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Mobility business models toward a digital tomorrow: Challenges for automotive manufacturers

Hugo Pérez-Moure [a], Jesús F. Lampón [b,*], Pablo Cabanelas [a]

[a] *University of Vigo, Faculty of Commerce, C/ Conde de Torrecedeira 105, 36208 Vigo, Spain*
[b] *University of Vigo, Faculty of Business and Tourism, Campus As Lagoas, 32004 Ourense, Spain*

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ABSTRACT

The development of digital business models is impacting the traditional value chain for mobility, implying changes as well as future challenges for automotive manufacturers. Taking a Global Value Chain approach, this work analyses the recent evolution, short-term direction, and medium- to long-term future vision of the adoption of digital mobility business models by automotive manufacturers. Results suggest that, while the firms analysed are currently incorporating relevant business models through autonomous vehicles, digital platforms, connectivity, and carsharing, they are mostly focused on marketplace exploitation through digital platforms and services related to connectivity. Key elements for the development of future mobility business models include data collection and management as well as interconnection. At the same time, digitalization is expected to reconfigure not only associated business models but also the relationships among actors within the value chain. These relationships will become more complex for automotive manufacturers, who may lose control of value-added activities and acquire dependence on certain actors such as technology and service partners, which are expected to play a pivotal role in meeting new opportunities. As a result, the decision-making power of value chain participants will likely be more widely distributed.

1. Introduction

Mobility resulting from the emergence of connected and autonomous vehicles (CAVs) as well as shared vehicles is transforming the value chain of the automotive industry, where all relevant actors are seeking to propose and adapt new business models (Cohen and Kouvelis, 2021). Due to its degree of novelty, this growing Mobility sector presents many challenges across diverse areas in which automotive actors hope to participate, including through digital platforms (Loonam and O'Regan, 2022) and in terms of connectivity (Bezai et al., 2021). Consequently, mobility has become a dynamic concept with a strong evolutionary component in associated business models (Turienzo, Cabanelas and Lampón, 2023).

Increasing digitalization has meanwhile fostered a phenomenon known as digital entrepreneurship (Kraus et al., 2019; Ruiz de la Torre and Sánchez, 2022) that entails new value propositions and the need to identify new market segments – and thus the transformation of business models (Michelini and Fiorentino, 2012). New information and communication technologies enable companies to exchange data, reformulate their range of offer to customers, and restructure the value chain based on real needs (Berman, 2012). This context has also given rise to new types of economy, such as servitization (Ruiz de la Torre and Sánchez, 2022) and the

* Corresponding author.
E-mail addresses: hugo.perez.moure@uvigo.es (H. Pérez-Moure), jesus.lampon@uvigo.es (J.F. Lampón), pcabanelas@uvigo.es (P. Cabanelas).

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share-economy (Kraus et al., 2019), along with novel marketplaces offering value-added services to users (Cusumano, Gawer and Yoffie, 2019).

However, digitalization does not impact all industries, value chains, and business models in the same way (Turienzo et al., 2023). The present research undertakes an analysis of services related to digitalization in the Mobility value chain and their implications for the adoption of business models and value propositions for Mobility as a Service (MaaS) (Jittrapirom et al., 2020; Arias-Molinares and García-Palomares, 2020; Becker et al., 2020). Mobility is already a key sector for many countries; consequently, changes to associated business models are occurring at an accelerated pace (Fournier, 2017; Athanasopoulou et al., 2019; Shammut et al., 2023) and must be better understood. Furthermore, the Mobility sector is currently among the most attractive for both investors and public actors, ranking fourth in R&D investment globally and first in Europe (ACEA, 2022). This points to the importance being given to the development of new technologies and solutions, as well as the confidence that agents are placing in Mobility's potential for growth and transformation (Turienzo, Cabanelas and Lampón, 2023).

Despite the importance of MaaS and the rapid evolution and adoption of technologies, the volatility of strategies implemented thus far has fostered uncertainty (Jittrapirom et al., 2020). Furthermore, implementation of these technologies does not generate immediate benefits and carries a high investment risk, leading to some hesitancy in their adoption (Llopis-Albert, Rubio and Valero, 2021). It is therefore crucial to assess the current state of relationships between manufacturers and digital companies, to comprehend the current MaaS strategy, and to project a road-map and future vision, which are currently lacking (Hensher, Mulley and Nelson, 2021).

From a theoretical point of view, recent analyses of mobility business models are mainly focused on internal resources and the capabilities of firms to adapt related value propositions in a dynamic technological environment (Teece, 2019; Lanzolla and Markides, 2021; Cabanelas et al., 2023; Turienzo, Cabanelas and Lampón, 2023). These studies are supported by Contingency theory, analyzing the main factors that change and condition the needs of firms as relate to business models (Lanzolla and Markides, 2021; Turienzo, Cabanelas and Lampón, 2023), and by Dynamic Capabilities theory, analyzing the resources (*e.g.*, assets, technologies) and capabilities (*e.g.*, identification of opportunities, customer adaptability) with which a firm can generate value for customers (Teece, 2019; Cabanelas et al., 2023). No prior work has incorporated the Global Value Chain (GVC) approach (Gereffi, Humphrey and Sturgeon, 2005; Sturgeon, Van Biesebroeck and Gereffi, 2008) into its theoretical framework for analysis of the evolution of business models related to Mobility. This approach permits the integration of other variables and actors into analysis (beyond the firms' internal resources and capabilities) and offers a broader perspective of precisely what business models are being developed by the diversity of firms within the value chain. The main objective of this paper is to study under the GVC approach the evolution of the implementation by automotive manufacturers – also known as Original Equipment Manufacturers (OEMs) – of business models associated with digitalization. The paper contributes to understanding how the configuration of the Mobility value chain and the relationships established between actors condition the offer of digital mobility services by OEMs. This then assists in analyzing the value propositions around MaaS, the evolution and short-term direction of digital mobility business models, and projections of a medium- to long-term future vision (to 2030, 2040, and 2050).

In pursuit of its research objective, this paper is structured into four sections. Section 2 presents the theoretical framework of the relevant digital business models as well as the GVC approach to Mobility. In the third section, the research methodology is given in detail. The results of the four OEMs under analysis are presented in Section 4. These results are then discussed, leading to the paper's main conclusions and an overview of future challenges and recommendations.

2. Theoretical Framework

2.1. Digitalization and business models

Scientific articles related to business models have been written without interruption since the 1950 s, but they have taken on special relevance in recent years (Taipale-Erävala, Salmela and Lampela, 2020; Medina, Mazaira and Alén, 2022). Insofar as a business model is put into practice with a clear focus on value creation (Palos-Sánchez et al., 2021), it should allow the structuring of new value propositions, the identification of market segments, and some definition of the structure of the relevant value chain (Michelini and Fiorentino, 2012; Kraus et al., 2019), along with traditional aspects such as customer focus (Gordijn and Akkermans, 2001; Osterwalder and Pigneur, 2010; Amit and Zott, 2001).

The importance of digitalization in contemporary business models has been opening new spaces for value creation (Kraus et al., 2019; Pérez-Moure et al., 2023), as the use of digital tools in business models carries an essential weight and results in diverse service options (Taipale-Erävala, Salmela and Lampela, 2020). New models related to digitalization arise around new capabilities that bring a series of changes associated with new information and communication technologies (ICTs), which allow the reformulation of a value proposition to the customer (Vangjel, 2021). As the real needs of customers evolve and new actors emerge to meet them, some reformulations will exert influence over the value chain (Berman, 2012). Without these new digital business models, it would be impossible to gain an understanding of future contexts (Turienzo, Cabanelas and Lampón, 2022; Ancillai et al., 2023; Shen, Sun and Parida, 2023).

At the same time, certain studies have highlighted the importance of servitization in current business models (Shashishekar, Anand and Paul, 2022). Various contemporary business models stem from the need to deal with a market where competition is strengthening, and this implies that companies (especially the most innovative) are focusing their value propositions on servitization (Schaeffer, 2017; Ruiz de la Torre and Sánchez, 2022; You, Sarpong and O'Regan, 2022). In the context of Mobility, all these changes have led to what is known as 'Mobility as a Service' (MaaS) – a user-centric model for mobility that includes assorted personalized and customized services (based chiefly on ICTs) and that each company approaches in its own way (Jittrapirom et al., 2020; Arias-Molinares and García-Palomares, 2020; Becker et al., 2020).[1]

Mobility technologies related to digitalization are currently reconfiguring the automotive industry and giving rise to new opportunities and business models (Gschwendtner, Sinsel and Stephan, 2021; Llopis-Albert, Rubio and Valero, 2021). The servitization of CAVs, digital platforms, and connectivity are among the most prominent elements of these mobility technologies (Butler, Yigitcanlar and Paz, 2021; Steinberg, 2022; Hind, Kanderske and van der Vlist, 2022; Cabanelas et al., 2023). As a result, these technologies are having a direct impact on the way connected and autonomous vehicles are used, while the related businesses models are significantly transforming the market in the automotive industry (Barreto, Amaral and Baltazar, 2020).

In short, in recent years, multiple business models have emerged that depend largely on the type of industry and value chain in which they are developed, where digitalization plays a fundamental role (Turienzo, Cabanelas and Lampón, 2023). Other aspects of certain importance include value creation, collaboration, and the strong competition encountered in new market niches (Guzmán-Cuevas, Cáceres-Carrasco and Soriano, 2009), and this leads to a focus on the value chain and the relationships built among its actors to satisfy customer demand.

2.2. The global value chain in Mobility

The global value chain is defined as the full range of activities that different actors perform to bring a product/service from conception to end use (Gereffi and Fernandez-Stark, 2011). Thus, the global value chain of a given industry is configured by two elements: the activities that define the distribution of value along the chain, and the key actors that perform those activities (Nicovich, Dibrell and Davis, 2007; Sturgeon et al., 2009). The GVC approach was developed to analyze the relationships among actors who specialize in distinct segments of a global value chain (Yi, 2003; Sturgeon, Van Biesebroeck and Gereffi, 2008). Concepts such as subcontracting, cooperation, and fragmentation of the value chain have become central elements in GVC analysis (Humphrey and Memedovic, 2003), involving specialized actors and how they cooperate and exchange knowledge (Humphrey and Memedovic, 2003; Gereffi, Humphrey and Sturgeon, 2005).

The GVC approach has most often been used to analyze the traditional automotive industry value chain (Humphrey and Memedovic, 2003; Sturgeon, Van Biesebroeck and Gereffi, 2008; Lampón, Cabanelas and Delgado-Guzmán, 2018), with much research focused on the product (vehicle), examining the configuration of a related production network (*e.g.*, components, modules, systems) and the manufacturing processes employed in construction of the vehicle (Sturgeon, Van Biesebroeck and Gereffi, 2008). Also subject to analysis are the diverse relationships between an OEM and its suppliers (Ozatagan, 2011; Schmitt and Van Biesebroeck, 2017; Lampón, Rodríguez-De La Fuente and Fraiz-Brea, 2022). In this traditional value chain, the OEMs control the key value-added activities (*e.g.*, vehicle design, motorization) and coordinate their suppliers through asymmetrical power relationships, determining most of the conditions for production and supply (*e.g.*, location, quality standards, product design) (Humphrey and Schmitz, 2002; Sturgeon, Van Biesebroeck and Gereffi, 2008).

The current technological and social context raises new questions about global value chains (You, Sarpong and O'Regan, 2022). Actors in these value chains must confront a large number of challenges in different areas, particularly in terms of how to adapt disruptive technologies (Malanowski et al., 2021; Loonam and O'Regan, 2022) and transparently share information (Manfredi and Capik, 2022). Among these challenges, emphasis is placed on the profound transformation that digitalization foments and on the need to integrate knowledge and technologies to generate value for customers (You, Sarpong and O'Regan, 2022).

Technological, economic, and social changes have been driving the automotive industry to incorporate technologies and companies considered non-traditional (Bezai et al., 2021; Turienzo, Cabanelas and Lampón, 2022). Changes include the prominence of information and communication technologies (*e.g.*, connectivity and the autonomous vehicle) (Fournier et al., 2017; Bezai et al., 2021), reactions to social trends (*e.g.*, 'peak car') (Focas and Christidis, 2017), and customer preferences (*e.g.*, on-demand mobility) (Lagadic, Verloes and Louvet, 2019).

[1] Some ambiguity surrounds this concept; the core characteristics of MaaS remain uncertain, and no assessment framework exists by which to classify such in a systematic manner (Jittrapirom *et al.*, 2017). Notably, previous works have included in their definitions that MaaS is based on multimodality and the use of different modes of transport. In the present research, multimodality is not covered, with analysis instead focusing on the challenges for OEMs and therefore the vehicles produced (passenger cars and light commercial vehicles). Our object of analysis being OEMs in the automotive industry, exclusion of the multimodal perspective permits us to better capture their shift toward service-oriented business models. To further examine multimodality would inherently entail the introduction of additional actors and modes of transportation, diverting attention from our primary objective (business models associated with OEMs, traditionally the key players in the realm of mobility).

This Mobility value chain is focused not on the traditional product (vehicle) but on services linked to digitalization, specifically once the vehicle has been produced and is in the hands of the customer. From the GVC approach, analysis of the Mobility value chain must include: an identification of the elements that configure it (activities and actors) (Sturgeon et al., 2009); the prevailing types of relationship in terms of control and dependence; and the distribution of power among actors (Yi, 2003; Sturgeon, Van Biesebroeck and Gereffi, 2008). In terms of activities, the GVC approach proposes identification of those that define the distribution of value along the chain (Sturgeon et al., 2009). In this case, the main activities would be key services (and associated business models) linked to digitalization that offer value-added for customers in the realm of mobility. The most relevant services indicated by prior works are mobility solutions for CAVs (Zhou et al., 2021; Cabanelas et al., 2023), services based on digital platforms (Jacobides et al., 2018; Steinberg, 2021), and services linked to connectivity and data exchange (Krafft et al., 2021; Hind, Kanderske and van der Vlist, 2022) as well as to car-sharing (Svennevik, Dijk and Arnfalk, 2021). All these services are mentioned in the literature as being crucial to future scenarios for Mobility (Barreto, Amaral and Baltazar, 2020; Tori, Te Boveldt and Keseru, 2023).

As regards the actors involved, in addition to traditional OEMs, various non-traditional automotive firms are part of the Mobility value chain (Bezai et al., 2021; Turienzo, Cabanelas and Lampón, 2022). The GVC definition includes those actors that work to bring a product from conception to end use (Gereffi and Fernandez-Stark, 2011), and the Mobility value chain must further include those actors offering related services (*e.g.*, car-sharing firms, digital platform service providers) as well as those linked to the development of technologies that support such services (*e.g.*, vehicle connectivity software, positioning and localization technologies) (Novikova, 2017; Guyader and Piscicelli, 2019).

In addition to chain configuration, the types of relationships among actors in a value chain will be key to its study (Pietrobelli and Saliola, 2008). Relationships are traditionally considered in terms of control, dependence, and decision-making power (Sturgeon, Van Biesebroeck and Gereffi, 2008). Previous works on the traditional automotive industry noted that OEMs have long exerted control over value-added activities, with great decision-making power within the value chain and low dependence on suppliers (Humphrey and Schmitz, 2002). From the GVC approach (Sturgeon et al., 2008) in the case of the Mobility value chain, this traditional low dependency and high decision-making power would extend to a greater number of digital activities and services.

In summary, digitalization has been reshaping the traditional automotive value chain, prompting manufacturers to offer services to meet new mobility needs and to control those activities that generate value for customers (Cabanelas et al., 2023). In this context, to better understand the future of mobility business models linked to digitalization, it will be crucial to identify how traditional OEMs have been adapting, as well as what relationships are being established with the numerous actors that configure the Mobility value chain (Schwabe, 2020).

3. Research methodology

3.1. Methodology and sample

A qualitative methodology (multiple case study) was chosen for this work. As regards the sample size for analysis, no exact number of cases need be selected in this methodology. Certain authors of reference have recommended no fewer than three (Yin, 2014) and no more than five (Creswell, 2014); because a case study has the capacity to analyze all the data collected, a very large number does not facilitate optimal management of that information, while a small number may fail to represent the reality of the universe under study (Cassell, Cunliffe and Grandy, 2018).

In this case, four automotive manufacturers were selected: Volkswagen, Stellantis, Toyota, and Honda. These four OEMs invest the most in innovation in technologies linked to Mobility as a Service (PwC, 2018). Furthermore, in terms of revenue, Volkswagen, Toyota, and Stellantis top the charts, while Toyota and Honda rank first in the number of cars sold (Thread in Motion, 2021, Focus2Move, 2023). To perform a detailed analysis of a small number of companies, the case study approach allows for thorough description as well as the comprehension and exploration of observable facts without the rigidity characteristic of a quantitative approach (Yin, 2014). Table 1 presents the data for the four companies analyzed.

3.2. Variables

When taking the GVC approach, two variables are key: the activities that define the distribution of value along the chain, and the actors that perform those activities (Sturgeon et al., 2009). In terms of such activities, our research is focused on those key services (associated business models) linked to digitalization that offer value-added for mobility customers. These business models are:

1. Servitization of CAVs: business models related to digital solutions for mobility with CAVs, such as the logistics of goods (Leminen et al., 2022) or advanced data-assisted solutions (*e.g.*, improved driving experience, traffic flow and safety) (Stocker and Shaheen, 2018).
2. Digital platforms (marketplaces): business models that originate around the same platform (i.e., *Amazon Cloud Services*) (Cusumano, 2010; Bratton, 2016) and that enable OEMs, other firms, and users to carry out transactions (Jacobides et al., 2018; Cusumano, Gawer and Yoffie, 2019; Steinberg, 2022).
3. Services linked to connectivity (data exchange): business models associated with the systems that allow information to be transmitted and shared through connectivity (Krafft et al., 2021; Hind, Kanderske and van der Vlist, 2022).
4. Car-sharing: business-to-consumer or peer-to-peer business models that offer vehicles for flexible sharing by means of applications with tariffs (Svennevik, Dijk and Arnfalk, 2021).

Table 1
Cases for analysis.

Case	N° employees (thousands)	Sales (€ billions)	Main approach to Mobility as a Service
Volkswagen	672	206	Strategy for MaaS centred on connected mobility services and software. The aim is to become leaders in MaaS.
Stellantis	292	145	MaaS mainly focused on electric mobility and exploiting customized software services.
Toyota	370	219	MaaS based on autonomous mobility combined with a wide range of services linked to the share-economy.
Honda	211	109	Adaptation of its mobility services to the real demands of people and society. The aim is to develop user-centric servitization (MaaS).

Source: Authors' elaboration.

5. Complementary services: additional services offered by OEMs to their customers to improve satisfaction (Butler, Yigitcanlar and Paz, 2021); for example, access to real-time traffic information or medical-care services.

As regards actors, in addition to the OEMs at the center of analysis, also considered here are actors that offer relevant services and those that develop the technologies that support such services (Novikova, 2017; Guyader and Piscicelli, 2019). Moreover, depending on how these actors establish relationships with the OEMs, mainly by way of cooperation[2] (Humphrey and Memedovic, 2003; Gereffi, Humphrey and Sturgeon, 2005), a classification can be made as follows:

1. Services providers: external firms that offer services related to mobility exclusively through a transactional relationship with the OEM.
2. Services partners: external or OEM-owned firms that offer services related to mobility through a collaborative relationship with the OEM.
3. Technology providers: external firms that offer technology related to mobility exclusively through a transactional relationship with the OEM.
4. Technology partners: external or OEM-owned firms that develop mobility technology jointly with the OEM.

Finally, understanding MaaS as a user-centric mobility model based on information and communications technologies (Jittrapirom et al., 2020), this research focuses on the value propositions offered by OEMs in terms of digital mobility services.

3.3. Data collection

To obtain information for business case studies, investigators commonly seek primary sources from the companies (Meyer, 2001), particularly as might be obtained through tools like interviews or focus groups (Roulston and Choi, 2018). In this case, the required information derives from large multinationals, involving various departments and contact with numerous geographically dispersed persons – too complex a situation for the employment of such tools. Thus, it was decided to collect data through secondary (internal) sources developed by the companies themselves and made publicly available (*e.g.*, corporate reports, internal technical documents) (Srinivasa and Rajat, 2012) along with other data elaborated by external bodies (*e.g.*, the specialized press, sectorial documents) (Ellen, Day and Davies, 2018). Although this approach loses the main advantage of primary sources (such as the accuracy of information derived from direct contact and observation), systematic application of this research process to secondary sources can obtain specific information from experts (Srinivasa and Rajat, 2012; Ellen, Day and Davies, 2018).

In data collection, an exhaustive review was undertaken of more than 300 documents, identified through keywords. Specifically, in addition to the names of the OEMs, the following words were included in this search: "business model", "new mobility", "connectivity", "car-sharing", "digital platform", "mobility as a service", "data exchange", "autonomous mobility", "marketplace", and "delivery as a service". In order to identify documents, a process was followed similar to that used by Leminen et al. (2022) and Santos et al. (2023). First, an exhaustive search was made of both internal and external documents, with the use of these two types of sources permitting access to specific and detailed information provided by experts (Ellen et al., 2018; Srinivasa and Rajat, 2012). To guarantee the reliability and quality of the documents obtained, the search concentrated on texts indexed in the EBSCO database[3] as well as corporate publications from the OEMs. Following this initial stage, a total of 347 documents were identified; duplicates were

[2] Two types of actors are considered in regard to cooperation: providers, establishing an exclusively transactional relationship without cooperation (delivering the request of the customer and billing); and partners, when there is some degree of cooperation (working in collaboration to understand, develop, and execute strategies to improve the results of the transaction) (Osterrieder, 2021). Partners can be OEM-owned companies (internal partners).

[3] EBSCO is a leading provider of research databases, e-journals, book collections, and e-books for universities, colleges, hospitals, corporations, governments, schools, and public libraries; consulted through the EBSCO Business Source Premier Database.

subsequently removed, reducing the number to 296. Criteria were then established to select relevant and high-quality documents. In addition to being issued by reliable sources, these had to have been published in the past five years[4] (from 2018 onward) at a minimum length of 500 words and focused on the variables analyzed (business models and value chain actors). After a rigorous screening process (as described in Fig. 1), a final review was carried out to exclude redundant content and documents that had mistakenly passed the previous stages. The result was a set of 49 documents (see the Appendix, which presents for each OEM the source of information, the title of each specific document analyzed, and the code name for identification).[5] Data collection was conducted from September to December of 2022.

3.4. Data analysis

Content analysis was used in the analysis of data (Prasad, 2008). This allows valid references to be made to a context – i.e., to examine a wide range of information, to interpret such, and to establish results or comparisons with relative objectivity and generalization (White and Marsh, 2006). This type of analysis applied to texts proves ideal when the information-gathering process is complex and includes many sources (Krippendorff, 2018).

During content analysis, the collected information on each OEM was structured into the digital mobility business models studied. The evolution, short-term direction, and medium- to long-term future vision in the adoption of these business models are all subjected to analysis, along with the actors related to digital services and the technologies that support such services. The results are summarized in two tables: one presents the main value proposition for Mobility and the key aspects and medium- to long-term perspectives of business models; the other shows the relationships between OEMs and actors in terms of dependence and control over key activities.

Additionally, the *MAXQDA 2022* software was used to establish interrelations among the key concepts (codes) contained in the documents. This software performs a systematic coding of the contents of documents to aid in interpretation, and the coding process consists of tagging and labelling different pieces of information collected (Schreier, 2012). The main objective of the coding process is to understand, identify, and make connections among the data collected by creating different categories (Elliot, 2018; Ngulube, 2015). Coding was executed through an iterative process refined through application and adjustment, where the codes employed were a word or a set of words (i.e., “Amazon”, “connectivity”, “autonomous vehicle”) representing units of analysis linked to descriptive elements (Creswell, 2015).

In this case, given the inductive nature of the research, coding was executed manually (Grbic, 2013), identifying different levels of coding of the type “OEM_Name > Type_of_Actor > Business_Model > Actor_Name”. This coding made it possible to establish labels based on definitions resulting from the literature (Schreier, 2012); for example, in the case of “Type_of_Actor”, the labels were: “Technology_Provider”, “Technology_Partner”, “Service_ Provider”, and “Service_Partner”.

Several criteria were set to determine the acceptance or exclusion of elements as codes. By adhering to these criteria, the coding enabled more precise analysis of the data at hand (*e.g.*, by establishing a logical order where a word had to be well-defined and match with key variables) (Punch, 2014; Saldaña, 2009). For instance, the term “platform” had to be preceded by “digital” to be considered a valid code. This allowed the elimination of potential confusion with other elements such as “modular platforms”. To ensure the quality and rigor of the coding process, the procedure followed was that recommended by Bryman (2012) and Saldaña (2009). This process included: (1) an initial coding as a quick read of the documents; (2) the creation of an index to facilitate the processing of information and respective labels; (3) an exhaustive review to refine the coding, eliminating or adding elements from the prior initial quick read; and finally (4) a detailed analysis based on this final coding.

The results produced by way of this software can be presented through various customized outputs. In this research, correlation analyses were performed through code co-occurrence maps that record the interrelation of codes across the lines that connect them. The larger the letters of codes and the thicker the lines, the greater the number of interrelations between codes.

4. Results

4.1. Volkswagen

4.1.1. Servitization of CAVs

This OEM’s business models associated with CAVs are not currently operational but remain in the development phase, with plans for near-future deployment [VW-3]. The company is developing autonomous driving with a strategic partner (ARGO AI). The goal is to launch commercial vehicles with autonomous driving for Mobility as a Service in the urban goods transport niche, to be started in the city of Hamburg [VW-3]. Nevertheless, this launch appears to be unlikely before 2030, when the software and all functions related to the connectivity of these autonomous vehicles are expected to be available [VW-1].

4.1.2. Digital platforms

Volkswagen has its own digital platform being jointly developed with the digital company Diconium, of which VW has acquired

[4] A period of sufficient length to observe the evolution and identification of trends, and recent enough to assist in forecasting the medium-long term future vision.

[5] This is expressed as the initials of OEM followed by a number corresponding to the document. For our purposes, the OEM code-initials are VW for Volkswagen, ST for Stellantis, TO for Toyota, and HO for Honda.

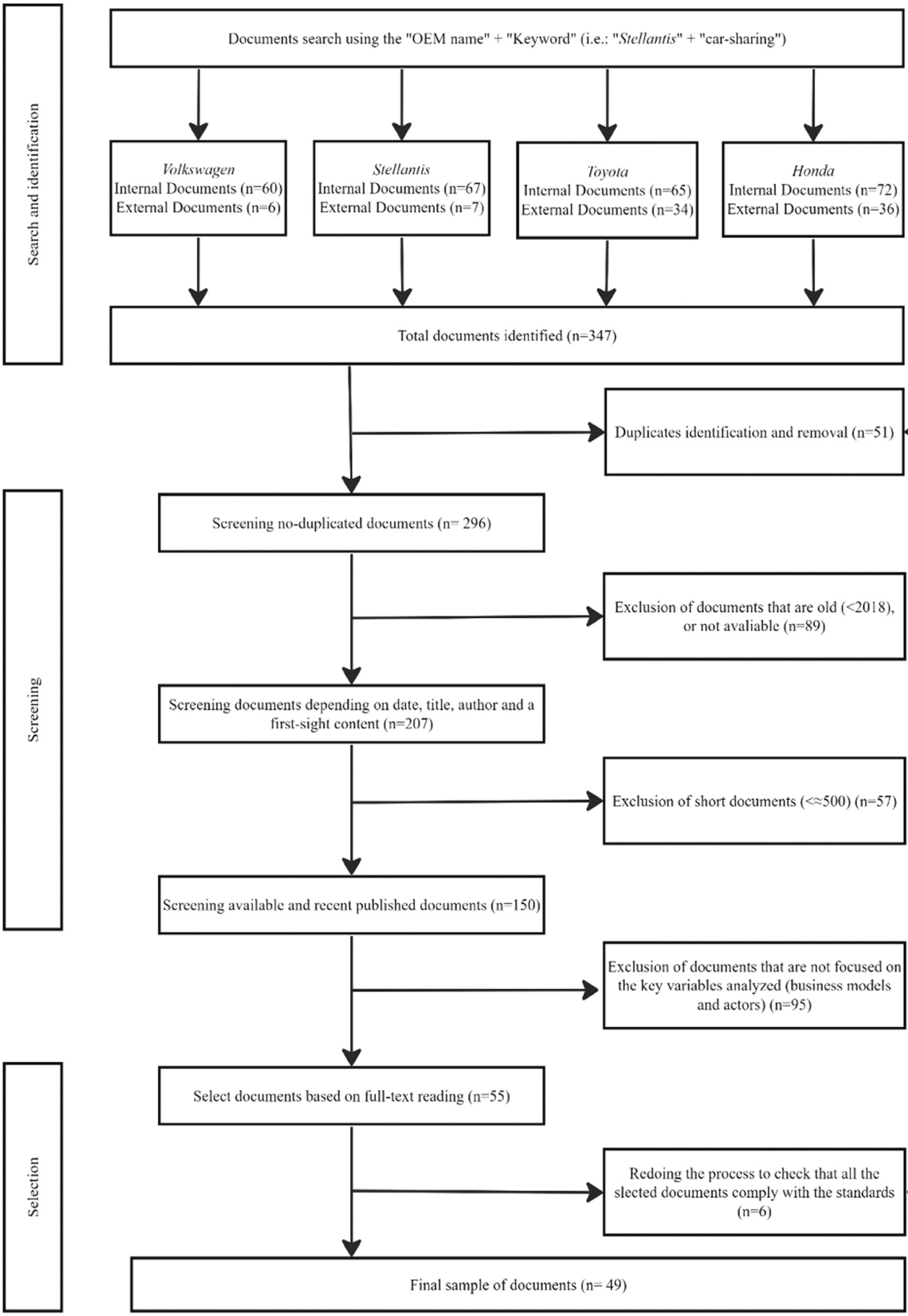

Fig. 1. Document selection process.
Source: Authors' elaboration.

49% in preparation for future scenarios [VW-4]. This is known as the *Volkswagen Automotive Cloud*, a global cloud platform that enables an ecosystem to provide digital value-added services for the cars of Volkswagen customers [VW-4; VW-7]. Volkswagen intends to provide a unified marketplace in which third-party companies will be able to deliver their services to any of the group's brands. In this marketplace supported by *Volkswagen Automotive Cloud,* the OEM will exploit the business model linked to the data stored and processed on the platform [VW-8]. Other companies (such as insurance, maintenance, or repair companies) will exploit their traditional business models with this data, and Volkswagen will use the platform to carry out transactions with these companies [VW-7]. Indeed, Volkswagen anticipates that by 2030, approximately one-third of its sales and consequent profits will stem from digital sales of this nature [VW-6].

4.1.3. Services linked to connectivity

Volkswagen is committed to becoming a provider of content and apps associated with connectivity [VW-1; VW-6]. Volkswagen vehicles collect signals from sensors, along with data relating to performance (such as near-accidents) and metrics of a vehicle's on-board systems and surroundings [VW-7]. The connected vehicles from VW brands allow the transmission of this data, which is then used to offer specific services – for example intelligent parking, an app that allows a parking space to be found and paid for automatically.

Other business models on offer and related to connectivity include a remote service that allows the use of a phone to lock/unlock the car, adjust the seats, and set the interior vehicle temperature, along with home-systems integration (*e.g.*, enabling devices within a house to turn on when the car is approaching) and software updates to obtain the latest revisions over-the-air and desired features on-demand [VW-7]. This software, named *CARIAD*, is being developed by Volkswagen itself and offers services such as route planning, voice control, and a travel assistant developed by Mobileye [VW-1; VW-6]. Volkswagen also offers a system to provide locations of electric charging-station and to recommended stops to avoid 'range anxiety' for customers seeking recommended charging stations [VW-1; VW-7].

Volkswagen will allocate approximately 5% of its profits toward fortifying its digital autonomy in anticipation of the challenges that lie ahead, focusing on 2050 in particular [VW-6]. By 2030, the company aims to have initiated a transformation centrally focused on services that are tightly integrated with connectivity and software [VW-1]. This transformation will result in the creation of safer and more intelligent vehicles in the long-term. Volkswagen's projections for 2030 are quite ambitious in the deployment of their software and associated services, with a forecast increase to 40 million software-connected vehicles and the expectation of continued growth thereafter [VW-1; VW-6].

4.1.4. Car-sharing

Within the car-sharing area of new mobility, Volkswagen is working with two companies dedicated to this type of service: *MOIA* [VW-5] and *WeShare.* Both are defined as environmentally friendly ride-pooling systems (fully electric in the case of *WeShare*) with vehicles owned by the company, where customers combine their journeys with others travelling in a similar direction. These include a mobile app for the customer through which passengers can book and pay. Although a plan exists for expansion in future decades [VW-3], implementation is currently limited; more than five years after its creation, the service has so far been established only in Berlin, Hamburg, and Hanover [VW-2; VW-9]. This situation may be perceived as indicating a lack of interest by the company in this business model, but the actual intention of Volkswagen is quite different. The sale of *WeShare* to the firm *Miles* aimed at consolidating the company's presence in the shared mobility sector, with *Miles* controlling greater geographic coverage (compared to *WeShare*). This agreement came accompanied by designs for long-term collaboration, where Volkswagen will provide electric vehicles for the *Miles* fleet, demonstrating its continued commitment to shared mobility. This will materialize through the delivery of 10,000 vehicles from Volkswagen to *Miles*, significantly increasing the VW brand's presence within this business model. It is crucial to emphasize that this change does not represent a modification in Volkswagen's intention but rather a strategic adaptation to strengthen its position in the expanding shared mobility market [VW-8].

4.1.5. Complementary services

Complementary services based on this OEM's digital platform or on connectivity are diverse. Based on V2I (Vehicle-to-Infrastructure) connectivity,[6] Volkswagen offers *Traffic Light Information*, which provides drivers in their virtual cockpits with the number of seconds remaining before a traffic light turns green. This system is available in the U.S. and will be operational in Europe in the near future. Indeed, it is already operating in Hamburg, with an underlying expectation of expansion [VW-2].

4.2. Stellantis

4.2.1. Servitization of CAVs

In services linked to CAVs, Stellantis seeks to offer Delivery as a Service in the medium-term future; therefore the company has a

[6] Vehicle-to-Everything communication (V2X) includes the following types: V2V (Vehicle-to-Vehicle), V2I (Vehicle-to-Infrastructure), V2N (Vehicle-to-Network), and V2P (Vehicle-to-Pedestrian).

collaboration agreement with Waymo exclusively for light commercial vehicles [ST-7]. Although Waymo also has agreements on autonomous driving with other OEMs, it has agreed with Stellantis to put a fleet of autonomous light commercial vehicles into service. The horizon for launching the service using SAE Level 3 automated driving[7] was originally 2025, but this date has been delayed [ST-7]. Indeed, it seems that this Delivery as a Service autonomous vehicle will not be completely available and functional until the first half of 2030, while Stellantis expects the jump from SAE Level 3 to Level 4 will take place between 2030 and 2040 [ST-8].

4.2.2. Digital platforms

After several initiatives and different technology partners, Stellantis is currently supporting its various digital platform business models on *Amazon Web Services* provided by that multinational. Through *Amazon Web Services*, Stellantis is engaging in the marketplace with the aim of directly offering its customers its own warranty services, accessories, on-demand insurance, maintenance, and vehicle rentals [ST-6]. With all these data, Stellantis aims to develop innovative services and to enhance customer value by offering "data as a service" from 2030 onward [ST-1]. Despite its agreement with Amazon, Stellantis plans to create the Stellantis Corporate Venture Fund, signalling its strategic shift toward developing an in-house platform over the next decade [ST-1]. Additionally, in agreement with Stellantis' electric future vision, the OEM has a B2B platform for support and assistance (*e.g.*, subsidies, taxes, technologies) for companies looking to start their transition to electric mobility [ST-3].

4.2.3. Services linked to connectivity

One of Stellantis' future objectives is to offer customer-centric services based on increased connectivity (called *STLA Brain,* using AI services) [ST-1; ST-6]. The collaboration between Amazon and Stellantis is introducing customer-centric connected experiences across the brand's vehicles – in particular, through the *STLA SmartCockpit* based on applications that power a rich array of features and services such as trip planning, voice assistance, and payment services; even *Alexa* (Amazon's virtual assistant) is being incorporated into Stellantis vehicles [ST-6]. The drivers are able to choose from among these apps, offered via connectivity and paid through subscription. The *STLA SmartCockpit* as well as the *STLA Brain* will begin implementation in 2024 but will not be fully operational until 2030. Stellantis forecasts more than 34 million connected vehicles by 2030, with services linked to connectivity increasing revenues by US$19.6 billion [ST-1].

Services associated with electric mobility are also among the pillars of the Stellantis vision. Based on its strategy of zero emissions by 2030, the company is setting up several business models to facilitate the use of its electric vehicles [ST-1; ST-9]. Supported by connectivity technologies and an app that serves as a locator for electric charging stations, Stellantis together with the company 'TheF Charging' manage a network with exclusive conditions for Stellantis customers and over 15,000 locations, with 2 million stations in city centers [ST-2; ST-5].

4.2.4. Car-sharing

Stellantis owns a company called Free2Move, which offers a fleet of vehicles of Stellantis brands to provide mobility solutions exclusively for professionals [ST-8; ST-9]. Free2Move's own application provides car-sharing, on-demand mobility services, and parking space reservation, among other features. These services are available only in two European cities, Paris and Madrid. Nevertheless, Stellantis expects Free2Move to expand over the next decade (2030–2040) [ST-9].

Furthermore, Stellantis is backing up this business model by acquiring a car-sharing venture of Mercedes and BMW that launched services of this type. Through the *Share Now* app, this company currently allows car-sharing to 3.4 million customers in 16 European cities [ST-10].

4.2.5. Complementary services

In line with the commitment to its future vision for electric vehicles [ST-1], Stellantis through an alliance with the company Kiri is managing a system to reward drivers with sustainable habits through 'eCoins', which can be spent in the Kiri marketplace. These eCoins are obtained through the *Uconnect services tool* app, where an *eco:Score* section measures driving efficiency on a scale from 0 to 100 [ST-4].

4.3. Toyota

4.3.1. Servitization of CAVs

Toyota's servitization of CAVs is being extensively developed through different subsidiaries and alliances with other companies. Toyota is collaborating with *Pony.ai* in the development of a virtual assistant (*Guardian*) as well as tests in Beijing and Shanghai in order to launch an autonomous vehicle [TO-14]. Other results include the *e-palette* for the movement of both people and goods in an autonomous manner [TO-3]. An *Autonomous Mobility Management System*, supported by a mobile app, allows the assignment of various tasks such as door-to-door deliveries; this is expected to be fully implemented in the final stage of 2030 [TO-3; TO-6; TO-9; TO-15]. The autonomous vehicle for these deliveries is already in circulation in one city in Japan (Woven) and is projected to be deployed in the short term in the main cities of that country [TO-3; TO-12;]. This existing door-to-door service works with companies such as Amazon, Pizza Hut, and especially Uber. Facing 2040, the company expects to fully deploy the *Autono-MaaS* concept [TO-12; TO-15], a new

[7] The Society of Automotive Engineers (SAE) classifies self-driving vehicles by several levels of autonomy, ranging from 0 (regular car) to 5 (human driver not required). Level 3 means that autonomous vehicles drive themselves, but only under ideal conditions, and with limitations (such as limited-access areas at certain speeds). A human driver is still required to take over should road conditions fall below ideal.

vehicle platform compatible with third-party autonomous driving kits and sensors ("Autono") for use in mobility applications ("MaaS").

4.3.2. Digital platforms

Toyota has developed its own digital *Mobility Service Platform*. The company is also collaborating with Amazon as a technology partner, although the platform remains Toyota's own [TO-2; TO-9]. The use of different devices to store data which are then processed by Toyota allows services to be offered directly to the customer, also permitting third parties to extend their own offers through the platform (to be based on *Amazon Web Services* functions). Offers include tailored maintenance plans, flexible leasing, and on-demand insurance (in collaboration with the MS&AD Insurance Group's Aioi Nissay Dowa Insurance Company) [TO-2; TO-8; TO-9].

4.3.3. Services linked to connectivity

For Toyota, building mobility for society represents a central axis, and the company is actively working toward its 2050 vision by developing a new strategy for connectivity services that aims to extend beyond the individual driver and engage with society as a whole [TO-1, TO-6]. Toyota is presently allocating half its revenue to future-oriented initiatives, with a particular focus on enhancing connectivity services related to safety and security [TO-1]. With the goal of connecting vehicles with society as a whole, Toyota will intend to offer personalized services through a localization process, not only addressing customer demands but also aligning with societal aspects particular to each country [TO-1, TO-6].

Grouping additional services into the *Toyota Smart Centre* is essential to Toyota's current and future strategy. This system integrates various services for connectivity such as over-the-air software updates, authentication systems, maps, virtual assistants, and automatic adjustment of the vehicle's interior conditions [TO-2; TO-4; TO-6; TO-8]. Similarly, key encryption via smartphone and continuous emergency services (route and driving recommendations) are enabled through different devices, including the *Trans-Log* and *Smart Key Box* that configure the *Early detection, Early resolution* system [TO-8; TO-9].

4.3.4. Car-sharing

Car-sharing is a fundamental business model for Toyota, and the OEM owns several companies to provide such services: Toyota Share, Hui, and Kinto [TO-2; TO-10; TO-11]. In all these cases, the fleets of vehicles belong to Toyota, but there are differences among them. Toyota Share operates only in Japan and is B2C in type, relying on an app to offer on-demand services. Hui is operating in partnership with Servco Pacific in the U.S., with operations similar to Toyota Share but currently available only in Hawaii [TO-2]. Kinto is operating in Europe and is aimed at both B2B and B2C activity. This is part of Toyota's global 2040 vision to evolve into a mobility company by providing all sorts of services related to transporting people around the world [TO-10; TO-11]. This firm makes vehicles available to companies for car-sharing while also connecting end-users through its mobile app, developed in cooperation with Ridecell; it is currently available in Dublin, Venice, Copenhagen, Madrid, Santiago de Chile, and Buenos Aires [TO-2; TO-11].

Toyota has also acquired portions of the car-sharing companies Grab (investing US$1 billion) and Didi (US$600 million) [TO-5; TO-7]. Grab operates throughout Southeast Asia (218 cities), where it is the leading company (6 million trips per day), and Didi operates in the Chinese market. The aim of these acquisitions is to insert the company's own vehicle brands into these car-sharing fleets in the short term, and especially (and even more importantly) to obtain future data linked to this service [TO-7].

4.3.5. Complementary services

Given Toyota's strong commitment to autonomous driving, complementary services are moving in this direction. Among the most innovative is the "door-to-door doctor" service, which uses the *e-palette* model and its app. Here the user would request medical service through the *e-Palette Task Assignment Platform* (*e-TAP*) application, and the vehicle would drive autonomously to their home. The autonomous vehicle model also allows space for integration of a medical room inside [TO-9].

4.4. Honda

4.4.1. Servitization of CAVs

Honda is at a relatively early stage, developing an autonomous vehicle with Cruise as its strategic partner. This vehicle began tests in Japan and is focused on passenger mobility. Honda forecasts that this vehicle will be officially on the road in the first half of 2030 [HO-7]. At the same time, together with Teito Motors and Kokusai, another autonomous vehicle in development and currently operating only in Tokyo is focused on shared mobility [HO-5].

4.4.2. Digital platforms

Honda is developing its services with Amazon for improvement of its digital platform. It is using *Amazon Web Services* for technical and commercial support [HO-14] – although Honda calls this platform the *Honda Connected Platform*, its functionalities are in fact offered through *Amazon Web Services*. Services and apps are derived from the capture and analysis of data collected from users of Honda vehicles [HO-13]. Honda anticipates full implementation of this platform by 2030, aiming to establish tripartite interaction involving the environment (infrastructure, traffic…), its MaaS system, and the platform itself. The primary goal is to amass a wealth of data, paving the way for vehicles to achieve complete connectivity with the environment from 2030 onward [HO-3]. The OEM is also currently developing the *Monet* platform with partners including Hino and Softbank to improve the capture of this data. Honda has invested US$2 million in this company (10% of *Monet*'s estimated value) [HO-12; HO-15].

4.4.3. Services linked to connectivity

Keeping Honda's intentions for 2030 in mind, connectivity-related services will become a key element in the OEM's business model. Through different devices, basic functionalities are being offered such as traffic information, vehicle status, weather, and over-the-air updates [HO-1; HO-3]. In addition, through various agreements and partnerships, the company is offering voice assistant services, navigation, and other applications using the *My Honda* mobile app, which can also be used to locate the vehicle, unlock it, or check its status. These different services can be selected by the user through a subscription service [HO-2; HO-13]. Although the services are currently on offer thanks to contracts with Apple and Amazon, Honda is also working with Google and Sony with an eye to the future [HO-8; HO-11; HO-14].

In order to increase and improve these services, Honda acquired the company Drivemode, specialized in developing apps linked to vehicle connectivity. Thus Honda hopes to enhance its applications completely by the future horizon of 2030 [HO-10]. It has also created a company with its strategic partner Neusoft to accelerate connectivity-related services in China [HO-9]. One of these apps permits the location of charging points for electric vehicles [HO-1; HO-6] and it is set for broader implementation, such as in taxis in India [HO-6].

4.4.4. Car-sharing

Honda owns a car-sharing company known as *EveryGo*. This service is available to all through a mobile app that can be used to reserve a vehicle, unlock it, proceed to payment, authenticate, and leave the vehicle. The uniqueness of this service is its option of renting a car by the hour or on a long-term basis. The *Honda EveryGo* service is only available in Japan and is not expected to receive broader implementation in other countries in the future [HO-4].

4.4.5. Complementary services

Thanks to V2X connectivity, Honda is developing a safety-enhancing system. The OEM is committed to improving safety, not only on the road but at all levels across coming decades. To this end, it is developing a system that can be used to detect theft and other crimes, reporting them directly to the police. In addition, using artificial intelligence, it is capable of recognizing patterns and pre-notifying the authorities. This project is undergoing testing in the city of Kakogawa [HO-1; HO-3]. Furthermore, despite Honda's traditional focus on automobile manufacturing, the company is now actively working to enhance its digital mobility services, with a forward-looking approach aimed at creating new value propositions in anticipation of the year 2050 [HO-3].

4.5. Comparative synthesis and interrelations

As a summary of the analyses undertaken in the previous sections, Table 2 presents for each manufacturer the main value proposition for Maas, the most relevant aspects and short-term direction of each business model, and the future medium- to long-term vision for digital mobility.

Table 3 illustrates the relationships between OEMs and their respective technology and services providers and partners in each defined business model, along with a summary of degrees of control and dependence within each company.

In addition, the code co-occurrence maps resulting from the use of *MAXQDA 2022* software are presented below. Fig. 2 illustrates the interrelationships between each OEM and the various mobility business models. Figures 3a to 3d identify the interrelationships between each of the four OEMs and other actors in the Mobility value chain (technology providers, technology partners, services providers, and services partners).

These figures illustrate the trends of each manufacturer in a clear and logical manner. Volkswagen focuses on connectivity as the main driver of its value proposition (Fig. 2). It maintains relatively high control over activities and works with few partners, relying on technology providers to develop the business models (Fig. 3a). Stellantis prioritizes both connectivity and digital platforms (Fig. 2), working with Amazon and other providers for development (Fig. 3b), which results in technological dependence on external companies. Toyota is committed to promoting servitization of CAVs and car-sharing in addition to digital platforms and connectivity (Fig. 2). It maintains relatively strong control over its core business models while collaborating with different actors in various areas (Fig. 3c). Honda is fully oriented toward digital platforms and connectivity (Fig. 2), with heavy reliance on numerous technology providers and partners (Fig. 3d).

5. Discussion

The results of this research indicate profound shifts in the mobility business models of automotive OEMs as well as in relationships within the Mobility value chain during coming decades. These changes point to the need for future adaptation to emergent business models by actors in the value chain, chiefly due to the introduction of disruptive technologies. In particular, the results confirm that these changes will stem mainly from digitalization (Kraus et al., 2019; Ancillai et al., 2023; Shen, Sun and Parida, 2023) but also from a highly interconnected market structured around the data collection and management, as required to offer high value-added services adapted to users; this market is expected to continue expanding in size and complexity. On the other hand, the extant literature indicates that digitalization does not impact all business models in the same way (Turienzo, Cabanelas and Lampón, 2023). Results show that companies address mobility through differences in their value propositions, with an eye to the short-term, medium-term, and long-term; the influence that digitalization exerts on business models will depend not only on each actor in the value chain but on the relationships established among them. This supports the proposition of some research on digital servitization calling for future studies to embrace dyadic or multi-firm perspectives (as opposed to traditional firm-centric views) to understand how companies are adopting (and will continue to adopt) business models to offer value for customers (Ancillai et al., 2023).

In regard to business models, the results reveal differences for each case. Services linked to servitization of CAVs are being addressed by all the OEMs, and this is in line with other research findings (Leminen et al., 2022; Ruiz de la Torre and Sánchez, 2022; You, Sarpong and O'Regan, 2022). Moreover, results indicate that servitization will mainly be focused on business models related to fleet services (*e.g.*, logistics of goods) (Leminen et al., 2022) rather than models related to advanced-data-assisted solutions (*e.g.*,

Table 2
Summary of results related to business models.

	Volkswagen	Stellantis	Toyota	Honda
Main value proposition of Mobility as a Service	Strong intention to create its own ecosystem, integrating all mobility services.	Commitment to electric mobility and the exploitation of software services.	Betting on mobility servitization trough CAVs.	Focus on offering multiple services linked to connectivity.
Services linked to CAVs	Under development. Focused on logistics.	Under development. Commitment to light commercial vehicles to offer Delivery as a Service.	Strong commitment to CAVs. Focus on servitization through the *e-palette* model. Enabling multiple tasks via mobile app.	Under development. Focus on shared passenger mobility.
Digital platforms	Own digital platform that provides services for the cars of Volkswagen customers; use of VW marketplace in which third-party companies will deliver their services.	Use of *Amazon Web Services* platform, on which it offers its marketplace. Use of the data to offer its own services. Stellantis also has a B2B platform to support companies in their future transition to electric mobility.	Own digital platform based on *Amazon Web Services* functions. The data is used by Toyota to offer its own services and allow third parties to extend offers.	Use of *Amazon Web Services* platform. The data are used to offer the company's own services.
Services linked to connectivity	Committed to being a content provider. Seeks to create its own ecosystem. Interaction between vehicles; allows software updates.	Committed to connectivity. Services chosen by the customer and paid for by subscription. Location services for charging points through connectivity for users of its electric vehicles.	Multiple devices for improving connectivity. Highlights include key encryption via smartphone and the *Early detection, Early resolution* system.	Commitment to connectivity. Services by subscription.
Car-sharing	Not well developed, although a plan exists for expansion. Includes a mobile app through which customers can book and pay.	Has two companies. One Stellantis-owned company is devoted to professionals, with presence in Paris and Madrid. Projected to expand over the next decade. Another company acquired from Mercedes and BMW (rollout in 16 European cities).	Owns companies that operate with its vehicles: presence in four European and two Latin American cities. Acquisition of car-sharing companies to obtain future data linked to this service.	Not well developed, available only in Japan. Implementation is not expected in other countries in the future.
Complementary services	Of note is V2I connectivity, which allows traffic-light status information. This system, available in the U.S., will be operating in Europe in the near future.	Rewards for sustainable habits, in line with its commitment to electric mobility.	Development of a door-to-door medical service using CAVs.	Commitment to connectivity-based services. One highlight is crime prevention.
Future medium-to long-term vision	Volkswagen is clear on the importance of digitalization for 2030. It intends to gain technological independence from providers and partners. Volkswagen's projections for 2030 are quite ambitious in the deployment of its software and associated connected services, forecasting an increase to 40 million software-connected vehicles.	Stellantis forecasts that a large portion of its profits will derive from digitally connected services in 2030. This OEM is betting on data as service, and its involvement of in data generation and exploitation seems clear. Stellantis expects more than 34 million connected vehicles by 2030 and that services linked to connectivity will increase revenues by US$19.6 billion. During the decade 2030 to 2040, autonomous vehicles for Delivery as a Service are expected to reach SAE Level 4, along with expansion of Stellantis' own car-sharing service.	Toyota has a long-term vision extending to 2050. By 2040, it expects to fully deploy its "Autono-MaaS" concept, a vehicle platform compatible with third-party autonomous driving for MaaS. Commitment to car-sharing as part of Toyota's global 2040 vision is planned to evolve into a mobility company by providing all services related to transportation. Building mobility for society represents a central axis, and Toyota is actively working toward its 2050 vision by developing new connectivity services to engage with society as a whole.	Honda has a long-term vision with sights set on 2050. The OEM suggests that its digital platform will interact not only with the vehicle but also with infrastructures and traffic. The goal is to amass a wealth of data, paving the way for vehicles to achieve complete connectivity with the environment from 2030 onward. In addition, in keeping with Honda's intentions for services linked to connectivity as remaining key to its future strategy, it aims to improve all related applications by 2030.

Source: Authors' elaboration.

Table 3
Summary of results related to value chain actors.

	Volkswagen	Stellantis	Toyota	Honda
Technology providers	Digital Platforms (*Diconium*) Connectivity (*Mobileye*)	CAVs servitization (*Waymo*) Digital Platforms (*Amazon*) Connectivity (*Amazon*)	Digital Platforms (*Amazon*)	Digital Platforms (*Amazon*) Connectivity (*Amazon, Apple, Google*)
Technology partners	CAVs servitization (*ARGO.AI*)	Connectivity (*TheF Charging, Kiri*)	CAVs servitization (*Pony.ai*)	CAVs servitization (*Cruise, Teito Motors, Kokusai*) Digital Platforms (*Hino, Softbank*) Connectivity (*Drivemode, Sony, Neusoft*)
Service providers			CAVs servitization (*Uber, Pizza Hut, Amazon*)	
Service partners	Car-sharing (*MOIA*)	Car-sharing (*Free2Move, Share-Now*)	Digital Platforms (*MS&AD Insurance Group*) Car-sharing (*Kinto, Toyota Share, Hui, Grab, Didi*)	Car-sharing (*EveryGO*)
Degree of control and dependence	Volkswagen maintains relatively control and some dependence, working with few providers and partners.	Stellantis has many providers and partners. Special dependence on Amazon as key provider in value-added activities. Low control and high dependence.	Toyota has many partners. Nevertheless, almost all are internal. Relatively control and some dependence.	Honda works with a large amount of technology providers and partners. Low control and high dependence.

Source: Authors' elaboration.

improved driving, traffic flow and safety, lower fuel consumption) (Stocker and Shaheen, 2018). The results further indicate that servitization of CAVs remains at an early stage. In fact, most OEMs are working toward a long-term vision in this field (2030 and beyond), and its future development depends largely on the technology actors present in the value chain.

In terms of digital platforms – regardless of whether the support system is a company's own or outsourced – all the OEMs under study are using these to develop a marketplace to start offering services to users and third parties. Results confirm how these platforms enable OEMs to carry out transactions related to different mobility solutions (Cusumano, Gawer and Yoffie, 2019; Steinberg, 2022), but they also indicate the necessity of interrelations among multiple value chain actors to pursue these digital business models, not only for the near future but for longer time horizons. This seems to be common knowledge among the OEMs – there is an evident collective effort toward digitization, with long-term goals already in place. Moreover, these firms are aware that by 2030, nearly one-third of their profits will derive from these initiatives. Many technology players and service providers are involved in developing the functionalities and exploiting the mobility solutions linked to digital platforms. Therefore, these digital platforms involve diverse actors that should be aligned in order to realize value propositions in the future; some authors have referred to such alignments as "ecosystem business models" (de Vasconcelos Gomes et al., 2023).

Furthermore, the OEMs are offering multiple personalized services that will enhance user experiences linked to connectivity, including for purposes of better car usage (*e.g.*, information on vehicle condition, remote maintenance services) and entertainment (*e.g.*, varied content or access to social media), and in relation to a user's personal preferences and daily life (*e.g.*, voice assistance, home-systems integration), as well as software updates that will be chosen by the customer and commonly paid for by subscription. This confirms the forecasts of prior works which found the main services with the greatest impact on mobility business models to include user-centric services, especially around personalization of the driving experience (Athanasopoulou et al., 2019). Expansion and enhancement of this trend are expected over the coming decades, as all OEMs have planned complementary initiatives for beyond 2030.

The results highlight the notion that companies that obtain (and can manage and employ) data – as by means of systems installed in connected vehicles of certain brands – will have a better capacity to develop business models based on that data during coming decades (*e.g.*, digital platforms, services linked to connectivity). The OEMs are betting on the potential of data as a service. In fact, certain initiatives (such as the acquisition of car-sharing companies) are now being implemented to obtain future data linked to this development. Moreover, the commitment to data generation and exploitation and the goal of amassing a greater wealth of data are included in the future visions of these OEMs.

Despite the importance underscored by previous works on the share-economy and on capacity-generation in new business models (Berman, 2012; Kraus et al., 2019), the results here presented indicate that initiatives being implemented by OEMs have a low impact in terms of market penetration. In particular, OEMs are aware that future scenarios for urban mobility will necessarily require car-sharing services (Mounce and Nelson, 2019), and they are promoting initiatives along those lines; but according to the findings, current markets remain poorly developed and concentrated into very few cities. These results can be explained by the strong competition present in those markets (Guzmán-Cuevas, Cáceres-Carrasco and Soriano, 2009). In a highly competitive setting of major technological disruption, being the first to offer certain services demanded by users will be a key element in leading the associated business models.

In terms of the relationships observed within the Mobility value chain, digitalization continues to be highly impactful, and it is expected that this trend will both continue and intensify during the next decade. Indeed, the results suggest a paradigm shift from a

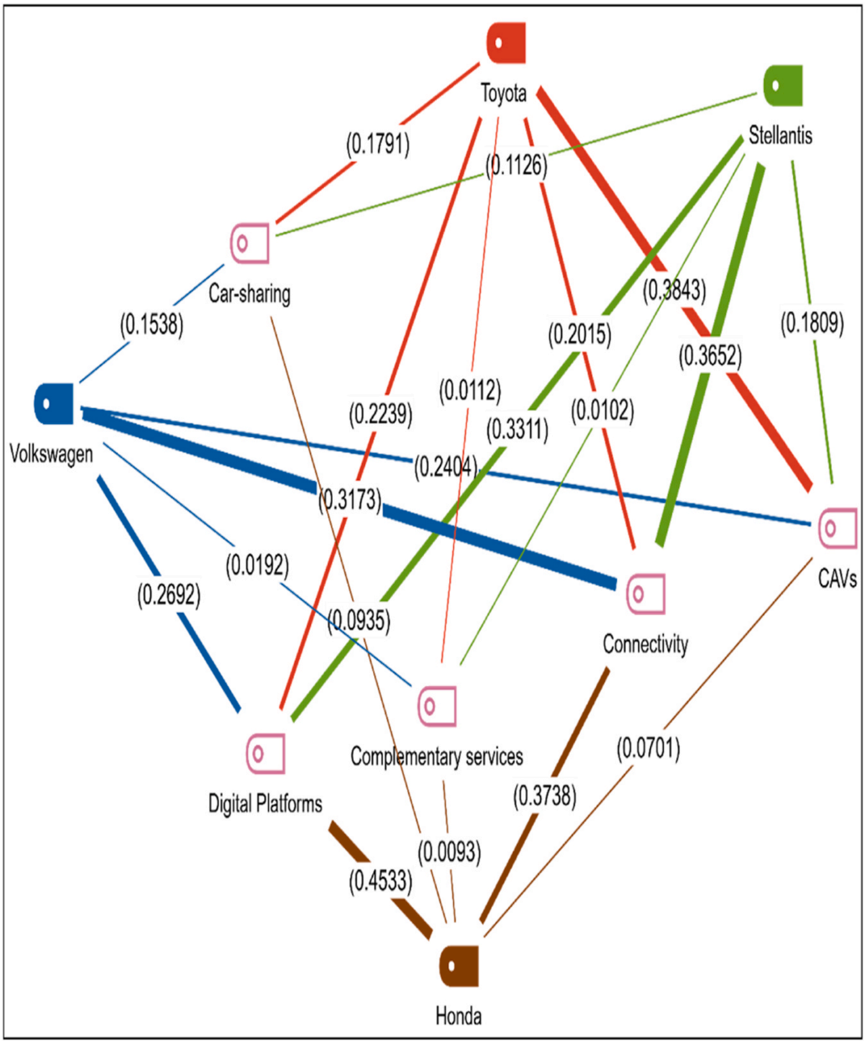

Fig. 2. Co-occurrence map, OEMs – Mobility business models.
Source: Authors' elaboration based on the code co-occurrence map provided by *MAXQDA 2022*.

traditional approach focused on the product (vehicle) to a point where the Mobility value chain will instead be focused on digital services and associated business models. In this context, guided by the intention to manage the future scenarios, companies are attempting to maintain control over high value-added activities, especially those related to digital services (Schwabe, 2020; Turienzo, Cabanelas and Lampón, 2022). However, future control over all such activities by OEMs is not a forgone conclusion. All remain dependent on various technology and service providers and partners, indicating that decision-making power will be shared with those actors.

6. Conclusions

Recent analyses of digital business models are focusing on the internal resources and capabilities of firms to adapt their value propositions in a dynamic technological environment (Teece, 2019; Lanzolla and Markides, 2021). Contingency theory (Lanzolla and Markides, 2021) and Dynamic Capabilities theory (Teece, 2019; Cabanelas et al., 2023) are serving as the main theoretical approaches to explain the adoption of digital mobility business models. The present research instead adopts the GVC approach as a theoretical framework to analyze these business models linked to digitalization, with emphasis on how OEMs are implementing such models. This approach allows the integration of other variables and actors into analysis, beyond the resources and capabilities internal to firms, thereby examining the broader question of which business models are being developed by the diverse firms within the Mobility value chain. Moreover, this approach is also useful for forecasting trends and future scenarios. The method of analysis based on the GVC approach focuses on the activities that define the distribution of value along the chain and the actors that perform those activities, thus assisting in the identification of medium- to long-term future visions for digital mobility business models.

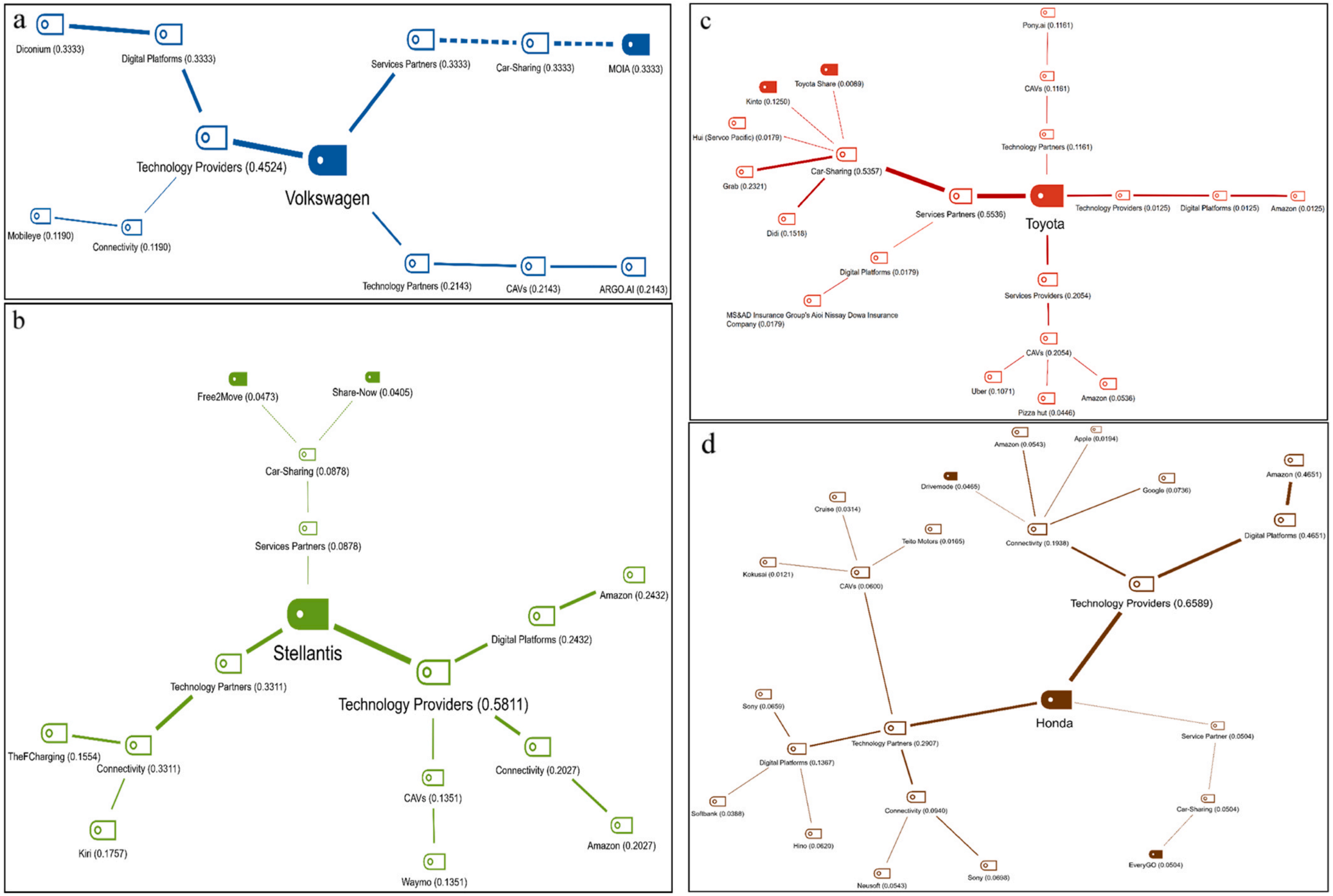

Fig. 3. a to 3d: Co-occurrence maps, OEMs – Value chain actors.
Source: Authors' elaboration based on the code co-occurrence map provided by *MAXQDA 2022*.

Based on analysis of the evolution of digital business models for mobility, several implications and challenges can be projected. In their value propositions for MaaS, OEMs are pursuing leadership positions through the comprehensive development and offer of digital mobility services, with interest in all aspects of mobility. Forecasts to 2030, 2040, and even 2050 all see the continued pursuit of these goals. The results indicate that not all these services and associated business models will develop in similar ways. Digital platforms and services linked to connectivity show great potential for OEMs, which can obtain the necessary data by means of the connected vehicles of their brands. This collected data will serve as the generator of value for customers and therefore the increased enjoyment of those digital services. In fact, all OEMs expect that in the coming decades, a third of their profits will derive from these digital mobility services. However, initiatives by OEMs in the realm of car-sharing have shown relatively mild results in market penetration, and strong future growth is not expected in this area, partly due to the difficulty of gaining market share from the global car-sharing giants that currently dominate this business model. Even more uncertainty is found in business models linked to the servitization of CAVs, mainly because OEMs do not control most activities related to those services, and no changes are expected even in the long-term. OEMs will in this case remain strongly dependent on technology providers and partners, making strategic collaboration key to the successful implementation of CAV servitization.

On the other hand, digitalization is reconfiguring not only mobility business models but also traditional relationships among actors in the value chain. In these relationships, OEMs are less able to control value-added activities and must accept a certain level of dependence on other actors. Powerful actors such as technology suppliers are taking advantage of opportunities while playing a vital role that, according to the results, will not likely diminish in the short-term. Indeed, decision-making power among value chain participants will likely be distributed more widely, and the decision-power structure will grow increasingly diffuse in coming decades.

Having closely reviewed the results of this research, significant implications become apparent for the long-term future. Despite prevalent uncertainty, it is now widely acknowledged that a substantial portion of the revenue of OEMs will derive from digital sources by the year 2030. The trend toward greater digitalization and servitization is compelling mobility companies to re-evaluate their approach toward 2040 and 2050. These companies will no longer be solely automotive manufacturers but will progressively transform into digital mobility enterprises. In this context, OEMs should focus investments on their own technological innovations, or on the acquisition of technologies, especially around business models where the results show comparatively better degrees of adoption – in digital platforms, services linked to connectivity, and related complementary services. Moreover, OEMs should promote and develop strategic partnerships with key technology and service firms, dependence on which will condition the final adoption of digital mobility services. Here an exhaustive process of evaluation of current partnerships and a selection of potential future partners would be recommended.

On the one hand, the shift in digitalization strategy also has geographical implications, as countries with higher levels of digitalization become more attractive to mobility companies seeking strategic partnerships. In fact, results highlight that digital mobility services are being (and will continue to be) more broadly implemented in developed countries (Japan, the U.S., European nations). Extending the time-frame to 2050, all countries (and especially less developed ones) should accelerate and enhance digitalization efforts in order to strengthen the future adoption of these digital business models. On the other hand, policies for decarbonization seem to be having a positive impact on digitalization and servitization – a key aspect, given that decarbonization will remain a clear priority until at least 2050. The results show that the deployment of electric vehicles has been accompanied by certain digital mobility services such as environmentally friendly car-sharing (ride-pooling systems), location of charging points through connectivity, remote battery monitoring (charge levels and performance), electric driving efficiency services that reward drivers with sustainable habits, and platforms to support companies in their transition to electric mobility.

Finally, additional analysis of long-term developments would assist in the drawing of robust recommendations and the suggestion of future lines of research in the field. Of particular interest would be insights into how cooperative relationships might be established with key actors, along with the definition of a better framework for collaboration. Such a framework should derive from in-depth analysis of key elements found in agreements (typology, terms and conditions, practices developed) currently established by OEMs and other actors, as well as impact-analysis of the performance of particular business models, considering both traditional metrics (such as quality of service or customer satisfaction) and digital metrics (such as online capabilities or the number online subscribers).

Annex

Data sources.

Case	Source	[Identification of the document] Document analyzed
Volkswagen	https://www.volkswagen-newsroom.com	·[VW-1] NEW AUTO: Volkswagen Group set to unleash value in battery-electric autonomous mobility world. ·[VW-2] Volkswagen and Hamburg extend strategic mobility partnership. ·[VW-3] Volkswagen Commercial Vehicles moves ahead with Autonomous Driving R&D for Mobility as a Service.
	https://www.volkswagenag.com	·[VW-4] Volkswagen invests in digital specialist Diconium. ·[VW-5] Leadership in Mobility-as-a-Service (MaaS). ·[VW-6] Volkswagen Delivers on NEW AUTO Strategy, Laying Basis for 2022. ·[VW-7] How Volkswagen Automotive Cloud will help shape the connected car of tomorrow. ·[VW-8] Volkswagen partners with MILES Mobility to accelerate expansion of car sharing portfolio
	www.greencarcongress.com	·[VW-9] Volkswagen lays out its NEW AUTO strategy: transforming from manufacturer to software-driven mobility provider; Scalable Systems Platform

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Stellantis	https://www.media.stellantis.com	·[ST-1] Dare Forward 2030. ·[ST-2] Stellantis and TheF Charging announce partnership to create new public charging network in Europe. ·[ST-3] B2B ELECTRIC PLACE: the new digital platform by Stellantis to assist companies in their mobility transition towards electrification. ·[ST-4] FIAT celebrates the success of the New 500′s "KIRI" project and introduces the new FIAT e.Coins. ·[ST-5] Stellantis and TheF Charging expand their public charging network via an agreement with Metropark, an FS Italiane Group company. ·[ST-6] Amazon and Stellantis Collaborate to Introduce Customer-Centric Connected Experiences Across Millions of Vehicles, Helping Accelerate Stellantis' Software Transformation. ·[ST-7] FCA and Waymo Further Expand Autonomous Driving Technology Partnership and Sign Exclusive Agreement for Light Commercial Vehicles.
	https://www.stellantis.com/	·[ST-8] 2021 Corporate Social Responsibility Report. Powered By Our Diversity, We Lead the Way the World Moves. ·[ST-9] Stellantis to Launch "Freedom of Mobility Forum" to Address the Most Urgent Mobility Issues Facing Today's Society.
	https://www.bloomberg.com	·[ST-10] Stellantis to Buy Mercedes and BMW's Car-Sharing Venture.
Toyota	https://global.toyota/en	·[TO-1] Toyota Unveils New Technology That Will Change the Future of Cars. ·[TO-2] Toyota's Connected & MaaS Strategy. ·[TO-3] Toyota Shows e-Palette Geared Towards Practical MaaS Applications. ·[TO-4] Reforming Our Company to Become a "Mobility Company". ·[TO-5] Toyota Expands Collaboration in Mobility as a Service (MaaS) with Didi Chuxing, a Leading Ride-hailing Platform. ·[TO-6] Sustainability Data Book. The latest version. ·[TO-7] Toyota Advances Mobility as a Service Strategy with Strategic Investment and Collaboration with Grab, the leading Ride-hailing Company in Southeast Asia.
	https://pressroom.toyota.com	·[TO-8] Toyota Launches New Mobility Ecosystem and Concept Vehicle at 2018 CES®. ·[TO-9] Toyota Connected Europe to bring advanced mobility services to the European market. ·[TO-10] Toyota launches KINTO, a single brand for mobility services in Europe.
	https://asia.nikkei.com	·[TO-11] Toyota to launch new corporate car-sharing service in Europe.
	https://www.forbes.com	·[TO-12] Toyota's Vision for Self-Driving: A Robot Pod Van and Uber, Amazon Collaboration.
	https://www.bloomberg.com	·[TO-13] Toyota Targets Big Fleets With Connected-Car Push Into Europe. ·[TO-14] Toyota invests US$400 m in Pony.ai to Deepen Driverless Pact startup.
	https://www.just-auto.com	·[TO-15] Toyota outlines future as a 'mobility services provider.
Honda	https://www.honda.co.jp/	·[HO-1] ITS World Congress. Experience Future Mobility Now. Hamburgo. ·[HO-2] My Honda Plus. Core connectivity. ·[HO-3] Honda Sustainability Report 2020. Direction for Realizing the 2030 Vision. ·[HO-4] EveryGo Honda Carsharing Service.
	https://global.honda/newsroom	·[HO-5] Honda Signs Memorandum of Understanding with Teito Motor Transportation and kokusai motorcars as Part of Aim to Launch Autonomous Vehicle Mobility Service in Central Tokyo. ·[HO-6] Honda to Begin Battery Sharing Service for Electric Tricycle Taxis in India in the First Half of 2022. ·[HO-7] Honda, Cruise and GM Take Next Steps Toward Autonomous Vehicle Mobility Service Business in Japan.
	https://hondanews.eu	·[HO-8] Honda and Google Collaborate on In-vehicle Connected Services. ·[HO-9] Honda Establishes Hynex Mobility Service, a New Joint Venture Company, to Accelerate Advancements Toward Next-generation Connected Services Business in China. ·[HO-10] Honda Acquires Drivemode, Developer of Smartphone Apps for Drivers.
	https://www.sony.com	·[HO-11] Sony and Honda Sign Joint Venture Agreement to Establish New Company, "Sony Honda Mobility Inc.", to Engage in Mobility Business.
	https://www.hino-global.com	·[HO-12] MONET Forms Capital and Business Partnership with Hino Motors and Honda
	https://telefonicatech.com	·[HO-13] Telefonica IoT and Honda about reduce motorbike robbery.
	https://aws.amazon.com	·[HO-14] Honda Builds Serverless Connected Car Platform for Millions of Cars on AWS. Honda Case Study – AWS.
	https://www.just-auto.com	·[HO-15] Hino, Honda, join Monet mobility partnership.

Note: Table contains titles of publications consulted as well as their original sources. The complete reference for each source has not been included but can be identified from the information given.
Source: Authors' elaboration

CRediT authorship contribution statement

Pérez-Moure Hugo: Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. **Lampón Jesús F.:** Conceptualization, Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing, Investigation, Validation. **Cabanelas Pablo:** Conceptualization, Formal analysis, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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