ADVANCES AND CHALLENGES IN THE AUTOMOTIVE INDUSTRY: DRIVING TOWARDS SUSTAINABLE MOBILITY

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DOI: https://dx.doi.org/10.6036/10487

***ABSTRACT**:*

***The digital transformation of the automobile industry linked with the new challenges of sustainable mobility, is generating important changes in the business models of automobile groups. The constant efforts to innovate in its vehicles and offer services associated with them are essential to guarantee its own sustainability. Automation, connectivity, electrification and shared mobility (ACES) are the four technological drivers of this sector and have been taken as a reference in this research to examine and learn how the main European automobile groups are addressing the global challenges associated with them. It is of special interest to offer this compilation of information that allows obtaining a current and well-founded vision of the advances in the sector, giving visibility to the commitment, effort and performance that these companies are carrying out. Likewise, the results obtained show different levels of integration and progress of the ACES factors in the automobile companies studied**.*

Keywords: Sustainable mobility, Automation, Accessibility, Shared mobility, automotive sector, ACES, Servitization, Industry 4.0

1. INTRODUCTION

The automotive sector is a highly competitive strategic sector within Europe and is currently undergoing a profound transformation due to the challenges of technological disruption directly affecting the manufacturing process, energy efficiency improvements in factories and management optimisation, all key elements to ensuring the sustainability and competitiveness of the European automotive sector in the face of strong competition from other global manufacturers. This industry is aware of the relentless need to innovate with technological differentiation in infrastructure, processes and products, leading to new business models [1].

Furthermore, the determining factors driving this transformation are new customer needs which, on the one hand, are rapidly advancing at the pace of society's digital progress and, on the other, have an increasingly demanding commitment to environmental sustainability. Thus, consumers are demanding new forms of sustainable urban mobility and new vehicle uses and characteristics, tending to move away from private vehicle ownership in favour of new approaches to shared mobility that must be addressed by the automotive industry [2,3]. In this sense, the sector is focusing its efforts on the production of electric, intelligent and autonomous vehicles, but equally relevant is its effort to offer innovative solutions in mobility and connectivity that provide intangible value associated with new services and an innovative change in the automotive business model [4]. The sector is facing a disruptive business model in which servitisation through the application of Industry 4.0 technologies and the promotion of collaborations and strategic alliances with telecommunications companies will play a key role [5].

According to the II Sustainable Mobility Observatory [6], the greatest expression of change in automotive companies' business models will be seen in the solutions they offer to mobility with multifunctional, integrated and digital platforms, and connected and monitored vehicles that contribute to greater road safety and efficiency. The arrival of 5G connectivity will be decisive in driving the Internet of Things (IoT) and, in parallel to the Internet of Vehicles (IoV) phenomenon [7], enabling the progress of connected and autonomous

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

cars [8]. The preferred claim of consumers will not be vehicles as we have traditionally conceived them, but the experience that the connected or automated vehicle is able to provide [9]. In this sense, Vehicles-to-Everything (V2X) technology will allow vehicles to be connected with their driver, with other cars and infrastructure (cities, roads, car parks, hotels, etc.) transmitting data in real time [2, 10]. The data generated by the use of connected vehicles will provide information of great strategic value for the sector, sharing awareness of the behavioural habits of users, vehicle status or other variables that, additionally, could become important sources of revenue for manufacturers with the monetisation of the data collected [11, 12] or by the incorporation of software package upgrades that improve customers' experience with the vehicle.

In this context, it is of interest to identify how the automotive industry is developing and integrating the technologies driving autonomous, connected and electrified mobility, as well as new forms of shared mobility demanded by users, known by its acronym ACES (Autonomous, Connected, Electric and Shared Vehicles) [13]. In recent years, publications in this field of study have diversified, focusing on aspects such as the market, sustainability, public policies, responsibility, safety and economic issues, among others [14]. However, the exchange of knowledge between academia and the automotive industry in a particular and individual way is scarce, leading to a lack of knowledge of the current progress of these companies, which makes this research a relevant and necessary contribution to cover the evidence in this field of research [15,16].

The objective of this work is to offer a current and substantiated vision of the advances of the European automotive sector in the new paradigm of a sustainable mobility ecosystem, providing a reference framework for those interested in this field of study. In this way, a compilation of information is offered, which promotes the visibility of the commitment, effort and performance of the main European automotive groups regarding the development and integration of technological solutions that allow them to transform themselves and adopt new strategies to compete in an industry that presents important challenges associated with ACES drivers for the new models of sustainable mobility, on which the sector has been betting in recent years.

2. ACES TECHNOLOGIES DRIVING THE AUTOMOTIVE INDUSTRY

Automated vehicles are those in which at least some aspects of a safety-critical control function (steering, acceleration or braking) occur without direct driver intervention [17] through the assistance and integration of new technologies. The Society of Automotive Engineers [18] recognises six levels of vehicle automation, from 0 (no automation in driving) to 5 (full automation), with levels 1 to 3 considered semi-autonomous and 4 being high driving automation. For their part, Lengton et al [19] define the connected car in terms of six levels of vehicle connectivity and functionality, up to the level where the vehicle is connected to everything around it, known as V2X. This includes vehicle to infrastructure (V2I), vehicle to data network (V2N), vehicle to vehicle (V2V), vehicle to pedestrian (V2P) and vehicle to device and power grid (V2D) connectivity. The integration of V2X connectivity will provide companies with greater service efficiency [4] and data business profitability [20], in addition to obtaining a huge volume of real-time data that will allow them to better understand individual customer needs.

In this scenario, sustainable mobility policies focused on configuring a more efficient transportation model are directly linked to the development of technologies that allow greener and safer cars, promoting the use of electric vehicles [21]. This is understood as a vehicle that is driven by one or more motors powered by an electric energy source and whose most characteristic elements are the charging port, the transformer, the battery, the controller and the motor. The significant advance in electric vehicle manufacturing favours the progress of connected and autonomous vehicles. This poses significant challenges that require the implementation of new technologies directly related to connectivity and communication in the vehicle, the latter, among others, driving the formation of alliances with technological giants [5].

Regarding the latest ACES drivers, shared mobility, in any of its modalities, provides short-term access to shared vehicles for both passengers and drivers to meet users' needs and convenience without requiring vehicle ownership [22]. The automotive industry faces, on the one hand, the reduction of private use and car ownership in favour of mobility as a service and, on the other hand, on-demand shared mobility services, in which the passenger is transported in ride-sharing or chauffeur services reserved for individuals or multiple passengers and that can be offered by any owner-driver (ride-haling, ride-pooling, ride-sharing) [3]. In this way, it focuses its efforts on the incorporation of on-demand shared vehicle services, in which the passenger is the driver themselves. Three main modalities stand out: the subscription-based on-demand vehicle service and the shared on-demand vehicle service that can either be Free-floating Car Sharing (FFCS) or Peer-to-Peer (P2P) (see Figure 1 in the supplementary materials section) [3].

This new scenario requires the application of new technological advances in the Industry 4.0 environment (IoT, Big Data, cloud computing, blockchain and cybersecurity) to meet the demands and expectations of consumers by increasing the digital and technological value of the product or service associated with driving (see Figure 2 in the supplementary materials section).

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

3. MATERIAL AND METHODS

To achieve the purpose of this work, an exploratory analysis is carried out, which requires a qualitative research process based on the collection and analysis of information coming mainly from the review of the documentation available on the websites of the companies under examination (reports, annual reports, news, newsletters, etc.), supplemented with other secondary sources of information (regulations, industry reports, articles and other online information). For the subsequent analysis and presentation of the results, the ACES drivers (see Table 1) are taken as a reference, facilitating their classification, description and development by category and/or topic, showing the progress and challenges of the selected European automotive companies, whose main characteristics are detailed in Table 2.

Boosters	Short description	Categories	References
A	Technology capable of performing driving tasks (tier-level automation)	- No automation (0) - Semi-automation (1-3) - Full automation (4-5 depending on scenario)	[17-18]
C	Connectivity capacity of the vehicle with the environment	- Vehicle to Infrastructure (V2I) - Vehicle to data network (V2N) - Vehicle to vehicle (V2V) - Vehicle to pedestrian (V2P) - Vehicle to device and electric red (V2D) - Vehicle to everything (V2X)	[19,23]
E	Inclusion of electric or hybrid batteries and other components	- Battery electric vehicles - Plug-in hybrid vehicles - Fuel cell and hydrogen vehicles	[16, 21, 24]
S	On-demand access to vehicles managed by service providers	- Subscription service - Shared service: • *Free-floating shared car* (FFCS) • *Point by point* (P2P)	[3, 22]

Table 1. ACES Drivers in the automotive sector
Source: Author's own elaboration

4. THE EUROPEAN AUTOMOTIVE INDUSTRY IN THE CONTEXT OF ACES DRIVING TECHNOLOGIES

4.1. CONNECTIVITY AND AUTONOMY

Currently, the vast majority of automated vehicles manufactured in Europe reach, at most, autonomy level 2 with the inclusion of different assistance technologies, as detailed in Figure 3. However, some groups such as Volkswagen, BMW and Daimler are ready to launch vehicles with level 3 autonomy, as supported by the recent regulation on autonomous driving that allows the driver to be inattentive in certain circumstances [25].

As illustrated in Table 3, the main objective of all manufacturers is to manufacture autonomous and connected cars, taking the electrification of the automobile for granted. In addition, information of interest is provided on the main features of their advances in connectivity and autonomous driving. Regarding the level of connectivity, there are important differences between the German industry and the remaining groups, with the former having integrated more advanced connectivity technologies and even reaching fully connected vehicles (V2X). The priority bet on the cooperation of the automotive companies with the telecommunications industry is relevant, becoming a differentiating element in the progress of connectivity and autonomous driving. It also highlights the different levels of integration of access to platforms, mobility services and monitoring or management of data in real time for the different manufacturers and other stakeholders.

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

GROUP (Headquarters)		Sales 2021 (€)	Market share (%)
Volkswagen (Germany)		2,437,110	25.1
BMW (Germany)		658,490	1.5
Daimler AG (Germany)		547,384	5.6
Renault (France)		1,028,925	10.6
Stellantis* (Netherlands)		2,124,269	21.9

*Group resulting from the merger of Peugeot S.A. (PSA) and Fiat Chrysler Automobiles (FCA) (January 2021).

Table 2. Major European automotive groups Source: Author's own elaboration

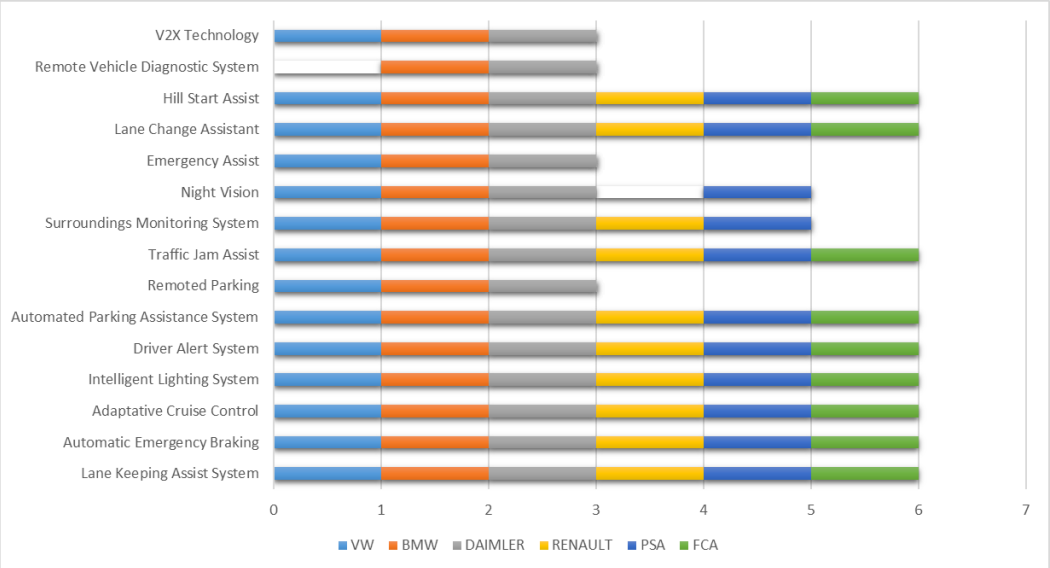

Fig. 3. Automotive Smart Assistant

Source: Author's own elaboration

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

GROUPS	MAIN INNOVATIONS
VOLKSWAGEN	– **Alliance with Microsoft** to develop self-driving vehicles (2021). Cloud computing services and artificial intelligence. – **Car Software**. Develop software for connected cars, new platforms, autonomous driving, vehicle and energy monitoring, digital business and mobility services. – **Subsidiary for autonomous driving; Volkswagen Autonomy (VWAT).** This groups together all the autonomous driving development activities from level 4. – The first applications of level 4 of autonomous driving are planned in the commercial sector (Robo Taxis and Robo Vans). – **Cooperation with Ford (2019)** in electric mobility and autonomous driving. – **Sedric Model** (level 5 autonomy). – **Traffic Jam Assist** Semi-automated driving in traffic jams and construction sites (Adaptive Control Cruise and Lane Assist; level 3 autonomy). – **Night driving assistance system** (detects people and animals) with infrared camera. – **Parking Assistant**. Automatic parking, even from outside the vehicle using a smartphone to control it remotely. – **Alert system** to the driver. – **V2X technology**. Connection to other vehicles and traffic infrastructures wirelessly to help prevent accidents. (New Golf, the first European car with this technology as standard).
BMW	– Inauguration autonomous driving campus (2018) – **Driver assistance systems**. (Automated driving up to 210km/h.) – **Jam assistant** up to 60km/h. – Speed, direction and lane control assistance. – Automatic parking with remote control. – **BMW iDrive.** Driving with innovative intelligent personal assistant, connected to the cloud. – **Remote diagnostics** of failures and incidents with data transmission. – Launch in 2021 of the BMW iNext. Electric, highly automated and fully connected in “Ease” mode. The interior changes by voice command or by touching the steering wheel. The steering wheel folds down to provide more space and the pedals sink to create a flat surface while the car drives autonomously (Level 3 autonomy).
DAIMLER AG	– **Cooperation with** NVIDIA to develop the most advanced computing architecture in a car. Customers will be able to purchase and add capabilities, software applications and subscription services. Automated driving features powered by the NVIDIA DRIVE platform. – **Cooperation with Bosch** to develop automated driving systems. – Wizards "Intelligent Drive". Standard: Active Break Assist, Attention Assist, Crosswind Assist. Optional: DISTRONIC with steering pilot (especially for traffic jams), Speed Limit Pilot (adjustable autonomous speed), blind spot assistant. – **Remote Parking Assist** and Active Parking Assist. – V2X communication. – **Level 4 autonomous driving in robot taxis** within cities.

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

RENAULT	– **Renault Nissan Mitsubishi Alliance** to promote the mobility of the future. – **Partnership with WAYMO** to promote autonomous driving technology. – Advanced driver assistance systems. Automatic emergency braking with cyclist and pedestrian detection. – Driving aids are grouped into three types: driving, parking (both are part of EASY DRIVE) and safety aids. – **EASY DRIVE**: Easy Park Assist, Traffic Sign Recognition, Blind Spot Warning. – **Pilot project with Sanef** to study the behaviour of vehicles at toll barriers and work zones.
PSA	– **VPA programme** "Autonomous Vehicle for All". – **Connected Pilot** (complete highway assistance), Park Pilot (parking without driver intervention), night vision (identify obstacles) and driver attention monitoring. – Participation in the L3Pilot project to test and validate autonomous driving as an efficient and safe means of transport. – **Collaboration with VINCI Autoroutes** to advance autonomous driving.
FCA	– **Collaboration with WAYMO** to deliver level 4 autonomous cars. – **Autonomous driving platform** made up of BMW, Intel, Mobileye and FCA. Open and scalable platform that will adapt to the needs of manufacturers and allow them to obtain flexibility and offer differentiation based on the brand (levels 3-5 autonomy). – **Intelligent Adaptive Cruise Control system** (iACC). This brakes and accelerates in response to any obstacle. Also included are Lane Assist, Intelligent Speed Assist, Urban Blind Spot and Driving Assist. – **New UConnect 5 infotainment system.**

Table 3. Advances in automation and connectivity in the European automotive sector

Source: Author's own elaboration.

4.2. ELECTRIC MOBILITY

Advances in electric mobility are part of the main strategic plans of all the European automotive groups studied in this research. The most relevant factor that focuses the objectives of these companies is to increase battery range and reduce environmental impact. In this respect, Daimler is positioned as the European brand with the best range (750km, EQS model in 2021), while FCA is the group with the shortest range (350km, Fiat 500 model). The electrification of urban mobility fleets is a common objective for all European brands. However, German companies are also concerned with launching top-of-the-range models for long-distance, all-electric trips, thus constituting a clearly differentiating aspect that provides a clear competitive advantage to these companies (see Table 4 in the supplementary materials section).

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

4.3. SHARED MOBILITY

Shared mobility purposes are not overly visible in the main objectives defined in the strategic plans of the companies under investigation. However, a more detailed study of the integration of shared mobility services of these groups provides us with interesting information on the projects they are developing (Tables 5 and 6). Most of them are pilots and only operate, for the moment, in certain European cities where market demands and infrastructure can guarantee a launch and test scenario, allowing the industry to analyse the success and failure factors that can lead to reconfigurations of the mobility services to be offered.

Subscription-based on-demand vehicle services are still at an early stage with pilot projects, but European automotive groups are showing interest in integrating these services into their business models and offering innovative solutions to niche markets where consumers do not demand long-term vehicle ownership (Table 5). Typically, this type of service includes, in addition to the use of a vehicle for a limited period of time, the maintenance, repair or replacement of the vehicle and the costs derived from taxes and even the insurance policy. Specifically, Daimler, with the aim of encouraging the consumption of electric mobility vehicles, focuses the offer of this type of services only to these electric vehicles. As for BMW and Renault, both have experimented with this type of subscription service, but their success has not been as desired and they are currently undergoing reconfiguration processes.

	VOLKSWAGEN	DAIMLER	PSA*	FCA*
Service	Self-above	EQ Subscription	free2move Car on Demand	Leasys Car Cloud
Launching	2018 Germany	2018 Germany	2019 France, Portugal, Spain	2019 Italy
Type of Vehicles	Electrical and Combustion 17 models	Electrical 2 models (EQC and EQV)	Electrical/Combustion 12 models (Opel, Citroen, Peugeot and DS)	Electrical/Combustion 12 models
Rates	From €399 - €1,299 + Extras	From €899 - €1,149 + Extras	From €270 - €625 + Extras	From €249 - €1,599 + Extras
High	€199-249 Minimum period of 3 months. Flexible cancellation after 3 months	€400 24 months, with flexible cancellation notice after 3 months	Has administrative costs Three options: 6 months, 12 months or without commitment	€199 - €249 Membership is purchased through Amazon
Available kilometres/month	800km (expandable additional cost)	1250km	850km - 2850km	1500km
Included services* (except fuel/cargo)	Vehicle swaps	-	Home delivery One vehicle change per year.	Changes of vehicles of the subscribed package Free recharge at authorised Mobility Stores (Certain models)

**All include maintenance, service, taxes and insurance.*

Table 5. Subscription-based proprietary services

Source: Author's own elaboration

For its part, the success of the floating on-demand vehicle service, pioneered by the corporate alliance of the PSA and FCA groups in 2016, is being consolidated. These services have become fundamental in the new innovative business paradigm with the servitisation of the product to counteract the effects of the trend towards vehicle non-ownership, which consequently affects the production and

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

sale of vehicles. In this modality, automakers have fleets of vehicles to share so that the user can drive when needed without owning the vehicle. The vehicles can be located at stations, which are specific places where the vehicle must be picked up and returned (*roundtrip*), or picked up and returned anywhere, for example, parked on the street (*one-way*).

Table 6 shows the options currently offered by European automakers for on-demand car-sharing on a floating basis. It should be noted that, for the time being, this service is only operational in strategic geographical locations, with the joint venture formed by Daimler and BMW, which allows them to gain competitiveness, currently offering the greatest geographical coverage.

	VOLKSWAGEN	DAIMLER & BMW	RENAULT ZITY	PSA & FCA
Service	WeShare	Share Now	Zity	Free2Move
Launching	2019	2019 Fusion DriveNow & Car2Go	2017	2016
Location	Berlin, Hamburg, Prague, Madrid, Budapest, Munich, Milan	Madrid, Paris, Dusseldorf, Hamburg, Copenhagen, Cologne, Frankfurt, Stuttgart, Munich, Berlin, Milan, Turin, Rome, Vienna and Budapest	Madrid and Paris	Madrid, Lisbon, Paris and Washington
Fleet	ID.3 and e-Golf	BMW 2 Series, BMW 1 Series, BMW i3, BMW X1, BMW X2Mercedez-Benz GLA, Mercedes-Benz A-Class, MINI 3, MINI 4, MINI Convertible, MINI Clubman, smart fortwo, Fiat 500	Renault Zoe	Peugeot e-208, DS 3, Citroen C-Zero, Citroen AMI
Type	Electrical	Electrical/Fuel	Electrical	Electrical
Unlock Fee	€1/Trip	Gratuitous	Gratuitous	€0.50/Trip
Travel Rate	€0.29/min €58/Day *€0.19/Min (WeShare+)* *€49/Day (WeShare+)*	€0.19 - €0.34/min From €15.99/2 Hours From €49.99/Day	€0.17 - €0.37/Min (Madrid €0.29) €19/2 hours €29/4 hours €49/6 hours €69/Day	From €0.31/Min €49/3-24 Hours
Standby Rate	€0.29/min *€0.05/Min (WeShare+)*	€0.19 - €0.34/Min	€0.09 - €0.19 Madrid (€0.12)	From €0.31
Kilometres/24h	100km *150km (WeShare+)*	200km	Unlimited	125km
Additional kilometres	€0.29/Km	€0.19/Km	Unlimited	€0.31/km
Additional features*	- Free charge - Free cleaning - Baby seat in all vehicles - Insurance coverage	- Free charging and refuelling - Free GPS - Insurance coverage	- The cheapest rate is always applied - Free parking in SER area - No KM limit - Saving pack	- Free charge - 20 minutes of free reservation - Insurance coverage
Registry	Gratuitous WeShare+ subscription €9.99/Month	€9 (gift €15 credit).	€5 (currently free)	Gratuitous
User Rating	4.0/5	4.5/5	3.3/5	4.4/5

** All include free parking in the operational area*

Table 6. Floating carpooling services | Source: Author's own elaboration

ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487

The factors that most influence the choice of brands are geographic availability and rates. Volkswagen's WeShare stands out in particular as the first company to include, within the floating car sharing service, the subscription-based model, providing savings to its users with the payment of a monthly fee.

The main peculiarity of P2P is that the fleet of vehicles offered belongs to individuals who transfer their vehicles to an operator that manages the system. In this modality, the car companies do not offer the service on their vehicles, but simply manage a platform that facilitates shared mobility between individuals. So far, only the FCA group has launched U-Go for its customers with a leasing contract or for those who have financed a car through FCA, enabling them to share their cars during periods when they will not be using them.

5. CONCLUSIONS

This tour of the European automotive industry brings us closer to the current state of the sector in an environment of technological disruption 4.0 and unprecedented sustainability. The results confirm the shift in the focus of automotive manufacturers from traditional vehicle manufacturing models to converting the vehicle into a servitised product that adapts to the characteristics of sustainable mobility demanded by consumers and environmental regulations. Thus, it is clear that the sector's progress is driven by automation, connectivity, electrification and shared mobility. However, the results reveal different levels of development within the European automotive groups.

On the one hand, the autonomy factor of electric vehicles has become a key element in achieving competitive advantage, led by the German group Daimler, whose commitment to these technologies goes beyond the objectives of the other European groups, both in terms of requirements to offer additional services and in the total conversion of all its models into electric vehicles. Likewise, the commitment to connectivity and shared mobility are consolidated across the drivers on which most actions and technological solutions are being developed, although these are in their infancy and show significant differences between the groups. On the one hand, the German subsidiaries stand out in the integration of V2X connectivity technologies and in collaborations with technology companies that guarantee this progress, as well as the monetisation of their data. On the other hand, shared mobility services are forcing automakers to focus on smaller market segments, namely city locations, to provide the different forms of shared mobility. Once again, German companies are leading these services in many European cities, in contrast to the Renault and Stellantis groups.

Although much progress has already been made, there are also many challenges to be met by the automotive sector before it is fully integrated into the new sustainable mobility ecosystem paradigm. This, in turn, will be conditioned by new regulations, by the availability of infrastructure that is fully adapted to this new environment favouring sustainable mobility and minimising environmental impacts, as well as by the collaboration of other stakeholders (technology, telecommunications and energy companies, and infrastructure operators) that will allow the definitive transition of the *"vehicle to the sustainable mobility ecosystem"*.

In view of these findings, and taking into account the exploratory nature of the work carried out and its limitations, we believe that it provides an adequate and necessary frame of reference through which to expand this field of study, which is immersed in continuous and rapid change.

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SUPPLEMENTARY MATERIAL

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ISSN: 0012-7361 eISSN: 1989-1490 / DYNA Vol.97 n.4 DOI: https://doi.org/10.6036/10487