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Editorial

Driving as a Service: Promoting a Sustainable Transition to Automated Driving

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1. Introduction

Automated vehicles (AVs) promise to make a revolution in the mobility paradigm and to bring benefits for traffic management and environmental quality, improving, in general, the quality of life in society [1]. At the same time, there is a great deal of expected impacts that must be softened to ensure a smooth transition to the automated driving paradigm. Since there is still a long path to pave until full automation is deployed for everyday activities, this transition period is the moment to develop and test safe and sustainable solutions for AV deployment.

Automated tasks are being slowly introduced in recent vehicles, even if the level of automation does not increase. In that sense, although driving automation is a disruptive technology, drivers are getting used to the support of technologies and reducing their tasks. We can argue that the driving experience is being co-created between the driver and the vehicle. Hence, vehicles are not envisioned as manually controlled machines anymore, but the driving experience becomes a service experience co-created through interactions and touchpoints. Accordingly, it seems natural to talk about the concept of *driving as a service*.

As part of the automated driving features, vehicles included improved Advanced Driver Assistance Systems (ADAS), such as Lane Keeping Assist System (LKAS) and Cooperative Adaptive Cruise Control (CACC) [2]. The deployment of these systems is driven by objectives developed at European and international levels to reduce road crashes, especially those with victims, and to reduce gas emissions [3,4]. At the same time, in the urban context, automated vehicles appear as innovative solutions for the vehicle sharing economy by introducing shared autonomous vehicle services [5]. Automated systems are also being studied in the road freight transport sector, with the concept of truck platooning gaining momentum [6]. In all the contexts mentioned, there is one common aspect: driving tasks are becoming more digital, and drivers are required to interact with new interfaces and learn new tasks. Thus, the driver must be placed at the center in a human-centric approach, as the one promoted by Human-Machine Interaction or Service Design approaches. All in all, when studying the idea of *driving as a service*, relevant concepts of the service-dominant logic can be adopted [7], such as the concepts of co-creation and integration.

In view of the main objectives of automated driving—safety and sustainability—and the need to integrate technology and drivers' tasks, several factors must be accounted for when promoting a sustainable transition to automated driving. As a multidisciplinary field, we argue that the automated driving ecosystem should be developed around two axes (Figure 1): a horizontal axis connecting people (drivers) with technology (vehicles, infrastructure, etc.), and a vertical one connecting governance and management (i.e., regulators, policymakers, and businesses' perspectives) with the environment. The axes intersect because policies targeted at environmental improvements mostly impose certain behavioral and technological constraints. This is visible in the literature since some studies have strong links to the development of technology and vehicles (Contribution 1), other studies focus

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on policy needs to adjust to the new paradigm (Contributions 2 and 3), and others evaluate the drivers' ability to adapt to and interact with the technology (Contributions 4 and 5).

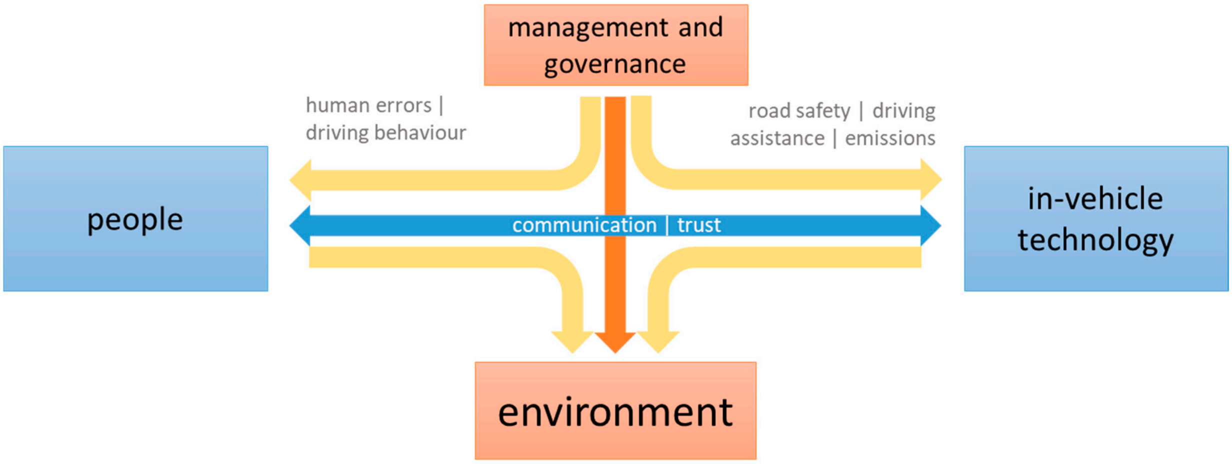

Figure 1. Foundational elements of the automated driving ecosystem.

With this editorial, our intention is to link the concepts and studies commonly focused on only one of the aspects of automated driving and discuss how the links between the two axes demonstrate the need for multidisciplinary work. The papers selected for this Special Issue demonstrate how the four ends of each axis collaborate in promoting a sustainable transition to automated driving. First, the elements of the horizontal axis are presented, and then the elements of the vertical axis.

2. People

As end-users, drivers play a key role in the transition to automated driving. There are two challenges that developers of original equipment manufacturers (OEMs) must consider: drivers' ability and drivers' willingness to use the technology. These two aspects will have a high influence on the acceptance of AVs from drivers, suggesting that AVs need to be trustworthy, useful, and usable.

According to Zhang et al. (Contribution 5), trust can be promoted through explanations, but these approaches may not be suitable for everyone and may have different impacts depending on the driver's age. Their findings suggest that drivers cannot be looked at as one homogeneous group, and studies with proper samples must be developed. Moreover, a heterogeneous target demands mixed approaches in building trust, pointing to the need to involve people in technological developments in several stages of design, as has been undertaken in other fields [8,9].

Still, even if drivers are willing to use the technology, road safety standards need to be met. Therefore, studies focused on drivers' behavior with technology are complementary to studies of technology acceptance. An example of human-centered methodology is the use of driving simulators to analyze drivers' behavior in dangerous scenarios [2]. Being that human error is a major cause of road crashes [10], driving simulators allow to mix different human factors and simulate driver behavior. For instance, Soares et al. (Contribution 4) studied the role of distractive tasks and their relation to the drivers' characteristics. The results highlight the impact of the nature of the distraction on the reaction time of the driver. In another study, the same authors analyzed the introduction of level 3 automation and pointed out the need to test different scenarios depending on how immersive the non-driving-related task (NDRT) is and what the origin of distraction is [2].

In this type of study, the research on human factors is easily merged with research on human-machine interactions (Contributions 2, 4, and 5). Again, this requires human-centered approaches that, in turn, are based on people's participation.

3. Technology

Vehicle automation is, by definition, technological. Whether it concerns the development of complete systems, such as ADAS, or components of systems, technological developments must be aligned with societal needs and goals. In fact, technology is too broad of a term, referring to a multidisciplinary field that involves several actors, including vehicle manufacturers, infrastructure operators, and service providers. Being such a broad area, it is easy for researchers and developers to focus on specific details of technology, but it is of high importance that actors in the ecosystem keep an integrated view of the developments, ensuring that hardware, algorithms, and software contribute together to a feasible and trustable product. Still, an integrated view is needed for a successful development and deployment of automated driving. The concept of *driving as a service* here discussed brings a holistic perspective, presenting the different roles technology can play in the automated driving ecosystem and the different actors that technology can impact.

An example of that is the work from Wilbrink et al. (Contribution 1) that studies the interactions between pedestrians and AVs to ensure good communication and the safety of all road users. In their study, different types of external human-machine interfaces were tested in a simulated environment. This work contributes to the understanding of the horizontal axis.

Furthermore, technology, as in algorithms and software, can also support the tasks of other actors other than pedestrians, drivers, and passengers, thus enlarging the automated driving ecosystem. Transport management operations are a direct beneficiary of a connected network, with the tasks of traffic engineers, city planners, and mobility service providers being improved in a smart city where data is available [11]. When considering the concept of *driving as a service*, integration with the road infrastructure and traffic management is an opportunity to improve the driving experience. In that sense, Yin et al. (Contribution 3) studied the optimization of intersections in a connected and automated vehicle environment. The algorithm presents a control strategy for traffic signals and depends on the rate of penetration of connected AVs in order to reduce pedestrians' delays. It is interesting how the authors used technology to optimize traffic while focusing on pedestrians, bringing pedestrians to the automated driving ecosystem, as did Wilbrink et al. (Contribution 1).

4. Management and Governance

As mentioned in the previous section, technology emerges as a tool to enhance user experience. In the transportation domain, the concept of *smart city as a service system* [12], the well-known concept of *mobility as a service* [13], or even the concept of *tourism as a service* [14] take advantage of data integration and digitalization to improve management processes and user experience. The knowledge that comes from the amount of data available potentiates this integrated and holistic perspective of an ecosystem where actors collaborate, creating value for each other. In line with those principles, the concept of *driving as a service* represents a service ecosystem where technology plays a dual role. First, technology is the tool that improves drivers' and passengers' travel experiences in a connected and automated vehicle environment. Second, connectivity enables data integration that can support management processes.

In terms of governance, the introduction of automated driving systems requires an update to the existing regulation, and, consequently, research is also concerned with developing recommendations for decisionmakers. As AVs are associated with green and more efficient fuels, Vasebi and Hayeri (Contribution 2) presented policy recommendations for the adoption of collective adaptive cruise control based on energy optimization algorithms. Other studies in the literature support regulatory developments with safety and acceptance studies to guide policymakers [15].

5. Environment

Even though environmental issues are not an immediate consequence of automation, environmental gains are one of the overarching objectives of AVs [16], together with electric vehicles. For this reason, policymakers should ensure these goals are met by creating proper regulatory measures. Those regulations represent the vertical axis connecting governance and the environment.

In order to attract more users, one of the main promises of the AV industry is the associated reduction of fuel consumption and consequent reduction in pollutant emissions. Together with increased climate change awareness, technology is being developed and implemented to promote environmentally friendly driving [17]. Even at lower automation levels, vehicles are equipped with gear shifting assistance to suggest more efficient driving. Other developments occur in the cruise control algorithms for higher automation levels. This is the case of CACC, which promotes a cooperative driving scenario where fuel consumption reduction is one of the main objectives [18].

CACC takes advantage of the uniformity in acceleration among several vehicles. In the road freight transport sector, possible gains come from truck platooning technology, where trucks take advantage of small distances between trucks to reduce fuel consumption. According to Vasebi and Hayeri (Contribution 2), this technology can help overcome two of the main challenges in energy-optimal algorithms. A collective ACC facilitates predicting leading vehicle behavior and consequently improves overall energy savings. Moreover, CACC promotes integrated traffic management, thus reducing the negative impacts on the traffic flow, contrary to a self-centered ACC.

6. Conclusions

The fast pace of current technological developments imposes several challenges on an also-changing society. New trends in people and goods mobility are promoted by new technology-based mobility services (e.g., integrated travel planners, ride sharing), and by the new digital business models that change people's behavior (e.g., e-commerce). The auto industry has been following the servitization trend for a few years, with increasing service offerings when purchasing a vehicle. Automated vehicle technology appears as the next level of service provision, bringing new service offerings to the ecosystem [19] and new challenges for a successful deployment in a transition context. In line with those developments, this editorial presents the concept of *driving as a service* and its relationship with the papers included in the Special Issue.

Overall, *driving as a service* represents the mindset required to further strengthen the automated driving ecosystem in a transitional context, supported by a multidisciplinary integration of different perspectives around two main axes connecting people, technology, governance and management, and environment. Adopting a service-dominant logic supports the design and development of human-centric solutions, ensuring value co-creation between drivers and service providers, thus helping manufacturers shift from a product-oriented to a service-oriented ecosystem.

We discuss the integration of several concepts and domains commonly associated with AV research and present an integrated analysis of how they are connected around two axes towards a common objective. With the environment as a high-level objective, regulators and policymakers cannot disregard the potential for improving road safety and traffic management. The latter is also a form of reducing air and noise pollution, thus promoting a better environment, mainly in urban settings. To achieve the desired goals, resources must be well managed, and people must be engaged as partners, as promoted by S-D logic principles of resource integration and co-creation [7]. Hence, only a sustainable transition can ensure the success of a digital and automated future. We argue that an integrated approach is required to ensure that the technology being developed is aligned with the objectives established and that people are willing and capable of adopting the proposed technology. This dynamic between management and governance working towards a better environment, through the development of people-centric technology, is represented in the vertical axis.

On the horizontal axis, connecting people and technology, we discussed the need to integrate safety and usability requirements. This is related to public acceptance and the maturity of the technology. In regard to AVs, several studies dealt with public acceptance [20] and the drivers' ability to interact with automated systems [2]. The support of service approaches for the integration of governance and management in multidisciplinary approaches has been proposed in the *smart city as a service* concept [12] and, for public transport, in the well-known, *mobility as a service* concept.

This collection of papers gathers research on the topics of human factors, human machine interaction, connected AVs, and traffic management, which together highlight the interactions between the dimensions discussed in this editorial.

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