 11, 12]. Alongside drivers and OEMs, new players outside the automotive sector are also entering this traditionally closed ecosystem, increasingly launching data-driven services such as remote diagnostics or road condition monitoring [4]. While OEMs are seeking to exploit their supremacy position with exclusive data access, independent service providers explore alternative gateways to get access to vehicle data, for instance, through emerging data marketplaces [12–14]. Accordingly, the current research addresses both the digital transformation of incumbents [15–17] and the penetration of emerging startups [8, 14, 18] competing or collaborating in the connected car market.

Since existing classifications for companies operating in the connected car ecosystem neither provide a holistic picture nor cover the essential perspective of car data monetization, we pose the following research question: *What are the key characteristics of data-driven business models in the connected car domain?* We address this question by developing a taxonomy to help classify connected car companies and their respective DDBMs. In general, taxonomies have proven to enable researchers and practitioners to understand and analyze subject areas by structuring and organizing knowledge, grouping similar objects from a domain based on common characteristics, and explaining the relationships between those characteristics [19, 20]. As the connected car remains in its infancy, there is little knowledge and guidance for analyzing existing and developing new DDBMs in this emerging research field, which we aim to extend this knowledge with our taxonomy development. To do so, we follow the iterative development process by Nickerson et al. [19]. Thereby, we build on a preceding literature review to conceptualize our taxonomy and analyze 70 real-life examples of connected car companies to revise it empirically. Structured along the four business model perspectives by Al-Debei and Avison [21] (i.e., value proposition, value architecture, value network, and value finance), we derive ten dimensions and 36 corresponding characteristics. We demonstrate the applicability and feasibility of our taxonomy by classifying the 70 selected companies and having three additional raters classify a small subset of exemplary companies for evaluation. The results of our article contribute to business model literature and facilitate a common understanding of connected cars' DDBMs. For researchers, our taxonomy forms the basis to investigate car data monetization, analyze DDBMs of connected cars, and develop design theories in this area. For practitioners, our taxonomy serves as a strategic management tool for designing novel and benchmarking existing connected car companies and their DDBMs. In general, the taxonomy provides a solid foundation for analyzing the connected car market, identifying novel DDBMs, and paving the way for future research endeavors on related topics.

The remainder of this paper is structured as follows: In Section 2, we lay the conceptual foundations about connected cars and introduce existing DDBM taxonomies. Following, Section 3 describes our methodological approach to develop the taxonomy. In Section 4, we introduce our comprehensive taxonomy and evaluate it against real-life examples. Section 5 discusses implications, limitations, and future research opportunities. Finally, Section 6 concludes the work.

2 Conceptual Foundations

2.1 Connected Cars and their Emerging Service Ecosystem

Within this work, we refer to the *connected car* as a vehicle capable of accessing the internet, communicating with its ecosystem, and generating and transmitting real-time data, which is in line with prior definitions [22, 23]. Equipped with multi-layered sensor technology, connected cars already capture an enormously growing amount of data and send it to OEMs' servers, enabling, for instance, usage-based insurance schemes or predictive maintenance [8, 24, 25]. Hence, an ecosystem for such data-based services emerges, composed of incumbents (e.g., traditional OEMs) and new players (e.g., startups) [4, 26].

In general, OEMs launch digital services such as BMW ConnectedDrive, Mercedes me connect, and VW Car-Net, including remote services, vehicle monitoring, and on-street parking information, among other benefits [18, 22]. Consequently, incumbent automakers look for additional data-based profit pools as they face increased competition from young arrivals such as NIO or Tesla. The latter offers on demand services to consumers through its Autopilot, including features such as performance- and battery-boosting software [27]. However, while OEMs have exclusive access to the generated car data, independent service providers have to identify other approaches to capture this valuable data [12–14]. The majority of startups, including Mojio, Vinli, and Zubie, utilize a telematics-equipped dongle connected to the on-board diagnostics (OBD) interface to allow remote access to the vehicle data [5, 18, 23, 25]). Whereas other startups such as Zendrive and Vialytics use the sensors built into modern smartphones to capture data while driving [14, 18]. Furthermore, emerging data marketplaces such as Caruso Dataplace or Otonomo offer another alternative for getting access to vehicle data [13, 28, 29]. Those marketplaces are third-party platforms acting as neutral intermediaries and allowing others to sell standardized data products [30]. The objective of car data marketplaces is to make data collected from different car brands available to independent service providers through a single point of access. From the OEMs' perspective, cooperation with marketplaces is worthwhile in order to profit from additional data sales [13].

2.2 Taxonomies for DDBMs

The term *taxonomy* is often used synonymously with other classification concepts such as *framework* or *typology* in the existing literature [31, 32]. Taxonomies help researchers and practitioners understand, analyze, and structure knowledge in emerging research areas by identifying common characteristics within an unambiguous conceptual framework [19].

Although DDBMs are still at an early stage [33], several taxonomies already exist in the literature, which may be divided into generally applicable and industry-specific taxonomies [34]. One of the first and renowned articles on industry-agnostic taxonomies proposed by Hartmann et al. [35] is based on a conceptual approach with dimensions deductively obtained from a systematic literature review. In contrast, Engelbrecht et al. [36] provide an empirically developed, generally applicable DDBM taxonomy based on experts' perceptions. Further publications adopt a combined conceptual-empirical approach to characterizing DDBMs (e.g., [34, 37, 38]). In addition to general taxonomies, various taxonomies exist in the literature that focus on DDBMs in specific industries, for instance, logistics data [33], manufacturing data [39], and urban data [40]. To the best of our knowledge, there is currently no taxonomy dealing with DDBMs that spotlights connected car data, allowing this work to represent the first industry-specific taxonomy on this subject, providing a sound basis for researchers as well as practitioners.

3 Methodological Approach to Taxonomy Development

Our taxonomy building process follows the methodological approach suggested by Nickerson et al. [19], which is based on the three-level indicator model of Bailey [41] and the design science research guidelines of Hevner et al. [42]. In essence, the method seems appropriate for our research endeavor as it facilitates the combination of theoretical knowledge from literature and empirical findings from practice. Moreover, numerous IS scholars successfully adopted this research approach to different contexts (e.g., taxonomy for carsharing business models [43], taxonomy for FinTech startups [32], taxonomy for analytics-based services [44]). Finally, to assess the applicability of our taxonomy, we adopt central elements from previous studies (e.g., [32, 37, 44]) and classify a selection of use cases with our taxonomy and subsequently conduct an evaluation with three individual raters.

3.1 Procedure

The proposed method by Nickerson et al. [19] represents an iterative approach that allows taxonomies to be created both conceptually grounded on the existing body of literature and empirically based on real-world cases. Initially, the researcher identifies meta-characteristics reflecting the purpose and basis of the taxonomy. Next, ending conditions need to be determined that define when the development process is terminated. Overall, eight objective (e.g., no new dimension added) and five subjective (e.g., explanatory) ending conditions[1] are proposed by Nickerson et al. [19], which we adopted for our research design. Subsequently, the actual taxonomy building process begins with one of two possible paths applied sequentially in multiple iterations. First, the conceptual-to-empirical approach follows a deductive procedure to derive dimensions and characteristics from theory. Second, in the empirical-to-conceptual approach, the researcher develops dimensions and characteristics inductively from a given sample of objects. Eventually, the procedure is iterated until the ending conditions are met.

3.2 Iterations

Meta-characteristic. Initially, we defined the meta-characteristics as the components of DDBMs for connected cars. As we consider the V^4 business model framework developed by Al-Debei and Avison [21] to be compelling for guiding this process, we derive our meta-characteristics from it. Hence, each dimension of the taxonomy must relate to one of the V^4 framework's dimensions—value proposition, value architecture, value network,

[1] A detailed list of all ending conditions can be found in the paper by Nickerson et al. [19].

and value finance. The selected framework fits our research endeavor for two reasons. First, it is one of the few business model frameworks that particularly addresses digital business models. Second, the framework covers the multi-dimensionality of business models, including the crucial dimensions from prior conceptualizations.

1st Iteration. For the first iteration, we chose the conceptual-to-empirical approach, allowing us to build upon the already existing body of literature. For this purpose, we rely on a previously conducted systematic literature review (SLR) [45] focusing on DDBMs in the connected car domain, in which a total of 45 papers were analyzed in depth. Whereas the SLR provided a general overview of this research area, we examined the identified articles to further use in developing the taxonomy. Based on the concept-centric approach [46] of the SLR, we identified twelve articles relevant to our research endeavor that address four key topics related to DDBMs of the connected car. Adopting these topics, we derived 16 characteristics and four initial taxonomy dimensions, namely value for customer [23,24], data access, [13,14,22,23], role in ecosystem [4,8,14,47,48], and revenue model [24,49–51] (references cited in this sentence stem from the SLR).

2nd Iteration. For the second and all further iterations, we opted for the empirical-to-conceptual approach and examined sample connected car companies from various sources. In order to efficiently build a large dataset and obtain a reasonably complete picture of global connected car companies, we decided to query different sources with each iteration. In Iteration 2, our source was the 45 articles from the previous SLR [45], which we filtered for relevant articles analyzing connected car companies. Here, we excluded duplicates and companies that are no longer active[2]. Finally, we extracted 18 real-life examples (i.e., companies), from six articles (i.e., [4, 8, 14, 18, 22, 48]). By analyzing the company websites of real-life examples, we added 13 characteristics and three further dimensions to our taxonomy, namely customer segment, vehicle ownership, and data monetization.

3rd Iteration. For the third iteration, we extended our sample with two practice reports from leading consulting firms: the "Connected Vehicle Trend Radar" by Capgemini [52] that includes 27 emerging connected car startups and the "Digital Auto Report 2020" by PWC [53], that contains 27 leading connected car companies. After removing duplicates, this yielded 42 company websites for further review. Finally, we excluded companies that do not explicitly focus on connected cars and are no longer active[2]. This yielded 32 companies, from whose analysis we derived seven characteristics and three further dimensions, namely data personalization, influence of car data, and influence of autonomy.

4th Iteration. For the fourth iteration, we queried Crunchbase, the world's largest startup database, to gain a deeper understanding of connected car startups. Using the search term "connected car" we obtained 147 companies, of which 144 remained after duplicates were removed. Then, we skipped companies that are no longer active[2] (28), do not provide an English website (7), or do not explicitly focus on connected cars (29; e.g., the music streaming service Deezer). Subsequently, we screened the remaining 80

[2] Companies with any inactivity information (e.g., on crunchbase.com) or no active web presence.

cases until we found a subset of 20 connected car companies with sufficient website information (this number seemed adequate to cover the startup view in the further taxonomy development). After having analyzed these 20 companies, we felt to experience saturation (no further dimensions or characteristics were identified) and decided to end the screening process at this point, mainly because we do not want to over-represent the startup share across all iterations. Since the additional sample confirmed our taxonomy's existing dimensions and characteristics, this iteration caused no changes. Finally, all objective and subjective ending conditions were met after this iteration, leading us to agree on the final set of dimensions and characteristics. Based on the aforementioned sources yielding 70 connected car companies (Table 1), we are confident that we cover a fairly complete picture of the global connected car domain.

Table 1. Connected car company sample for the 2nd to the 4th iteration of taxonomy development

No.	Company Name	I	No.	Company Name	I	No.	Company Name	I	No.	Company Name	I	No.	Company Name	I
1	Aeye	3	15	Carmera	3	29	**Hum**	4	43	Nonda	4	57	SiriusXM	3
2	Affectiva	3	16	**Caruso Dataplace**	2	30	IMS (Insurance & Mobility Solutions)	4	44	**Otonomo**	2	58	Smartcar	4
3	Airbiquity	3	17	CarX	4	31	Innoviz Technologies	3	45	Ottoo	4	59	Smartdrive	3
4	Anagog	3	18	Continual	4	32	Innovusion	3	46	**OwlCam**	3	60	Teralytics	3
5	Aplicom	4	19	Cortica	3	33	KOBA Insurance	4	47	Pace Car	4	61	**Vimcar**	3
6	Apple CarPlay	2	20	Dashroad	4	34	Koola	4	48	PARK NOW	3	62	Vinli	2
7	Audi Connect	2	21	Drivemode	4	35	**Mercedes me connect**	2	49	Parkopedia	3	63	Visual Threat	4
8	Automile	2	22	Evopark	3	36	MetaWave	3	50	Passport Parking	3	64	Volvo Sensus Connect	2
9	Autotalks	3	23	Fensens	4	37	Metromile	2	51	Phantom Auto	3	65	Voyomotive	4
10	Autox	3	24	Geotab	3	38	Mojio	2	52	Pony AI	3	66	VW Car-Net	2
11	Bliq	3	25	GM OnStar	3	39	Momenta	3	53	Porsche Car Connect	2	67	Wayray	3
12	**BMW ConnectedDrive**	2	26	GoFar	4	40	MotorQ	4	54	Reviver	3	68	Wejo	3
13	CARFIT	4	27	Google Android Auto	2	41	Nauto	2	55	RideCell	3	69	Zendrive	2
14	CarIQ	4	28	High Mobility	2	42	Nexar	3	56	Sensetime	3	70	**Zubie**	2

Notes: I = Iteration in which the company was examined. Companies ranked by the three independent raters are in **bold** (cf. Section 4.2)

4 Results

4.1 Taxonomy of Connected Car DDBMs

This section presents our taxonomy of DDBMs for connected car companies. Table 2 provides an overview of the ten key dimensions with their 36 corresponding characteristics. Following the recommendations of Nickerson et al. [19], we employed three dimensions with characteristics that are mutually exclusive. However, for the remaining seven dimensions, it was more reasonable to model the characteristics as non-exclusive [32, 33, 44]. This decision is due to the wide variety of services, data sources, and stakeholders related to business models for connected cars, resulting in enormous complexity. Accordingly, the right-hand column of Table 2 indicates whether a dimension is exclusive (E) or non-exclusive (N). For exclusive dimensions, exactly one characteristic is observable at a time. In contrast, for non-exclusive dimensions, potentially multiple characteristics are observable at a time. In addition, the superscript numbers in Table 2 indicate the iteration in which dimensions or characteristics were added or revised. In the following, we introduce the dimensions and characteristics in detail.

Value Proposition. The first perspective deals with the compelling value propositions delivered by connected car companies by operating complex services to satisfy various customer needs. This perspective comprises three dimensions, namely value for customers, influence of car data, and influence of autonomy.

Table 2. Taxonomy of data-driven business models in the connected car domain

	Dimension	Characteristic						E/N*
Value Proposition	Value for customers[1]	Safety & security[1]	Convenience[1]	Cost reduction[1]	Traffic efficiency[1]	Infotainment[1]	Data accessibility[2]	N
	Influence of car data[3]	Car data core business model[3]			Car data-enabled business model[3]			E
	Influence of autonomy[3]	Enhanced value by autonomy[3]		Reduced value by autonomy[3]		Autonomy not relevant[3]		E
Value Architecture	Data personalization[3]	Anonymized data[3]			Personal data[3]			E
	Data access[1]	Exclusive access[1]	OBD2-dongle[1]	Central server[1]	Retrofit[1]	Smartphone[2]		N
Value Network	Role in ecosystem[1]	Service provider[1]		Platform provider[1]		Technology provider[2]		N
	Customer segment[2]	B2C[2]		B2B[2]		B2G[2]		N
	Vehicle ownership[2]	Private ownership[2]		Fleet ownership[2]		Mobility on demand[2]		N
Value Finance	Data monetization[2]	Selling data[2]		Selling analysis[2]		Selling services[2]		N
	Revenue model[1]	Direct sale[1]	Subscription fee[1]	Licensing fee[1]	Transaction fee[1]	Usage fee[1]	On demand[2]	N

*E = Exclusive dimension (one characteristic observable); N = Non-exclusive dimension (more than one characteristic observable)
Dimensions and characteristics were added or revised in the following iteration: [1] first, [2] second, or [3] third iteration

1. *Value for customers* deals with the benefits to the distinct customers delivered by the value proposition. Regardless of what services car data enables, monetizing them is only viable if the customer experiences its value and the cost is worth the benefit [54, 55]. Consequently, customers are only willing to share the required personal and vehicle data if they see direct benefits from connected services [8, 25, 56, 57]. Overall, connected car services typically fall into six broad categories, namely safety & security (e.g., emergency call services), convenience (e.g., concierge services [47]), cost reduction (e.g., usage-based insurance [58]), traffic efficiency (e.g., dynamic route planning [23]), infotainment (e.g., smartphone integration [22]), and data accessibility (e.g., data access via marketplaces [13]).
2. *Influence of car data* captures the importance of car data to realize certain business models. Finally, with the current rise of connected vehicles, their generated data, including geolocation, fuel consumption, and driver condition, can be exploited [4,8]. Nevertheless, vehicle data is more important for some connected services than for others. First, there are services (e.g., predictive maintenance) that are only implementable through access to particular vehicle data [2]. Second, there are services (e.g., workshop booking) that also operate without vehicle data; however, the full potential is only unleashed by its use.
3. *Influence of autonomy* describes the impact of the vehicle's autonomy on the business model's main or aggregate value proposition. Accordingly, the business model changes considerably, as the driver no longer needs to fully concentrate on the critical task of driving [59–61]. Consequently, preferences are shifting from driving experience or technical performance to aspects such as information and entertainment. For example, today's infotainment systems, which deliver audio and primary

interactive content, may offer virtual reality movies or video games once the driver takes on a passenger role [2]. Hence, full vehicle autonomy may increase the value created through certain data-driven services (e.g., networked parking services) while also decreasing the value of others (e.g., driving style suggestions).

Value Architecture. The second perspective characterizes an organization's architecture, including its technological architecture and organizational infrastructure, which allows the provision of connected services. It comprises two dimensions, namely data personalization and data access.

4. *Data personalization* refers to the collected vehicle data, which can be divided into two main types. First, anonymized data, also commonly abbreviated as aggregated data, does not contain personally identifiable information (PII) that allows a specific car to be identified from the crowd [13, 25]. For instance, when providing data to a smart city to improve road conditions through automatic pothole detection, anonymized data is sufficient [8,11,62]. Second, personal data contains PII generated either by vehicles or by peripheral devices (e.g., smartphones) [25]. For example, it is necessary to identify the specific car for usage-based insurance systems, as the data-based pricing model adapts to the user's driving behavior [58,63–65].
5. *Data access* distinguishes different technical gateways that enable connected car actors to access the required data a car generates. While OEMs have exclusive access, independent service providers must find alternative avenues to capture this data [12–14]. One option is the OBD port, into which the driver can plug a telematics-equipped dongle to allow remote access to the vehicle data (e.g., [5, 23, 25]). Data access is also possible through a central server, where data storage, processing, and customer interaction is managed by a data marketplace (e.g., Caruso Dataplace, Otonomo) providing standardized vehicle data by multiple OEMs [13,23]. In addition to accessing in-vehicle data, some startups are leveraging the potential of self-developed retrofitted sensors (e.g., dash cams) or traditional smartphone sensors (e.g., GPS, accelerometer, or luminance) to collect driving data [14, 18].

Value Network. The third perspective refers to the various stakeholders entering the connected car ecosystem. Here, we also consider the customer, who under the realm of connected car business models is often not a passive actor but co-creator of value (e.g., data collection) [47, 57]. The perspective comprises three dimensions, namely role in ecosystem, customer segment, and vehicle ownership.

6. *Role in ecosystem* describes certain roles that actors must assume in the connected ecosystem or value chain. For example, as service providers, they offer end-customer solutions for specific use cases (e.g., usage-based insurance), thereby monetizing car data [8, 14, 18]. Other actors provide a cloud-based data exchange platform for sharing and accessing data about connected cars across multi-sided marketplaces [4, 12, 13]. In addition, technology providers offer devices (e.g., dash cams) that make vehicles smart and connected while monetizing the data they collect.
7. *Customer segment* defines the distinctive groups of people or organizations to which a company aims to provide its offerings [66]. The most generic classification distinguishes between business-to-business (B2B) and business-to-consumer (B2C)

[35,67]. We extend this dimension to include business-to-government (B2G) [34,37], as, for instance, city planners can use road condition data for maintenance and repair works [8, 11].

8. *Vehicle ownership* is about who owns the vehicles for data collection to realize the desired DDBM [43]. Consequently, the connected cars are owned either by private drivers for personal use, fleet operators for commercial use, or mobility service providers for rental or shared mobility. For instance, private drives directly benefit from driving recommendations, gamification aspects, or remote diagnostics based on assessing their shared vehicle data [8, 48, 68]. Moreover, fleet operators and mobility service providers can increase uptime by avoiding breakdowns or unplanned repairs by using predictive maintenance to prevent accidents [56, 69, 70].

Value Finance. The fourth perspective represents how stakeholders in the connected car ecosystem generate revenue from their DDBMs. It comprises two dimensions, namely data monetization and revenue model.

9. *Data monetization* refers to capturing the monetary value from data [9, 71]. Here, a distinction can be made between three approaches [9]: First, the most straightforward approach involves selling car data directly to another party, as OEMs do to data marketplaces (e.g., Caruso Dataplace) [72]. In particular, data marketplaces go one step further by selling harmonized multi-brand data from different OEMs to independent service providers, giving them a data access option. The second approach involves selling data-based analyses but constraining access to the original data [72]. Third, several companies develop and sell data-driven services such as driving style suggestions or fleet management solutions.
10. *Revenue model* represents the structure of how a company generates revenue or income from each customer segment [66]. Most widely known is the direct sale, where the ownership of an asset (e.g., data) is transferred in return for money [35,38,66]. Another way to capture value is through usage fees, which can be charged per kilometer (e.g., usage-based insurance) [5, 58, 64]. Moreover, subscription fees can generate revenue for continuous service access [17, 49, 59]. Transaction fees are charged for an intermediate service such as trading vehicle data through marketplaces [13]. Licensing fees are generated by giving customers permission to use protected intellectual property in exchange [35, 38, 66]. Last, we have on demand pricing tailored to a customer's individual request (e.g., for additional data access).

4.2 Application and Evaluation of the Taxonomy

To get an impression of the applicability of our taxonomy, we classified the DDBMs of all 70 connected car companies that we used to develop the taxonomy. Here, the aforementioned definitions of characteristics and dimensions served as a guiding codebook. Based on this common understanding, a single author classified the 70 companies. In summary, Table 3 shows the distribution of each dimension. Concerning the relative frequencies presented in Table 3, we had to deal with publicly unavailable information that resulted in missing values for seven companies in the data access dimension and 22 companies in the revenue model dimension. Due to this missing data, the proportions of the characteristics in the affected dimensions may be even higher than obtained.

Table 3. Distribution of characteristics based on the classification of the author

	Dimension	Characteristic					
Value Proposition	Value for customers	Safety & security (57%)	Convenience (43%)	Cost reduction (47%)	Traffic efficiency (47%)	Infotainment (14%)	Data accessibility (17%)
	Influence of car data	Car data core business model (81%)	Car data-enabled business model (19%)				
	Influence of autonomy	Enhanced value by autonomy (30%)	Reduced value by autonomy (21%)	Autonomy not relevant (49%)			
Value Architecture	Data personalization	Anonymized data (19%)	Personal data (81%)				
	Data access	Exclusive access (10%)	OBD2-dongle (26%)	Central server (11%)	Retrofit (37%)	Smartphone (26%)	
Value Network	Role in ecosystem	Service provider (80%)	Platform provider (19%)	Technology provider (39%)			
	Customer segment	B2C (50%)	B2B (67%)	B2G (7%)			
	Vehicle ownership	Private ownership (77%)	Fleet ownership (59%)	Mobility on demand (39%)			
Value Finance	Data monetization	Selling data (13%)	Selling analysis (23%)	Selling services (83%)			
	Revenue model	Direct sale (26%)	Subscription fee (36%)	Licensing fee (3%)	Transaction fee (10%)	Usage fee (6%)	On demand (9%)

Cumulated relative frequencies can be different from 100% if a dimension is non-exclusive or in case of missing data.

By analyzing the statistics from Table 3, we made some noteworthy observations: Looking at the value proposition to the customer, it is noticeable that the percentages of infotainment and data access are relatively low compared to the other characteristics. This might change with the proliferation of self-driving cars, as vehicle occupants focus on media and infotainment services rather than on the road [59]. In addition, the prevalence of intermediaries providing data access will increase as connected vehicles become more widespread. Despite the difficulty accessing car data, they form the core of 81% of the business models studied, which would not be feasible without it. Further, half of the companies investigated designed their business model to remain independent of increasing autonomy; around a third would even be strengthened by autonomous driving. In the data personalization dimension, only one-fifth of all companies build their business model on anonymized data. The underlying reason could be that there are few ideas on how to use anonymized data to establish profitable services [8, 73]. For the data access dimension, the different characteristics are relatively evenly distributed, with the exception of exclusive access and central server. This observation may be related to the fact that most connected car companies are independent startups that want to avoid the tedious process of purchasing in-vehicle data from OEMs or intermediaries and therefore rely on retrofitted dashcams, dongles, or smartphones [14]. Most companies using retrofit solutions or dongles for data acquisition also develop them, thus slipping into the role of technology providers. However, the vast majority of companies participate in the ecosystem as service providers. Concerning the customer segment, primarily consumers (B2C) and businesses (B2B) are addressed. One reason for the low number of B2G business models could be the insufficient coverage of connected vehicles [74] to realize services such as intelligent road condition monitoring or traffic management systems based on aggregated data. In terms of vehicle ownership, we found that a clear majority of private vehicles are used to collect the required data. Nevertheless, the mobility landscape will change in the future as shared mobility becomes more prevalent and new corporate fleet customers enter the market [75]. Finally, more than one-third of the examined companies rely on generating revenue through subscription-based revenue models. Therefore, they might hope that recurring revenues from subscription fees will exceed the predominantly one-time costs incurred by connected services [24].

Further, to prove the feasibility of our taxonomy, a subset comprising eight of the 70 companies (Table 1) was classified by independent raters. Here, we received complete responses from three raters, on which our analysis is based. In selecting the eight evaluation cases, we ensured that most of the required information was available on the companies' websites. The classification results were compared using Fleiss' [76] kappa to measure the level of agreement. Therefore, we calculated the average agreement of the raters for all 36 dimensions and the eight selected cases. This yielded a value of 61% for Fleiss' [76] kappa, which according to Landis and Koch [77] corresponds to "substantial agreement". Additionally, the responses from the three individual raters were compared to the initial classification by one of the paper's authors. The results revealed a value of 62% for Fleiss' kappa, which also indicates "substantial agreement". Thus, it can be assumed that our taxonomy is suitable for a consistent classification and concise description of connected car companies' DDBMs.

5 Discussion, Limitations and Future Research

As for theoretical implications, our research ties in and contributes to the descriptive knowledge on connected cars and associated DDBMs, exploring a domain that is still in its early stages [11, 64]. Thereby, our main contribution is a theoretically grounded and empirically validated taxonomy that summarizes the key characteristics describing DDBMs of distinct connected car companies in ten dimensions. The domain-specific view of our taxonomy complements existing general, industry-agnostic DDBM classifications. Although generally applicable taxonomies pose a good reference point and may help distinguish connected car companies based on aforementioned dimensions such as value proposition, customer segment, or revenue model, they are insufficient to fully understand the connected car phenomenon and the configuration of underlying DDBMs. Accordingly, our taxonomy is the first to focus on the connected car domain, proposing novel dimensions such as influence of autonomy, data access, or vehicle ownership. From a theoretical perspective, our taxonomy serves as a basis for analyzing, designing, and configuring DDBMs for connected cars, investigating connected car startups, and strategically classifying incumbents' offerings. Furthermore, our taxonomy provides a common language and structure for the investigated research field, helping scholars position their work therein. We also follow Parvinen et al.'s [9] call for a better understanding of data monetization by examining different roles in the ecosystem and their approaches to create and capture value from data. Summing up, our work offers deeper insights into the structure of data-driven business models and will help classify research in this area.

In terms of managerial implications, the taxonomy allows practitioners to navigate the still largely unexplored field of DDBMs more effectively. Based on empirical development using 70 real cases, our taxonomy provides a comprehensive market overview and status quo analysis of the connected car ecosystem. Practitioners, such as traditional OEMs, will gain a detailed understanding of how startups leverage vehicle data to enable innovative services and learn about different ways to monetize their valuable data assets. Moreover, our taxonomy represents a strategic management tool for developing novel and documenting existing business models in the automotive industry. Therefore, current startups or incumbents can use the taxonomy to systematically analyze competitors or identify combinations of characteristics that have not been employed so far. Thus, in systematically generating new ideas, practitioners may benefit from our work using our taxonomy as a basis for applying a morphological analysis [44, 78].

As any study, ours is not without limitations. First, with the field of connected mobility and resulting business models constantly evolving, the taxonomy needs to be constantly updated to remain useful in the future. Second, our sample of analyzed connected car companies does not raise the claim to be exhaustive. Particularly in the fourth iteration, we only analyzed 20 startups. Therefore, our work is limited by the fact that since not all remaining startups have been analyzed in the last iteration, there might be the chance that further dimensions may have been derived from the companies that have not been analyzed. Nevertheless, in future research, we plan to further evaluate the taxonomy by means of expert interviews with representatives from research and practice for another confirmation or revision. Third, our results stem only from publicly available information. However, the websites provided by the connected car companies often contain limited information on their business model, especially concerning revenue models. Hence, in future investigations, it can be valuable to contact certain companies with missing data to obtain a complete data set. Fourth, our reported results rely on the classification of one author (70 companies) and three individual raters (eight companies). To improve the validity of the results, we believe that our taxonomy should be tested quantitatively for completeness and applicability. Therefore, we intend to let further individuals rate the whole set of companies. Finally, building on our research, a cluster analysis could identify archetypes of DDBMs in the connected car domain, i.e., typical combinations of characteristics across all ten dimensions included. These archetypes could help provide a theoretically sound basis for developing connected car DDBMs.

6 Conclusion

Against the backdrop of the increasing importance of car connectivity and data monetization, we examined ten dimensions and 36 corresponding characteristics that describe DDBMs for connected cars. In sum, we executed four iterations, one being conceptually based on a SLR and three iterations being empirically grounded on a data set of 70 connected car companies. By applying our taxonomy to the dataset, we demonstrated the feasibility of the taxonomy to analyze and understand the DDBMs of various connected car companies. Overall, our conceptually grounded and empirically validated taxonomy contributes to the existing literature by extending the descriptive body of knowledge on DDBMs and connected cars.

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