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Article

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Revolutionizing the road: How sustainable, autonomous, and connected vehicles are changing digital mobility business models

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ABSTRACT

Major trends in the automotive industry are reconfiguring digital mobility business models. From a comprehensive, combined Dynamic Capabilities and Ecosystems approach, this study characterizes the digital mobility business models linked to sustainability, connectivity, and Autonomous Vehicles (AVs) adopted by four car-makers (Volkswagen, Stellantis, Toyota, and Honda). Results show that carmakers differ in their focal digital mobility value propositions, based mainly on the carmakers' own mobility strategies. Volkswagen exhibits an integral proposition with personalized services, while Stellantis is focusing on electric mobility and its solutions, Toyota on autonomous and connectivity services, and Honda on a user-centric perspective via connected and shared mobility. The main sources of income are multiple personalized services linked to connectivity that specifically provide driver assistance, along with remote and digital platform services. Those carmakers pursuing sustainable, autonomous, or shared mobility strategies find their primary income sources in services like remote electric driving, autonomous door-to-door deliveries, and car-sharing. Such services are deployed not only due to technical resources, such as digital skills and data exchange systems, but primarily through organizational capabilities like a "team-player mentality" and a customer-focused vision. Finally, differences in sustainability have been highlighted, but in general terms, all manufacturers are striving to address the battery and charging-point issue through various business models to promote electric mobility. Carmakers are governing a digital mobility ecosystem configured by multiple service and technology providers that are developing transportation solutions.

1. Introduction

Mobility is being transformed by various relevant social and technological trends. Among these, the previous literature highlights sustainability issues as key, as well as connected and autonomous driving technologies (Barreto et al., 2020; Cohen & Kouvelis, 2021). Sustainability issues are related to the development of electric vehicles (EVs) and the reduction of CO₂ emissions (Lampón, 2023; Lampón & Muñoz-Dueñas, 2023). Connected technologies are reconfiguring mobility in terms of the exchange and sharing of data among vehicles, people, and mobility infrastructures (Krafft et al., 2021). The emergence of autonomous driving technologies is changing some of the new mobility services (Turienzo et al., 2023b). Additionally, autonomous vehicles (AVs) are expected to have a major impact on mobility in the short term (Athanasopoulou et al., 2019).

In parallel, digitalization is transforming the automotive industry and its business models (Llopis-Albert et al., 2021; Pérez-Moure et al., 2023). Digitalization has opened new avenues for value creation through the implementation of digital tools, which have resulted in an array of service options (Kraus, Palmer, Kailer, Kallinger, & Spitzer, 2019; Taipale-Ervala et al., 2020). New business models related to digitalization are emerging thanks to the capabilities associated with communications technologies and information management, which have led to redefining a company's value proposition to customers (Berman, 2012; Shen et al., 2023). Digitalization also has an impact on the traditional key aspects of business models, particularly on the resources needed by firms for implementation (França & Ferreira, 2016), and on the main services that generate income for the firm (Bohnsack et al., 2014).

From a theoretical perspective, among the different approaches that

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support the analysis of digital business models, Dynamic Capabilities (DC) has been widely used (Lanzolla & Markides, 2021; Cabanelas et al., 2023; Turienzo et al., 2023a). The DC approach focuses on the internal aspects managed by firms to generate value for customers in response to new market needs (Teece, 2019; Cabanelas et al., 2023). Furthermore, some recent papers have adopted the Ecosystem approach (Jacobides et al., 2018) to evaluate specific aspects of mobility business models (de Vasconcelos et al., 2023) – e.g., to analyze business models related to digital platforms (de Vasconcelos et al., 2023). This Ecosystem approach allows a firm's internal key elements to be complemented with external contributors (e.g., players and activities) (Hou et al., 2020); these new insights from abroad complement how a firm creates, delivers, and captures value to adopt digital mobility business models.

Taking these precedents into account, this study aims to characterize the digital mobility business models adopted by carmakers through a multiple case study based in a content analysis. The main novelty of this research is the use of a comprehensive theoretical approach to support the findings. This allows the research to be conducted through a broader perspective, including not only the firm's internal capabilities but also external contributions provided by the mobility ecosystem. Previous studies have overlooked the ecosystem role (Teece, 2018) or have afforded insufficient importance to this concept (Cabanelas et al., 2023; Lagadic et al., 2019) despite recognizing its impact. Ecosystem relationships and actors are now more complex than ever before, so internal capabilities must be considered, to give the ecosystem concept the importance it deserves. The paper contributes to understanding how carmakers have been adapting their business models to the new reality – that is, how they adapt their value propositions, the key resources involved in implementing those models, the services offered to generate principal income, and the roles and activities of the ecosystem players that facilitate such adoption.

To achieve that objective, this document has been structured into five sections. Section 2 presents the literature review related to digital mobility business models. The empirical study is detailed in Section 3. The results and their discussion are presented in Sections 4 and 5, respectively. The conclusions are presented in the final section.

2. Literature review

2.1. Digitalization and value creation in mobility related business models

Business models are put into practice with a clear focus on value creation (Palos-Sánchez et al., 2021; Medina et al., 2022). That focus should allow the structuring of new value propositions and the identification of market needs (Kraus, Palmer, Kailer, Kallinger, & Spitzer, 2019), along with traditional aspects such as customer focus (Osterwalder & Pigneur, 2010). In this sense, mobility technologies related to digitalization are currently reconfiguring the automotive industry and giving rise to new opportunities and business models (Llopis-Albert et al., 2021). The emphasis within mobility is placed on the profound transformation that digitalization implies, and on the need to integrate knowledge and technologies to generate value for customers (You et al., 2022).

Digitalization is thus reshaping traditional mobility business models, prompting carmakers to offer services to meet new mobility needs (Cabanelas et al., 2023). At the same time, digitalization favours the servitization present in current mobility business models (Shashishekar et al., 2022). Several business models stem from the need to deal with a market where competition is strengthening, and this implies that companies are focusing their value propositions on servitization (Ruiz de la Torre & Sanchez, 2022).

This growing digitalization in mobility is reinforced and influenced by sustainability, connectivity, and AVs (Barreto et al., 2020; Cohen & Kouvelis, 2021). First, sustainability is related to the use of EVs and their implications in terms of emissions reduction (Lampón & Muñoz-Dueñas, 2023). EV will benefit from digitalization through different service

propositions – e.g., a third party can offer digital services related to charging stations (Robinson et al., 2014; Madina et al., 2016). The navigation system selects the best charging station location (Vervaeke & Calabrese, 2015). Companies have introduced electric vehicle parking and routing systems that use control algorithms; an optimized navigation system can improve the efficiency of electric car rental systems by decreasing the average travel time and reducing the energy consumption (Rothkrantz et al., 2013). Second, connectivity is related to the exchange and sharing of data among vehicles, people, and mobility infrastructures (Krafft et al., 2021). Several digital services are related to connectivity, such as those linked to data exchange (Krafft et al., 2021), those based on digital platforms (Steinberg, 2021), and those required for car-sharing (Lagadic et al., 2019; Svennevik et al., 2021). Personalized connected services and enhanced user experiences are based on digitalization, as in the cases of better car usage (e.g., information on vehicle condition, remote maintenance services) or entertainment (e.g., varied content or access to social media), as well as software updates chosen by the customer and commonly paid for by subscription (Athanasopoulou et al., 2019). Third, the development of autonomous driving technologies opens new possibilities in transport services (Athanasopoulou et al., 2019). Digitalization is having a direct impact on the way AVs are used, while the related business models are significantly transforming the market (Barreto et al., 2020; Zhou et al., 2021). Different digital business models linked to AVs can be addressed by carmakers (Leminen et al., 2022; Ruiz de la Torre & Sanchez, 2022; You et al., 2022), and these models are focused mainly on fleet services (e.g., logistics) (Leminen et al., 2022) and on advanced-data-assisted solutions (e.g., improved driving) (Stocker & Shaheen, 2018).

2.2. Digitalization, dynamic capabilities, business models, and the ecosystem

Current literature also highlights that digital mobility services and their related business models involve different players (de Vasconcelos et al., 2023; Pérez-Moure et al., 2023). These players participate in value creation for customers by offering digital mobility services (e.g., car-sharing firms, digital platform service providers) as well as the technologies that support such services (e.g., vehicle connectivity software, positioning, and localization technologies) (Guyader & Piscicelli, 2019; Pérez-Moure et al., 2023).

In this context, it is necessary to define a theoretical framework that can help characterize mobility business models linked to digitalization. This framework should help to analyze how carmakers are adopting these models, and to identify the main players and their roles, as well as how the digital ecosystem of mobility is being configured (Jacobides et al., 2018).

Different approaches are being used to support the analysis of digital business models (Lanzolla & Markides, 2021; Cabanelas et al., 2023; Turienzo et al., 2023a). Among them, DC has been the widely used (Ancillai et al., 2023). This is a theoretical approach founded on the core competencies of the firm which enable it to modify short-term competitive positions, which in turn can establish long-term advantages (Teece, 2010). The DC approach is suitable for evaluating the emergence of business opportunities, particularly as regards firms' adaptation to new contexts (Wang & Hsu, 2018). It provides a fit-for-purpose approach for analysis of the dynamism of markets and the evolution of customer demands (Preikschas et al., 2017).

DC helps to identify how value is created, delivered, and captured, which are key aspects of business model analysis. A business model is a conceptual tool that contains a set of elements and allows the expression of a company's logic for earning money (Osterwalder & Pigneur, 2010). A firm builds its business model by creating a value proposition for customers, making various choices to generate revenue that encompass a range of resources and capabilities. Firms offer value propositions based on their own particular strategy (Wirtz et al., 2015; Lasmar et al., 2019). Key resources involved are essential for characterizing the

business models (França & Ferreira, 2016; Witschel et al., 2019) as well as the services that generate the main income for the firms (Bohnsack et al., 2014; Cabanelas et al., 2023).

Recently, contributions have incorporated other approaches to include all the players that participate in the development of the mobility business models, such as the Global Value Chain approach (Pérez-Moure et al., 2023) or Ecosystem approach (de Vasconcelos et al., 2023). In the case of the Ecosystem approach (Jacobides et al., 2018), some divergences are present in the literature concerning conceptualization. A common point is the conceptualization of the ecosystem as a structure (Kapoor, 2018; de Vasconcelos et al., 2021) that encompasses actors, governance, links, roles, and activities (Ganco et al., 2020). From this Ecosystem approach, interdependence is key to the mutual impact of players on their ability to create value (Adner & Feiler, 2019; Adner & Kapoor, 2010). The structural view of ecosystems states that collective action can create interdependence (Shipilov & Gawer, 2020). In this context, firms seek to align this interdependence structure among ecosystem players to generate a focal value proposition (Adner, 2017; de Vasconcelos et al., 2021). This Ecosystem approach allows for the analysis of external elements (e.g., players and activities) (Hou et al., 2020) that are key to business model adoption. It identifies the sets of players that provide solutions to customer needs.

Fig. 1 presents the theoretical framework that includes the key elements based on the DC and Ecosystem approaches to analyze the selected digital mobility business models.

3. Empirical study

3.1. Methodology and sample

In keeping with the purpose of this research, a qualitative methodology was selected (Yin, 2014). The case study enables a comprehensive examination of a limited number of companies through the description of facts, without the inflexibility often found in a statistical approach (Creswell, 2014; Bryman, 2012). Furthermore, a case study is suitable when reaching out the sample is difficult. In the case of carmakers, most are multinational companies, implying that data is difficult to access and other types of methodology are difficult to undertake. Here quantitative methods (or other qualitative approaches such as interviews or expert

panels) are not suitable (Yin, 2014). On the other hand, a multiple case study allows one to examine, contextualize, compare, and connect theory and practice with efficiency, deepness, and detail (Creswell, 2014). As regards the sample size for analysis, it is not necessary to choose a specific number of cases in order to apply this methodology. Too many cases can impede analysis of the information collected, while too small a number may not represent the universe under study (Cassell et al., 2018). In this study, four carmakers were selected: Volkswagen, Stellantis, Toyota, and Honda.

The selection process followed a multi-step approach to ensure a comprehensive and representative sample of car manufacturers within the industry. Firstly, an initial information screening process was conducted to assess the standing of each manufacturer in the sector. This step aimed to gain insights into the manufacturers' overall performance and relevance. Secondly, in alignment with the core themes of the study, which focused on digitalization and sustainability, as well as examining the ecosystem and dynamic capabilities of carmakers, specific criteria were established. These criteria included factors such as sales figures, investment in research and development (R&D), Corporate Social Responsibility (CSR) scores, and the number of brands owned by each manufacturer. In the final phase of the selection process, carmakers that met the criteria in at least three out of the four mentioned indexes were included in the study. This approach ensured a well-rounded and diverse representation, not only within academic contexts but also within the industry, across different countries in Europe, and for a broader audience. The four selected carmakers emerged as noteworthy candidates for the study. These four carmakers invest the most in innovation in digital technologies (PwC, 2018) and are at the top in world sales (Toyota and Honda) and/or in number of brands owned (Volkswagen and Stellantis) (PTC Group, 2023). Furthermore, they hold leading positions in the main sustainability indices, such as S&P Global, CDP Climate and Water, and CSRHub (Eupedia, 2020). Luxury brands were not considered for inclusion as they did not adequately represent the broader spectrum of the industry.

3.2. Variables

The variables to be analyzed serve as the core for application of the methodology and are as follow:

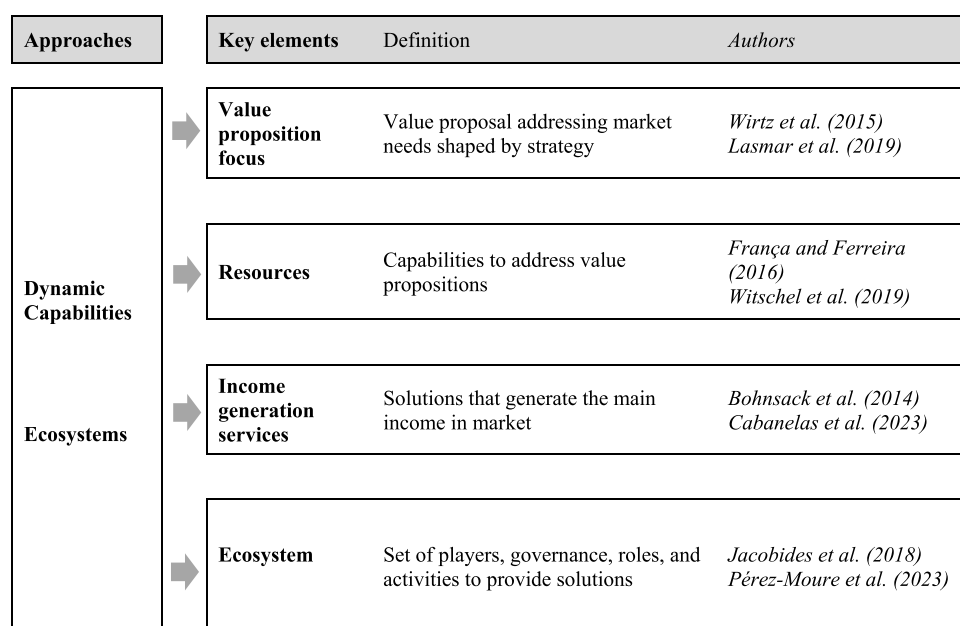


Fig. 1. Theoretical framework for characterizing digital mobility business models. Source: Authors' elaboration.

- *Value proposition focus* is the value proposal (Wirtz et al., 2015) regarding sustainable, connected, and automated mobility when addressing new market needs; this is shaped by the strategy of each company (Cabanelas et al., 2023).
- *Resources* are the relevant assets (tangibles and intangibles) and capabilities involved in development and the offering of value propositions regarding sustainable, connected, and automated mobility (França & Ferreira, 2016).
- *Income generation services* are digital mobility services that generate the main income for companies (Bohnsack et al., 2014). Services associated with sustainable mobility create value through digitalization with the objective of managing energy (Ziegler & Abdelkafi, 2022). Services linked to connectivity are related to the exchange and sharing of data (Krafft et al., 2021). These include personalized services chosen by the customer and commonly paid for by subscription (Athanasopoulou et al., 2019) or services offered through digital platforms (Cusumano et al., 2019; Steinberg, 2021). Services related to digital solutions for mobility with AVs include the logistics of goods and mobility of people (Leminen et al., 2022) and advanced data-assisted solutions (Stocker & Shaheen, 2018).
- *Ecosystem* includes players, roles, and key activities (services and development of technologies that support these services) related to sustainable, connected, and automated mobility (de Vasconcelos et al., 2023).

3.3. Data collection and data analysis

Information was collected through secondary sources, in particular publicly available internal companies' sources (e.g., corporate reports, firms' internal technical documents) (Srinivasa & Rajat, 2012) and data elaborated by external organizations (e.g., the specialized press, sectorial documents) (Ellen et al., 2018). Although this approach sacrifices direct contact and observation of primary sources, the systematic application of the collecting process through these secondary sources allows us to obtain valuable information that has been expertly developed and presented (Ellen et al., 2018). The fieldwork was carried out from March to July of 2023.

To collect the documents, a process of identification, screening, and selection (Leminen et al., 2022; Santos et al., 2023) was carried out:

- An identification process of documents indexed in the EBSCO database as well as corporate publications from the carmakers (Ellen et al., 2018; Srinivasa & Rajat, 2012). This identification was performed using keywords. In addition to the "name of the carmaker" AND "business models", the following keywords were included in the search (AND / OR): "sustainability", "clean mobility", "electric vehicle", "connectivity", "data exchange", "car-sharing", "digital platform", "digital services", "mobility as a service", "autonomous mobility", and "delivery as a service". More than 400 documents were identified.
- A screening process involved selecting relevant and high-quality documents. In addition to being issued by reliable sources, these had to have been published in the past five years at a minimum length of 500 words.
- A final selection process was carried out by eliminating the documents that did not focus on the variables analyzed. The final number of selected documents was 57. The Appendix offers the sources of information used, titles of the documents, and the code assigned. This code is defined as [Initials of carmaker # Sequential number of the document], the initials being VW for Volkswagen, ST for Stellantis, TO for Toyota, and HO for Honda.

Content analysis was used to analyze the data (Prasad, 2008). Access to a context provides a means to evaluate a broad range of information, to interpret it, and to arrive at conclusions with a reasonable level of objectivity and universality (White & Marsh, 2006). This type of analysis

applied to texts proves ideal when the information-gathering process is complex and includes many sources (Krippendorff, 2018). The results of this content analysis were structured for each carmaker into the digital business models related to sustainable mobility, connectivity, and AVs. Finally, a synthesis of results was organized by the main elements of the business models (value proposition focus, resources, income generation services, and ecosystem players).

4. Results

4.1. Volkswagen

4.1.1. Business models associated to sustainable mobility

Volkswagen vehicles incorporate a system that collects data on battery performance and conditions to determine battery status. Based on this information, the carmaker provides an integrated navigation service that indicates the locations of charging stations and recommends stops, with the aim of alleviating customer concerns about battery discharge [VW#1; VW#9].

Additionally, it offers car-sharing services, defined as an environmentally friendly ride-pooling system (partially electric) with vehicles owned by Volkswagen, where customers share their journeys [VW#10; VW#11] and can book and pay through a mobile app [VW#7].

4.1.2. Business models linked to connectivity

The integration of software into the vehicle and digital customer experience is a crucial core competency. When implementing data-based business models, the company seeks to attract new customer groups and tap into additional sources of income [VW#2; VW#5]. The company implemented agile and customer-centric development of digital services into the market within a short period. Moreover, the company is involved in the continuous systematic provision of data. Data are set as value drivers for digital business models [VW#6]. Volkswagen provides content and apps associated with connectivity [VW#8; VW#1]. The connected vehicles from VW brands allow the transmission of data such as metrics from a vehicle's on-board systems or vehicle positioning [VW#9], which are then used to offer specific services – for example intelligent parking (which allows a parking space to be found and paid for automatically), route planning, voice control, and a travel assistant developed by the technology provider Mobileye [VW#1; VW#8]. Other available business models include a remote service that enables the use of a phone to lock/unlock the car, adjust the seats, and set the interior temperature, as well as home system integration (e.g., allowing devices within a house to turn on when the car is approaching).

Volkswagen has a global cloud digital platform that was developed by the digital company Diconium. Volkswagen offers a centralized marketplace where third-party companies can offer their digital services to enhance the connected vehicles of Volkswagen customers [VW#9]. In this marketplace, the carmaker exploits data stored and processed on the platform [VW#10]. Third-party companies such as insurance, maintenance, or repair companies offer their traditional business models using this data, and Volkswagen carries out transactions with these companies through the digital platform [VW#9, VW#11].

4.1.3. Business models related to AVs

The carmaker's business models pertaining to AVs are not yet operational but are still in the development stage. The company is partnering with a strategic entity to develop autonomous commercial vehicles for urban goods transport by 2025 [VW#3; VW#4].

4.2. Stellantis

4.2.1. Business models associated to sustainable mobility

Stellantis deploys a customer-focused strategy that extends to the entire organization. Initiatives include providing day-to-day smart charging offers to customers, tapping into different partnerships to

expand charging options, and accelerating smart grid use [ST#10]. Services associated with electric mobility are among the cornerstones of Stellantis, and the company has set up several digital business models to facilitate the use of its EVs [ST#1; ST#9]. In collaboration with TheF charging and leveraging connectivity technologies, plus an app that serves as a locator for electric charging stations, Stellantis manages a network of charging stations with exclusive conditions for its customers and spanning over 15,000 locations, including 2 million stations in city centres [ST#2; ST#5]. In addition, Stellantis has launched a new company called Free2Move Charge in the US (with plans to expand to Europe). This is a 360-degree ecosystem that will provide seamless charging and energy management solutions to meet all the needs of EV customers, no matter where or how they charge their vehicles [ST#13].

In line with the commitment to electric vehicles [ST#1], Stellantis through an alliance with the company Kiri has launched a system to reward drivers with sustainable habits through 'eCoins', which can be spent in the Kiri marketplace. These eCoins are obtained through a service tool app, where the driving efficiency is scored [ST#4]. Stellantis offers several complementary services associated with sustainable mobility. The company has a B2B platform for support and assistance (e.g., subsidies, taxes, technologies) for companies starting their transition to electric mobility [ST#3].

4.2.2. Business models linked to connectivity

Stellantis is involved in a software development strategy based on its own technical skills and capacity to recruit talent to leverage technical expertise, thus adding development resources to existing ones [ST#1; ST#11]. This strategy is supported by the continuous motivation of employees to be innovative and to adhere to company's management methods and principles. Moreover, Stellantis in collaboration with Amazon is introducing customer-centric connected experiences across the brand's vehicles based on applications that offer a wide range of services such as trip planning, voice assistance, payment services, and Amazon's virtual assistant [ST#6]. Drivers can select these applications offered via connectivity and pay through subscription.

Furthermore, Stellantis supports its digital platform business models on Amazon's digital platform. Through the platform, Stellantis exploits this digital marketplace directly offering its own warranty services, accessories, maintenance, and vehicle rentals [ST#6].

4.2.3. Business models related to AVs

Stellantis has a collaboration agreement with a partner to put it into service by 2025 a fleet of autonomous light commercial vehicles offering door-to-door services [ST#7; ST#12].

4.3. Toyota

4.3.1. Business models associated to sustainable mobility

Subscribers to the Toyota Public Charging Network can access to this information through their connected service apps. Navigation systems can display a list of the nearest public charging stations and their locations. Alternatively, smartphone apps such as Zap-Map allow users to search for public charging points, plan longer journeys, pay on participating networks, and share updates with fellow EV drivers [TO#4; TO#16].

4.3.2. Business models linked to connectivity

Toyota is fully committed to advancing its digitalization. To promote this, company leadership understands that all employees need to become agents of change. As such, Toyota is using "citizen development" as an effective means to find solutions. This implies that employees can use development tools to improve digitalization. The main activities of the citizen developer community include knowledge sharing, expertise sharing, and support. Such support can strengthen skill acquisition to achieve flexibility in the digital transformation [TO#6; TO#16].

Toyota provides a comprehensive connectivity solution incorporating various services, including authentication systems, maps, virtual assistants, and automated adjustment of the vehicle's interior settings. [TO#1; TO#3; TO#5; TO#7]. In addition, key encryption via smartphones and emergency services (route and driving recommendations) are enabled [TO#7; TO#8].

Toyota has been developing its own digital platform in collaboration with Amazon as a technology partner [TO#1; TO#8; TO#14], using different devices to store data that are then processed by Toyota to offer services directly to the customer and to allow third parties to extend offers through the platform. Services 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#1; TO#7; TO#8].

Finally, a car-sharing service is offered by Toyota, and the carmaker owns several companies to provide such services for both B2B and B2C activities [TO#1; TO#10]. In all these cases, the fleets of vehicles belong to Toyota and rely on an app developed in cooperation with Ridecell to offer on-demand services.

4.3.3. Business models related to AVs

Toyota is committed to developing digital solutions for AVs. The company's teams work in a high-velocity environment and employ agile development practices. This "team-player" and "get things done" mentality fosters close collaboration with stakeholders to find solutions [TO#11; TO#15]. Toyota's servitization of AVs has been extensively developed through different providers. Toyota has developed the *e-palette* for the movement of both people and goods in an autonomous manner [TO#2]. The *e-palette* system, supported by a mobile app, allows the assignment of various tasks such as door-to-door deliveries [TO#5; TO#2; TO#8; TO#14]. Meanwhile, Toyota's partnership with Pony.ai facilitated the creation of a virtual assistant designed for this self-driving vehicle [TO#13]. Complementary services that accompany AVs are an important part of the offer, such as 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* application, and the autonomous medical vehicle would drive to their home [TO#8].

4.4. Honda

4.4.1. Services associated with sustainable mobility

In the area of EVs, Honda operates unique battery services. Honda has developed a portable battery system called the Mobile Power Pack. Through a mobile application, charging points are monitored where it is not necessary to accompany the vehicle [HO#10; HO#11].

In order to increase and improve these services, Honda with its strategic partner Neusoft is accelerating connectivity-related services [HO#9]. One of these digital technology developments allows the location of charging points for electric vehicles [HO#1; HO#6; HO#12].

4.4.2. Business models linked to connectivity

Honda works to strengthen its ability to create solutions that drive value creation for customers while involving its teams. Moreover, cooperation through mutually complementary relationships with business partners is key to adopting its digital services [HO#8]. Through different devices, basic functionalities are offered such as traffic information, weather, and vehicle status [HO#1; HO#3; HO#12]. The company provides voice assistant services, navigation, and other applications through various providers such as Apple and Amazon, which can be accessed via a mobile app. Users can also use this app to locate their vehicle, unlock it, or check its status. These services can be selected through a subscription service [HO#2; HO#14; HO#15]. The carmaker is currently developing with partners (Hino and Softbank) the improvement of data capture of this information [HO#13; HO#16].

Honda operates a car-sharing service that can be accessed through a mobile app. This app allows users to reserve a vehicle, unlock it, initiate

payment, verify their identity, and return the vehicle [HO#4].

4.4.3. Business models related to AVs

Honda is at a relatively early stage, developing an autonomous vehicle with a strategic technology provider. This vehicle began tests in Japan in 2021 and is focused on passenger mobility [HO#7]. At the same time, it has another autonomous vehicle in development that is focused on shared mobility [HO#5].

4.5. Synthesis of results by key elements of business models

As a summary of the analysis, Table 1 presents the elements of digital mobility business models for each manufacturer. The value proposition focus refers to the main business models that address new market needs, as shaped by the strategy defined by the company. The resources included are relevant assets and capabilities involved in development and that offer value propositions. In terms of income generation, services that generate the main income for carmakers are presented. Regarding the ecosystem, the players and activities developed related to these key services are included.

5. Discussion

The results indicate that carmakers have differed in their adoption of

digital mobility business models, focusing on different value propositions. Volkswagen seeks to offer an integral digital mobility proposal with multiple customized services. Stellantis is focused on sustainable mobility and related digital solutions. Toyota is focused on digital mobility servitization of AVs combined with various connected services. Honda is oriented toward connected and shared digital mobility services. These findings reveal that different value propositions are suitable in a particular technological setting (as here in the context of digital mobility). Moreover, these findings are in line with the previous literature (Wirtz et al., 2015; Lasmar et al., 2019) as the different value propositions observed are based on the carmakers' own mobility strategies.

In terms of resources, carmakers require broader technical and digital skills and knowledge to offer digital mobility services. This confirms that the adoption of digital mobility business models is conditioned by the need for systems and tools for exchange and sharing (Hind et al., 2022; Bican & Brem, 2020). However, the results also highlight that carmakers also need other, even more relevant capabilities in the implementation of this business model. In particular: organizational capabilities such as the "team-player" and "get things done" mentality; organizational flexibility to respond to ever-changing conditions in this digital context; or a customer-focused vision, extended to the whole organization.

Among the most implemented income generation services are

Table 1
Summary of results by key elements of digital mobility business models.

	Volkswagen	Stellantis	Toyota	Honda
Value proposition focus	Integral digital mobility proposal with multiple customized services.	Based on electric mobility exploiting its related solutions.	Focused on autonomous mobility combined with a connected service.	Focused on user-centric through connected and shared mobility.
Resources	Integration of software into the vehicle and the digital customer experience as core competencies. Agile and customer-centric development of digital services with a short time to market. Continuous systematic provision of data. Data is set to become a value driver for digital business models.	Customer focused vision, extended to the whole organization, toward smart electric charging. Technical skills in software development and capacity to recruit talents to leverage technical expertise adding new development resources. Continuous improvement to innovate and to adopt better management methods.	Promotion of employees as agents of change in digital transformation. Organizational Flexibility to respond to ever-changing conditions in digital context. Team player and "get things done" mentality. Active collaboration closely with stakeholders and partners to find solutions.	Digital Solution centre for creating new value through the development of services using digital technology in mobility, connected cars and energy management. Focusing on work to strengthen the ability to develop solutions driving value creation. Cooperation through Mutually complementary trusting relationship with business partners.
Income generation services	Environmentally friendly car-sharing service (ride-pooling system). Remote service to battery monitoring (charge level, performance...) that include a navigation service to locate charging points. Connected routing services (intelligent parking location, route planning, voice control, and travel assistant). Remote connected service through phone to lock/unlock the car, adjust the seats, vehicle temperature, and home-systems integration. Entertainment services (e.g., varied content, social media). Data service to third-party (insurance, maintenance, and repair companies) through digital platform.	Location service for charging points through connectivity for users of its electric vehicles. Remote electric driving efficiency service that rewards drivers with sustainable habits. Services for support of electric mobility firms to a B2B platform. Connected services to driver assistance (e.g., trip planning, virtual assistants, or payment services). Warranty services, accessories, maintenance, and vehicle rentals through digital platform.	Connected services to driver assistance such as maps, virtual assistants, and automatic adjustment of the vehicle's interior conditions. Connected security services (key encryption, authentication, and emergency systems). Services of tailored maintenance plans, flexible leasing, and on-demand insurance through digital platform. B2B and B2C car-sharing service through a mobile app. Autonomous mobility service door-to-door deliveries supported by a mobile app. Remote virtual assistant service for its autonomous vehicles. Complementary services with AVs (e.g., door-to-door doctor service).	Service of portable batteries supported by a mobile application to monitors the electric vehicles' location for charge. App service location of charging points for electric vehicles. Connected services to driver assistance (e.g., traffic information, weather, navigation, and voice assistant). Remote connected service through phone to lock/unlock the car and check the status. Car-sharing service through a mobile app to reserve, unlock, pay, and leave the vehicle.
Ecosystem	Few actors involved in its ecosystem. Basically, interact with technology providers. Diconium (digital platform technology), and Mobileye (connectivity technology).	Ecosystem made up of few (strategic) providers. Amazon (strategic provider for connectivity and digital platform technology and services) TheF Charging and Kiri (strategic providers for sustainable services).	Broad ecosystem made up of multiples providers. Amazon (digital platform technology) MS&AD Insurance Group (digital platform service) Ridecell (car-sharing technology) Pony.ai (AVs technology).	Broad ecosystem made up of multiple technology and service providers. Neusoft (sustainable technology) Hino and Softbank (connectivity technology) Apple and Google (connectivity services).

Source: Authors' elaboration.

multiple personalized services and enhanced user experiences linked to connectivity, such as routing and driver assistance services (intelligent parking location, route planning, virtual assistants), remote services to lock/unlock and adjust vehicle conditions, and services through digital platforms (e.g., insurance, maintenance). Moreover, the results show a strong relationship between value proposition focus and income generation services (Osterrieder et al., 2021; Bohnsack et al., 2014) in which key services are offered by carmakers. The locations for electric charging points, remote electric driving efficiency services, autonomous mobility door-to-door deliveries, and remote virtual assistant services for AVs, and car-sharing services are relevant only for carmakers with a strong commitment to sustainable, autonomous, and shared mobility strategies, respectively.

In terms of the digital mobility ecosystem, diverse players play an important role in these carmakers' adoption of digital mobility business models. Regardless of the intensity of participation or involvement of these players, all carmakers maintain links with service and technology providers to develop value-added digital solutions for customers. In some cases, these ecosystem players are considered strategic by carmakers.

In summary, all of the manufacturers studied have developed unique forms of new mobility, but with common points. This can be seen within the value proposition capability, where all base their value on digital transformation (but in different ways) such as connectivity services or electric or autonomous mobility. In terms of resources capabilities, all the companies are investing in software development and other digital resources – but again, with different propositions. Regarding capabilities for income generation services, all the companies are trying to diversify their income sources through business models related to digital services, but each is focused on different areas. Thus, their internal capabilities are similar in general terms, but the development of each depends on each actor and its strategy and understanding of new mobility. Of course, the individual approach is not enough, and the companies are all conditioned by the ecosystem (as external capabilities). In the past, these companies all played an important role and had decision-making power, but the scenario has changed, and this dynamic capability has become relatively complex and difficult to manage.

The results indicate that the internal capabilities and resources offered by the Dynamic Capabilities approach in the analysis of digital mobility business models (Cabanelas et al., 2023) should be complemented by the Ecosystem approach to incorporate the set of players that offer services and technologies that support the adoption of these business models.

6. Conclusions

6.1. Theoretical contribution

This research uses a comprehensive theoretical approach to support the characterization of digital mobility business models. The theoretical framework built under the Dynamic Capabilities and Ecosystem approaches allows the inclusion of a firm's key internal (Cabanelas et al., 2023) and external (de Vasconcelos et al., 2023) elements to analyze the adoption of these types of business models. The framework includes ecosystem elements (players and governance, roles, and activities developed) to the key traditional elements of business models (value proposition, resources involved, and income generation services deployed).

Under this framework, the results show that carmakers differ in their focal digital mobility value proposition, which is based mainly on their own particular mobility strategy. The main source of income stems from multiple personalized services linked to connectivity. In particular, these provide driver assistance as well as remote and digital platform services. However, each carmaker also offers key services that focus on their own value proposition. Remote electric driving services, autonomous mobility door-to-door deliveries, or car-sharing services are the

main income generation services for carmakers that focus on sustainable, autonomous, or shared mobility strategies, respectively. These services are deployed because the companies have technical resources (e.g., digital skills and knowledge, systems to exchange and share data), especially through organizational capabilities to respond quickly to changing conditions in this digital context (e.g., team-player mentality, organizational flexibility, or customer-focused vision). Finally, different digital players play an important role in the adoption of digital mobility business models. Carmakers govern a digital mobility ecosystem by establishing links with service and technology providers to develop their value-added digital mobility solutions for customers.

This proposal involves the integration of both Dynamic Capabilities and Ecosystem theories. In this framework, the emerging theory of Dynamic Capabilities finds complementary strength in the ecosystem, thereby offering a holistic, genuine, and progressively comprehensive perspective on the sector or organization under examination. This collaborative approach results in a refined definition of dynamic capabilities as an organization's capacity to not only adapt and flourish but also to effectively navigate and excel in an ever-changing ecosystem by effectively addressing the challenges presented. In essence, dynamic capabilities encapsulate the organization's proficiency in skilfully managing its participation within a perpetually evolving ecosystem. This entails the ability to adapt to the ecosystem's dynamics and intricate relationships, to recognize latent opportunities, and to cultivate the requisite agility to thrive within this continually transforming context.

6.2. Practical implications

The results indicate that the digital business models related to sustainable, connected, and autonomous mobility are not deployed by carmakers in the same way. In their diverse offers of digital mobility services, the results suggest that although carmakers do have a focal value proposition, they pursue leadership positions through the comprehensive development of business models, with interest in almost all digital mobility services. Therefore, it is important that in the immediate future carmakers review their value propositions and focus their resources on the development of key and profitable services. These resources are not unlimited, and the development of digital technologies requires heavy investments that must be rationalized. In this refocusing process, it is essential that each carmaker abandon business models with a low impact on their results. From an efficiency standpoint, rationalization of the offer is preferable to comprehensively addressing all business models related to digital mobility.

The results indicate that the relationships established with digital mobility ecosystem players are key to carmakers' adoption of digital mobility business models. The interaction with digital services and technology providers conditions efficiency in the development of digital mobility solutions. This implies a need for new resources and capabilities. In particular, the results propose that an active and close, mutually complementary, and trusting collaboration with services and technology providers to find value-added solutions for customers should be implemented throughout the carmakers' entire organizations.

In managerial terms, it is crucial to recognize that the ecosystem is far more intricate than a mere web of networks and alliances or complementary actors. Understanding and acknowledging the ecosystem's complexity is paramount, especially for the readership of a scientific journal, as this influences the evolution of business activities while also profoundly shaping power dynamics within the sector. Comprehension of the ecosystem in which a company operates is instrumental for making informed decisions regarding the cultivation of specific capabilities as well as strategic direction. Moreover, it empowers companies to proactively navigate potential threats. Such in-depth understanding and application of ecosystem theory holds significant implications for the academic community, offering a rich source of research opportunities and the potential to challenge and expand existing theoretical frameworks. Incorporating the ecosystem into management

considerations – moving beyond a simplistic perception of networks and alliances as mere complementarities – enables companies to maximize the utilization of their resources, be they financial, human, or technical; and this could well imply a change in value propositions.

6.3. Final remarks and future research

In summary, this study underscores the proposal that car manufacturers are pursuing digital mobility business models with distinct value propositions. The digital ecosystem’s complex dynamics have reshaped carmakers’ strategies, and they must adapt to navigate the evolving landscape and respond to emerging challenges effectively. While these car manufacturers share commonalities in their digital transformation endeavours, their areas of focus vary around approaches to connectivity, sustainability, autonomy, and shared mobility. This diversity demonstrates the relevance of tailoring value propositions to specific technological settings. The study highlights the need for a broad spectrum of technical and digital skills to provide digital mobility services. Organizational capabilities such as teamwork, adaptability, and customer-centricity are equally crucial in the digital landscape. Income generation primarily revolves around personalized services and enhanced user experiences linked to connectivity. Key services align closely with each car manufacturer’s core strategy. The digital mobility ecosystem plays a

vital role, emphasizing the importance of forging robust relationships with other ecosystem players. Car manufacturers must actively collaborate to create value-added solutions for customers. In a theoretical context, the study calls for the integration of internal capabilities and external considerations from both the Dynamic Capabilities and Ecosystem approaches. This holistic perspective enhances the analysis of digital mobility business models. Practically, the study urges car manufacturers to revisit and refine their value propositions, align resources with key services, and collaborate strategically within the digital mobility ecosystem. It also underscores the importance of adaptability in a rapidly evolving digital mobility landscape.

Mobility is currently immersed in a disruptive process, and some of the related digital technologies remain in an emerging state. This implies that the study of these digital mobility business models should be continually updated. Future research is needed anticipate technological and social trends, which could confirm the findings of this current analysis. Future research should also incorporate some carmakers not yet analyzed; in addition to the traditional European and Japanese carmakers included in this study, others such as North American car manufacturers might be considered. This would offer a global perspective of the key elements in the adoption of the digital mobility business models.

Appendix

Case	Source	[Identification of the document] Document analyzed
Volkswagen	https://www.volkswagen-newsroom.com https://www.volkswagenag.com	- [VW#1] NEW AUTO: Volkswagen Group set to unleash value in battery-electric autonomous mobility world.
		- [VW#2] Volkswagen is accelerating transformation into software-driven mobility provider.
		- [VW#3] Volkswagen Commercial Vehicles moves ahead with Autonomous Driving R&D for Mobility as a Service.
		- [VW#4] Volkswagen focuses development for autonomous driving
		- [VW#5] Volkswagen Group drives forward intelligent mobility solutions
		- [VW#6] Group Management Report. Sustainable Value Enhancement. Information Technology
		- [VW#7] Leadership in Mobility-as-a-Service (MaaS).
		- [VW#8] Volkswagen Delivers on NEW AUTO Strategy, Laying Basis for 2022.
		- [VW#9] How Volkswagen Automotive Cloud will help shape the connected car of tomorrow
		- [VW#10] Volkswagen partners with MILES Mobility to accelerate expansion of car sharing portfolio
		- [VW#11] With the Group strategy NEW AUTO 2023.
Stellantis	https://www.media.stellantis.com https://www.stellantis.com/	- [ST#1] CSRR. Powered By Our Diversity, We Lead The Way The World Moves.
		- [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 eCoins.
		- [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.
		- [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.
		- [ST#10] Stellantis Intensifies Electrification While Targeting Sustainable Double-Digit Adjusted Operating Income Margins in the Mid-term.
Toyota	https://global.toyota/en https://pressroom.toyota.com https://asia.nikkei.com https://woven.toyota/en/ad-adas-technology/ https://www.bloomberg.com	- [ST#11] Transforming to a Mobility Tech Company
		- [ST#12] Stellantis Accelerates Autonomous Driving Journey with Acquisition of aiMotive, a Leading Artificial Intelligence and Autonomous Driving Start-up
		- [ST#13] Charging Your Way: Stellantis Launches Free2move Charge to Make it ‘Easy to Always Be Charged’
		- [TO#1] Toyota’s Connected & MaaS Strategy.
		- [TO#2] Toyota Shows e-Palette Geared Towards Practical MaaS Applications.
		- [TO#3] Reforming Our Company to Become a “Mobility Company”.
		- [TO#4] Where can I charge my car?
		- [TO#5] Sustainability Data Book. The latest version.
		- [TO#6] What matters to Toyota is realizing digitalization that drives the future.
		- [TO#7] Toyota Launches New Mobility Ecosystem and Concept Vehicle at 2018 CES®.
		- [TO#8] Toyota Connected Europe to bring advanced mobility services to the European market.
		- [TO#9] Toyota launches KINTO, a single brand for mobility services in Europe.
		- [TO#10] Toyota to launch new corporate car-sharing service in Europe.
- [TO#11] Driving safety for all.		
- [TO#12] Toyota Targets Big Fleets With Connected-Car Push Into Europe.		
- [TO#13] Toyota invests US\$400 m in Pony.ai to Deepen Driverless Pact startup.		

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	https://www.just-auto.com	· [TO#14] Toyota outlines future as a 'mobility services provider'.
		· [TO#15] Toyota Announces New Self-Driving Auto Software, Challenging VW And Daimler
Honda	www.toyotaconnected.co.jp/en/	· [TO-16] Toyota Connected
	https://www.honda.co.jp/	· [HO#1] ITS World Congress. Experience Future Mobility Now. Hamburg.
		· [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 AV 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.
		· [HO#8] Honda Sustainability Report 2019.
	https://hondanews.eu	· [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] ITS World Congress. Experience Future Mobility Now. Hamburg.
		· [HO#11] Honda Introduces Initiatives for the Utilization of Honda Mobile Power Pack, portable and swappable batteries
		· [HO#12] Summary of 2023 Honda Business Briefing – Honda's corporate transformation initiatives including electrification
		–
	https://www.hino-global.com	· [HO#13] MONET Forms Capital and Business Partnership with Hino Motors and Honda
	https://telefonicatech.com	· [HO#14] Telefonica IoT and Honda about reduce motorbike robbery.
	https://aws.amazon.com	· [HO#15] Honda Builds Serverless Connected Car Platform for Millions of Cars on AWS. Honda Case Study – AWS.
	https://www.just-auto.com	· [HO#16] Hino, Honda, join Monet mobility partnership.

Source: Authors' elaboration

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