FABIO ANTONIALLI

BUSINESS PLATFORMS FOR AUTOMATED DRIVING SYSTEMS: A PRODUCT-SERVICE SYSTEM APPROACH FOR MOBILITY AS A SERVICE.

LAVRAS - MG
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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Administração, área de concentração em Gestão Estratégica, Marketing e Inovação, para a obtenção do título de Doutor.

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Ficha catalográfica elaborada pelo Sistema de Geração de Ficha Catalográfica da Biblioteca Universitária da UFLA, com dados informados pelo(a) próprio(a) autor(a).

Antonialli, Fabio.
Business platforms for automated driving systems: a product-service system approach for mobility as a service / Fabio Antonialli. - 2018.
189 p. : il.

Orientador: Joel Yutaka Sugano.
Coorientadores: Arthur de Miranda Neto; Isabelle Nicolaï.
Tese (Doutorado) - Universidade Federal de Lavras, 2018.
Bibliografia.

1. Autonomous Vehicles. 2. Urban Mobility. 3. Business Platforms. I. Sugano, Joel Yutaka. II. Miranda Neto, Arthur de. III. Nicolaï, Isabelle. IV. Título.

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PLATAFORMAS DE NEGÓCIOS PARA SISTEMAS AUTOMATIZADOS DE CONDUÇÃO: UMA ABORDAGEM DO SISTEMA DE PRODUTOS-SERVIÇOS PARA A MOBILIDADE COMO SERVIÇO

Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Administração, área de concentração em Gestão Estratégica, Marketing e Inovação, para a obtenção do título de Doutor.

APROVADA em 10 de Dezembro de 2018.

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LAVRAS - MG
2019

Para meu amor, minha amiga, meu porto-seguro, Lara.

Para meus pais, meus alicerces, Yolanda e Luiz Marcelo.

Para meu irmão, Renan.

Para meus avós.

Para todos empreendedores, pesquisadores e trabalhadores que almejam um futuro melhor.

EU DEDICO

AGRADECIMENTOS

Primeiramente, sou grato a Deus e a minha família, especialmente à meu pai, professor e exemplo Luiz Marcelo Antonialli, à minha mãe Yolanda Maria Pinto Antonialli e à meu irmão Renan Antonialli, que sempre estiveram ao meu lado, me apoiando e encorajando.

À minha amada esposa, Lara Siqueira Oliveira Carvalho pela cumplicidade, amizade e paciência e por sempre estar ao meu lado.

À minha parceira de corrida e melhor amiga de quatro patas, Cristal Antonialli, apesar de não ser humana, você foi fundamental nesta conquista.

Ao meu professor orientador Joel Yutaka Sugano (PPGA/UFLA) pelo apoio, instruções e ensinamentos. Ao meu coorientador, professor Arthur de Miranda Neto (DEG/UFLA), pela confiança e incrível oportunidade de doutorado sanduíche a mim concedida para conduzir parte de minha pesquisa na França durante 2017. E por último mas não menos importante, à professora Isabelle Nicolaï (minha coorientadora na França) por me receber de braços abertos na escola CentraleSupélec (Laboratoire Génie Industriel) assim como pela paciência e incríveis ensinamentos e instruções.

Aos meu colegas de Pós-Graduação, pelo companheirismo durante essa caminhada, em especial à meus “irmãos por escolha” Bruna Habib Cavazza e Rodrigo Marçal Gandia por embarcarem comigo nessa jornada, compartilhando das alegrias e agonias e juntos superando os desafios.

Ao grupo de estudos em Redes, Estratégia e Inovação (GEREI/UFLA) por ter sido minha segunda case durante três desses quatro anos. À todos os colegas e funcionários do Departamento de Administração e Economia da UFLA e do Programa de Pós-Graduação em Administração (PPGA/UFLA), em especial à Deila Pereira. Aos meus queridos colegas Daniel Leite Mesquita, Thaís Assis, Guilherme Alcântara e Eduardo Lasmar, pela ajuda em diversos momentos da pesquisa.

A todos os professores e pesquisadores do Laboratório de Mobilidade Terrestre (LMT/UFLA), em especial ao professor Danilo Alves de Lima.

Aos membros da minha banca de defesa por aceitarem o convite e por todas as sugestões e críticas.

Aos professores, funcionários e colegas da École CentraleSupélec, em particular aos membros do Laboratório de Engenharia Industrial (LGI). A todos os colegas e funcionários da Maison du Brésil pela incrível acolhida.

Às agências de fomento CAPES e CNPq pelas bolsas de estudo a mim concedidas para a condução deste trabalho de tese.

A todos empreendedores, pesquisadores e demais colaboradores que de forma direta ou indireta me ajudaram na coleta de dados para a pesquisa.

De modo geral, agradeço muito a todos que de uma forma ou de outra contribuíram e torceram por mim durante esses quatros anos de trabalho duro.

Do fundo do meu coração,
muito obrigado!

"A dream you dream alone is only a dream.

A dream you dream together is reality."

JOHN LENNON

RESUMO GERAL

O crescente número de veículos existentes no mundo vem fazendo com que cidades sofram com problemas severos oriundos do trânsito. Com estimativas de 66% da população mundial vivendo em cidades em 2050, a mobilidade está se tornando um fator-chave que afeta o bem-estar e qualidade de vida dos cidadãos. Atrelado à popularização da economia de serviços, os Veículos Autônomos (VAs) representam uma mudança potencial e disruptiva para o atual modelo de negócios dos transportes urbanos, trazendo a promessa de mudar o futuro da mobilidade afetando não somente os modais de transporte mas a sociedade como um todo. Diante deste contexto, este estudo teve como objetivo propor e discutir cenários de plataformas de negócios para Veículos Autônomos sob a perspectiva do Sistema de Produto-Serviços em contextos distintos de mobilidade urbana. Partindo de uma ontologia construtivista, a pesquisa apresenta carácter qualitativo, descritivo, exploratório e preditivo sendo realizada por meio da coleta de dados em fontes secundárias - literatura acadêmica e cinza e primárias - via entrevistas, grupos focais e questionários com pesquisadores e professionais em mobilidade urbana no Brasil, França, Bélgica e Estados Unidos. Os resultados apontam que à chegada dos veículos autônomos no mercado se dará de forma mais disruptiva com os veículos sendo oferecidos como serviços ao invés de produtos, conclui-se também que os motivos para se usar um carro serão reconfigurados com diferentes pesos para os fatores instrumentais, simbólicos e afetivos. As principais tipologias de uso para os VAs serão desmembradas entre ofertas *Business-to-Business*, *Business-to-Consumer* e *Peer-to-Peer* para ambos transporte de passageiros e de cargas, tais como: *ride-hailing*, *ride-sharing*, *car-pooling*, *microtransit* e transporte na última milha. Esses modelos de negócios se configuram como plataformas multilaterais, as quais podem ser subsidiadas ou não pelo provedor da plataforma e podem oferecer serviços de mobilidade de um ponto A ao B por meio de soluções uni-modais ou multimodais; com isso, quatro cenários futuros foram criados de forma a extrapolar exemplos reais para um contexto onde VAs se configuram como um modal de transporte. Por fim, buscou-se entender qual seria a melhor estrutura de governança para guiar as transações em cada um dos cenários embasando-se nos ativos específicos tangíveis (modais de transporte) e intangíveis (dados). Conclui-se que para os cenários onde a plataforma é dona da frota (cenários A e C) as estruturas de governança tendem a ser mais hierárquicas, o que reduz os custos de transação mas eleva os custos operacionais. Por outro lado para os cenários B e D onde não há subsídios, a governança tende a ser mais híbrida, com custos operacionais inferiores e custos de transação mais altos. Em suma, em contextos de big data, estruturas mais complexas de plataformas de mobilidade tendem a criar a necessidade de estruturas de governança mais sofisticadas (*smart contracts* via *blockchain*) além de um comportamento mais dinâmico dos *stakeholders* envolvidos.

Palavras-chave: Veículos Autônomos. Mobilidade Urbana. Plataformas de Negócios.

GENERAL ABSTRACT

The growing number of vehicles in the world has been causing cities to suffer from severe problems derived from traffic. With estimates of 66% of the world's population living in cities by 2050, mobility is becoming a key factor affecting citizens' well-being and quality of life. Linked to the popularization of the service economy, Autonomous Vehicles (AVs) are a potentially disruptive change to the current business model of urban transportation, promising to change the future of mobility affecting not only the transport modes but society as a whole. Given this context, this study aimed to propose and discuss business platforms' scenarios for Autonomous Vehicles under the perspective of a Product-Service System within distinct urban mobility contexts. Starting from a constructivist ontology, the research presents qualitative, descriptive, exploratory and predictive nature, being carried out through data collection in secondary sources - academic and gray literature - and primary sources - via in-depth interviews, focus groups and questionnaires with researchers and professionals in urban mobility in Brazil, France, Belgium and the United States. The results indicate that the arrival of the AVs in the market will occur in a more disruptive way with vehicles being offered as services instead of products, it is also concluded that the reasons for using a car will be reconfigured with different weights for the instrumental, symbolic and affective motives. The main typologies of use for AVs will be divided among Business-to-Business, Business-to-Consumer and Peer-to-Peer offers for both passenger and cargo transportation, such as: ride-hailing, ride-sharing, car-pooling, microtransit and last mile transport. These business models are configured as multi-sided business platforms, which may or may not be subsidized by the platform provider and may offer mobility services from point A to B via uni-modal or multimodal solutions, thus, four future scenarios were created in order to extrapolate real current mobility examples to a context where VAs are configured as a transport mode. At last, we tried to understand what would be the best governance structure to guide the transactions in each of the scenarios, based on tangible specific assets (transport modes) and intangible assets (data). We conclude that for the scenarios where the platform owns the fleet (scenarios A and C), governance structures tend to be more hierarchical, thereby reducing transaction costs but increasing operational costs. On the other hand, for scenarios B and D where there are no subsidies, governance tends to be more hybrid, with lower operating costs and higher transaction costs. In short, in big data contexts, more complex structures of mobility platforms tend to create the need for more sophisticated governance structures (with smart contracts via blockchain) and a more dynamic behavior of the stakeholders involved.

Keywords: Autonomous Vehicles. Urban Mobility. Business Platforms.

SUMÁRIO

FIRST PART

1 INTRODUTION

The present study addresses the issue of Business Platforms for Automated Driving Systems as a Product-Service System in the context of Mobility as a Service. This introductory section is composed of the contextualization and motivation to the study, presenting theoretical delimitations, the research question, the objectives and the justifications of research. Finally, the doctoral thesis structure is discussed.

1.1 Research contextualization and motivation

With more than a half of the world's population currently living in urban areas, mobility is increasingly becoming a key factor affecting citizens' well-being and quality of life as well as influencing on urban geography, this defines where people work and live and therefore, on the way people commute (EUROPEAN COMMISSION, 2017; MELIS et al., 2016).

In the course of the 20^{th} century, automobility has become the dominant mode of transportation (URRY, 2004). At the same time, car-based transportation systems are responsible for a variety of negative environmental impacts, both on a global and local level (EPPRECHT et al., 2014) such as noise and air pollution, emission of greenhouse gases, traffic jams, road accidents, fragmentation of ecologically valuable land, increased health costs, just to name a few.

The current mobility regimes' dependence on fossil fuels, along with the threat of possible resource shortages intensify the need for a radical transition of contemporary transportation systems toward more efficient and sustainable schemes, as stated by Afabuzzaman and Mazloumi (2011). Furthermore, Fournier (2017) highlights that today's mobility paradigm based on fossil fuels and individual mobility is reaching its environmental, economic and social limit, to a point that the privately owned car will be more and more challenged as a solution to satisfy mobility needs.

As a consequence, Enoch (2015) states that such traditional transport model could suffer an exponential decline in the coming years. The main objective now is to enhance mobility and accessibility while, reducing congestion, road accidents and pollution in cities (CAO; WANG, 2017; AMBROSINO et al., 2016). Hence, efficient urban mobility is unlikely to be achieved without the provision of efficient, extensive and accessible transport options (AMBROSINO et al., 2016), since we are moving away from a set-up in which involves owning a vehicle, and towards transportation system in which journey satisfaction is determined by diverse means, ease of access and low cost; that is, users today are not only seeking more rational management of journey times and mobility costs; they want to choose mobility rather than be subjected to it (ATTIAS, 2017a).

With new economic models emerging, major changes are taking place in the car industry, with a rising proportion of Mobility as a Service (MaaS) activities (ALLANO, 2017). In this sense, manufacturers are combining products and services in order to provide greater value to the customer and to facilitate longer more profitable business relationships (JOHNSON; MENA, 2008).

With that, rises the concept of Product-Service System (PSS), which comprises a system of product, services, supporting networks and infrastructure designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models. Thus, product design and manufacturing can no longer be the only source of competitive advantage and differentiation of companies (DE ZAN et al., 2015), therefore, a PSS is as a market proposition that extends the traditional functionality of a product by incorporating additional services where the emphasis is on the “sale of use” rather than the “sale of product” (BAINES et al., 2007; WONG, 2004).

Thus, making this PSSs models a reality will mean rethinking the way innovation process is organized so that the chosen production model fits in with mobility requirements (ATTIAS, 2017a). Given the aforementioned, the concept of Mobility as a Service (MaaS) has been gaining ground in recent years, by presenting a shift away from the existing ownership-based transport system toward an access-based one (JITTRAPIROM et al., 2017; MULLEY, 2017; KAMAGIANNI et al., 2016).

Mobility as a Service predicts a paradigm with service providers offering travelers easy, flexible, reliable, well-priced and environmentally sustainable everyday travel, mixing public transport, car-sharing, car leasing and road use, with more efficient goods shipping and delivery possibilities. It is a way of putting users, both people and goods, at the core of transport services, having the very real opportunity to match customer needs more closely to service supply (HENSHER, 2017; MULLEY, 2017).

In this sense, Hensher (2017) states that literature on MaaS appears to focus on the changing role of the car, becoming a vehicle that is used but not owned, with cars available to be booked for a point-to-point trip, with or without a driver in the future as Autonomous

Vehicles (AVs) come on stream in volume. Hence, Schoitsch (2016) points out that AVs are inserted in the most significant historical change for the society, economy, automobile and public transport industry.

Better known as Automated Driving Systems (ADS), AVs are cars with motion and action capabilities that don’t require any sort of conductor (driver) or teleoperation control (FRAZZOLI; DAHLEH; FERON, 2002). ADS is a recommendation terminology adopted by the Society of Automotive Engineers (SAE) to refer to vehicles with different automation levels and avoid multiples definitions with ambiguous meanings (SAE, 2016). This includes several terminologies widely used in the literature, like autonomous vehicles/cars, self-driving cars, car-like robots, intelligent vehicles, driverless cars, etc. In this work, they are those of the levels 4 and 5 defined by SAE, which do not require any kind of human intervention during its operation (SAE, 2016).

By representing a potentially disruptive and beneficial change to the current transportation business model, AVs are bound to change the future of urban mobility, and such transformation will not only affect the means of transport but society as a whole. (ATTIAS, 2017b; MUTZ et al., 2016; SCHREURS; STEUWER, 2015; ENOCH, 2015). Hereupon, AVs can provide significant economic, environmental, and social benefits (MUTZ et al., 2016; FAGNANT; KOCKELMAN, 2015; U.K. DEPARTMENT FOR TRANSPORT, 2015).

Such vehicles will facilitate driving, increase road safety, reduce emissions of pollutants, reduce traffic jams, as well as will allow drivers to choose to do different things other than driving (ATTIAS, 2016b; ENOCH, 2015; SCHELLEKENS, 2015; SCHREURS; STEUWER, 2015). Access to fully automated vehicles will also improve mobility for those who cannot or do not want to drive, improving their quality of life (ATTIAS, 2016b; POORSARTEP, 2014).

As Fournier (2017) points out, value propositions of mobility solutions will therefore deeply impact the future, since new vehicles and services will emerge; new players will reshape the value chain thus, challenging traditional Original Equipments Manufacturers (OEM’s) with new products and services; even customers will be part of the value chain and become “prosumers”. This way, the implementation of Autonomous Vehicles as PSSs’ models within MaaS can have significant impacts to the existing business model of public transport, especially on the level of integration with private transport providers (JITTRAPIROM et al., 2017).

Therefore, such integration of products (AVs) and services (urban commute) may be realized by using the so-called multi-sided business platforms, which according to Jittrapirom et al. (2017) is the business model better fitted for MaaS solutions; in a sense that platform models facilitate interactions between travelers and suppliers of transport services in an improved and smarter way (PARKER; VAN ALSTYNE; CHOUDARY, 2016; GAWER, 2014).

Multi-sided business platforms are a transformative type of business model that by the widespread popularization of information technologies (specially the internet and mobile gadgets) have been transforming businesses, economies and society as a whole (PARKER; VAN ASLTYNE; CHOUDARY, 2016).

A multi-sided platform creates value by orchestrating interactions between external producers and consumers by bringing together two or more distinct but interdependent groups (people or entities), it creates value by connecting such groups without necessarily having the possession of any transacted good (CHOUDARY, 2015; EVANS; GAWER, 2016).

The ecosystemic feature of business platforms entails a wider network of actors (stakeholders) influencing how the focal firm (platform provider) creates and captures value (KAMARGIANNI; MATYAS, 2017). That is, by considering MaaS as a business ecosystem it is possible to have a more holistic view of the multi-sided network effects and multiple stakeholders' participation within the platform (PARENTE; GELEILATEB; RONG, 2018), hence, a business ecosystem includes customers, suppliers, competitors and other stakeholders who coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies (MUEGGE; 2013; MOORE, 1993).

Furthermore, with electronics gaining weight in the technological configuration of transport modes, vehicles are being converted into sensor platforms, that is, they are being transformed into big data orchestrators (GERLA et al., 2014; MIKUSZ; JUD; SCHÄFER, 2015). As pointed out by Milne and Watling (2018), big data in transport planning will replace much of the information previously collected manually, thus, the greater the number of information providers, the more difficult it may become to coordinate the information and control polices based upon it. Therefore, governance arrangements are critical to the success of mobility data platforms (VEENEMAN et al., 2018).

Hence, the motivation of this study is based on the assumptions that the upcoming paradigm shift in urban mobility, the rise of multi-sided platform models such as PSS and MaaS and the inclusion of Autonomous Vehicles as a transportation modal will lead to significant changes in the current business models of the automotive and urban mobility industries, especially regarding how data will be managed and owned within these ecosystems and how governance will be carried out.

1.2 Research question, objectives and justifications

The development of Autonomous Vehicles is an important disruptive innovation that promises to have a great impact on the issues of urban mobility (ATTIAS, 2017a; MUTZ et al., 2016; ENOCH, 2015). These new AVs trends are concomitant with the generalization of the service economy in which owning a car will no longer be seen as a priority for users, particularly for urban citizens.

Such evolution goes beyond seeing an Autonomous Vehicle simply as a new product, but rather to consider mobility as a Product-Service System being an object of both technological and market innovation. From this perspective, the business platforms model is shown as an interesting option for the viability and consolidation of Autonomous Vehicles while a PSS in the context of Mobility as a Service (JITTRAPIROM et al., 2017).

In this sense, for this doctoral thesis we have considered Autonomous Vehicles (AVs) as a Product-Service System (PSS) within the concept of Mobility as a Service (MaaS), which in turn is considered as a Multi-sided Business Platform. Hence, the overall research question that guides this study is: **What are the business platforms models for Autonomous Vehicles as a Product-Service System in the context of Mobility as a Service and how will the governance of these models be configured?**

Based on such inquiries the **general objective** of this doctoral thesis is:

Propose and discuss business platforms' scenarios for Autonomous Vehicles under the perspective of a Product-Service System within distinct urban mobility contexts and understand how governance will take place.

To achieve this objective, this doctoral thesis is subdivided into the following **specific objectives**, aiming to:

1. **Draw new value curves for Autonomous Vehicles over traditional ones when considering AVs as a service and as a product and to discuss the main reasons to use an AV over a traditional car.**

2. **Design a typology model for the uses of Autonomous Vehicles in the scope of a Product-Service System and propose relevant Key-Performance Indicators.**
3. **Create future scenarios for the Business Platforms of Autonomous Vehicles in urban mobility contexts.**
4. **Characterize distinct types of governance models in different scenarios of autonomous urban mobility platforms considering the context of big data.**

The research justifications for this doctoral thesis are guided by the imminent arrival of Autonomous Vehicles (ATTIAS 2017a; MUTZ et al., 2016; ENOCH, 2015; SCHREURS; STEUWER, 2015), due to the significant technological advances in the field as well as, movements of Original Equipment Manufacturers (OEMs) in search of this (r)evolution and indications of research centers all around the world (LIMA, 2015; WEICK; JAIN, 2014).

Autonomous Vehicles are inserted in what can be considered as the most significant historical change for society, economy, automotive and public transport industry. The arrival of such technology is bound to disrupt many existing markets as well as create new ones (ATTIAS, 2017a; FOURNIER, 2017). Some positive impacts of the arrival of AVs may be: increased mobility; better use of urban spaces; reduced congestion costs; increased road safety; user comfort; fuel consumption and pollutant emissions reductions (U.K. DEPARTMENT FOR TRANSPORT, 2015) as well as the inclusion of groups such as elders, handicapped and those people who do not want or cannot drive. On the other hand, some possible negative impacts are: social risks (as in terms of rebound effects); personal data protection issues (e.g., hackers attack); increased insurance costs; loss of revenue related to individual traffic reduction (e.g., reduction in parking revenues, therefore, impact on local income); loss of jobs (e.g., taxi drivers, truck drivers and bus drivers may lose their means of subsistence and occupations); possible needed investments in infrastructure; and rules and regulations.

Certainly, Autonomous Vehicles will bring impacts that go far beyond the economic and ecological ones. In this way, the development of studies related to AVs must consider impacts on every society and its individuals, as well as factors inherent in its long-term implementation process. Therefore, the imminence of this arrival includes the need of understanding and developing new business models, hence, noting the emergence of a new productive ecosystem linked to servitization of Autonomous Vehicles is extremely important (KAMARGIANNI; MATYAS, 2017; IIVARI, 2016; CORWIN et al., 2016); as well as the importance to consider the impacts that this radical innovation can have on society, especially on the governance structure and functioning of institutions (WILLIAMSON, 2005).

Also worth mentioning is that business and management research on the field of vehicular automation are still incipient (GANDIA et al., 2018; CAVAZZA et al., 2017), therefore this doctoral thesis helps to contribute at adding in the development and consolidation of the thematic in the field of studies of social sciences as well as it helps on the advancement of Mobility as a Service, Product-Service System and Business Platform research.

In this sense, the theoretical approaches of Product-Service System (TUKKER, 2004; WONG, 2004; MONT, 2002) and Business Platforms (PARKER; VAN ALSTYNE; CHOUDARY, 2016; CHOUDARY, 2015; GAWER; CUSOMANO, 2002; SUGANO, 2005) seems appropriate to understand how Autonomous Vehicles will fit in future contexts of Mobility as a Service.

1.3 Thesis structure

This thesis was written in the form of scientific articles as provided on the “Manual of standards and structure of academic works” from Federal University of Lavras (UFLA, 2016). In this sense, the main components of this scientific document are:

Part one:

The **Introduction** is composed by the sections: Contextualization and motivation; Research question, Objectives and Justifications, and this final subsection; Project structure. The **Theoretical Background** is composed of the main concepts needed to the development and understanding of the research topic proposed in this project, being those: Urban Mobility in specific the news trends of Mobility as a Service; Autonomous Vehicles and their use within Product-Service Systems; Business Platforms in specific the Multi-sided Business Platform model and at last; Big Data and the role of Governance Structures. As for the **Methodology**, the details are described within each article on part two of this thesis; in part one, it is described the research ontology and research type. Next we present the **General Considerations** highlighting a synthesis of the main findings of each article as well the main research gaps and trends for future studies and the research limitations. At last, the bibliographical references of part one are listed according to the “*Associação Brasileira de Normas Técnicas*” - ABNT.

Part two:

In this session, the four articles that make up this doctoral thesis are presented: **article 1** - Human or machine driving? Comparing autonomous with traditional vehicles value curves and motives to use a car; **article 2** - Autonomous Vehicles as a Product-Service System: Typologies of uses; **article 3** - Business Platforms for Autonomous Vehicles within Urban Mobility, and; **article 4** - Governance of autonomous urban mobility platforms: A conceptual analysis within big data context.

2 THEORETICAL BACKGROUND

The aim of this section is to present the theoretical foundation that underpins this doctoral thesis, as a way to provide an initial theoretical-analytical support to the understanding of the research problem and, in this sense, to subsidize the conceptual boundaries to be used. It is worth emphasizing that it is not the scope here to exhaust the whole theoretical framework, but rather to outline the main models and theories for conducting the research.

2.1 Urban Mobility - a shift towards "servitization"

Nowadays, around 54 per cent of the world's population is currently living in urban areas (POPULATION REFERENCE BUREAU, 2016). Ranking by continent those figures are in order of 81% of North America, 80% of Latin America and Caribbean, 74% Europe, 69% Oceania, 49% Asia and 41% Africa. Furthermore, such global proportion is expected to increase to 66 per cent by 2050 when the world's population is expected to reach nine billion people (FOURNIER, 2017; EEA, 2013).

These people live their daily lives in the same space, and for their mobility, share the same infrastructure provided by their cities. In this sense, mobility is a key factor affecting citizens' well-being and quality of life influencing on urban geography, defining were people work, live, and therefore, on the way people commute (EUROPEAN COMMISION, 2017; MELIS et al., 2016). As pointed out by Attias (2017a) mobility is linked to social organization and can profoundly modify the attitudes of modern society to time, space, and inter-personal relationships.

Among the range of modals that comprise urban mobility (buses, trains, metros, tramways, bicycles, etc.), the automobile has historically been placed within the central core, being defined as a personal or family tool used for traveling from point A to point B as best as possible, as fast as possible, and with optimum safety, comfort and ergonomics.

In the 1950s, there were approximately 50 million automobiles in the world, by 2014 there were nearly 900 million and such number is steadily rising with a global trend of 3% per year with estimates of 1.3 million by 2030 and 2 billion by 2050 (FOURNIER, 2017; GAO et al., 2016). Nevertheless, we only spend about 15 days per year in our cars and a whole other year of our lives looking for a parking place (KLAPPENECKER et al., 2014) which accounts approximately for 95% idle time for the vehicle. Which when considering the socio-economic reality of the past recent years (focusing on downsides like noise, pollution, purchase prices, usage costs, etc) the car's image has been changing to automobile to "auto-immobile" (ATTIAS, 2017a) that is: a burden, a liability.

A direct consequence of this elevated number of vehicles is that worldwide, cities are increasingly facing problems caused by transport and traffic. Only in Europe, urban mobility currently accounts for 40 per cent of all CO2 emissions of road transport and up to 70 per cent of other pollutants from transport (EUROPEAN COMMISSION, 2017). In this regard, contemporary transport practices increasingly compromise the well-being of existing populations. Perhaps most importantly, the way we travel today is constraining and compromising the environment of generations still to come (MULLEY, 2017).

Therefore, the priority objective is now to enhance mobility and accessibility while, at the same time, reducing congestion, road accidents, and pollution in cities, given that the realization of more environment-friendly transportation systems is now a worldwide goal (CAO; WANG, 2017; AMBROSINO et al., 2016). In order to address this challenge, it is necessary to improve the conditions for sustainable travel through development of vehicle technology and infrastructure but also changes in people's travel behaviors, aiming on reducing private car dependency and the share of trips made with fossil-fueled vehicles (KARLSSON; SOCHOR; STRÖMBERG, 2016).

Still according to the authors, several types of interventions have been implemented to encourage individuals to shift their travel behavior, such as targeting psychological factors, or trying to motivate people through rewards and punishments, however further studies are needed to evaluate the results of such measures.

On a macro level, some countries are also taking actions as an attempt to solve this problem, Germany intends to ban the manufacturing of internal combustion engine vehicles by 2030 (SCHMITT, 2016), similarly France and England are planning to do so by 2040 and even emerging economies such as China and India have already set plans on banning the production and sale of vehicles powered only by fossil fuels (PETROFF, 2017). This trend is spreading worldwide with many other economies making efforts towards a future without fossil fuels dependency.

As elucidated by Fournier (2017), the current mobility paradigm based on fossil fuels and individual mobility is reaching its environmental, economic and social limits. Hence, the privately owned car will be more and more challenged as a solution to satisfy mobility needs in crammed urban areas with good public transport and more and more restrictive city regulation and taxes for vehicles.

Fundamental requirements in mobility are time, cost and comfort (KAMAU et al., 2016), according to the authors:

> Individual car ownership satisfies the comfort component to some extent, as well as the time component. However, owning and maintaining a car is prohibitive for many due to cost and convenience implications. In selecting other public modes of transportation, a taxi or rental car would provide a more comfortable ride with little to none waiting time and conforms to the passengers' mobility requirements. However, the cost is too high and cannot be sustained as a regular mode of transport. On the other hand, shared public transport such as bus or train is more affordable but requires the passenger to conform their schedule to a set timetable that operates no matter the changes in demand. (KAMAU et al., 2016, p. 1).

Efficient urban mobility is unlikely to be achieved without the provision of efficient, extensive and accessible transport options, in a sense that urban areas require robust mobility solutions which are well integrated in the overall urban planning system (AMBROSINO et al., 2016). For the authors, if this new understanding of transport solutions is to be achieved policy-makers, urban and mobility planners, and city stakeholders must undertake strong initiatives by adopting a multimodal and integrated approach.

Such argument is corroborated by Attias (2017a, p.10): "the mobility range is reconfigured and diversified to become multimodal (…) we are moving away from a set-up in which accessing mobility, i.e. freedom, involves owning a vehicle, and towards transportation in which journey satisfaction is determined by diverse means, ease of access, and low cost".

Still according to the author, "new behavior patterns, uses and mobility requirements are emerging that no longer view vehicles as an object of pleasure, freedom, and social mobility, and in which usage can substitute ownership". Studies in Germany, United States, and France have shown a decrease in people's interest on owning an automobile (FOURNIER, 2017), these social changes indicate that people (especially younger generations, such as millennials and generation Z) are very favorable to alternative solutions such as: car-sharing, car-pooling and rental. That is, "users today are not only seeking more rational management of journey times and mobility costs; they want to choose mobility rather than be subjected to it" (ATTIAS, 2017a p.8).

2.1.1 Mobility as a Service (MaaS)

As an attempt to provide an answer to these demands, the concept of Mobility as a Service (MaaS) has been gaining ground in recent years, since it presents a shift away from the existing ownership-based transport system toward an access-based one (JITTRAPIROM et al., 2017; MULLEY, 2017; KAMAGIANNI et al., 2016). As stated by Jittrapirom et al. (2017):

> MaaS is a very recent mobility construct, that can be thought of as a concept (a new idea for conceiving mobility), a phenomenon (occurring with the emergence of new behaviors and technologies) or as a new transport solution (which merges the different available transport modes and mobility services). (JITTRAPIROM et al., 2017, p. 14).

It is noteworthy, that given its promising prospects, there is still a high degree of ambiguity surrounding the concept with multiple sources vying to offer definitions of MaaS (JITTRAPIROM et al., 2017), but the essential idea is to see transport or mobility not as a physical asset to purchase (e.g. a car) but as a single service available on-demand incorporating a multimodal array of transport services (AMBROSINO et al., 2016).

The first comprehensive definition of MaaS was offered by Hietanen (2014), the author describes MaaS as a mobility distribution model that deliver users' transport needs through a single interface of a service provider by combining different transport modes to offer a tailored mobility package, like a monthly mobile phone contract.

Similarly, Karlsson, Sochor and Strömberg (2016) states that:

> MaaS aims on offering customized transport services to fit the individual traveler's needs and requirements, which can be achieved by uniting already existing transport solutions and transport providers, including public transport, taxi, car and bike sharing, as well as rental cars, and offering them in a package to customers through a single subscription service. (KARLSSON; SOCHOR; STRÖMBERG, 2016, p. 3266).

That is, MaaS is a way of putting users, both people and goods, at the core of transport services, offering tailor-made mobility solutions based on individual needs (MULLEY, 2017). For the author, there are three main concepts that define MaaS (MULLEY, 2017 p.248-249):

a) **Transport on Demand:** to meet a customer's needs, a MaaS service provider arranges the most suitable transport means, be it public transport, taxi or car rental, or even ride-, car- or bike-sharing.
b) **A Subscription Service:** users do not need to buy travel tickets or sign up for separate transport accounts since a MaaS account provides the freedom to choose the mobility you need, for an agreed period or pay-as-you-go subscription.

c) **Potential to create new markets:** for transport providers, MaaS can offer new sales channels, access to untapped customer demand, simplified user account and payment management, as well as richer data on travel demand patterns and dynamics.

Via MaaS systems, consumers can buy mobility services that are provided by the same or different operators by using a single platform; hence, the idea behind the concept is integrated and seamless mobility, which can be achieved based on ticket & payment integration; mobility packages and; Information and Communication Technologies - ICT (KAMARGIANNI et al., 2016).

On an effort to provide a more comprehensive understanding of the construct, Jittrapirom et al. (2017) carried out a critical literature review to identify the core characteristics of MaaS, where Table 1 summarizes their findings.

Table 1 - Description of MaaS' core characteristics (continue)

Core Characteristic	**Description**
1. Integration of transport modes	Brings together multi-modal transportation allowing the users to choose and facilitating them in their intermodal trips. Transport modes that may be included: public transport, taxi, car-sharing, ride-sharing, bike-sharing, car-rental, on-demand bus services.
2. Tariff option	Offers users two types of tariffs in accessing its mobility services: 1) mobility package (bundles of various transport modes and includes a certain amount of km/minutes/points that can be utilized in exchange for a monthly payment); 2) "pay-as-you-go" (charges users according to the effective use of the service).
3. One platform	Relies on a digital platform (mobile app or web page) through which the end-users can access to all the necessary services for their trips: trip planning, booking, ticketing, payment, and real-time information.
4. Multiple actors	Ecosystem is built on interactions between different groups of actors via a digital platform: demanders of mobility (private customer or business customer), a supplier of transport services (public or private) and platform owners (e.g. third party, PT provider, and authority). Other actors (e.g. local authorities, payment clearing, telecommunication and data management companies) can also cooperate to enable the functioning of the service and improve its efficiency:
5. Use of technologies	Combines different technologies: devices, such as computers and smartphones; reliable mobile internet network (WiFi, 3G, 4G, and LTE); GPS; e-ticketing and e-payment system; database management system and integrated infrastructure of technologies (i.e. IoT).

Table 1 - Description of MaaS' core characteristics (conclusion).

Core Characteristic	Description
6. Demand orientation	Seeks to offer a transport solution that is best from customer's perspective to be made via multimodal trip planning feature and inclusion of demand-responsive services.
7. Registration requirement	End-user is required to join the platform to access available services. The subscription not only facilitates the use of the services but also enables the service personalization.
8. Personalization	Ensures end-users' requirements and expectations are met more effectively and efficiently by considering the uniqueness of each customer. System provides specific recommendations and tailor-made solutions on the basis of users' profiles, expressed preferences, and past behaviors (e.g. travel history). Additionally, they may connect their social network profiles with their MaaS account.
9. Customization	Enables end-users to modify the offered service option in according to their preferences. This can increase MaaS' attractiveness among travelers and its customers' satisfaction and loyalty.

Source: Adapted from Jittrapirom et al., (2017, p.16).

"MaaS predicts a paradigm with service providers offering travelers easy, flexible, reliable, well-priced, and environmentally sustainable everyday travel, mixing public transport, car-sharing, car leasing, and road use, with more efficient goods shipping and delivery possibilities" (MULLEY, 2017 p.248). "It opens up opportunities for greater customer service and potential reductions in public subsidy for public transport service, it has the very real opportunity to match customer needs more closely to service supply" (HENSHER, 2017 p.90).

It is worth mentioning however, that "one of the biggest hurdles for transition to a Mobility as a Service business model is the need for a cultural shift, away from personal car ownership and reliance, towards the multiple, often shared and public mobility offerings" (Mulley, 2017 p. 249). Evidences across car-reliant cultures are pointing to a slow - but general - decline in car use and ownership, which can be noticed in all age groups but specially for the Millennials (MULLEY, 2017; SHAHEEN; COHEN, 2016; KARLSSON; SOCHOR; STRÖMBERG, 2016).

> Millennials appear to have a different cultural view of personal car ownership (…) they are technologically and culturally enabled for MaaS (…) however, perceptions need to change more widely than simply in the Millennial generation. Attitudes to ownership need to change (…) this shift is required for the majority of the population. (MULLEY, 2017, p. 250).

Changing attitudes can lead to changing consumer preferences, which in turn can lead to new travel behaviors; there are some signs of this happening with the year-on-year growth of car-sharing schemes in all areas of the globe (SHAHEEN; COHEN, 2016).

Mulley (2017, p.250) also highlights that besides this required shift in attitudes, there are two other factors pushing towards MaaS:

1) public health recognition of the contribution that active travel (both walking and cycling) can play in population health and in the reduction of lifestyle disease. The top-down public health messaging of greater physical activity gives MaaS wider options with active travel being offered as the trip or, in combination with the burgeoning delivery of cycle hire schemes, as first and last mile options. This is complemented by the (bottom up) greater take up of active transport, albeit from a low base, spanning from school-age participants through all working ages and maybe beyond, as older people remain fitter into the future.
2) a second push comes in the denser urban areas where planning approaches, particularly the abandonment of minimum car-park spaces in planning applications, and lack of space have some capacity to proactively discourage private car use.

It seems clear that the future will involve a mobility revolution combined with a cultural revolution of the entire industry. A number of transport summits in recent years (e.g., HANNON et al., 2016) have looked to the future of transport as informed by electric autonomous vehicles, big data analytics, internet of things, disruptive technologies, and customer service in the digital age.

“The majority of the literature on MaaS appears to focus on a changing role for the car, becoming a vehicle that is used but not owned, with cars available to be booked for a point-to-point trip, with or without a driver in the future as autonomous vehicles come on stream in volume” (HENSHER, 2017 p. 91). This is a very significant point, given that today there are just a couple thousands of driverless cars around the world - almost all in testing stages - however the estimates are that in 2035 that number will be around 10 million vehicles (NASCIMENTO; SALVADOR; VILICIC, 2017). Even though, it is worth noting that the majority of these 10 million AVs (in a forecasted universe of 1.3 billion cars by 2030) are likely to be luxury cars (MORDOR INTELLIGENCE, 2018).

Implementation of MaaS can have significant impacts to the existing business model of public transport, especially on the level of integration with private transport providers

(Jittrapirom et al., 2017). Such integration of services may be realized by using the so-called platform technology, which facilitates interactions between travelers and suppliers of transport services in an improved or smarter way (PARKER; VAN ALSTYNE; CHOUDARY, 2016; GAWER, 2014).

According to Jittrapirom et al., (2017) multisided platforms are models for MaaS and, besides few practical examples to date, experience can be gained from other industries such as ICT, telecommunications, and airlines industry (HAGIU; WRIGHT, 2015).

MaaS is not only about the integration of mobility services, but also requires a complete restructuring of the supply chain of mobility service providers. Over the next topics of this theoretical background the concepts and theories of Autonomous Vehicles as a Product-Service system and Business Platforms are better explored.

2.2 Autonomous Vehicles: an overview

Autonomous Vehicles (AVs) - better known as Automated Driving Systems (ADS); Self-driving Cars; Driverless Cars or even; Robotic Cars or Robotaxis - are vehicles with motion and action capabilities that don't require any sort of conductor (driver) or teleoperation control (FRAZZOLI; DAHLEH; FERON, 2002). The development of such cars is an important innovation that promises to have a great impact on the issues of urban mobility representing a potentially disruptive and beneficial change to the current transportation system business model (ATTIAS, 2017b; ENOCH, 2015; SCHELLEKENS, 2015; SCHREURS; STEUWER, 2015).

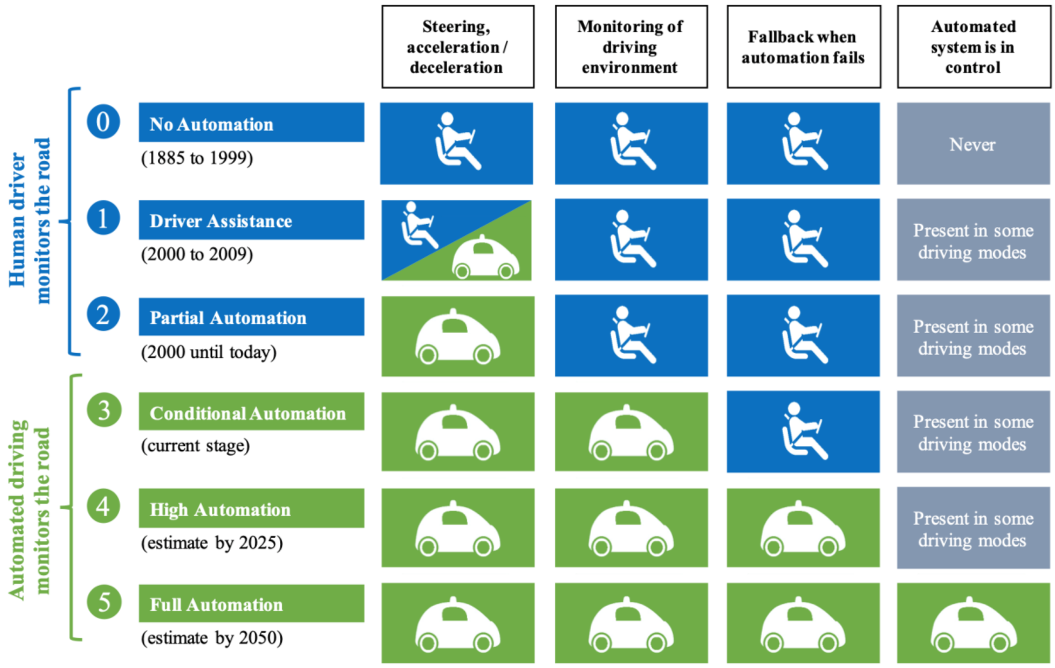
According to Lima (2015), the earliest records of AVs development happened in Japan in the mid-1970s, with a car-prototype that was able to track white street marks with computer vision at speeds up to 30 km/h. Only 10 years later, the first car-like robot would emerge in Europe in Bundeswehr University Munich (UniBW) on Germany as part of the PROMETHEUS project (GANDIA et al., 2018; LIMA, 2015).

Also in the 1980s, it was seen the first american contribution with a project called "No hands across America" from the Carnegie Mellon University (CMU) which has developed a car (Navlab 5) capable of performing autonomous navigation from Washington DC to San Diego with 98% automated steering and manual longitudinal control.

The watershed though, on AVs research and development, came on 2004 in the United States with a series of public annual challenges, named DARPA Gran Challenges (GANDIA et al., 2018), in which DARPA stands for: Defense Advanced Research Projects Agency of the United States. By means of them, countless contributions and advances have been made on vehicular automation over the past years (RESCHKA, 2015; POORSARTEP, 2014). As a consequence, many research centers and carmakers worldwide have continued advancing on the development of AVs.

The "Surface Vehicle Recommended Practice" from the Society of Automation Engineers (SAE, 2016) provides a taxonomy describing the full range of levels of driving automation in on-road motor vehicles. As depicted on Figure 1, there are six levels of driving automation, ranging from ZERO (no driving automation), to FIVE (full driving automation).

Figure 1 - SAE's automation levels.



Source: Adapted from SAE (2016) based on Nascimento, Salvador and Vilicic (2017).

It is worth mentioning that SAE's automation levels are descriptive and informative, rather than normative, and technical rather than legal with the elements indicating minimum rather than maximum capabilities for each level. Furthermore, the French authors Attias and Mira-Bonnardel (2017), state that levels 4 and 5 are considered by their country's authorities as really disruptive and in the future, French urban spaces will quite surely implement these last two levels on dedicated areas or lanes.

Autonomous technology is now the greatest bet of the big automakers, led in the United States by Ford, GM and Tesla and in Europe by Audi, Mercedes and Volvo, as well as the California technology giants such as Google and Uber (Nascimento, Salvador & Vilicic, 2017). According to the authors, Google's AVs (Waymo) have reached the mark of more than

5 million kilometers driven on American avenues, streets and roads and Uber's AVs have also reached over 1.5 million driven kilometers in their testing cities of Pittsburgh, Phoenix and Toronto.

In the meantime, numerous carmakers such as: Audi, BMW, Cadillac, Ford, GM, Mercedes-Benz, Nissan, Toyota, Volkswagen and Volvo, are already undergoing tests with AVs (FAGNANT; KOCKELMAN, 2015), not to mention that vehicles with semi-autonomous capabilities SAE's (2016) from level 2 and 3 of automation are already being marketed - such as Tesla's Roadster; Model S and Model X as well as Mercedes-Benz's S65, Infiniti's Q50S, BMW's 750i xDriv which are all within SAE's level 2 and most recently Audi's A8 which according to Nascimento, Salvador and Vilicic (2017) is the first mass produced vehicle to have a level 3 embedded autonomous driving system. However, it is important to note that these current semi-autonomous vehicles that are already being marketed mainly focus on the upper classes of the population, since they are luxury vehicles.

Also worth mentioning are the partnerships among companies, which have been a very common way for the development and advances of new AVs' technologies (e.g. BMW's alliance with Intel and Mobileye) and even for training new professionals in the field, such as the partnership among Mercedes Benz, McLaren, Otto, Nvidia, and Udacity (University of the Silicon Valley) to create an online course for training engineering professionals in the area.

Governments of several countries have also become interested in the significant benefits of vehicular automation. The United States was the first country to introduce legislations allowing the testing of AVs on their streets and roads. In several European countries (e.g. Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and England) lawmakers are considering ways to accommodate the development and testing of AVs' technologies on their roads as well. Similarly, Asian countries such as Japan, Singapore, China and South Korea are interested that international regulations are updated to allow the development of automated vehicle technologies (Schoitsch, 2016; U.K. Department for Transport, 2015).

Significant advances are also being made within the academia, as pointed out by Gandia et al. (2018), Cavazza et al. (2017), Lima (2015), Weick and Jain (2014) research centers and universities world-wide are striving to advance studies on technology mobility, vehicle-infrastructure interaction, and management and business-related issues for the consolidation of autonomous vehicles.

By representing a potentially disruptive and beneficial change to the current transportation business model, AVs are bound to change the future of urban mobility, and such transformation will not only affect the means of transport but society as a whole (ATTIAS, 2017b; MUTZ et al., 2016; SCHREURS; STEUWER, 2015; ENOCH, 2015). In this context, such vehicles will facilitate driving; increase road safety; reduce emissions of pollutants (since they will be electric); reduce traffic jams; as well as will allow drivers to choose to do different things other than driving (ATTIAS, 2017b; ENOCH, 2015; SCHELLEKENS, 2015; SCHREURS; STEUWER, 2015). Thus, access to fully automated vehicles will also improve mobility for those who cannot or do not want to drive, improving their quality of life (ATTIAS, 2017b; POORSARTEP, 2014). As a result, AVs can provide significant economic, environmental and social benefits (MUTZ et al., 2016; FAGNANT; KOCKELMAN, 2015; U.K. DEPARTMENT FOR TRANSPORT, 2015).

Nevertheless, there are still many questions that need to be answered before AVs reach the roads, to name a few: security and reliability issues; the possible impacts of autonomous driving on mobility behaviors and human-machine interactions; consumer acceptance; as well as regulatory and liability frameworks (NASCIMENTO; SALVADOR; VILICIC, 2017; SCHREURS; STEUWER, 2015; SCHELLEKENS, 2015). Those are relevant questions that need to be addressed and taken seriously by both governments and carmakers, since, according to Poorsartep (2014) technology itself is no longer the major hindrance for AVs' implementation, the major road blocks that AVs must now face are consumer acceptance and regulatory frameworks. Moreover, Guerra (2015) points out that it is still complex to understand how life will be affected by this disruptive innovation in a sense that the timing, scale, and direction of the AVs' impacts are uncertain and the opportunities to influence investment decisions are limited.

Therefore, according to Enoch (2015), the traditional transport model (dominated by private cars, taxis, and buses) could suffer an exponential decline in the coming years, giving rise to means of transport called "intermediaries" (mostly designed in the form of shared vehicles) such as AVs. In this sense, Schoitsch (2016) points out that the AVs are inserted in the most significant historical change for the society, economy, automobile and public transport industry.

Being so, these new AVs trends are concomitant with the generalization of so-called service economics - where owning a car will no longer be seen as a priority for users; thus, vehicles tend to be increasingly shared and the "mobility" function becomes the goal of market and business analysis.

2.2.1 Product-Service System (PSS), a business model approach for AVs

"While the industry has experienced some inertia in the past, over the past 15 years, there has been acceleration in innovations with the emergence of new types of vehicles, new services, new needs and uses that break with the traditional car model" (ATTIAS, 2017a p.2). For traditional carmakers (which have nevertheless experienced one or several industrial revolutions) the current revolution is totally different; because it calls into question the actual purpose of their production as well as their positioning in mobility value chains, where services are likely to increasingly represent a larger share than products (ALLANO, 2017).

In this regard, while cooperation with traditional players is necessary, Original Equipment Manufacturers (OEMs) find themselves obliged to form alliances with new entrants, often far removed from their core business; such as Google, Uber, Lyft, Apple among other tech-companies (ATTIAS; MIRA-BONNARDEL, 2017). Therefore, the traditional business model of selling cars as products is losing ground to alternative forms of commerce.

With new economic models emerging, major changes are taking place in the car industry, with a rising proportion of mobility service activities (ALLANO, 2017). As pointed out by Johnson and Mena (2008) manufacturers are combining products and services in order to provide greater value to the customer and to facilitate longer more profitable business relationships.

The concept of Product-Service System (PSS), also named as "functional sales", or "functional products", was first proposed by the United Nations Environment Program (UNEP) in the late 1990s, being first academically referenced by Goedkoop et al. (1999) as a marketable set of products and services capable of jointly fulfilling a user's need. Its core idea is to provide solutions to customers by the integration of "products" and "services", meeting customers' requirements while reducing resource consumption and environmental impacts (QU et al., 2016, p.2). Since then the concept has been gaining interest from both academia and practitioners in different fields, including urban mobility as exemplified by Baines et al., (2007) with a car-sharing model in Switzerland.

The premise behind PSS is that product design and manufacturing can no longer be the only source of competitive advantage and differentiation of companies (DE ZAN et al., 2015), therefore, a PSS is as a market proposition that extends the traditional functionality of a product by incorporating additional services where the emphasis is on the "sale of use" rather than the “sale of product”, therefore, the customer pays for using an asset, rather than purchasing it (BAINES et al., 2007; WONG, 2004).

One of the most used definitions of PSS is the one given by Mont (2002, p.239) in which the author states that a PSS is “a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models”. In their seminal literature review on PSS (BAINES et al., 2007) not only recognize the relevance of Mont’s definition but also made an effort to summarize the most recurrent definitions of the concept, their findings are depicted in Table 2.

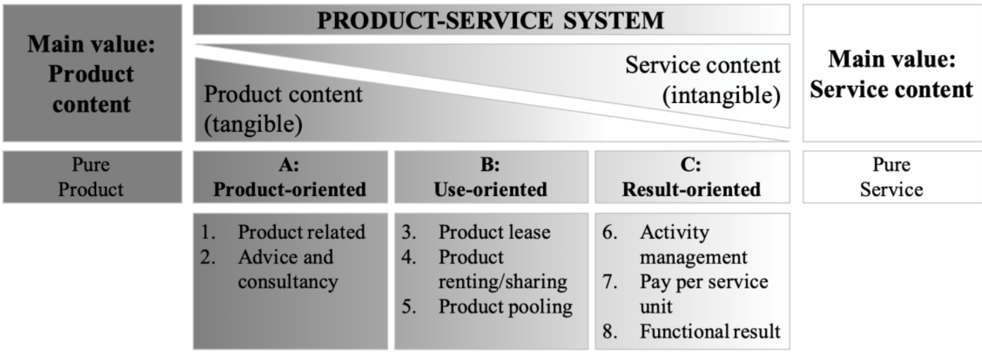
Table 2 - Popular definitions of Product-Service System.

Author	PSS definition
Goedkoop et al. (1999)	System of products, services, networks of “players” and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models.
Centre for Sustainable Design (2001)	A pre-designed system of products, supporting infrastructure and necessary networks that fulfil users’ needs on the market, have a smaller environmental impact than separate product and services with the same function fulfilment and as self-learning.
Mont (2002)	A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models.
Manzini (2003)	An innovation strategy, shifting the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services, which are jointly capable of fulfilling specific client demands.
Brandsotter (2003)	Consists of tangible products and intangible services, designed and combined so that they are jointly capable of fulfilling specific customer needs. Additionally trying to reach the goals of sustainable development.
Wong (2004)	A solution offered for sale that involves both a product and a service element, to deliver the required functionality.
Elima (2005)	A system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models.

Source: Adapted from Baines et al. (2007, p.1545).

Another important contribution to the PSS literature is the work from Tukker (2004) in which the author drew a categorization of eight PSS archetypical models that vary on a spectrum in which on one end the main value rests on product content (tangible) and on the other on service content (intangible), Figure 2 summarizes the author’s framework.

Figure 2 - Archetypical Product-Service System models.



Source: Adapted from Tukker (2004, p.248)

As shown on Figure 2 the eight typologies of PSS proposed by Tukker (2004) are divided into three macro categories:

a) **Product-oriented PSS**: the business model is still mainly geared towards sales of products (TUKKER, 2004), while including in the original act of sale additional services such as after-sales service to guarantee functionality and durability of the product owned by the customer (maintenance, repair, re-use and recycling, and helping customers optimize the application of a product through training and consulting). The company is motivated to introduce a PSS to minimize costs for a long-lasting, well-functioning product and to design products to take account of product end-of-life (re-usable/easily replaceable/ recyclable parts) (BAINES et al., 2007).
b) **Use-oriented PSS**: the traditional product still plays a central role, but the business model is not geared towards selling products. The product stays in ownership with the provider, and is made available in a different form, and sometimes shared by a number of users (TUKKER, 2004). In this case the company is motivated to create a PSS to maximize the use of the product needed to meet demand and to extend the life of the product and materials used to produce it (BAINES et al., 2007).
c) **Result-oriented PSS**: the client and provider in principle agree on a result, and there is no pre-determined product involved (TUKKER, 2004). Companies offer a customized mix of services (e.g. web information replacing directories, selling laundered clothes instead of a washing machine) where the producer maintains ownership of the product and the customer pays only for the provision of agreed results (BAINES et al., 2007).

Within each main category, there are PSSs with quite different characteristics, and based on Tukker's (2004) framework - and considering the premises of Mobility as a Service - Autonomous Vehicles are likely to be positioned on macro category B, that is, use-oriented PSSs, which according to the author is composed of three archetypical models:

a) **Product lease**: the service provider has ownership, and is also often responsible for maintenance, repair and control. The lessee pays a regular fee for the use of the product; in this case, normally he/she has unlimited and individual access to the leased product;
b) **Product renting or sharing**: the product in general is also owned by a service provider, who is also responsible for maintenance, repair, and control. The user pays for the use of the product. The main difference to product leasing is, however, that the user does not have unlimited and individual access; others can use the product at other times. The same product is sequentially used by different users;
c) **Product pooling**: This greatly resembles product renting or sharing. However, here there is a simultaneous use of the product.

In this sense, a business model in which cars are offered as services is gaining strength and it's being tackled by many companies and scholars. As Burns, Jordan and Scarborough (2013, p.101) stated: "using a shared, self-driving, and purpose built fleet of vehicles could reduce the total cost of ownership from US$1.60 per mile down to US$0.50 per mile, this is more than a 10-fold improvement compared to personally owned vehicles".

Nonetheless it is worth mentioning that the adoption of a PSS strategy brings with it significant cultural and corporate challenges. The majority of authors (e.g. GOEDKOOP et al., 1999, MANZINI et al., 2001; MONT, 2002) see the main barrier to the adoption of a PSS as the cultural shift necessary, for a consumer to place value on having a need met as opposed to owning a product. Wong (2004) argues that the success of a PSS solution in the consumer market is highly dependent on being sensitive to the culture in which it will operate.

Thus, making this PSSs models a reality will mean rethinking the way innovation process is organized so that the chosen production model fits in with mobility requirements (ATTIAS, 2017a). As Fournier (2017 p.21) emphasizes: "value propositions of mobility solutions will therefore deeply impact the future, since new vehicles and services will emerge; new players will reshape the value chain thus, challenging traditional OEM's with new products and services; even customers will be part of the value chain and become prosumers".

Over the next section of this theoretical background we will better detail the business model of platforms, which, as previously pointed out by Jittrapirom et al. (2017), is a model that perfectly fits MaaS and, consequently, the autonomous vehicles within this framework.

2.3 Platforms as business models

“Platform” is a technological jargon, quite often referred as an architectural foundation upon which third party companies build their technologies, products and/or services (GAWER; CUSOMANO, 2015; CUSOMANO, 2010; GAWER; CUSOMANO, 2002). However, as Sugano (2005) pointed out, the word platform has been extended beyond the technological terminology, being incorporated into the business realm.

One of the earliest mentions of this “transaction towards business” come from the works of Japanese professors Jiro Kokuryo and Ken-Ichi Imai (IMAI, 2000; IMAI; KOKURYO, 1994; KOKURYO, 1995; KOKURYO, 1999) in the mid and late-1990s in which they state that a “Business Platform” implies organizational relationships between a platform provider and suppliers of complementary products aimed on building complex systems that otherwise would not be possible to produce without the joint effort of each party (CARVALHO; DIAS; SUGANO, 2016; SUGANO, 2005).

According to Sugano (2005), Kokuryo and Imai’s premise is that the role of a business platform is to act as “promoter of transactions” by fulfilling the following functions: 1) searching for a transaction partner; 2) providing credibility and trust during the transaction; 3) providing standardized procedures (protocols) for transactions; 4) providing a fair evaluation of economic value (price) for products and services and; 5) providing a bundle of services for the delivery of products.

“Business platforms seek to enable interactions between companies in order to create value by the combination of inter-organizational resources (...) it can be seen as an architecture built to unite companies’ complementary capabilities in order to develop complex products or services” (FIGUEIRA, 2013, p.40). As a way to illustrate such definition, let us take a seminal example from Sugano (2005):

> Let’s think about how digital cameras have been used. This product’s main utility is to produce pictures that satisfy the owner’s needs for either printed or digital photos. However, when these pictures are uploaded to the Web, for example into an online album site, their utility is enlarged because they can be viewed regardless of location. Now, let’s also consider that the provider of this online album service and its customers agree to share their photos to

> publishers, providers of online printing, fax or even cable TV channel services. The joining of those distinct firms' capabilities into the same online album site (the business platform) has the potential to create value for the photos in ways previously unthinkable. (SUGANO, 2005, p. 6).

From this example, it is possible to extract some key theoretical concepts that acts as foundation pillars for the definitions of business platforms, such as:

a) **Transaction cost theory** (WILLIAMSON, 1979; 1991): which states that a firm organizes itself aiming on minimizing the opportunity costs derived from production processes. That is, weighing any given cost in making any economic trade when participating in a transaction;
b) **Core competences** (PRAHALAD; HAMEL, 1990): harmonized combination of multiple resources and skills that distinguish a firm in the marketplace and therefore are the foundation of companies' competitiveness;
c) **Resourced-based view - RBV** (BARNEY, 1991): building up on the core competences, resources such as tangible and intangible assets that the company controls and that can be used to create and implement strategies. Such resources must be valuable, rare among competitors, difficult to imitate, and without close strategic substitutes;
d) **Modularity** (MILES et al., 1997; ZENGER; HESTERLY, 1997; HOETKER, 2006; ARNHEITER; HARREN, 2006; BALDWIN; CLARK, 2000): modularization within firms leads to the disaggregation of the traditional form of hierarchical governance. It leads to a structure, in which the modules integrate strongly interdependent tasks, while the interdependencies between the modules are weak. Overall, modularization enables more flexible and quicker reaction to changing in general or market conditions;
e) **Information technology - IT** (SHAPIRO; VARIAN, 1999; IMAI, 2000): enabling relationships between organizations without, necessarily, a physical location. It provides an open infrastructure architecture in which various business activities can be coordinated at marginal production costs practically close to zero;
f) **Open innovation** (CHESBROUGH, 2003): utilizing external as well as internal ideas as inputs to the innovation process, combined with employing internal and external paths to market for the results of innovative activities;

g) **Business models dynamics** (OSTERWALDER, 2004; OSTERWALDER; PIGNEUR, 2010): describing the rationale of how organizations create, deliver, and capture value. It represents core aspects of a business, including purpose, business process, target customers, offerings, strategies, infrastructure, organizational structures, sourcing, trading practices, and operational processes and policies;
h) **Business ecosystems** (MOORE, 1993): considering a wider network of firms that influences how a focal firm (platform provider), creates and captures value. It entails a more holistic view of multisided network effects and multiple stakeholders' participation.

In this sense, because of certain (products'/services') commonalities, such as a common underlying technology, a common set of basic components, or targeting a related set of customers, companies' offerings can be managed as families with a common underlying logic: "the platform" (GAWER; HENDERSON, 2007; GAWER; CUSOMANO, 2002). That is: "a leading firm provides the core infrastructure (platform) for third parties' business development, which in turn, bring into the platform complementary pieces (modules) of business processes that complete the entire system" (SUGANO, 2005 p. 13).

Figueira (2013) states that platform thinking is thus defined as the process of identifying and exploiting the shared logic and structure in a firm's activities and offerings to achieve leveraged growth and variety. Thereafter, platforms create value for innovative ecosystem participants by structuring the innovation process around core and complementary elements and by creating the network effects that accelerate the adoption and use of platforms (GAWER; CUSOMANO, 2015; SHAPIRO; VARIAN, 1999).

Thus, business platforms have the ability to catalyze innovations by operating as a "bridge" between the real (physical place) and the virtual (informational space) (SUGANO, 2005). Therefore, platform ecosystems are common feature of the networked economy (PARKER; VAN ALSTYNE; CHOUDARY, 2016; CHOUDARY, 2015; EISENMANN; PARKER; VAN ALSTYNE, 2006; SHAPIRO; VARIAN, 1999).

The real, physical world or as simply put by Sugano (2005) as "place" is the physical arena where resources can be seen and touched, in which value creation is often accomplished with the movement of goods or services across the value chain - or as posited by Parker, van Alstyne and Choudary (2016): the "pipeline" business model. "Place" is also the *locus* for innovation, given the high pace of transformation in technology and business that is nowadays becoming pervasive in our economy.

The informational space, or simply “space” arises from the connections of information-based devices in the physical world (SUGANO, 2005). For the author, in “space” the information about a product/service can be separated from the product/service itself, and the effect of such separation on companies’ profits can become as critical as the actual product/service. In “space” what moves around is information (data) and not the product/service *per se*; as a consequence, customers’ convenience increases as information is available within the network; and transaction costs are drastically reduced.

Therefore, a platform is nothing more than a huge network of relationships between organizations around a core technology (CARVALHO; DIAS; SUGANO, 2016). For the authors, this network occurs dynamically, with organizations located in any region of the globe, which may have formal or informal relationships, exchange information physically or virtually, being from the same sector or from totally different sectors and having common goals or not; however, they are all in some way in a complementary relationship. It is a co-evolving ecosystem (KAMARGIANNI; MATYAS, 2017; IIVARI, 2016, MOORE, 1993) composed of a core provider (service provider), complementors and an interface that seamlessly link such complementors to the core (PARKER; VAN ASTYNE; CHOUDARY, 2016, SUGANO, 2005).

As Gawer and Cusomano (2002), Sugano (2005) and Shapiro and Varian (1999) point out, it is worth highlighting some key characteristics of the platform business model:

a) The premises of a business platform are based on the complementarity relationships between a core product/service or technology and other complementary products/services; and whose development in the central product/service entails a rearrangement of the system as a whole. Similarly, the development of innovations in the complementary sectors may also entail an adjustment in the core product/service. This means that the development of the platform is systemic, presenting externalities that can be positive or negative;
b) It is necessary that the platform provider has the domain of the architecture of the platform and the specifications of the interfaces that connect the complementary ones to the central product/service; thereby creating favorable bargaining conditions for the platform provider. In other words, the provider must assume the leadership position in the platform;

c) The critical point of a platform is to stimulate its adoption by the vast majority of users until it becomes a *de facto* standard in the market. Network effects and positive feedback are fundamental concepts to help the platform reach *de facto* standard.

In order to achieve that, Sugano (2005) states that the pattern of a platform's dissemination occurs essentially horizontally among a group of adopter companies or individuals, since a same business function is shared with multiple companies in the same or different industries. Baldwin and Woodard (2009) and Gawer (2010; 2009) highlight another important characteristic of business platforms: they are evolvable. According to the latter author, platforms are designed and used in three main settings: inside firms (product platform), across supply chains, or as industry platforms.

a) **Inside firms' platforms:** Also known as "product platforms" it happens in the context of new product development, and can be defined as a set of subsystems and interfaces that form a common structure from which a flow of derived products can be efficiently developed and produced. The main benefits of developing and using a product platform are: fixed cost reduction, efficiency gain in product development through the reuse of common parts, and in particular the ability to manufacture a wide array of products (GHAZAWNEH, 2010; GAWER, 2010);
b) **Supply chain platforms:** Very common in the automotive industry, this platform type extends the product platform concept to the context of a supply chain. The concept is similar to the product platform, the difference is that instead of being produced internally, the different elements of the final system are developed and manufactured by different suppliers along the value chain (FIGUEIRA, 2013, GAWER, 2010). Parallel to products platforms, the goal is also to increase efficiency and reduce costs (GAWER, 2010). For the author the benefits of this platform are: reduction of the variety of maintenance parts, productive efficiency, design flexibility and increase in products' variety;
c) **Industry platforms:** are composed of technological blocks that act as foundations on which a range of companies (group or independently organized) develop a portfolio of interrelated technologies products and/or services (GAWER & CUSOMANO, 2015; FIGUEIRA, 2013; GAWER, 2010). A key distinction

between the supply chain platform and the industry platform is that in the case of industrial platforms the firms involved do not necessarily buy and sell from one another, they are not necessarily part of the same supply chain and may not share common characteristics (GAWER, 2010). According to the author, the main empirical evidences of this type of platform are in fields of: computer science, telecommunications and other technology-intensive and information-intensive industries. However, such evidence is not limited to these contexts. At last, it is worth highlighting that there is a similarity to product platforms in that industry platforms provide a foundation of reusable common components or technologies, but they differ in that this foundation is ‘open’ to outside firms (GAWER; CUSOMANO, 2015).

Over the next subtopics of this theoretical background, the concept of “industry platform” (scope of this doctoral thesis) is better detailed, specifically its multi-sided characteristic enabled by the popularization of information technologies as well as the active of role of big data and how it may affect the governance models of such platforms.

2.3.1 Multi-sided business platforms: from consumers to prosumers

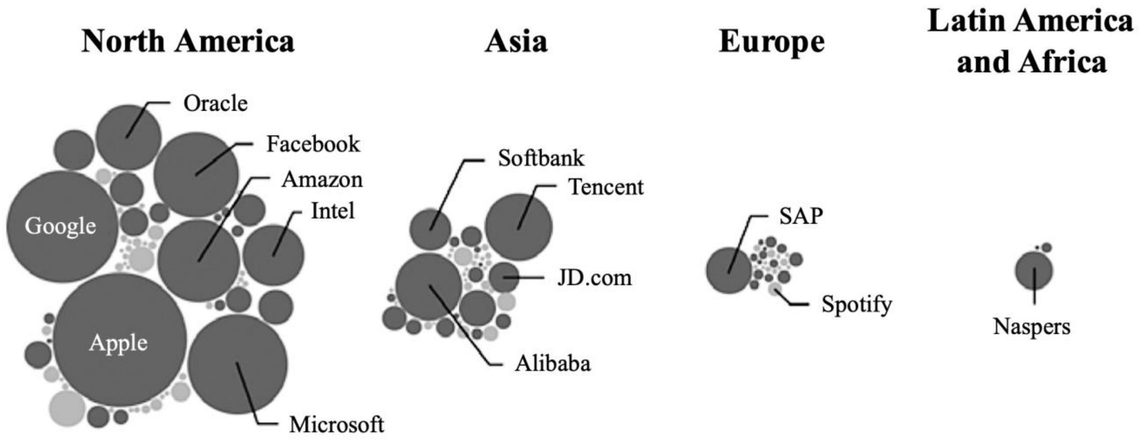
Industry platforms also commonly referred as “Multi-sided Platforms” (EVANS; GAWER, 2016; PARKER; VAN ALSTYNE; CHOUDARY, 2016; CHOUDARY, 2015; OSTERWALDER; PIGNEUR, 2010; EVANS, 2003; ROCHET; TIROLE, 2003) are responsible for a revolution that is affecting many industries across the globe. They are an important business phenomenon that have existed for a long time, but over the past 7-8 years proliferated with the widespread of information technology (PARKER; VAN ASLTYNE; CHOUDARY, 2016; OSTERWALDER; PIGNEUR, 2010).

Some successful examples of such platforms are: the Visa credit card, Microsoft Windows, Google search engine, Nintendo Wii, Android, Facebook, Youtube, Airbnb, Spotify, and Wikipedia. Such phenomenon is also seen within urban mobility with successful examples such as: Uber, Lyft, BlablaCar, GrabTaxi, and Didi Chuxing to name a few.

Multi-sided platforms are a transformative business model concept that is radically changing business, the economy, and society at large (PARKER; VAN ASLTYNE; CHOUDARY, 2016; EISENMANN; PARKER; VAN ALSTYNE, 2006). According to the authors, this phenomenon is so expressive that three of the world’s five largest firms as measured by market capitalization - Apple, Google, and Microsoft (to date) all run platform business models. Furthermore, incumbent giants from Walmart and Nike to John Deere, General Electrics, and Disney are all scrambling to adopt the platform approach to their businesses.

On a worldwide survey conducted in 2016, Evans and Gawer (2016) drew a distribution of platform firms per continent. As shown in Figure 3, North America is on the lead holding the most platform firms creating value (as measured by market capitalization) than any other continent. Asia comes in second, having China with its large homogeneous market growing fast. Europe comes in third with its more fragmented market, having less than a quarter of the value of such firms in North America. At last, the developing regions of Africa and Latin American are not far behind.

Figure 3 - Multi-sided platform firms' distribution per continent as measured by market capitalization.



Source: Adapted from Parker, van Asltyne and Choudary (2016) and Evans and Gawer (2016).

One of the key drivers for such revolution is the widespread popularization of information technologies, specifically the internet and mobile technology over the recent years, which, according to Choudary (2015), has allowed the:

a) **Democratization of access:** with the spread adoption of smartphones, laptops, tablets and other wearable connected devices as well as significant advances and popularization of mobile internet (3G; 4G; LTE and WIFI), people now have access to global markets wherever they are at any given time, being able to have access to unlimited sources of information at their fingertips;

b) **Democratization of production:** people today are no longer simply consumers of content, they have the ability to produce, to share, to create value on their own. It is not only about taking pictures and recording videos to post on Instagram, Facebook, or YouTube; think about 3D printers, people now have the ability to become manufacturing plants themselves; they can become hosts by having a room listed on Airbnb; become content producers by posting videos on YouTube, and even become taxi drivers by signing up to Uber for instance;
c) **Democratization of intelligence:** the Internet of Things (IoT) is transforming simple daily objects (such as thermostats, light bulbs, speakers, refrigerators, and cars) into connected, self-learning devices that are all the time gathering data and sending it to the cloud.

Therefore, for the author, if the internet had not come up, we would never have seen the emergence of platform business models; we would still be stuck in "pipeline business models" which had been, until recent years, the prevailing dominant business model wherein value is created in a linear fashion, with centrally employed staff and owned assets.

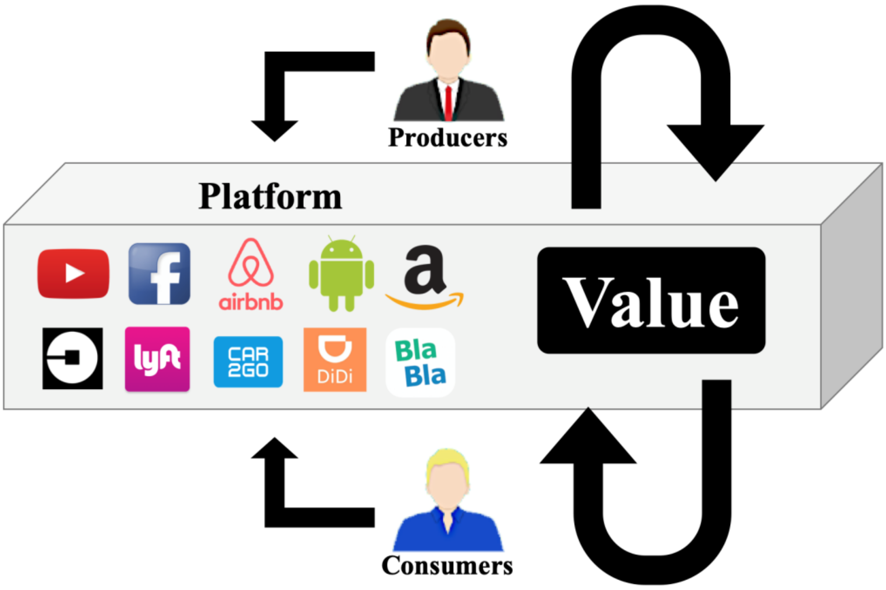
As exemplified by Choudary (2015), TV Channels work on a Pipe model but YouTube works on a Platform model. Encyclopedia Britannica worked on a Pipe model but Wikipedia has flipped it and built value on a Platform model. Furthermore, Uber the world's largest taxi company does not own a single taxi; Facebook the largest media company does not create the media, Alibaba the largest retailer does not own the inventory and Airbnb the world's largest accommodation provider does not own any rooms."

Unlike pipes, multi-sided platforms create value by orchestrating interactions between external producers and consumers (EVANS; GAWER, 2016; PARKER; VAN ASLTYNE; CHOUDARY, 2016; OSTERWALDER; PIGNEUR, 2010; EISENMANN; PARKER; VAN ALSTYNE, 2006). At the technology layer, external developers can extend platform functionality using Application Programming Interfaces (APIs) while at the business layer, users (producers) can create value on the platform for other users (consumers) to consume.

Therefore, the role of multi-sided platforms is to bring together two or more distinct but interdependent groups of customers (people or entities), creating value by connecting these groups without necessarily having the possession of any transacted good (EVANS; GAWER, 2016; OSTERWALDER; PIGNEUR, 2010). Therefore, with the goal of enabling interactions between producers and consumers, the technology (algorithm) is just a tool that will facilitate the exchange (PARKER; VAN ASTYNE; CHOUDARY, 2016).

Figure 4 illustrates in synthesis the operation of a multi-sided business platforms. In the center we have the platform itself (represented here by several successful platform firms, with highlights to the second row that contains examples of platform firms within urban mobility); on the top we have the producers (having Airbnb as example: the hosts, people who have rooms, houses, apartments, etc., available for rent); on the bottom we have the consumers (in Airbnb's case: the guests, people who are looking for an accommodation to rent); therefore, the role of the platform operator (Airbnb) is bring both sides together (producers and consumers) and create value for all in the process.

Figure 4 - Multi-sided platform design.



Source: Prepared by the author.

A platform must be built around a "core interaction", that is the "unit of value" to be exchanged must be clearly defined as well the involved participants and the desired algorithm filters (TURA, KUTVONEN; RITALA, 2017; PARKER; VAN ASTYNE; CHOUDARY, 2016; EVANS; GAWER, 2016; EISENMANN; PARKER; VAN ALSTYNE, 2006; EVANS, 2003), hence, the main aspects of multi-sided business platforms are: pull, facilitate and match.

a) **Platforms must be able to "pull" the two sides together:** the platform's value for a particular user group depends substantially on the number of users on the platform's other side. This is what many authors refer as the "chicken and egg dilemma", that is: without consumers there are no producers and without producers there are no consumers;

b) **Platforms must "facilitate" interactions:** unlike pipeline businesses, platforms don't control value creation; therefore, they must make it as easy as possible for producers to create and exchange valuable goods and services via the platform by reducing barriers to usage but at the same time by building governance rules for curating such value units and other producer-created content in order to encourage desirable interactions and discourage undesirable ones;

c) **Platforms must correctly "match" producers to consumers:** by constantly capturing data and better filtering the results a successful platform creates efficiencies by matching the right users with one another and ensuring that the most relevant goods and services are being exchanged. The more data the platform has to work with - and the better designed the algorithms used to collect, organize, sort, parse, and interpret the data - the more accurate the filters, the more relevant and useful the information exchanged, and the more rewarding the ultimate match between producer and consumer.

It is worth emphasizing that the "chicken and egg dilemma" is a serious issue that can hinder the success of platforms, therefore, finding a way around this problem is crucial for platforms' development. Parker, van Astyne and Choudary (2016) ranked in their book eight possible ways for beating such dilemma. Among those, we highlight here one solution that has also been described by Osterwalder and Pigneur (2010) which is the so-called "one-way multi-sided platform".

The idea behind this concept is to subsidize one side of the platform (normally the customer segment). By doing so the platform operator incurs costs to provide tools, products, services, or other benefits that will attract users to one side of the platform. Once there is a critical mass of users on one side, users will be attracted to the other side, leading to an inflexion point where "one-way platforms" become "two-way platforms" based on network effects and positive feedback loops hindering mute the need for subsidies. The following example better illustrates the aforementioned definition:

> One example (of one-way multi-sided platform) is "Metro", the free daily newspaper that originated in Stockholm and can now be found in many large cities worldwide. It launched in 1995 and immediately attracted a large readership because it was distributed free of charge to urban commuters in

> train and bus stations throughout Stockholm. This allowed it to attract advertisers and rapidly become profitable. (OSTERWALDER; PIGNEUR, 2010, p. 79).

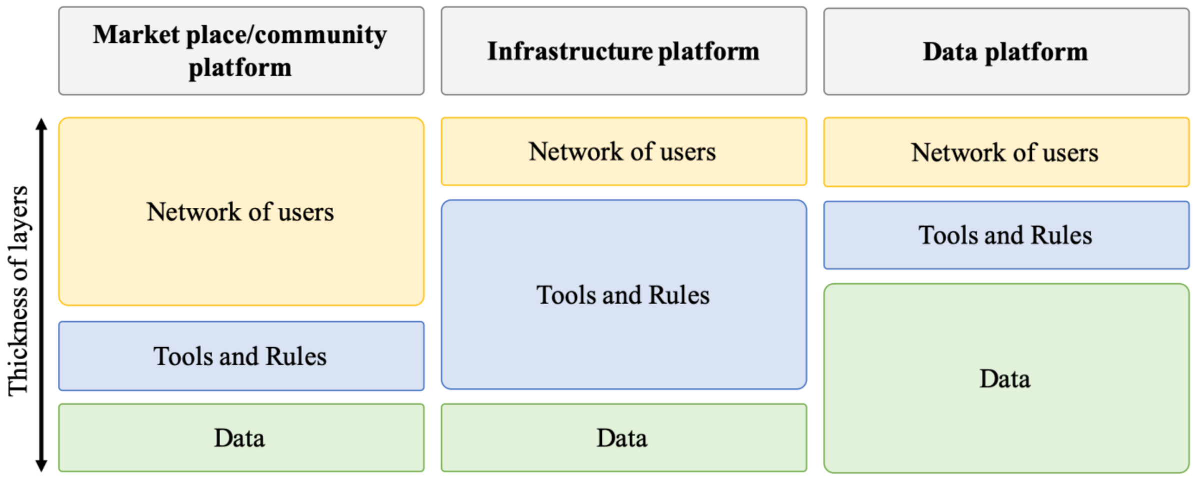
Another important aspect of multi-sided industry platforms is that besides having an underlying common logic of connecting producers to consumers and creating value in the process, such business model may present itself in different configurations. As Choudary (2015) exemplifies:

> From the perspective of software developers, Android, Salesforce, and Facebook Connect are all platforms, yet they are vastly different. Medium and WordPress are called blogging platforms, but they have little in common with software development platforms. YouTube, Facebook, and Instagram are described as social platforms, while Uber, Airbnb, and their ilk are referred to as “marketplace platforms (CHOUDARY, 2015, p. 98).

As the author states, all these businesses are vastly different from each other but they all share a common underlying structure composed of three distinct layers: 1) network of users; 2) tools and rules; and 3) data. This set of layers was called by the author as the “platform stack framework”.

“The platform stack demonstrates that a taxonomy of platforms doesn’t require us to define different families of platforms, in a sense that well-defined boundaries do not exist. Platforms do not fall in different families; they are best represented as different configurations of one stack” (CHOUDARY, 2015, p.113). Therefore, what will define the different configurations is how thick (expressive) one layer is compared to the others. Figure 5, better details such concept.

Figure 5 - Multi-sided platforms configurations.



Source: Prepared by the author based on Choudary (2015, p.105-138)

As described in Figure 5, platforms with a thicker network layer fall within the authors' "market place/community" platform configuration, that is, social networks companies (such as: Facebook; Twitter; Instagram) and shared economy companies (e.g., Uber; Blablacar); tools and rules as well as data are, of course, important elements in these platforms, but what set them apart is the massive network of producers and consumers that interact on the platform.

"Infrastructure" platforms, also called by the Choudary (2015) as "Developer" and "Content production" platforms on the other hand are known by very well defined tools and rules, Android for instance sets clear specifications for developers to build their Apps on. Finally, "data" platforms comprise those companies that are very good on gathering information and making good use out of them, "Internet of Things" (IoT) devices (such as: AVs) are well fitted within this categorization. It is worth mentioning, that the boundaries between each platform configuration is relatively blurred, therefore, certain platform firms may be in between the defined configurations.

Furthermore, Choudary (2015) states that the ultimate ambition of many platform companies is to become "data orchestrators", that is to have an expressive data layer on their platform stacks. Given that in the digital age, "data is the new dollar", data capture must be encouraged within all platform's business models, since as pointed out by Seiberth and Gründinger (2018) data are not only transforming isolated markets, they transform the whole economy, with several leading companies worldwide embracing data-driven business models. Thereby, as Peter Sondergaard (Global Head of Research at Gartner) stated: "information is the oil of the 21st century, and analytics is the combustion engine" (WEST-OLIVER, 2014, p.2).

2.3.2 The Role of Big Data and Governance on Urban Mobility Platforms

As posited by Aris et al. (2015), by 2020 IoT devices would generate economic value-add of 1.9 trillion dollars with the transportation sector accounting for 6% of it. In addition, Ferràs-Hernández, Tarrats-Pons and Arimany-Serrat (2017) highlight that with electronics gaining weight in the technological configuration of transport modes, along with the need for sustainable solutions and the emergence of sharing platforms, the dynamics of the whole sector is witnessing a paradigm shift.

The car - which will likely be self-driven - is being converted into a sensor platform, it is being transformed into a big data orchestrator, (GERLA et al., 2014; MIKUSZ; JUD;

SCHÄFER, 2015; SHAPIRO, 2016). Furthermore, as pointed out by Casey and Valovirta (2016, p. 5), infrastructure, vehicles and end-user handsets are becoming increasingly intelligent and instrumented with sensors and broadband connectivity. For the authors, this creates a wide range of smart mobility services, from usage-based vehicle insurance to multimodal trip planning and to seamless door-to-door mobility services.

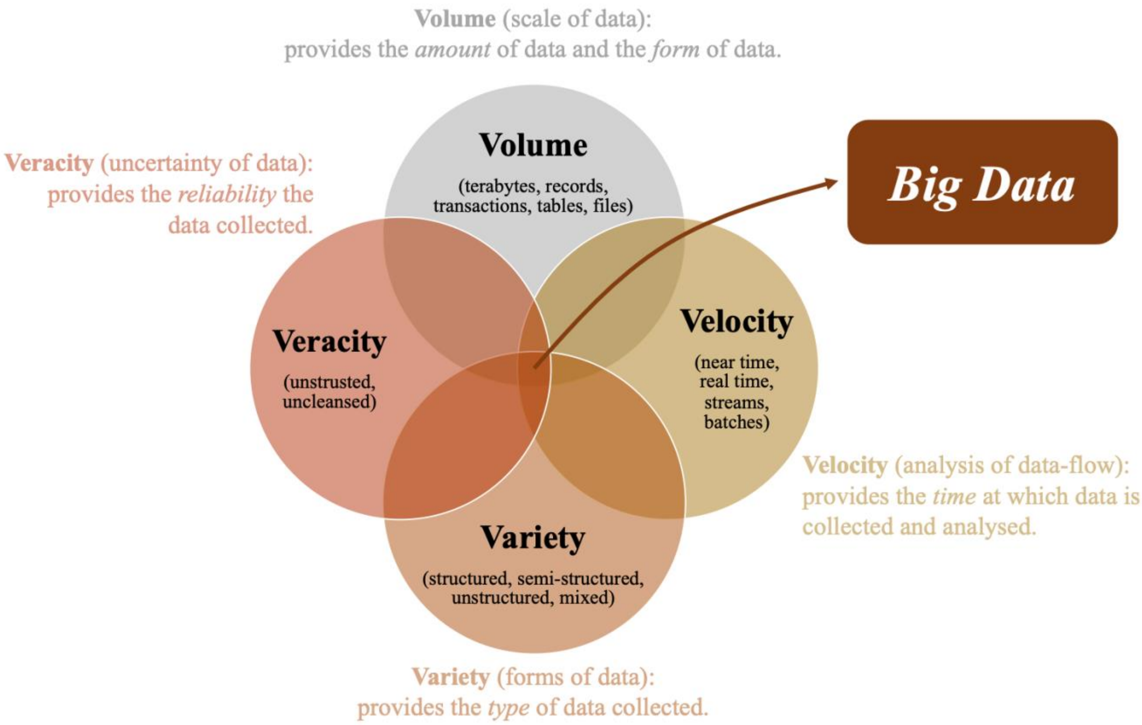
Thus, the automotive value chain - which has traditionally been closed by incumbents - is becoming a value chain open to digital experts (FERRÀS-HERNÁNDEZ; TARRATS-PONS; ARIMANY-SERRAT, 2017).

Thus, with the rise of big data technology, the urban mobility operational landscape is rapidly changing with the emergence of "connected" vehicles (GRAHAM et al., 2016) and according to Gissler (2015) it is estimated that by 2025, all new passenger vehicles will be connected.

In the age of IoT, data is everywhere and the term "big data" represents a large data pool with significant variety and complexity (MANYIKA et al., 2011). For Sheng, Amankwah-Amoah and Wang (2017, p.98), big data can be defined as "extremely large amounts of structured, semi structured or unstructured data continuously generated from diversified sources, which inundates business operations in real-time and impacts on decision-making by mining insightful information".

That is, big data is the consequence of large amounts of data resulting from increased automation, improvements in sensing, storage and communication technologies, exceeding capabilities to use and understand with traditional tools and methods (SANCHEZ-MARTINEZ; MUNIZAGA, 2016). Figure 6 depicts the four important dimensions of big data: volume, variety, velocity and, veracity.

Figure 6 - The 4 V's of big data.



Source: prepared by the authors based on Chen, Mao and Liu (2014).

Big data can therefore, address transportation issues in a more efficient and (near) real-time manner (TRANOS; MACK, 2018). As stated by Graham et al. (2016):

> While in traditional operations models, big data is used to enhance visibility over existing processes, in emerging operations models big data is one of the primary inputs enabling the provision of the service (...) since these service operations' rely more heavily on intangible inputs, namely information (...). With big data, companies are able to monitor supply and demand in real-time and even to identify challenges ahead of time (...) new entrants are using big data to innovate entirely new operations models to deliver new products and services based on a closer understanding of customer's on-going needs. (GRAHAM et al., 2016, p. 4-5).

Complementarily, Milne and Watling (2018) state that big data in transport planning will replace much of the information previously collected manually. However, for the authors, the greater the number of information providers, the more difficult it may become to coordinate that information and control policies based upon it. Thus, the challenge is that not only technical, since governance arrangements are critical to the success of mobility data platforms (VEENEMAN et al., 2018).

According to Bevir (2013), governance refers to processes, social practices and activities performed by institutions or actors. That is, it is the institutional framework in which transactions are actually carried out or decided (LEITE; LANZER; SERRA, 2009).

The drive for greater efficiency and cost reductions has forced many organizations to specialize in a limited number of key areas (MCIVOR, 2009; HAMEL; PRAHALAD, 1990), thereby, the studies of governance mechanisms have an applied orientation, with emphasis on the modes of contractual relations among firms (WILLIAMSON, 2005).

As highlighted by Antonialli, Antonialli and Santos (2017), the theory of governance structures was developed by the 2009 Nobel Prize winner in economics Oliver Williamson way back in 1991, whose purpose was to present new institutional arrangements beyond the market. The main premise defended by Williamson (1991) was to show that the market is not the only suitable arrangement for the purpose of organizing the economic system, thus contradicting what is advocated by the orthodoxy economics (SANTOS; MIRA, 2014; FIANI, 2013).

According to the theory proposed by Williamson, transactions can be organized under three distinct structural governance alternatives: market; hybrid and; hierarchy (CROOK et al., 2013). Therefore managers should select the governance structure that minimizes the firm’s transaction costs, complementarily, such choice must be made by comparing the cost of each governance structure with the others (SILVA; SALES, 2007; WILLIAMSON, 1991). Table 3 presents the three forms of governance proposed by Williamson (1991), as well as their main features.

Table 3 -Governance modes and their main features. (continue)

Governance mode	Main features
Market (exchange of services)	• Suitable for transactions with low assets’ specificity, it doesn´t have specific rules for a given individual transaction, only general rules that can be applied to any transaction. • Bureaucracy costs are almost absent. Adaptation to possible disorders will be by autonomous adaptation, where buyers and sellers react opportunistically, thinking on individual gains. • The contracts assume a classic format, where formal clauses specify the characteristics of the transactions involved with the identity of the parties being irrelevant and the transactions highly monetized.

Table 3 - Governance modes and their main features. (conclusion)

Governance mode	Main features
Hierarchy (authority)	• Occurs when the governance costs are lower than those on the market or on hybrids modes. Decisions occur by authority. The activities that could occur among multiple firms occur within a single company. • There is a replacement of autonomous adaptation by coordinated adaptation. The mutual interdependence relationships are so important that there is a need to adopt business solutions requiring the imposition of administrative controls, which generates high bureaucracy costs. • The type of contract used in this structure is relational because transactions are more flexible, with the possibility of continuous negotiation. Thus, there is the prevalence of indulgence, or a law of implicit contracts.
Hybrid or Network (mutual adjustment)	• Distinct from markets and hierarchies for being specialized in dealing with bilateral dependence. When compared to the market, sacrifices incentives in favor of a greater coordination among the parties, as compared to the hierarchy, sacrifices cooperativeness in favor of a greater intensity of incentives. • Asset specificity is intermediate, so the adaptation choice depends on (i) whether or not there is a bilateral dependency; and (ii) if the distribution gains are well established or not. • Contracts are of the neoclassical type; where prices play an important role as an adjustment factor, but are restricted by the presence of specific assets, at the same time safeguards are difficult to implement.

Source: adapted from Antonialli, Antonialli and Santos (2017, p.3-4).

Whereas transactions are moved from market to hybrid forms and hierarchies, an increase in authority allows for greater monitoring and control by simplifying conflicts' resolution (CROOK et al., 2013). On the other hand, the lack of authority in the market is compensated by the presence of incentives. Hierarchies provide fewer incentives because typically only a small portion of compensation to employees in the firm is tied directly to performance (WILLIAMSON, 2005).

With that, the following question arises: which form of governance should the firm adopt? As stated by Williamson (1991), Otto and Chobotová (2003), Menard (2006), Leite, Lanzer and Serra (2009) the answer to this question relates to the attributes of the transactions themselves, which are:

1) **Uncertainty:** unpredictable aspects of transactions that may be caused by the agent´s behavior, organizational deficiencies, inadequate institutions and serendipity. The greater the uncertainty, the greater the transaction costs;

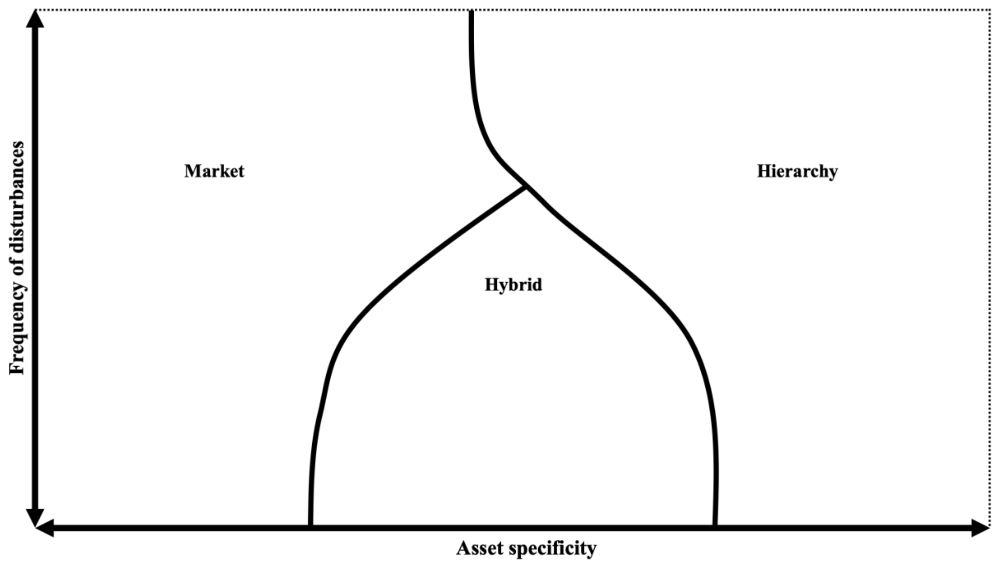
2) **Frequency:** number of times in which the transactions occur. Frequent transactions tend to make the costs fall, because they facilitate the establishment of governance systems that are not the market (classic contracts) and;
3) **Assets specificity:** degree to which assets can be re-employed. It is the most important attribute of a transaction, since it determines the volume of transaction costs.

As investment in assets (both tangible and intangible) increases, the cost to perform the transaction via market is higher than in more complex structures. Therefore, the greater the degree of assets' specificity, the greater the need for safeguards to prevent opportunistic behavior from the other party (MOURAD; ZYLBERSTAJN, 2010).

Thus, when an asset presents lower specificity, market is the best form of coordination, due to its lower cost. From the moment that the specificity increases to a medium level, the hybrid form is the most suitable. And, when asset specificity is high, hierarchy is the best alternative to avoid opportunistic behavior and minimize transaction costs.

Frequency of disturbances (uncertainty) also plays an important role in transactions; once predicting futures events is uncertain, no contract is complete; therefore opportunistic actions are imminent (SILVA; SAES, 2007). Figure 7, proposed by Williamson (1991), describes the governance mechanisms combined according to asset specificity and frequency of disturbance.

Figure 7 - Governance responses to changes in disturbances frequency and asset specificity.



Source: adapted from Williamson (1991, p.292).

Hereupon, a proper governance structure is pivotal for enhancing all possibilities that mobility data platforms could achieve. According to Yap & Munizaga (2018), in such platforms, technical challenges can be solved easier, whereas institutional or governance challenges tend to be more complex.

For the authors, this complexity is the result of the necessary coordination and cooperation between public and private stakeholders that are not always aligned. Thus, as posited by Veeneman et al. (2018): the more a platform relies on personal data, the more privacy regulations condition the set-up of the platform; the more stakeholders are involved, the harder it is to accomplish direction and; the more technical ambition the platform has, the more misfits with existing institutions.

This context elevates the need for a clear and efficient governance structure and coordination in a sense that for mobility data platforms, data have to cross several institutional borders, including organizational ones, between departments, public-private ones and the barriers between supply and demand. Therefore, governance is important to contribute to the efficiency and effectiveness of arrangements over those borders (PROVAN; KENIS, 2008).

3 METHODOLOGY

Academic research needs to be strategically managed, integrating its objectives with the demands of society, developing knowledge (theory) that is actually applied (practice) in the sense of seeking solutions to everyday problems, as well as new ways of improving the world (SOUZA; SOUZA; ZAMBALDE, 2016).

With the general objective of propose and discuss business platforms' scenarios for Autonomous Vehicles under the perspective of a Product-Service System within distinct urban mobility contexts, we stablished in this section the research ontology and research type and the description of the methodological procedures that guided the investigations - taking into account that this doctoral thesis was written in forms of academic articles.

With a constructivist ontological foundation, the present research is classified as descriptive and qualitative with the use of the mixed-methods approach for data collection, comprised of secondary data collection on academic and grey literature, on-line questionnaires, in-depth interviews and focus groups. As for data analysis, content categorical analysis was carried out based on Bardin (2010) and Vergara (2005).

The methodological strategy was guided by the constructivist ontology because it corresponds to a vision of reality where subject and object are in interaction for the construction, creation, organization, and development of knowledge (RODWELL, 2015; MARIZ et al., 2005). In this way, considering structural, cognitive, communication, interpretation, and flexibility issues, constructivist research provides practical guidelines for understanding and managing a context, which also allows for expanded indications on how to deal with similar problems (RODWELL, 2015).

According to Gil (2008), descriptive research aims on describing the characteristics of certain populations or phenomena. For the author, one of its peculiarities is the use of standardized techniques of data collection, such as questionnaires, in-depth interviews and systematic observation.

Yin (2011) states that qualitative research is based on the interpretation of the phenomena and the attribution of meanings, being the natural environment a direct source for data collection and the researcher, the key instrument. In this sense, the qualitative research is indicated when there is a greater concern with the understanding of a theme, not aiming at the generalization (BAUER; GASKELL, 2008).

Therefore, the qualitative approach is based on a broad question that involves descriptive data collected through the direct contact of the researcher with the context, aiming on understanding the phenomena according to the perspective of the participants of the circumstance under study (GIL, 2008; MALHOTRA, 2001; GODOY, 1995). For Malhotra (2001), it is a type of non-structured and exploratory research based on small samples that provides insights and understanding of the problem's context. Its main feature is the use of open-ended questions, with no predetermined answers (MCDANIEL; GATES, 2003).

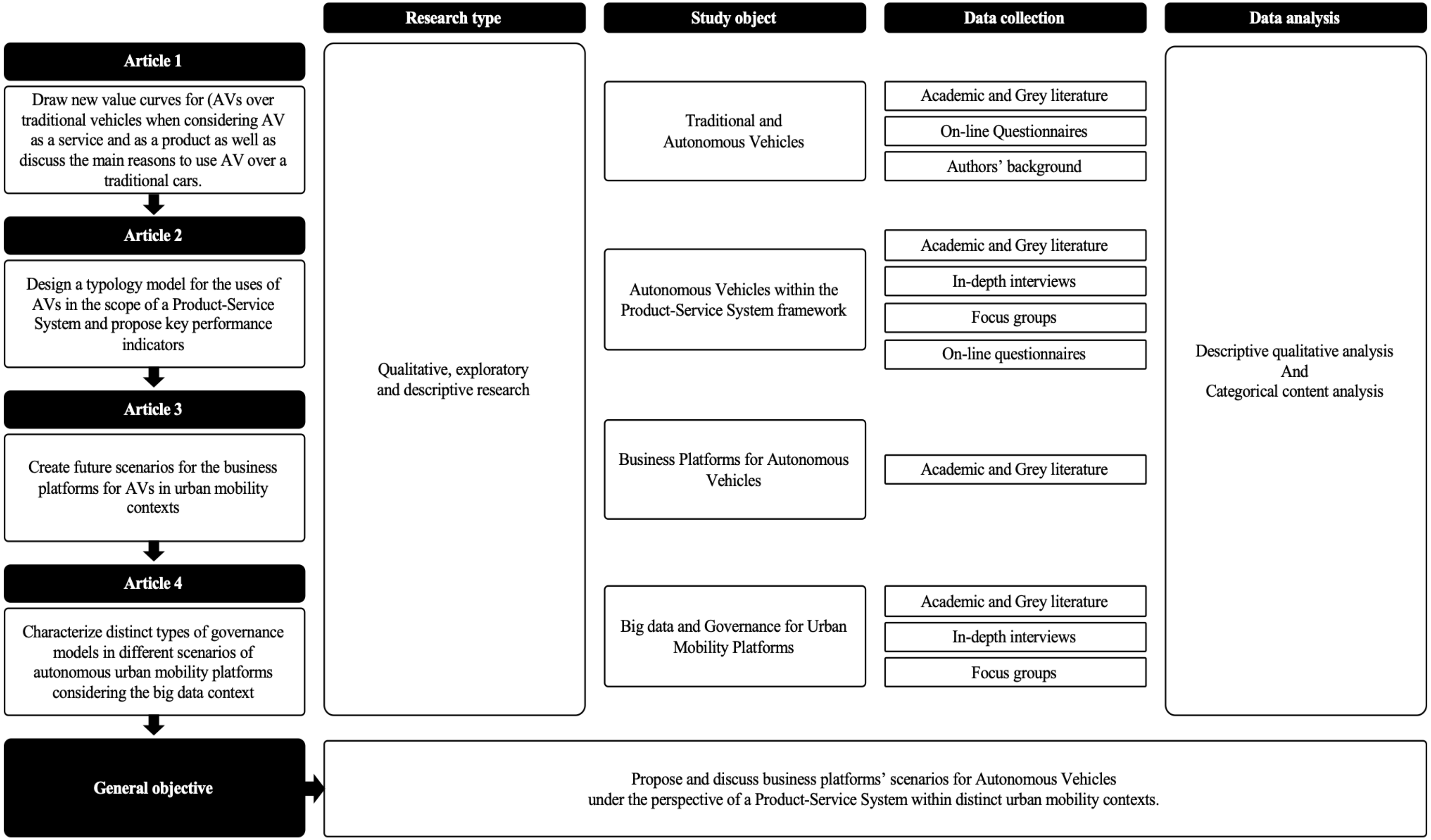
It should also be noted that the sequence that underlies this doctoral thesis is as follows: Article 1 - **Human or machine driving? Comparing autonomous with traditional vehicles value curves and motives to use a car**, Article 2 - **Autonomous Vehicles as a Product-Service System: Typologies of uses**, Article 3 - **Business Platforms for Autonomous Vehicles within Urban Mobility** and; Article 4 - **Governance of autonomous urban mobility platforms: A conceptual analysis within big data context**.

Over part two of this thesis, the details of the methodological procedures are described within each paper that make up this doctoral thesis.

3.1 Summary of the thesis' methodology

Figure 8 provides an overview of the research outline that had been carried out in this doctoral thesis.

Figure 8 - Summary of the research methodology.



Source: Prepared by the author

4 GENERAL CONSIDERATIONS

As this thesis was drawn up in the form of articles, the detailed conclusions are displayed on Part Two of this manuscript within each of the four articles. However, the main considerations are presented here as well as some suggestions for future studies and research limitations.

From the general objective of proposing and discussing business platforms for autonomous vehicles under the product-service system perspective within mobility as a service, this thesis was elaborated in such a way that the results obtained in the first article were meant to serve as a basis for the elaboration of the second article, which in turn served as a basis for the third and so on.

With this, we initially sought on paper 1 to understand in what possible ways Autonomous Vehicles will most likely reach the market, by positing the following question: would they arrive as goods (products to be purchased) or would they arrive as services to be used? In this sense, based on the four-action framework proposed by Kim and Mauborgne, (2005) we initially sought to draw the value curves for AVs both as a product and a service over the value curves of traditional (human-driven) vehicles.

The results have shown that both curves for AVs (product and service) present a mirror-like behavior when compared to the curve of traditional vehicles, in a sense that attributes once taken for granted on traditional cars appear on both AVs' curves as either eliminated or reduced, and after crossing the inflection point, the attributes considered as non-essential and/or non-existent for traditional cars will most likely be raised or even created in the autonomous cars. That is, results point to the arrival of a new vehicle concept that might include different ownership forms, more free time for users to enjoy "infotainement" options on the commute, as well as social integration of elders, handicapped users and other groups.

The value curve of AVs as a service is even more distinct than the curve of AVs as a product when compared to the traditional vehicles, in a sense that, besides having all the attributes related to the technological issues of AVs' deployment, it is also necessary to consider in this business model, all the attributes related to the implementation of such vehicles in the market as services, rather than as products.

The first conclusion reached on article 1 is that AVs' arrival in the market as services (instead of products) is a disruptive innovation that promises to cause great impacts in the current transportation and mobility industry, simultaneously causing the extinction adaptation of many markets, adaptation of many others and the consequent creation of new ones.

Furthermore, based on both human and machine attributes used to draw the value curves, a second questioning was raised taking into account the instrumental, symbolic and affective motives for vehicles' usage as depicted by Steg (2005). By proposing an analytical framework it was observed that as automation levels increase, machine driving components also increase (while human attributes decrease), in this sense it is most likely that Steg's motives to use a car will be reconfigured, with a probable increase in the instrumental motives and a reconfiguration of the symbolic and affective ones in a sense that the car will come to be seen much more as an on-demand service rather than a personally owned asset.

On the premise elucidated on paper 1 - that AVs will most likely first hit the market in the form of services - the second paper of this thesis initially aimed on designing a typology model for the uses of such cars in the scope of a Product-Service-System by identifying their characteristics, specificities as well as the key performance indicators

By considering Tukker's (2004) PSS archetypical model, AVs are seen as better fit within category B - "use oriented" and based on that, two main set of uses typologies were drawn: 1) transport of passengers and; 2) transport of cargo. Both typologies were further divided into two main sets of business models: 1) Business-to-Consumer (B2C) and/or Business-to-Business (B2B) and 2) Peer-to-peer (P2P). For passenger's transport the main usage forms were depicted as: ride-hailing, ride-sharing, car-sharing, last mile and, microtransit commute, as for cargo transport the use forms the same as passenger's transport with the exception of microtransit.

Results show that business platform models such as ride-hailing, ride-sharing and carsharing, especially regarding the transport of passengers, are already a reality present in the daily lives of millions of urban-dwellers worldwide and, by considering the insertion of AVs in this equation, there is a great potential for change / impact of these platforms to increase even further, translating into new ways of "thinking" traffic as we have today, hence, AVs may act as important catalysts in the process of transforming urban mobility.

Furthermore, by considering AVs as a PSS many traditional dimensions of the business model need to be rethought, as well as the new array of performance indicators (mostly focused on the user experience). That is, in addition to the economic-centered KPIs (e.g., fuel autonomy, vehicle's miles traveled, maintenance costs) it is fundamental to think on aspects related to usage flexibility, users' comfort and well-being, connectivity and accessibility options as well as reliability and security issues.

As identified in article 2, the typologies of use proposed for AVs as PSS are configured as both B2B and B2C as well as P2P multi-sided business platforms, in this sense the third paper of this doctoral thesis sought to create future scenarios for such business platforms within urban mobility contexts.

Based on desk research, four scenarios were created and exemplified (based on real world examples, extrapolated to a future reality with AVs). The first scenario (A) would entail B2C unimodal mobility, that is: getting from point A to B on a single transport mode delivered by a single firm subsidizing the consumer segment (the platform provider owning the fleet of vehicles) - which already happens with the experimental Uber, Lyft and Waymo's AVs fleet in several American cities. Scenario B on the other hand, would also deliver unimodal mobility from point A to B, but the platform provider would not own the fleet, AVs would be owned by ordinary peers, that via the platform API would offer services to other peers (this is the current business model of P2P ridesharing companies like Uber, Lyft and, Didi Chuxing).

Scenario C would work similarly to scenario A, however offering a multimodal commute from point A to B, that is, the platform provider (SHIFT Project 100) would own all the multimodal autonomous fleet and offer bundled transport modes solutions to commuters. At last, scenario D would work similarly to scenario B - however offering a bundled B2C and P2P multimodal commute - and this, may turn scenario D in the most complete but also the most complex among all four. By delivering multimodal commute via two-way multi-sided platforms governance of such ecosystem might become quite challenging, once orchestrating public and private transport offerings can be quite complex.

It is concluded that besides the unlikelihood of scenario C, any of the other three have potential to become a reality. We also reached the conclusion that on scenarios A and B, the prevailing business models will continue to be P2P ridesharing (supported by the business platform managerial theory) while on scenarios C and specially on scenario D, Mobility-as-Service (MaaS) seems to be the most coherent business model to be applied (supported both by the business platform and business ecosystem managerial theories).

As described by Choudary (2015) the ultimate goal of platform companies is to become "data orchestrators", that is, to have an expressive data layer on their platform stacks. With that, big data will become increasingly relevant to the decision making process and consequently to the business models of platform-based companies. In this regard, - and particularly in urban mobility platforms - orchestrating such data among all involved stakeholders may prove quite complex; hence, as pointed out by Veeneman et al. (2018) and Yap and Munizaga (2018) finding the adequate governance structure is essential for the survival and growth of these business models.

In this sense, considering the scenarios created on paper 3, the fourth and last article of this thesis aimed to conceptually explain how big data impacts on governance structures of future autonomous urban mobility platforms. Considering the governance structures proposed by Williamson's (1991) - market, hierarchy and hybrid - a range of 24 tangible and intangible assets was listed and plotted on charts for each scenario considering the assets' specificity degree frequency of disturbances.

Results have shown that scenarios C and A (respectively) presented predominantly hierarchical governance structures while scenarios D and B (respectively) presented more hybrid structures.

Thus, by being more hierarchical, scenarios A and C displayed the highest operational costs among all four, that is, by owning the fleet the platform provider has to bear the costs of maintaining the platform itself as well as all direct and indirect costs of their fleet maintenance. On the other hand, scenarios B and D displayed lower operating costs, but in turn presented higher transaction costs, in a sense that, by not owning the fleet, such platforms rely on contractual and trust relations with other parties - which gives margin to information asymmetry, opportunistic behavior and consequently a rise on transaction costs.

With regards to frequency of disturbances, the results showed that the greater the number of transport modes, the greater the frequency of disturbances. Although, for scenarios A and C the frequency of disturbances tends to be smaller than in scenarios where the platform provider does not own the tangible assets (scenarios B and D).

Therefore, the ownership degree of the tangible assets is pivotal on determining both the specificity degree and level of disturbance of the intangible assets (data) which consequently determines the governance structure of each mobility platform. At last, as urban mobility platforms gain complexity, more big data is generated, which in turn leads to the need of more complex and complete regulations, mainly via smart contracts on blockchain (as a way of reducing opportunistic behavior and consequently the transaction costs).

Considering the fact that autonomous vehicles are not yet a mainstream business and a market reality, many of the studies around the topic still have an exploratory, descriptive and prospective bias. In this sense, it is suggested future studies that seek to model more concretely the precepts raised by such initial works.

Regarding the findings of paper 1, it would be interesting that future studies seek to validate the value curves with empirical and statistical approaches by using a larger sample of respondents as well as to further investigate the outputs of the proposed analytical framework. With regard to the typologies listed in paper 2 we suggest further studies both empirical and theoretical as a way of testing and validating whether the proposed KPIs are fit for each of them. We also suggest further studies on possible emerging hybrid typologies (e.g., bundle of cargo and passengers' transport) and, at last deeper studies aiming to jointly study the PSS approach with the theories on business ecosystems.

As for paper 3, since the work carried out was a prospective study based on desk research, it lacks empirical validation to test the scenarios. Ergo, further studies are needed to test each scenario feasibility as well as to corroborate or refute the listed inferences. Furthermore, it is suggested deeper studies to test the evolutive aspect of the scenarios as well as to test whether one-way or two-way platforms are the best option for inserting AVs in urban mobility contexts a service. At last, on paper 4, further studies are needed in order to validate or refute - via modelling strategies and statistical methods - each governance scenario feature and the propositions described in the paper.

As research limitations, we highlight the difficulty in contacting and obtaining data from companies and industries as well as from market professionals that are currently developing and advancing the technologies and business models on vehicular automation, thus data collection with mobility researchers (students and professors) instead of industry members could bring up subjective aspects into the performed research methods. Furthermore, the overall methodology adopted in this thesis presents an inherent subjective biases, therefore, such conceptual and exploratory character requires validation though computational modeling and more robust databases.

However, we believe that the results set forth in this doctoral thesis constitute an important (even though modest) contribution to the advances in the studies of business models and business platforms for autonomous vehicles within urban mobility contexts, since, as pointed out by Gandia et al. (2018) and Cavazza et al. (2017), the contributions of applied social sciences to the AVs' field of study are still incipient, in this sense, there is still a long road of research and findings to be explored.

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SECOND PART - ARTICLES

ARTICLE 1 - HUMAN OR MACHINE DRIVING? COMPARING AUTONOMOUS WITH TRADITIONAL VEHICLES VALUE CURVES AND MOTIVES TO USE A CAR

Preliminary version of the paper published on the proceedings of the 12th European Conference on Innovation and Entrepreneurship [ECIE, 2017].

Antonialli, F., Cavazza, B. H., Gandia, R. M., Nicolaï, I., Miranda Neto, A., Sugano, J. Y., Zambalde, A. L. (2017). Autonomous Vehicles: Are they "Riding" in a Blue Ocean?. *Proceedings of the European Conference on Innovation and Entrepreneurship*, [ECIE]. Paris, France, 12.

Paper ready to be submitted to TU Delft Transport Institute journal "*European Journal of Transport and Infrastructure Research*" - ISSN: 1567-7141, JCR: 0.674.

Human or machine driving?
Comparing autonomous with traditional vehicles value curves and motives to use a car.

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Abstract: Autonomous Vehicles (AVs) are expected to provide accessibility for people in need, reducing costs and time in transportation systems and offering comfort for people who do not (or cannot) drive. Even though there has been an establishment of a theoretical field regarding AVs, little has been discussed about the real managerial implications regarding their arrival in the market. Therefore, this study aims at drawing new value curves for Autonomous Vehicles (AVs) over Traditional Vehicles (TradVs) when considering AVs as a service and as a product as well as discussing the main reasons to use an AVs over a traditional car. As for methodology, this research is classified as qualitative of exploratory-descriptive nature in which data were collected based on primary data (with AVs specialists in France, Belgium and Brazil) and secondary data (academic and grey literature) and was analyzed by descriptive qualitative analysis. The results point out to the arrival of a “new” vehicle concept that includes: different ownership forms; free time for users (no driving required); ‘infotainment’; social integration of elder and handicapped people. When analyzing the new value proposition of the AVs we realize that, in fact, these vehicles have in their business model several attributes that fit them into a new market perspective when compared to the current TradVs scenario. It is worth mentioning that for AVs as a service, the value curve is even more distinct from TradVs. By drawing an analytical framework, we observed that as automation levels increase, machine driving components of the vehicle also increase, so there is an expectation that the motives to use a car are likely to change, with an increase in instrumental attributes (e.g., quality, flexibility, convenience, safety) and a reconfiguration of the symbolic and affective aspects since the car will come to be seen not simply as a privately owned asset but much more as an on-demand service.

Keywords: Autonomous Vehicles; Automated Driving Systems; Value Curve; Four Action Framework; Car-use motives.

1. Introduction

Autonomous Vehicles (AVs), better known as Automated Driving Systems (ADS) are cars with motion and action capabilities that do not require any sort of conductor (driver) or teleoperation control (Frazzoli, Dahleh & Feron, 2002). ADS is a recommendation terminology adopted by the Society of Automotive Engineers (SAE) to refer to vehicles with different automation levels and avoid multiples definitions with ambiguous meanings (SAE, 2016). This includes several terminologies widely used in the literature, like autonomous vehicles/cars, self-driving cars, car-like robots, intelligent vehicles, driverless cars, etc. In this work, they are those of the levels 4 and 5 defined by SAE, which do not require any kind of human intervention during its operation (SAE, 2016).

In this context, the first AV appeared in the mid-1980s with Carnegie Mellon University's Navlab and ALV projects in 1984 and Mercedes-Benz and Bundeswehr University Munich's Eureka Prometheus Project in 1987. Since then, several advances have been made in this area and numerous major companies and research organizations have developed AVs prototypes.

According to Mutz et al. (2016), there is a strong expectation that, in the future, AVs could be used to provide accessibility for people in need, reducing costs and time in transportation systems, and offering comfort for people who do not (or cannot) drive. Although the reality of AVs may seem distant, it is increasingly evident its advances and imminent arrival in the near future (Attias, 2017).

It is important to highlight that, even before the ultimate arrival of the AVs, many radical changes have been occurring into the automotive industry. For a long time, such industry was predominately explained by an unique business model: the sale of a car as privately owned asset. When we think about the car within this perspective, we must consider that besides its instrumentals configurations, there are important symbolic and affective aspects related to the car and its owner that must be discussed (Steg, 2005).

Several agencies and companies around the world are making progress in AVs' development. The Advanced Agency for Advanced Defense and Advanced Project Development (DARPA) in the United States, for instance, organized three competitions where research teams were challenged to create solutions for autonomous navigation (Buehler, Iagnemma, & Singh, 2008; 2009). According to McKinsey & Company (2016), autonomous driving technology is advancing rapidly due to road safety concerns, potential cost savings, and technology innovations. The current state of technology along with expected improvements and the already- announced plans of several large OEMs and others, make it likely that fully self-driving vehicles (level 4 autonomous driving capability) will be available by the mid-2020s.

Even though there has been an establishment of a theoretical field regarding AVs, it is not yet evident the main aspects that permeate the thematic, as well as its conceptual base, tendencies and characteristics. In the scope of business and management this lack of studies is even more pronounced (Gandia, et al., 2017). Little has been discussed about the real managerial implications regarding the arrival of AVs in the market (Cavazza et al., 2017). Several authors consider the arrival of these vehicles as one of the biggest disruptive innovations in the automotive market (Attias, 2017; Enoch, 2015).

In this context, one can raise the following questions: What are the value propositions of Autonomous Vehicles as a product and as service over traditional vehicles? Which are the main reasons to use an Autonomous Vehicle over a traditional one?

Based on such questions, this study aims at drawing new value curves for AVs over traditional vehicles when considering AVs as a service and as a product and to discuss the main reasons to use an Autonomous Vehicle over a traditional car.

Considering that AVs are embedded in the most significant historical change to automobile industry and transportation (Attias, 2017; Enoch, 2015), this paper could contribute to broaden the understating of AVs' insertion in the market for both the academia and practitioners. In a sense that governments, universities and car-manufacturers worldwide identify AVs as key-research factor, therefore, such imminent arrival includes impacts on several spheres, being important to consider the impacts of such disruptive innovation not only on cities and society, but on structure and functioning of companies as well.

2. Theoretical Background

2.1 Value Curves and the Four Action Framework

In their seminal book *"Blue Ocean Strategy: how to create uncontested market space and make the competition irrelevant"*, Kim and Mauborgne (2005) question the reason for organizations to continue a fierce dispute within saturated markets (red oceans) where large investments are made in pursuit of sustainable and profitable growth when the result is often only a small market share gains (Kaplan, 2012).

Therefore, for a company to be in a "blue ocean", the premise is to make competitors irrelevant by avoiding such fierce competitive battles and by offering customers with something unique and yet untapped in a given business segment, thereby producing value innovation - aligning innovation with immediate utility in a competitive price (Kim & Mauborgne, 2005; Osterwalder & Pigneur, 2010).

To answer the questions: how to make competition irrelevant? how to unveil unexplored markets and create the blue ocean? Kim and Mauborgne (2005) developed a four-action framework that allows one to systematically explore ways of rearranging attributes that generate value for clients in order to offer entirely new experiences while keeping the cost structure low. As shown in Figure 1, the matrix generated from these four actions leads companies to act based on the answers to build new value curves for their products/services.

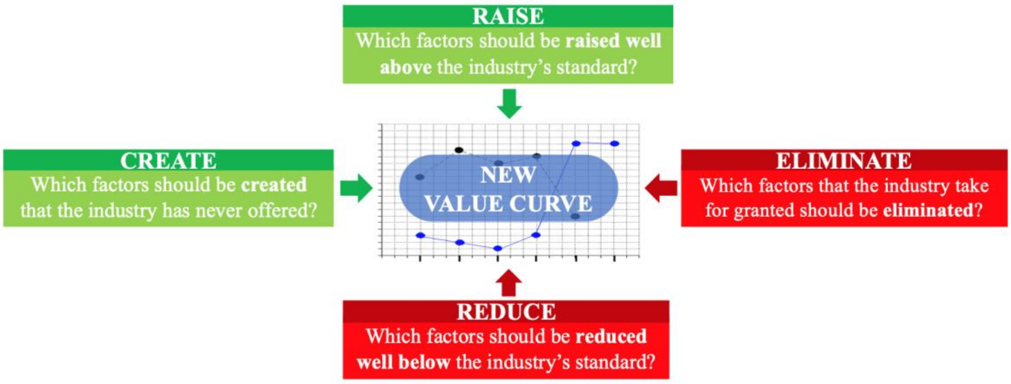

Figure 1. Four action framework reflecting on the creation of a new value.
Source: adapted from Kim and Mauborgne (2005).

The "Blue Ocean Strategy" calls into question the need for companies to seek a position where competition is not included, in order to avoid large investments in already saturated markets. In this sense, demand is created rather than contested, hence, there is ample opportunity for growth that is both profitable and rapid (Kim & Mauborgne, 2005; Osterwalder & Pigneur, 2010), competition is therefore irrelevant because the "rules of the game" are waiting to be defined (Kim & Mauborgne, 2005). The authors also point out that a large part of the blue oceans have not yet been mapped, as the focus of the works on strategy in recent decades have been concentrated in the red oceans with fierce competition.

The "strategic move" is the appropriate unit of analysis to explain the creation of blue oceans and high-performance support. Therefore, such strategic movement is a set of managerial decisions and actions that provide important products and services capable of creating new markets (Kim & Mauborgne, 2005). In this sense, the authors conclude that a blue ocean is created when a company achieves an innovation that simultaneously creates value for both the buyer and the company.

2.2 Autonomous Vehicles and the Traditional Car Industry

According to Lima (2015), the first AV prototype was developed in Japan in the mid-1970s, being able to track white street marks with computer vision at speeds up to 30 km/h. Only 10 years later, the first car-like robot would emerge in Europe in Bundeswehr University Munich (UniBW) on Germany as part of the PROMETHEUS project. Also in the 1980s, it was seen the first American contribution with a project called "No hands across America" from the Carnegie Mellon University (CMU) which has developed a car (Navlab 5) capable of performing autonomous navigation from Washington DC to San Diego with 98% automated steering and manual longitudinal control. However, the watershed on AVs research and development, came on 2004 in the USA with a series of public annual challenges, named DARPA Gran Challenges. By means of them, countless contributions and advances have been made on AV throughout the 21st century (Reschka, 2015; Poorsartep, 2014).

AVs represent a potentially disruptive and beneficial change to the current road transportation system business model, since such vehicles will facilitate driving; increase road safety; reduce emissions of pollutants; reduce traffic jams; as well as will allow drivers to choose to do different things other than driving (Attias, 2017; Enoch, 2015; Schellekens, 2015; Schreurs & Steuwer, 2015). Thus, access to fully automated vehicles will also improve mobility for those who cannot or do not want to drive, improving their quality of life (Attias, 2017; Poorsartep, 2014). As a result, AV can provide significant economic, environmental and social benefits (Mutz et al., 2016; Fagnant & Kockelman, 2015; U.K. Department for Transport, 2015).

AVs technology is now the greatest bet of big carmakers, led in the United States by Ford, GM and Tesla and in Europe by Audi, Mercedes and Volvo, as well as some technology giants like Google and Uber (Nascimento, Salvador & Vilicic, 2017; Fagnant & Kockelman, 2015). According to the former authors, Google's AV (Waymo) have reached in 2017 the milestone of more than five million kilometers driven on American avenues, streets and roads and Uber's AV (in partnership with Volvo) have reached over 1.5 million driven kilometers in their testing cities of Pittsburgh, Phoenix and Toronto. Not to mention that vehicles with semi-autonomous capabilities SAE's (2016) levels 2 and 3 of automation are already being marketed - such as Tesla's Roadster; Model S and Model X as well as Mercedes-Benz's S65; Infiniti's Q50S, BMW's 750i xDriv (all level 2) and most recently Audi's A8 which as stated by Nascimento, Salvador & Vilicic (2017) is the first mass produced vehicle to have a level 3 embedded system.

The Society of Automation Engineers (SAE, 2016) provides a taxonomy describing the full range of driving automation levels, which as depicted on Figure 2 ranges from ZERO (no driving automation) to FIVE (full driving automation).

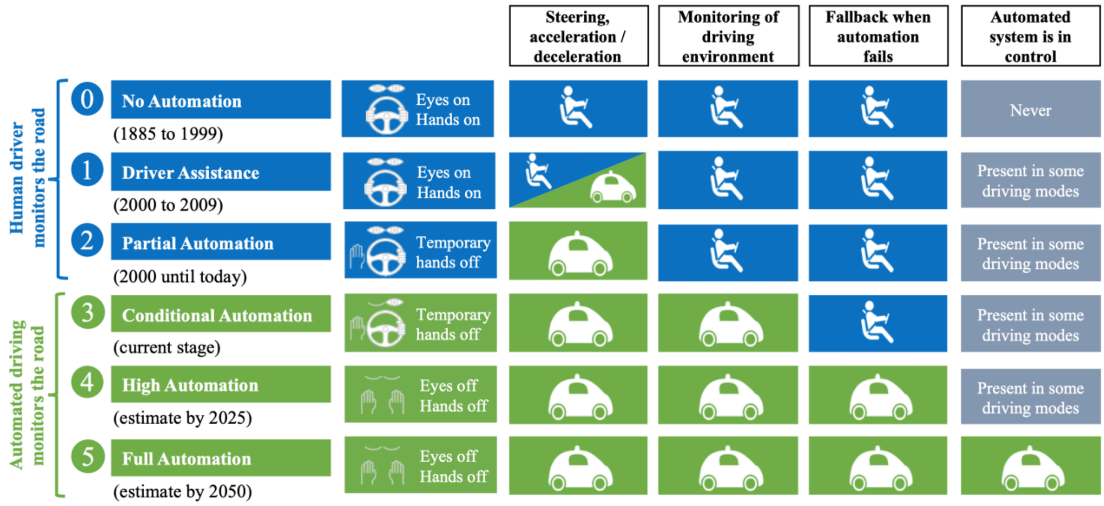

Figure 2. Summary of SAE's automation levels
Source: adapted from SAE (2016) based on Nascimento, Salvador and Vilici (2017) and Hawes (2016).

It is worth noting that on levels 4 and 5 an AV can autonomously drive and monitor the road environment without the need of human intervention in case of constraints (US. Department of Transportation, 2016). Furthermore, the French authors Attias and Mira-Bonnardel (2017), state that levels 4 and 5 are considered by their country's authorities as really disruptive and in the near future French urban spaces will quite surely implement these last two levels on dedicated areas or lanes.

As the aforementioned authors pointed out, the automotive industry is going through some radical changes, and it's been struggling to find the right positioning. For a long time, such industry was predominately explained by an unique business model: car sales (as products). Within this perspective, a car should be understood more than just a simple artefact for mobility, since, according to Steg (2005, p.147) "car use not only fulfils instrumental functions, but also important symbolic and affective functions". For the author, behavioral models aiming to explain the reasons to have a car should not only focus on instrumental factors related to usage (e.g.: speed, flexibility, and convenience), since, "for many people, the car seems to be a status symbol, people can express themselves by means of their car" (Steg, 2005 p.148).

However, this traditional business model of selling cars is losing ground to alternative forms of commerce (Attias & Mira-Bonnardel, 2017). Evidences across car-reliant cultures are pointing to a slow (but general) decline in car use and ownership (Mulley, 2017; Shaheen & Cohen, 2016; Karlsson, Sochor & Strömberg, 2016) - which may be a side-effect of the 2008 worldwide economic crisis and even due to venture capital avaialbility. Thereby, a business model in which cars are offered as a bundle of products and services - that is: a Product-Service System [PSS] (Tukker, 2004) - is gaining strength and it is being tackled by many companies and scholars. As stated by Burns, Jordan and Scarborough (2013):

> "(…) using a shared, self-driving, and purpose built fleet of vehicles could reduce the total cost of ownership from US$1.60 per mile down to US$0.50 per mile, this is more than a 10-fold improvement compared to personally owned vehicles" (Burns, Jordan & Scarborough, 2013, p.101).

"As a result, traditional players in the industry find themselves obliged to form new alliances with companies in emerging sectors (e.g. performance economy, circular economy, digital economy, etc.)" (Attias & Mira-Bonnardel, 2017, p. 72), therefore an important part of the opportunities offered by PSS lies on the correlation between product and service activities (Mahut et al., 2015).

At last, it seems clear that the future will involve a mobility revolution combined with a cultural revolution of the entire industry and society. Nevertheless, there are still many questions that need to be answered before AV reach the roads, to name a few: security and reliability issues; impacts of AV driving on mobility behaviors and human-machine interactions; consumer acceptance; cities revenues; as well as regulatory, ethical and liability frameworks (Nascimento, Salvador & Vilicic, 2017; Scherurs & Steuwer, 2015; Schellekens, 2015).

Those are relevant questions that need to be addressed and taken seriously by governments and carmakers, since, according to Poorsartep (2014), technology itself is no longer the major hindrance for AVs' implementation, the major roadblocks are now consumer acceptance and regulatory frameworks.

3. Methodology

Considering that this paper aimed at drawing new value curves for Autonomous Vehicles (AV) over traditional vehicles when considering AVs as a service and as a product as well as discussing the main reasons to use AVs over a traditional cars, the research design adopted in the present study was characterized as qualitative of exploratory-descriptive nature.

It is exploratory in a sense that the AVs field of study is still little addressed in the business literature and thus, there is a lack of business-like academic knowledge regarding this object of study (Gandia et al., 2017; Cavazza et al., 2017); it is also descriptive because it aims at describing and analyzing phenomena (Malhotra, 2001; Gil, 2008) - here the AV value curve configuration under the Disruptive Innovation paradigm and the Four Action Framework perspectives. Figure 3, highlights the research design carried out in this study.

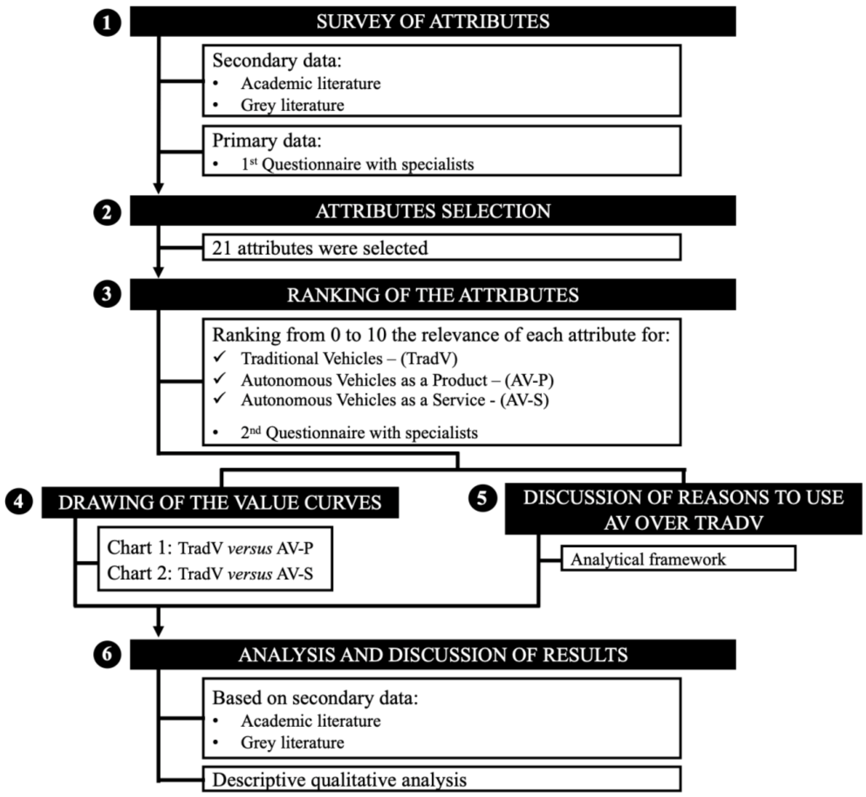

Figure 3. Research design for this proposed paper.
Source: prepared by the authors

Stage 1 consisted on surveying the attributes for creating the value curves in order to compare the Autonomous Vehicles[1] both as products and as services with Traditional Vehicles. Such attributes survey was based on secondary data (academic and grey literature) - similarly to what Enoch (2015) has adopted in his work as well as primary data collection

[1] It is worth highlighting that SAE's level 4 of automation was considered as a reference in this study, similarly to Schellekens (2015) on his study about the self-driving cars and the chilling effect of liability law.

with open-ended questionnaires with 12 specialists in the subject of AVs from different areas of knowledge (e.g. Engineering, Business, Economics, Law, etc.) in France, Belgium and Brazil.

In total, 26 attributes were raised on the survey, from those, 21 were selected on stage 2 being categorized into: a) human attributes (9) and b) machine attributes (12), the other 5 attributes were considered as “environment attributes” therefore were not included in the analysis for drawing the value curves.

After selecting the 21 attributes, stage 3 consisted on sending a second questionnaire to the same 12 specialists (approached on stage 1) in which they were asked to rank each attribute from ZERO - not necessary/present at all, to TEN - extremely necessary/present) for each vehicle category: Traditional Vehicles; Autonomous Vehicles as Products and; Autonomous Vehicles as Services.

Inspired on Kim and Mauborgne (2005) four action framework, stage 4 consisted on drawing the value curves based on the arithmetic means for each attribute ranked by the specialists on the previous stage. By considering the Traditional Vehicles as a basis for comparison, two distinct value curves were drawn: chart 1) Traditional Vehicles (TradV) *versus* Autonomous Vehicles as a Product (AV-P) and; chart 2) Traditional Vehicles (TradV) *versus* Autonomous Vehicles as a Service (AV-S).

After drawing the curves and discussing the human and machine attributes that should be eliminated, reduced, created and raised for each scenario (chart 1 and 2), stage 5 consisted on creating an analytical framework in order to discuss and analyze the reasons for using Autonomous Vehicles over Traditional Vehicles based on Steg’s (2005) premises as well as on other relevant works.

In parallel, stage 6 consisted on analyzing and discussing the results obtained on stages 4 and 5 - based on secondary data in order to support the findings (academic and grey literature) - via descriptive qualitative analysis (Sanderlowski, 2000; 2010; Kim, Sefcik & Bradway, 2016).

4. Results and discussion

We present here the value curves for TradVs compared to AVs-P and AVs-S. For better results’ understanding we considered the TradVs’ value curve (grey lines) as a standard for analysis. Therefore, based on Kim and Mauborgne’s (2005) four-action framework, Figure 2 displays the attributes that must be eliminated, reduced, created and raised.

By analyzing the charts of Figure 4 (1- TradVs *versus* AVs-P; and 2 - TradVs *versus* AVs-S) it can be noticed in both cases a "mirror-like" behavior of the curves. That is, indispensable TradVs' attributes appear on both AVs curves as eliminated and/or reduced; and after crossing the inflection point, the trend remains, since attributes considered as non-essential and/or non-existent for TradVs are raised and/or created in the AVs' curves.

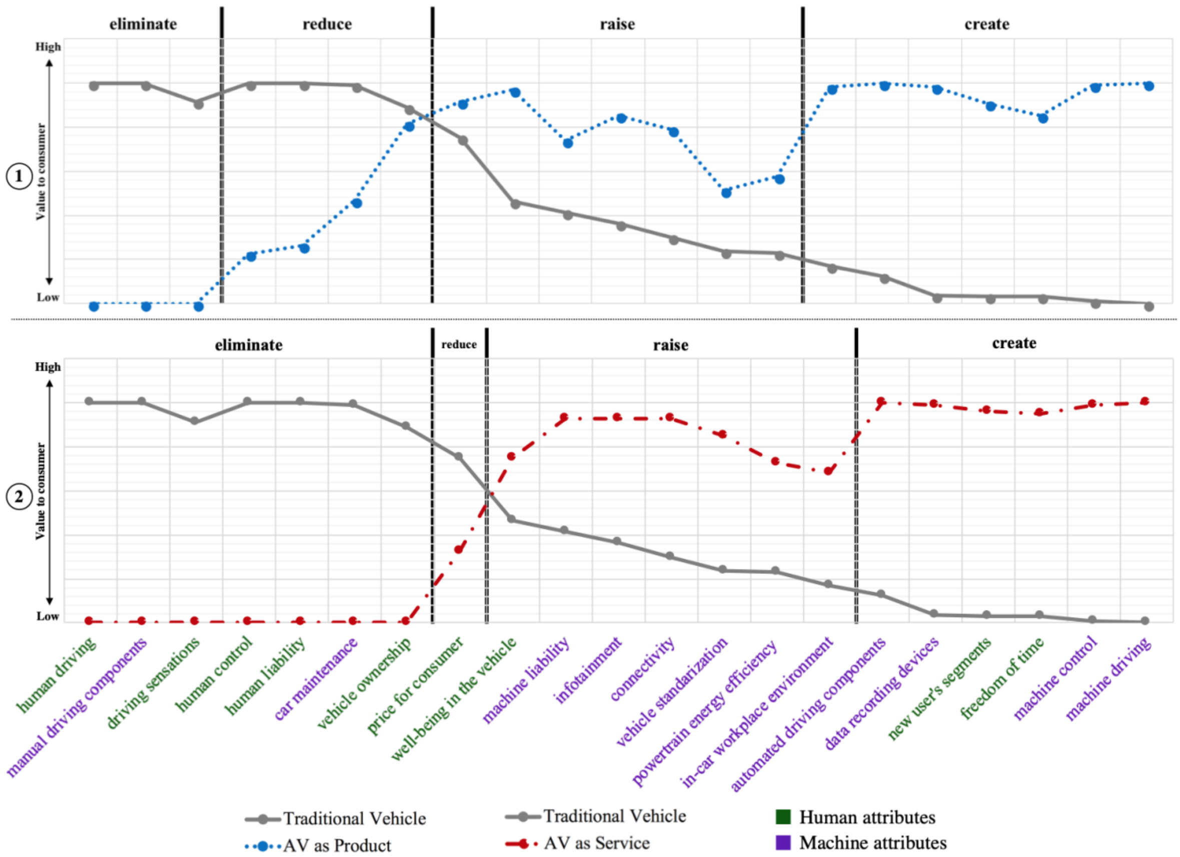

Figure 4. Traditional Vehicles versus AVs as Product and AVs as Service value curves.
Source: research data, inspired by Orsato (2009, p.184), Bottacin, Madureira and Pedroso (2014, p.13).

4.1 Eliminated attributes

Of the 21 attributes ranked in this study, results show that for AVs-P the first 3 (**human driving**; **manual driving components** and; **driving sensations**) will be eliminated. It is interesting to note that 2 of these 3 attributes are considered as "human attributes" whereas only manual driving components is a "machine attribute" (Robertson et al., 2017)

All the three eliminated attributes are considered indispensable for a traditional vehicle, since automated driving is not present, a human driver will always be needed, as well as manual driving components such as pedals; steering wheel, mirrors and so on. Therefore, the driving sensations (being those either positive or negative) will also always be present (SAE, 2014).

On the other hand, in the value curve for AVs-S we observed that, besides these 3 attributes, other four (**human control**; **human liability**; **car maintenance**; **vehicle ownership**) will likely be eliminated (Robertson et al., 2017). Such attributes are likely to have respectively a direct impact on: the labor market, insurance market, service market, tax and financial service markets.

As expected, the three eliminated attributes for AVs-P will also not be present here, since a level 4 AV will not require human driving, therefore rendering mute manual driving components as well as driving sensations. The other four attributes will be eliminated, since the car will not be an asset owned by the passenger but offered by a service provider (such as Uber; Lift; Didi Chuxing; among other car-sharing services) (Antonialli et al., 2018).

In this sense, the user (passenger/rider) is likely not to have human control (the routes might be previously stablished by the service provider as well as other in-car attributes and features), as well as might not be liable in case of accidents; will likely not bear maintenance costs and of course, will not need to own the vehicle, given that in this scenario he/she will be a simple consumer (user) from a service provider (Fagnant & Kockelman, 2015; Cavazza et al., 2017).

4.2 Reduced attributes

In this category, four attributes that will be reduced on AVs-P. Those being: **human control**; **human liability**; **car maintenance** and; **vehicle ownership**. Similarly to the eliminated attributes, only 1 out of the 4 attributes to be reduced is considered as a "machine attribute".

Human control will be reduced because even though the act of driving will be autonomous, the car owner might still have control regarding routes to be taken; when and where to pull over if needed; as well as other car controls such as lights; A/C; sounds, etc.; that the car will still be a personally owned asset, however no driving will be truly required. Therefore in case of an accident it will be more complex to blame the owner of the vehicle, once now he/she will no longer be in control of the vehicle, instead will a simple passenger (rider) (Hevelke & Nida-Rümelin, 2015; Cavazza et al., 2017).

Car maintenance will likely be reduced (Brennan & Barder, 2016 p.9) once there is a growing trend among OEMs and researchers that such AV will be electric. An electric powertrain is much more simple than an Internal Combustion Engine (ICE), it has much less moving parts (approximately 200 against around 2000 in an ICE); Also, since driving will be automated, wear and tear of components is likely to be reduced when compared to a human driver (Gustafsson & Johansson, 2015).

As for ownership, we hypostatize a small reduction for a couple of reasons, such as: possible high price tag of the vehicle; high insurance costs; lack of interest by part of the consumers, among others. If in one side, we can observe a significant change in the traditional configuration of having / owning a vehicle for a new one with AVs, on the other hand there is still a lot to be surpassed if we consider that (Steg, 2005).

It's important to highlight that, mainly in this configuration, considering symbolic and instrumental aspects / reasons for having a car such as the pleasure of being behind the wheel, the choice of the car's configurations, design and layout, it is more prudent to state that attributes like human control and vehicle ownership are likely to decrease but not disappear, as Michele Kreber (auto-trader senior) points out: "People want driverless performance when they're commuting and maybe on long road trips, but they want the option to drive themselves" (Phelan, 2018).

As for human liability, such an attribute will still be considered that even with the machine having the driving control, the owner of the car, the carmaker, the insurance company, etc., could be held liable for any accident or infraction Hevelke & Nida-Rümelin, 2015).

Regarding AV-S, the only attribute to be reduced is **price for consumer**, which, when comparing AVs-S and AVs-P curves, it is clear that owning an AV will likely be much more costly than using it as a service (at least for the initial introductory stage), corresponding to Burns, Jordan and Scarborough (2013, p.101) statement about costs reduction of sharing an AV over own a car. Furthermore, a 2016 World Economic Forum study identified that 37% of consumers said that they are likely to share a ride in a self-driving taxi with strangers (WEF, 2018), this way, it is observed that there is users' predisposition to share AVs-S.

It's also worth mentioning here the study of Wadud (2017), that seeks to compare the costs (and benefits) of vehicle automation for private vehicles among different income groups and commercial vehicles in the taxi and freight sectors in the UK. According to the author the main findings of the study is that "commercial operations clearly benefit more from automation because the driver costs can be reduced substantially through automation. Among private users, households with the highest income will benefit more from automation because of their higher driving distances and higher perceived value of time, which can be used more productively through full automation" (Wadud, 2017 p. 163).

4.3 Raised attributes

Among the seven attributes to be raised for an AV-P, five are considered as “machine attributes” and only two (price for consumer and well-being in the vehicle) are considered as “human attributes”.

In this context, the more components a vehicle has, more aggregated value it has, and consequentially, more expensive it will likely be. In this sense, an AV with all the needed sensors, radars, lidars and cameras for safely driving the car, will probably be more expensive than a traditional vehicle (**price for consumer** as an end product) - at least in the near future (Litman, 2018 p. 7; KPMG, 2012).

Shifting the discussion to comfort, as pointed out by SAE (2016) a level 4 AV will no longer need human intervention, therefore fallback in case of automation fails will be on the system, not on the human. In this sense the internal layout of the car can be completely redesigned, allowing bigger focus on **well-being in the vehicle** for both leisure and work. Therefore other attributes such as: **infotainment** (bundle of information and entertainment) and **connectivity** might also be raised, these two attributes together represent an important part of the AVs’ concept, since the central proposal for this type of vehicle is to offer of a series of possibilities to the user, radically changing the in-car experience (Yun et al., 2016; Cavazza et al., 2017).

As discussed in the attributes to be eliminated, while human liability will probably be reduced, **machine liability** will likely be raised. In the case of an accident, the burden will not fall entirely on the car owner, but rather on the car itself, that is, OEMs liability will likely be higher (Lederman, Garrett & Taylor, 2016). Examples of this are accidents involving autonomous or semi-autonomous vehicles (Tesla, Uber, etc.) and the machine named, instead of an human, as the cause of the accident [e.g. "tesla car that crashed and killed driver was running on autopilot, firm says" Guardian staff and agencies (2018)].

In the perceivable future, AVs will begin to take the streets on a larger scale, yet still much less when compared to traditional vehicles. Therefore the number of models and brands available for autonomous vehicles will be more limited, which will lead to a higher initial **vehicle standardization** of marketed models, an example is Tesla’s portfolio of vehicles, the company currently markets only four models: Roadster, Model S, Model 3 and Model X - all imbedded with level 2 autonomous capabilities.

At last, as previously mentioned on the attributes to be reduced, it is likely that these AVs will be electric (or hybrid), therefore it is believed that **powertrain energy efficiency** will be raised as well (Brennan & Barder, 2016; Gustafsson & Johansson, 2015; Gandia et al, 2017).

As for AVs-S, for the seven attributes to be raised, only one is labeled as a “human attribute” - **well-being in the vehicle** (similarly to AVs-P), since there is no need to drive, the tendency is that well-being inside the vehicle will be raised (Yun et al., 2016; Cavazza et al., 2017). It is worth noting however, that differently from AVs-P when offered as a service an AV might be shared by different commuters, in this sense well-being might not be as high as in a personally owned AV - especially considering that on an initial moment, those private AVs would be mostly aimed towards luxury markets, as the examples of the current Tesla, Audi, Volvo and Mercedes vehicles with semi-autonomous capabilities.

All the other six attributes to be raised are considered as “machine attributes”, five of them (**machine liability**; **infotainment**; **connectivity**; **vehicle standardization** and **powertrain energy efficiency**) are also likely to be raised on AVs-P. The only difference is that the attribute **in-car workplace environment** would be created on an AVs-P however raised on an AVs-S. In fact, if we consider that cars are (in general) by default liminal spaces between, home, work, and third places. It makes sense to think that future car concepts will bring the convergence of these spaces, thanks to the self-driving prophecy (Ozenc, 2017; Zakharenko, 2017).

4.4 Created attributes

As for the attributes that need to be created for an AV-P when compared to TradVs, only two were not considered as “machine attributes”, being those: a) **new user’s segments** - since level 4 AVs enable groups previously neglected by OEMs, such as people with disabilities; people who cannot or do not want to drive, the elderly and even underaged to have access to the usage and even ownership of a vehicle (Attias, 2017), and b) **freedom of time** - since driving will no longer be needed; the user will have freedom of time to do other activities such as reading a book; watching a movie; sleeping, etc (Ozenc, 2017; Zakharenko, 2017).

Regarding the “machine attributes” that might need to be present in such vehicle, the attribute **in-car workplace environment** is closely linked to well-being inside the vehicle (attribute to be raised) and freedom of time (attribute to be created), since in TradVs all the in-car layout is designed for “on the road focus” - that is: human driving. However as previously mentioned, on a level 4 AV driving is no longer a necessity, therefore the in-car layout can be completely redesigned giving greater focus to other activities, such as work while in the commute - which could be a great time saver for many people that spend many ours of their days stuck on traffic jams (Ozenc, 2017; Zakharenko, 2017).

The other four “machine attributes” that may be necessary for an AV-P compared to TradVs are: **automated driving components**; **data recording devices**; **machine control** and; **machine driving**, that is, all are technical attributes necessary for the proper and safe driving of the vehicle (SAE, 2014; 2016).

Since level 4 vehicles are not yet being marketed (only level 2 and 3 are currently available for purchase), automated driving components for complete dynamic driving tasks still need to be created, also machine control - to monitor the driving algorithms, sensors, cameras, radars, lidars; as well as data recording devices - such as airplane “black boxes” purpose of facilitating the investigation of accidents and incidents (Barbosa et al., 2016; Bose, 2015) and last but not least: machine driving - that is, the driving algorithm itself that would be responsible for all driving decisions that should be taken; e.g: knowing when to change lanes; when to make left and right turns; when to stop; when to parallel park, etc (Morris, Madzudzo & Garcia-Perez, 2018).

Finally, regarding AVs-S, the six attributes to be created for AVs-S would also going to be created on AVs-P, and among them four are considered as “machine attributes” (**automated driving components**; **data recording devices**; **machine control** and; **machine driving**) and two are “human attributes” (**new user’s segments** and **freedom of time**).

4.5 Reasons to use Autonomous Vehicles over Traditional Vehicles

After drawing the value curves for AVs over traditional vehicles, the next step was to discuss the main reasons that might lead people to use an Autonomous Vehicle over a traditional car. Based on the previously discussed attributes, it is worth noting the distinction between human and machine attributes and the way that such distinctions could lead to different motives to use a car, based in instrumental, symbolic and affective attributes as suggested by Steg (2005). Figure 5 depicts an analytical framework for explaining the reasons to use an AV over a TradV.

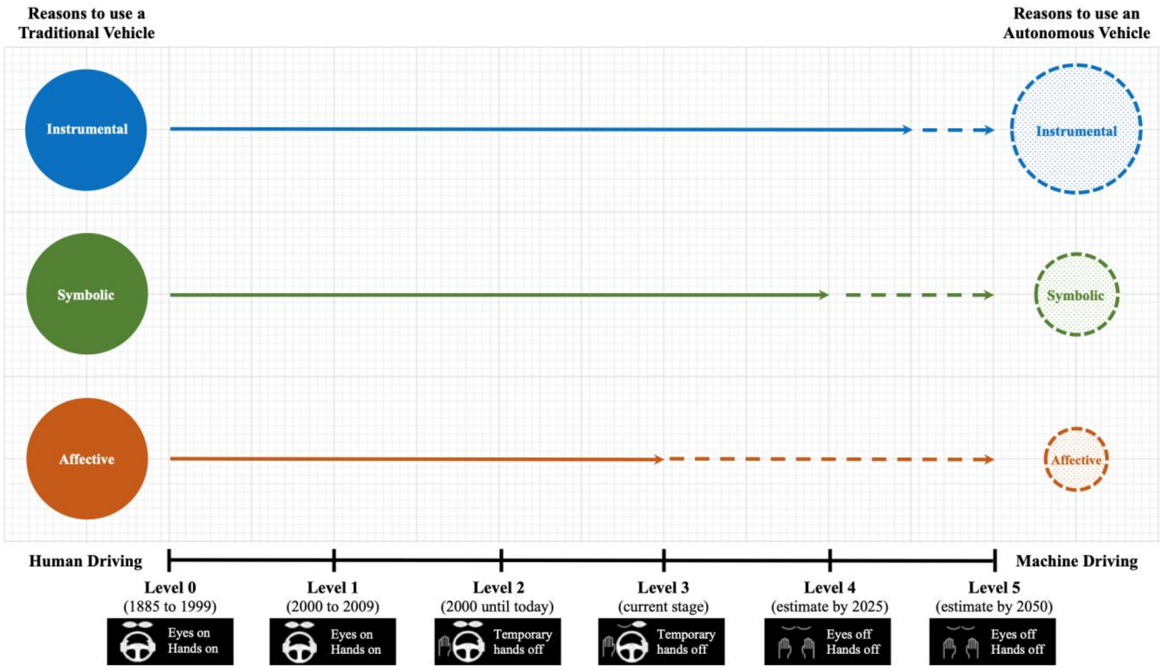

Figure 5. Analytical framework for reasons to use an AV over a Trad-V.
Source: research data, inspired by Steg (2005), SAE (2016), Nascimento, Salvador and Vilici (2017) and Hawes (2016).

The closer the attributes ranked in Figure 4 are from SAE's lower automation levels (0, 1, 2 and 3) - in which total or partial human intervention is needed - it is possible to trace a parallel with the motives that lead people to use traditional cars, as discussed by Steg (2005) - see Figure 5. This is evident by relating Figure's 4 human attributes, such as "human driving", "driving sensations", "human control", "vehicle ownership", "price for consumer" and "well-being in the vehicle "; to instrumental motives (e.g.: "the car quality is more important to me than its brand" and "I only have a car to travel from A to B"), symbolic (e.g.: "a car provides status and prestige" and "you can know a person by looking at his/her car") and affective (e.g., "I love driving" and "I like to drive just for fun") described by Steg (2005, p.154).

As shown in Figure 5, from 1885 up to the current stage of automation (SAE level 3), Steg's (2005) reasons to use a car have not changed dramatically, however, it is not possible to know for sure how such motives will be configured to the extent that SAE's higher automation levels (4 and 5) develop and consolidate in the future market.

On the other hand, as the attributes shown in Figure 4 approach SAE's higher automation levels, it is possible to observe - by the dashed lines and circles on Figure 5 - that Steg's (2005) current motives to car use will likely be configured in different manners than today's. In a sense that various human attributes required at lower levels of automation (such as "human driving", "human control" and "human liability") will gradually be replaced by machine attributes (such as "machine driving" and “machine liability").

Thus, a rupture regarding the motives to use a car might be observed starting from the introduction of a vehicle that would not require human intervention at all times (starting on SAE’s level 3). For over 100 years, instrumental, symbolic and affective motives, derived from the role of a driver in the control of a vehicle, will give way to new and yet still uncertain approaches. As Hodson (2016) points out: “we will discover how our behavior changes when we have autonomous vehicles on the road”.

However, when analyzing Figure 5 it is possible to infer that the reasons for using an AV will likely have superior instrumental motives to those existing for a TradV. In contrast, the affective and symbolic motives suggested by Steg (2005) will probably change in a “machine driving” scenario. This can be inferred by considering the absence of attributes to be raised and created (Figure 4) related to symbolic and affective motives (Steg, 2005), we observed that the almost complete presence of "machine attributes" (exceptions of "new user’s segments" and "freedom of time") may be responsible for such phenomenon. In other words, in a vehicle in which the person will no longer need to have driving control, it seems evident the reduction or transformation of affective values such as "driving sensations".

It is worth highlighting that the size and proportional of the circles in Figure 5, are simply a theoretical extrapolation in order to facilitate the understanding of the framework. Hence, further deeper empirical studies are needed to better define such circles’ proportions.

Likewise, considering that one of AVs’ proposals is to provide mobility solutions from a machine control standpoint over the possibility of human driving mistakes, and such control promises to bring greater assertiveness to mobility (Fagnant & Kockelman, 2015), the creation of attributes such as "machine control" and "machine driving" (Figure 4) positively correlate with currently available instrumental motives, such as "I only have a car to travel from A to B" (Steg, 2005).

At last, it is worth emphasizing that given analytical framework proposal is not to suggest a generalized increase of instrumental motives, as well as a reduction of affective and symbolic ones, but of those currently known as motives to traditional car use (Steg, 2005). We believe that new affective motives may arise, as well as symbolic, to the detriment of those valued by the current user of a TradV, factors that are still unknown but need to be taken into account by AV's OEMs and stakeholders.

5. Concluding remarks

This work aimed at drawing new value curves for Autonomous Vehicles (AVs) over Traditional Vehicles when considering AVs as a service and as a product as well as discussing the main reasons to use an AV over a traditional car.

By analyzing the results one can notice that indispensable TradVs' attributes appear on both AVs curves as eliminated and/or reduced; and after crossing the inflection point, attributes considered as non-essential and/or non-existent for TradVs are likely to be raised and/or created in the AVs' curves.

By the four-action framework and value curve models (Kim & Mauborgne, 2005), the results point to the arrival of a "new" vehicle concept that includes: different ownership forms; free time for users (no driving required); 'infotainment'; social integration of elder and handicapped people; in all, factors that will cause the extinction of some markets and creation of others.

The AVs' value curves display different characteristics when compared to TradVs. When analyzing the new value proposition of the autonomous vehicles we realize that, in fact, these vehicles have in their business model several attributes that fit them into a new market perspective compared to the current picture of TradVs.

It is worth mentioning that for AVs-S, the value curve is even more distinct from the TradVs' curve, since besides having all the attributes related to the technological issues of the vehicle, it is necessary to consider all the attributes related to the implementation of this vehicle in the market as a service and not a product. Since, as pointed out by Kenney (2017 p.3) "investors may be undervaluing mobility-as-a-service severely today, and that in 5 years autonomous taxi networks could command a market capitalization of over $5 trillion. In comparison, the global automotive manufacturing industry probably will be roughly one third of that size". In this sense, the author concludes that AVs-S "presents a massive growth opportunity for technology players or automakers that are able to piece together a successful autonomous strategy".

After drawing the value curves for AVs over traditional vehicles, the next step was to discuss the main reasons that might lead people to use an AV over a TradV. It is worth noting here the distinction between human and machine attributes and the way that such distinctions could lead to different motives to use a car, based in instrumental, symbolic and affective attributes as suggested by Steg (2005).

On the proposed analytical framework, we can observe that as automation levels increase (SAE, 2016), machine driving components of the vehicle also increase (while human attributes tend to decrease), so it is likely that Steg's (2005) motives to use a car will be reconfigured, with a probable increase in the instrumental motives (e.g., quality, flexibility, convenience, safety) and a reconfiguration of the symbolic and affective ones since the car will come to be seen not simply as a privately owned asset but much more as an on-demand service.

As limitations of the research we highlight the emergence of the topic which incurs in difficulties to find scientific academic content to support the discussions as well as difficulties in gathering primary data (e.g.: lack of specialists in the area and confidentiality of the information specially from OEMs) which might incur in some level of bias. Regarding future studies, it would be interesting to validate the value curves with empirical and statistical approaches as well as to go deeper in the outputs of the analytical framework. In this sense we believe that the attributes found in this study could be the first step to further discuss in-depth such issues.

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ARTICLE 2 - UTONOMOUS VEHICLES AS A PRODUCT-SERVICE SYSTEM: TYPOLOGIES OF USES

Preliminary version of the paper published on the proceedings of the 26th International Colloquium of GERPISA.

Antonialli, F., Cavazza, B.H., Gandia, R.M., Sugano, J.Y., Zambalde, A.L., Nicolai, I., Miranda Neto, A. (2018). Typologies of uses for Autonomous Vehicles as a Product-Service System. *Proceedings of 26th International Colloquium of Gerpisa*. São Paulo, Brazil, 26.

Paper under evaluation on the Springer's journal "*Transportation*"

ISSN: 1572-9435, JCR: 3.151.

Typologies of uses for Autonomous Vehicles as a Product-Service System

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Abstract: Shared mobility is one of the fastest-growing facets of the sharing economy and it is particularly interesting in contexts of crammed urban centers that struggle with population growth and increasing density. The imminent arrival of Autonomous Vehicles (AVs) have the potential to accelerate and fundamentally change this scenario. With that,
this paper aimed at describing a typology model for the uses of AVs in the scope of Product-Service Systems. The research design was characterized as qualitative of exploratory-descriptive nature and data collection was based on both primary and secondary data. Firstly considering Tukker's (2004) Product-Service System archetypical model, Autonomous Vehicles are better fit within category B - "use oriented". After, two main set of uses typologies can be considered: 1) transport of passengers and; 2) transport of cargo. This two macro typologies were then subdivided into categories according to the its specific scope and aim. Further, both passengers and cargo typologies were divided into two main sets of business models: 1) Business-to-Consumer (B2C) and/or Business-to-Business (B2B) and 2) Peer-to-peer (P2P). Results show that models such as ride-hailing, ride-sharing and carsharing, especially in passenger transport, are already a reality present in the daily lives of thousands of urban-dwellers. By considering the insertion of AVs in this equation, we see the potential for change / impact of these modes to increase even more, translating into new ways of "thinking" the traffic as we have today. By outlining the typologies of use of AVs as a PSS as well as the main examples of the developments that may occur in each typology, the role that AVs will play in the near future is undeniable, acting as important catalysts in the process of transforming mobility.

Keywords: Autonomous vehicles; Typologies of uses; Product-Service System; Passengers Transport; Cargo Transport

1. Introduction

The concept of sharing economy encompasses business models where people offer and share underutilized resources (goods and / or services) in creative new ways via digital platforms that intermediates decentralized exchanges among peers (Clewlow & Mishra, 2017; Acquier, Daudigeos & Pinkse, 2017; Cohen & Kietzmann, 2014) and it has been widely discussed in the literature.

Several key sectors of the economy have been developing new business models based on such principles. The automotive and transportation sector is one of the most prominent in this context (Jin et al. 2018; Bothun et al., 2015; Cohen & Kietzmann, 2014). In fact, shared mobility - the shared use of a motor vehicle, bicycle, or other low-speed transportation mode - is one of the fastest-growing facets of the sharing economy and it is particularly interesting in the context of cities that struggle with population growth and increasing density (Shaheen, Cohen & Zohdy, 2016; Cohen & Kietzmann, 2014).

In this sense, the possible imminent arrival of Autonomous Vehicles (AVs) have the potential to accelerate and fundamentally change this scenario. Undeniably, the development of AVs is an important innovation that promises to have a great impact on the issues of urban mobility. In the specific case of higher levels of automation - such as levels 4 and 5 - as defined by SAE (2016), the vehicle can travel without the intervention of a human operator (driver).

In this context, there are several innovations to come, as well as the creation of new demands, with the inclusion of specific publics that are currently not present in the market, such as the disabled or the elderly, ensuring a completely new perspective in terms of mobility. In fact, there is a strong expectation that in the future, AVs can be used to provide accessibility for people in need, reducing costs and time in transportation systems, and offering comfort to those who do not want or cannot drive (Mutz et al., 2016).

These new AVs trends are concomitant with the generalization of the service economy in which owning a car will no longer be seen as a priority for users, particularly for urban citizens. The traditional transport model, dominated by cars, taxis and buses, may suffer an exponential decline in the coming years, giving rise to “intermediates” means of transport, mostly designed around the concept of sharing (Enoch, 2015). In this sense, the car tends to be increasingly shared and the “mobility” function becomes the focus of market analysis. Thus, having a shared AV vehicle can result in significant benefits: the AV after completing a commute can, for example, return to the fleet and recharge its battery or depart for a new mission. This opens up an economic and environmental potential that can and should be explored.

Innovations like these lead to imagining mobility in new ways, and can be "freshly" interpreted as a combination of two parameters: personal and shared vehicle and personal and shared trips. Such evolution goes beyond of seeing the AV simply as a new product, but rather to consider mobility as a Product-Service System (PSS) being this an object of innovation. Manzini and Verzzoli (2003) conceptualize PSS as an innovation strategy that alters the focus of the business of designing (and selling) only physical products, to designing (and selling) a system of products and services that are jointly able to meet specific customer demands, where customers' demands are met by service satisfaction, rather than the supply of a product.

This paradigm changes towards the PSS concept (Manzini & Vezzoli 2003; Boehm & Thomas, 2013) imposes new reflections on the conditions of innovation, and raises several questions such as: Do AVs fit the PSS model? What are the characteristics of AVs from the perspective of the PSS? What are the main typologies of uses and performance indicators for AVs as a PSS? In this context, this paper aimed at drawing a typology model for the uses of Autonomous Vehicles in the scope of a Product-Service System and propose relevant key performance indicators.

Besides this introduction, our paper is structured as follows. Section 2 discusses the concept of Shared Mobility, its main aspects and characteristics; further, the concept of autonomous vehicles is provided, highlighting the evolution of the field, main concepts used and the triple-helix context, finally we discuss the Product-Service System (PSS) as a business model approach for shared mobility. Section 3 presents the research methodology, explaining the necessary steps to achieve our objective. Section 4 presents the results and discusses the proposed analysis in two stages: the discussion of the typologies of uses for Autonomous Vehicles as a Product-Service System and the proposition of relevant Key Performance Indicators. Finally, in Section 4, we present concluding remarks, summarizing the main findings and highlighting the possibilities for future research.

2. Theoretical Background

2.1. Shared Mobility - a fast growing sector within sharing economy

The notion of shared mobility is a part of a broader concept known as the "sharing economy" which encompasses business models where people offer and share underutilized resources (goods or services) in creative new ways via digital platforms that intermediates decentralized exchanges among peers (Clewlow & Mishra, 2017; Cohen & Kietzmann, 2014; Acquier, Daudigeos & Pinkse, 2017). Many other terms such as: on-demand economy, gig economy, collaborative consumption, collaborative economy and access-based economy have been used to characterize these for- and nonprofit organizations (Jin et al. 2018; Parente, Geleilateb & Rong, 2018).

Over the past few years, a confluence of important events such as "the ubiquity of the internet and mobile devices, the abundance of goods in idle capacity, growing consumer awareness regarding environmental sustainability, and the economic recession leading to higher unemployment rates" (Parente, Geleilateb and Rong; 2018, p.53) have spurred the rapid development and adoption of sharing economy. With that, sharing business models have emerged both in developed and developing countries in several key sectors of the economy such as: hospitality and dining (e.g., CouchSurfing, Airbnb, Feastly, LeftoverSwap), retail and consumer goods (e.g., Neighborgoods, SnapGoods, Poshmark, Tradesy, Rent the Runway), media and entertainment (e.g., Amazon Family Library, Wix, Spotfy, SoundCloud, Earbits), professional services (e.g., Elance, TaskRabbit), financing (e.g., Kickstarter, Patreon) and automotive and transportation (e.g., RelayRides, Hitch, Uber, Lyft, Getaround, Sidecar) (Bothun et al., 2015; Cohen & Kietzmann, 2014; Jin et al. 2018).

These sharing economy firms connect users (renters) to owners (providers) through peer-to-peer (P2P) or business-to-consumer (B2C) platforms, allowing rentals and exchanges in more flexible, social interactive terms (Parente, Geleilateb & Rong, 2018). Furthermore, Eckhardt and Bardhi (2015) emphasize that customers do not only engage with sharing economy firms just to experience new social interactions, but mainly to avoid ownership liabilities and take advantage of lower costs.

Shared mobility - the shared use of a motor vehicle, bicycle, or other low-speed transportation mode - is one of the fastest-growing facets of the sharing economy and it is particularly interesting in the context of cities that struggle with population growth and increasing density (Shaheen, Cohen & Zohdy, 2016; Cohen & Kietzmann, 2014).
It enable users to obtain short-term access to transportation as needed, rather than requiring ownership. As depicted in Figure 1, it includes various categories of uses divided between 1) sharing a vehicle (e.g., car-sharing and bike-sharing) and, 2) sharing a passenger ride (e.g., ride-sharing, on-demand ride services and microtransit).

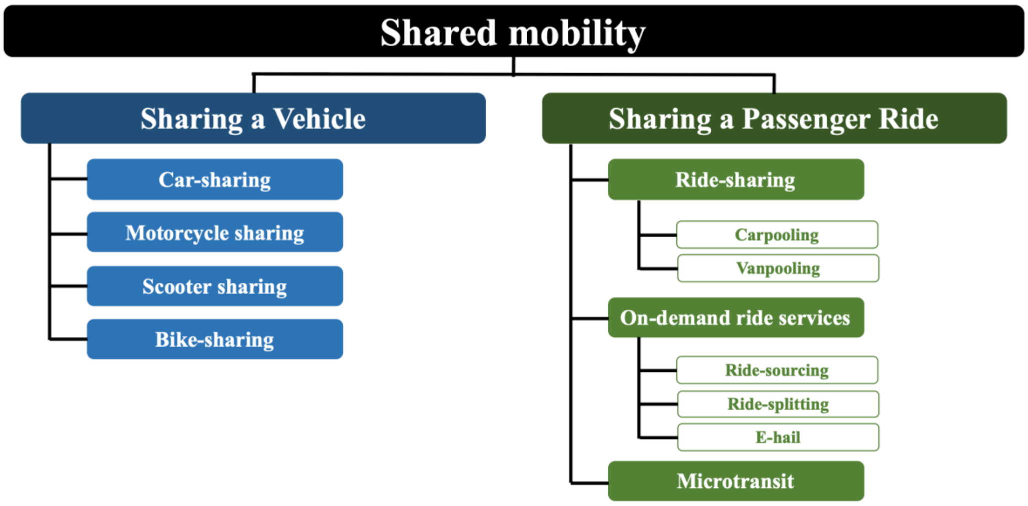

Figure 1. Shared mobility categories.
Source: inspired by Shaheen, Cohen and Zohdy (2016), adapted from Jin et al. (2018).

Thus, it is clear that personal mobility is evolving and may look very different in the future, with that, market perspectives should become more granular and understanding customers will be essential, in a sense that evolving disruptive technologies (such as Autonomous Vehicles) are able to unlock new use cases and value within the personal mobility landscape (Heineke et al., 2017).

According to Sprei (2018) and Heineke et al. (2017), four disruptive trends are changing the rules in the mobility sector: autonomous driving, shared mobility, connectivity and, electrification. In this regard, the largest disruptive potential lies in the combination of these innovations in the form of shared autonomous electric vehicles (Sprei, 2018). As stated by Heineke et al. (2017), less than 1% of passenger miles traveled today are carried out using shared mobility services, for the authors (on a U.S. survey) this number is expected to increase by around 80% once robo-taxis are available.

With that, there has been some enthusiasm surrounding autonomous and semi-autonomous driving and the shared economy (Dia & Javanshour, 2017). For the authors, autonomous mobility on-demand systems are novel and transformative mode of transportation that have the potential to reduce carbon emissions and vehicle accidents as well as improve efficiency in urban mobility and meet people's demand for travel.

2.2. Autonomous Vehicles - a brief overview

Autonomous Vehicles (AVs) - also known as Automated Driving Systems (ADS); self-driving vehicles; driverless cars or even; robotic cars - are vehicles that can maneuver with reduced or no human intervention (Manyika et al. 2013; Frazzoli, Dahleh & Feron, 2002).

According to Lima (2015) and Kröger (2015), the earliest records of an autonomous passenger vehicle date back to the late-1970s, when, a group of Japanese researchers conceived an AV prototype able to track white street marks with computer vision at speeds up to 30 km/h. Another important advancements came about a decade later from Bundeswehr University in Germany which developed a visually guided AV able to detect objects on the road (in front of and behind the vehicle) and from Carnegie Mellon University (United States) which presented a partially autonomous vehicle that drove from Pittsburgh to San Diego as part of a project named “No Hands across America”.

However, the watershed on AVs research and development, came on 2004 in the USA with a series of public annual challenges, named DARPA Gran Challenges funded by the United States Department of Defense, by which countless contributions and advances have been made on AVs throughout the 21st century (Gandia et al., 2018; Reschka, 2015; Poorsartep, 2014). The interest in vehicular automation has been increasingly drawing attention of several stakeholders that make up the triple-helix:

- **Governments:** The United States was the first country to introduce legislation allowing testing of AVs, while in several European countries (Finland, France, Germany, Italy, the Netherlands, Spain, Sweden and England) and globally, lawmakers are considering ways to accommodate the development and testing of AVs technologies on their roads. Asian countries like Japan, Singapore, China and South Korea are also interested that international regulations are updated to allow the development of AVs’ technologies (Schoitsch, 2016; U.K. Department for Transport, 2015).
- **Industry:** numerous carmakers -Audi, BMW, Cadillac, Ford, GM, Mercedes-Benz, Nissan, Toyota, Volkswagen and Volvo - have already started testing driverless cars (Fagnant & Kockelman, 2015). It should also be noted that vehicles with semi-autonomous capabilities are already being marketed: Tesla’s Roadster, Model S and Model X, Mercedes-Benz S65, Infiniti Q50S and BMW 750i xDriv, which are all within SAE’s (2016) level 2 of automation, and most recently Audi’s A8 which according to Nascimento, Salvador and Vilicic (2017) is the first mass produced vehicle with SAE’s level 3 imbedded autonomous driving. It is also worth noting that partnerships among companies have been a very common way for advancing AVs’ technologies (e.g., BMW’s alliance with Intel and Mobileye; Uber partnership with Volvo and Ford for a self-driving fleet, and the same for Lyft and General Motors) and even for training new professionals in the field, such as the partnership among Mercedes Benz, McLaren, Otto, Nvidia and Udacity to create online courses for training engineering professionals in the area.
- **Academia:** research centers and universities world-wide are striving to advance studies on mobility technology, vehicle-infrastructure interaction as well as

management and business-related issues for the consolidation of AVs (Lima, 2015; Weick & Jain, 2014).

By representing a potentially disruptive and beneficial change to the current transportation business model, AVs are bound to change - for the better - the future of urban mobility, bringing significant improvements on how people live, work and commute (Attias, 2017; Hazan et al., 2016; Mutz et al., 2016; Schreurs & Steuwer, 2015; Enoch, 2015). Since, such vehicles are a novel and transformative transportation mode, some of the anticipated benefits aim at reducing carbon footprints, vehicle accidents, transportation costs and time as well as increasing traffic efficiency, productivity and social inclusion (Dia & Javanshour, 2017; Mutz et al., 2016). However, issues related to security and reliability, human-machine interactions, consumer acceptance, job losses, as well as regulatory, ethical and liability frameworks should be considered and taken seriously by all involved stakeholders before AVs reach the mainstream market (Scherurs & Steuwer, 2015; Schellekens, 2015, Poorsartep, 2014).

In this sense, AVs are inserted in the most significant historical change for the society, economy, automobile and public transport industry (Attias, 2017; Schoitsch, 2016; Poorsartep, 2014), therefore, the traditional transport model (dominated by private cars, taxis and buses) it is likely suffer an exponential decline in the coming years, giving rise to means of transport called "intermediaries" (mostly designed in the form of shared vehicles) such as AVs (Enoch, 2015). At last, it's important to highlight that the technology itself is no longer the major hindrance (Poorsartep, 2014); the major road blocks that AVs must now face are consumer acceptance and regulatory frameworks (Attias, 2017; Enoch, 2015; Schellekens, 2015).

2.3. Product-Service System (PSS) - a business model approach for shared mobility

The automotive industry is going through some radical changes, and it's been struggling to find the right positioning, in a sense that while cooperation with traditional players is necessary, OEMs find themselves obliged to form alliances with new entrants, often far removed from their core business such as Google, Uber, Apple among other tech-companies, therefore, the traditional business model of selling cars is losing ground to alternative forms of commerce (Schmidt, Reers & Gerhardy 2018; Attias & Mira-Bonnardel, 2017; Helbig et al., 2017).

With new economic models emerging, major changes are taking place in the car-industry (Allano, 2017), especially if we consider the developing of AVs. As pointed out by Johnson and Mena (2008) manufacturers are combining products and services in order to provide greater value to the customer and to facilitate longer more profitable business relationships.

This bundled offer of products and services constitutes the concept of a Product-Service System (PSS), that can be defined as consisting of tangible products and intangible services designed and combined with the aim of fulfilling users' needs or of a given function while reducing resources consumption and environmental impacts (Tukker, 2004; Qu et al., 2016). In other words, PSS, also known as "functional sales" or "functional products" may be defined as a solution offered for sale that involves both a product and a service element, to deliver a required functionality and have a lower environmental impact than traditional business models (Wong, 2004; Qu et al., 2016; Mont, 2002).

Another important contribution to the PSS literature is the work from Tukker (2004). The author drew a categorization of eight archetypical PSS models with quite diverging economic and environmental characteristics. As depicted on Figure 2, PSSs vary on a spectrum in which on one end the main value rests on product content (tangible) and on the other on service content (intangible). In between that are three main PSS categories: a) **Product-oriented** - the business model is still mainly geared towards sales of products, but some extra services are added; b) **Use-oriented** - the traditional product still plays a central role, but it stays in ownership of a service provider, and is made available in a different forms, and sometimes shared by a number of users and; c) **Result-oriented:** the client and provider in principle agree on a result, and there is no pre-determined product involved.

Within each of the aforementioned categories, there are PSSs with quite different characteristics, and based on Tukker's (2004, p.248-249) framework AVs as a PSS are likely to be positioned on macro category B, that is, use-oriented PSSs in which according to the author is composed of three different PSSs:

- **Product lease:** the provider has ownership, and is responsible for maintenance, repair and control; the lessee pays a regular fee for unlimited and individual product access.
- **Product renting or sharing:** here also, the product in general is owned by a provider, who is responsible for maintenance, repair and control; consumers pay for the use of the product, however differently from leasing, he/she do not have unlimited and individual access; others can use the product at other times.
- **Product pooling:** greatly resembles product renting or sharing; however, here there is a simultaneous use of the product by different consumers.

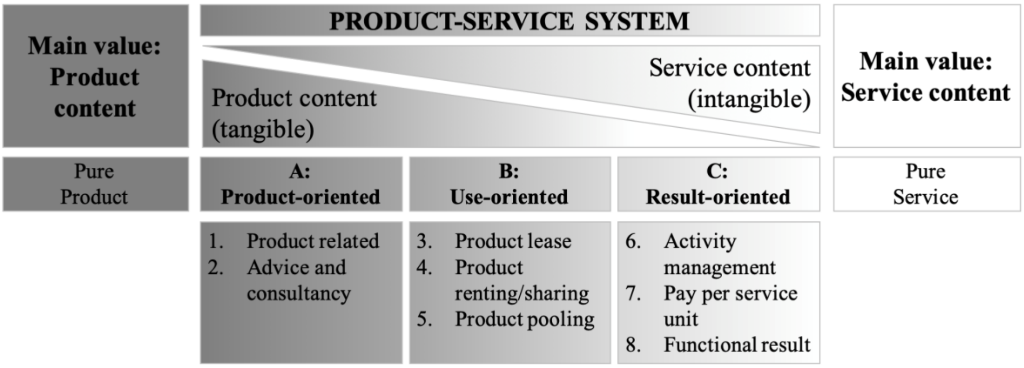

Figure 2. Archetypical PSSs business models.
Source: adapted from Tukker (2004, p.248).

In this sense, a business model in which cars are offered as services is gaining strength and it's being tackled by many companies and scholars. "As a result, traditional players in the industry find themselves obliged to form new alliances with companies in emerging sectors (e.g., performance economy, circular economy, digital economy, etc.)" (Attias & Mira-Bonnardel, 2017, p. 72). Nonetheless, AVs represent a potentially disruptive and beneficial change to the current road transportation system business model.

Therefore, such disruptive innovation (AVs as a PSS) presents a solution to an unmet need (Nogami & Veloso, 2017), since it represents an innovation in products, services, and business models that offer different solutions and alternatives to the market, (Christensen, 2001).

3. Methodology

With the aim of drawing a typology model for the uses of Autonomous Vehicles in the scope of a Product-Service System and propose some key performance indicators, this study adopted research design was characterized as qualitative of exploratory-descriptive nature. Figure 3, details the adopted research design.

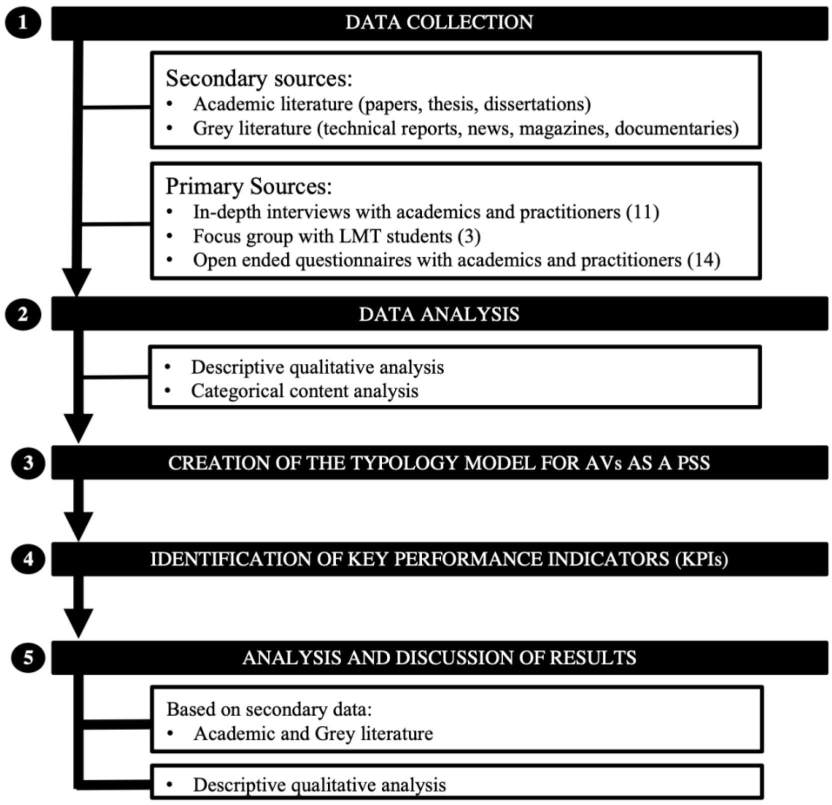

Figure 3. Research design for this proposed paper.
Source: prepared by the authors.

Stage 1 consisted on gathering data from both primary and secondary sources. In order to prepare the interview script and the questionnaires used in the primary data collection, we first resorted to accessing and reading secondary data, such as: technical reports from governments, car-manufacturers, consulting companies as well as academic literature on the field (journal and conference papers, thesis and dissertations).

After the gathering of secondary data, we were able to formulate the interview script and open ended questionnaires. Both instruments were submitted to pre-tests with professors and doctoral students from Brazil and France before conducting the primary data collection. As for the in-depth interviews, we were able to reach 10 academics (being 7 professors; 1 post doc, 01 doctoral student and 1 master students); and 2 practitioners in France. We were also able to use the interview script to conduct a focus group with undergrad students from the Terrestrial Mobility Laboratory from Federal University of Lavras - Brazil. Regarding the open-ended questionnaires, from the interviewed actors and through the snowball technique (Atkinson & Flint, 2001), we sent the questionnaire via GoogleDocs to 14 specialists corroborating with the outputs of the in-depth interviews (academics and/or practitioners involved with AVs research).

On stage 2, all interviews were transcribed and all questionnaires were tabulated, thus, generating a qualitative matrix for data analysis and categorization. We used categorical content analysis (Bardin, 2010; Vergara, 2005), for creating a set of qualitative categories of analysis in which some categories were previously established according to the aim of the paper and others were included and / or excluded during the analysis process. We also carried out descriptive qualitative analysis (Sanderlowski, 2000; 2010; Kim, Sefcik & Bradway, 2016) of the secondary data in order to complement the creation of the typologies and key performance indicators.

After analyzing the gathered data, stage 3 consisted on creating the different typologies for Autonomous Vehicles as a Product-Service System, emphasizing their main characteristics and features. Next on stage 4, we aimed at elucidating relevant Key Performance Indicators (KPIs) for the created typologies.

In parallel, stage 5 consisted on analyzing and discussing the results obtained on stage 3 - based on secondary data in order to support the findings (academic and grey literature) - via descriptive qualitative analysis.

4. Results and discussion

4.1. Typologies of uses for Autonomous Vehicles as a Product-Service System

Based on both primary and secondary data, we were able to draw a set of use typologies for Autonomous Vehicles as a Product-Service System. Firstly considering Tukker's (2004) Product-Service System archetypical model, Autonomous Vehicles are better fit within category B - "use oriented". That is, the traditional product (AV) still plays a central role, however the business model is not geared towards sales of the product, but rather on sales of usage (Tukker, 2004; Bardhi & Eckhardt, 2012).

This finding is aligned with many OEMs new market strategies, in a sense that these companies are no longer seeing themselves simply as car-sellers, instead, they are positioning in the market as mobility providers (Schmidt, Reers & Gerhardy, 2018; Heineke et al., 2017). According to the latter authors, a classic OEM could grow from its traditional core of building vehicles for ownership towards developing provider capabilities; it could participate in new mobility services for end consumers in order to capture value that is generated in new areas of the landscape. Furthermore, as stated by Albert Prya, a Frost & Sullivan's mobility research analyst:

> "OEMs will eventually move towards integrating all their mobility services on a single platform so that customers have a one-stop shop for their mobility needs" (Schöneborn, 2017).

Thus, the product is not simply sold to consumers for private use, instead there is the possibility of ownership by a service provider which makes it available to consumers (both companies and individuals) via different forms (Baines et al., 2007).

Figure 4, depicts the created typologies of use for AVs as a PSS. By analyzing the figure, two main set of uses typologies can be considered: 1) transport of passengers (in blue) and; 2) transport of cargo (in green). It is worth highlighting that during data collection for this study, we were able to identify that autonomous passengers' transport has been the main focus of academic research as well as grey literature, although based on primary data results, we believe that autonomous cargo transport could also prove to be an interesting market alternative for AVs' insertion.

As depicted by Heutger and Kückelhaus (2014), the logistics industry is likely to adopt self-driving vehicles much faster than most other industries. For the authors, liability issues are less pressing when the vehicle is transporting goods instead of people (considering the lower risk of human injuries and fatalities), furthermore a large portion of vehicles involved in logistics move materials in private warehouses and controlled open-air sites - therefore traffic externalities and interferences (e.g., other vehicles, pedestrians, animals, etc.) are likely to be reduced.

Thus, the next evolutionary step for cargo is going beyond warehousing operations, with broader applications across the entire supply chain, particularly in outdoor logistics operations, line haul transportation, and last-mile deliveries (Heutger & Kückelhaus, 2014). With that, new ways of transporting and delivering goods are also emerging, these courier network services have the potential to change the nature of the package and food delivery industry, as well as the broader transportation network (Shaheen, Cohen & Zohdy, 2016).

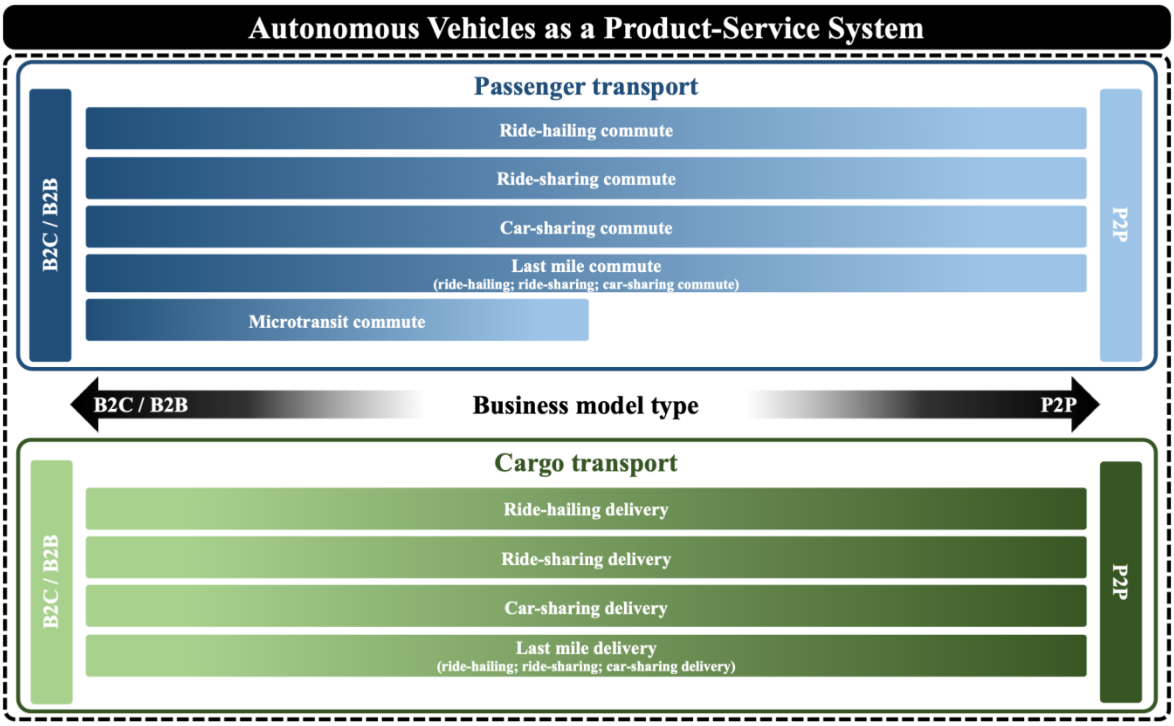

Figure 4. Typologies of uses for Autonomous Vehicles as a Product-Service System.
Source: prepared by the authors based on research data.

Further, we were able to subdivide both passengers and cargo typologies into two main sets of business models as indicated by Mira-Bonnardel and Attias (2018), Nijland and van Meerkerk (2017), Shaheen, Cohen and Zohdy (2016), Strasser et al. (2015), Cohen and Kietzmann (2014) and, Shaheen, Mallery and Kingsley (2012):

1) **Business-to-Consumer (B2C) and/or Business-to-Business (B2B)** - the service provider (or its partners) owns the fleet of vehicles and not only is in charge of managing the rides, the application and the algorithm of the service, but is also responsible for all fleet costs (maintenance, storage, parking, insurance and fuel). This strategy is currently being adopted by car-sharing companies such as Zipcar in Canada and the United States, and Car2go in several European and North American cities (Nijland & van Meerkerk, 2017).
2) **Peer-to-peer (P2P)** - also known as C2C (consumer to consumer) or O2O (owner to owner), the service provider does not own the vehicles (such cars would belong to ordinary people, who, when not using their AVs can lease or rent them to the service provider that would further make such cars available to its clients), consequently the service provider does not have to bear all the costs of ownership and maintenance of the fleet, therefore is able to focus efforts on managing the platform (rides, the application and the service algorithm). Such business proposition is the current prevailing business model of companies such as Uber, Lyft and Didi Chuxing, since by hiring freelancer drivers, these platform firms simply orchestrate interactions, connecting supply (drivers with their cars) with demand (commuters) (Parker, van Alstyne & Choudary, 2016; Macmurdo, 2015). This model is also adopted by car-sharing organizations, where private individuals offer their own cars for rent on online

platforms, such as Drivejoy in Spain and Snappcar in the Netherlands (Nijland & van Meerkerk, 2017).

For each type of the aforementioned business models, we were able to divide them even further into different usage sub-typologies. For passengers' transport (both B2C/B2B and P2P) we extracted five: 1) ride-hailing; 2) ride-sharing; 3) car-sharing; 4) last mile and 5) microtransit commute. As for cargo transport (both B2C/B2B and P2P as well) we identified the same typologies as for passengers, except for microtransit, however instead of focusing on passengers' commute, the focus is on logistics, freight and goods delivery.

Nevertheless, it is worth mentioning that additional services may be required for certain typologies. For instance, cargo autonomous transport may require an additional load and unloading service (to and from the autonomous vehicles). As for passengers' transport an additional assistance service may be necessary for those people with reduced mobility, elders, children and etc. Therefore, we emphasize that the scope of this study does not go deeply into all possible additional services that may be required for the described typologies, but we recognize that such services may be necessary and even essential for the proper functioning of some of the proposed models below.

4.1.1. Ride-hailing

When ride-hailing services were first launched, they were commonly referred to as "ride-sharing" or "peer-to-peer mobility" services (Clewlow & Mishra, 2017, p.4). However, the authors highlight that these terms were somewhat misguiding, hence in 2013, a California Public Utilities Commission ruling officially defined such services as Transportation Network Companies (TNCs). Although, they are still often colloquially referred to as ride-sourcing (Rayle et al., 2014) or ride-hailing companies.

Complementarily Jin et al. (2018) highlight that as TNCs' business models are becoming increasingly sophisticated, it is easy to confuse different forms of the offered shared mobility services, being the pair "ride-hailing and ride-sharing" the most easily confused. For the authors:

> "The popular media often use ride-sharing to refer to the services provided by Uber and Lyft, which is harmless as long as the readers understand it. However, confusion of these two concepts in research can produce inaccurate results" (Jin et al., 2018, p.101).

Ride-hailing is a platform where individuals can hail and pay for a ride from a professional or part-time driver through smartphone mobile applications (Clewlow & Mishra, 2017; Shaheen, Cohen & Zohdy, 2016; Zha, Yin & Yang, 2016). This kind of PSS has grown exponentially in popularity over the past four years, providing service to a majority of metropolitan regions spanning over 66 countries, mainly by the widespread applications of mobile internet, smartphones, and cloud computing, since it has the potential to replace not only taxicabs, but also other modes of transportation, such as public transit, walking, biking, driving, and ridesharing (Contreras & Paz, 2018, Jin et al., 2018; Chen, Zahiri & Zhang, 2017; Clewlow & Mishra, 2017).

Created in San Francisco (California) Uber was one of the first TNCs to emerge in 2009, since then, several other similar companies have entered this new market, such as: Lyft, Sidecar, Hailo and Didi Chuxing, mainly focusing on the transport of people (Contreras & Paz, 2018; Clewlow & Mishra, 2017). With that, such services have rapidly revolutionized travel and redefined the concept of the taxicab experience. In the last two years alone, the number of daily trips via ride-hailing platforms in New York City has grown fivefold, to about 350,000 trips per day, with an average of one in five urban Americans (21%) claiming to have used ride-hailing services at least once in their lives (Contreras & Paz, 2018; Choudhari, Byers & Terzi, 2018; Clewlow & Mishra, 2017). In China, Didi Chuxing completed 1.4 billion races in 2016, being 200 million in December alone and in 2017 became the 2nd largest startup of China and Asia after Xiaomi (smartphone manufacturer) with an estimated value of $50 billion (Alba, 2016; Pham, 2017).

With TNCs continuing to push the envelope and explore new techniques for improving and expanding service, Contreras and Paz (2018) states that the future of ride-hailing services has the potential to revolutionize even further the functionality of urban transportation systems by the use of self-driving vehicles. As pointed out by 2016 Boston Consulting Group report:

> “As with sharing a conventional car, haling an AV will be substantially cheaper and less aggravating than owning a car in the traditional way: instead of bearing these burdens themselves, co-owners pay a membership fee to fleet service that provides management and maintenance services and makes sure that owners get the type of car they need for each trip. But door-to-door autonomous technology makes car sharing even more attractive, by eliminating or reducing several common barriers” (Hazan et al., 2016, p.5).

Therefore, Rayle et al. (2016) states that, in this typology users expect better service quality such as: ease of payment; short waiting times; ease to hail a car; among other factors, and do not mind paying a bit more for such amenities.

As for passenger's transport, this automation phenomenon had already started in some American cities with TNCs such as Uber, Lyft and Waymo testing their self-driving fleets via B2C business models (Tascarella, 2016; Kokalitcheva, 2016; Madrigal, 2018).

Regarding cargo transport, some initiatives towards autonomous ride-hailing have also started to take shape, last march Uber took a leap forward with the announcement that the ride-hailing giant is now operating its fleet of self-driving trucks on its freight-hauling app. Shipments are taking place in Arizona (where they are also testing their AVs), the company is using a transfer hub model, in which the trucks drive autonomously on the highway and human drivers take over for the last miles (Hawkins, 2018; Kerr, 2018).

4.1.2. Ride-sharing

Also known as shared ride-hailing, dynamic ride-hailing, carpooling or even ride-splitting (Bischoff et al., 2018; Contreras & Paz, 2018; Clewlow & Mishra, 2017; Chen, Zahiri & Zhang, 2017; Shaheen, Cohen & Zohdy, 2016) this typology can be considered an extension of ride-hailing where individuals (or cargo) can be matched in real-time to share rides on similar routes (Clewlow & Mishra, 2017).

This kind of PSS is often limited to densely populated inner city districts, whereas non-pooled options are often available in larger areas. Furthermore, pooled TNCs can be direct competitors of public transport and taxis in many markets (Clewlow & Mishra, 2017; Kim, Baek & Lee, 2018), however in some cities co-operations between both services have evolved, especially regarding first- and last-mile issues (Bischoff et al., 2018; Stiglic et al., 2018).

Nevertheless, ride-sharing has shown great potential in improving mobility services in terms of accessibility and sustainability, since pooling may reduce the overall vehicle miles traveled and thus mitigate congestion, travel costs, fuel consumption and vehicle emissions (Bischoff et al., 2018; Rayle et al., 2014; Santi et al., 2014). Additionally, these pooled services offer generally lower fares to customers, in a sense that clients compromise on sharing the vehicle with other users and in return pays less for the ride (Farhan & Chen, 2018; Bischoff et al., 2018).

In 2014, both Uber and Lyft announced the pilot of algorithms to match passengers who request service along similar routes in real-time, enabling them to share rides: UberPool and LyftLine (Farhan & Chen, 2018; Zha, Yin & Yang, 2018; Clewlow & Mishra, 2017). It is

also worth highlighting that other business models and apps are emerging in an attempt to enable traditional ride-sharing (in which the driver has the same route as the passengers), such as: Waze’s Rider and Scoop (Bischoff et al., 2018; Clewlow & Mishra, 2017)
Regarding cargo, although no real initiatives of companies to provide a shared service of cargo delivery were found (to date), it is believed that this typology is a logical evolution as soon as autonomous trucks are available. The sharing of structures for logistics is a reality in environments such as yards, ports, and airports logistics.

According to Heutger and Kückelhaus (2014 p.25), there are already some initiatives such as the research project called SaLsa62 that aims to safely test autonomous transport vehicles in yards. “With sensors installed in the yard infrastructure, these vehicles detect other objects and their position which allows the combined operation of automated vehicles, forklifts, and people in an efficient and safe manner”. Also another pioneering example is at the Harbor Container Terminal Altenwerder in Germany, which is one of the most modern container handling facilities in the world:

> “Container handling is almost completely automated. A total of 84 driverless vehicles transport containers between the wharf and the storage areas via the fastest possible routes. Navigation is performed using 19,000 transponders that are installed in the ground. This greatly increases the speed and efficiency of container handling in comparison to traditional transport methods using trucks and cranes” (Heutger & Kückelhaus, 2014, p.26).

As depicted by Loeb, Kockelman and Liu (2018) and Chen, Zahiri and Zhang (2017), Shared Autonomous Vehicles (SAVs) have attracted significant public and private interest and will facilitate ridesharing behavior, because of their opportunity to simplify and improve vehicle accessibly and reliability, avoid parking costs, reduce fleet size, and, ultimately, save many travelers (and cargo companies) time and money.

4.1.3. Car-sharing

This typology resembles vehicles’ rental by providing access to automobiles (for both passengers and cargo) without incurring capital and maintenance expenses associated with vehicle ownership (Farhan & Chen, 2018; Shaheen, Cohen & Zohdy, 2016). Most car-sharing services have been developed in high-density metropolitan areas, allowing users to accomplish several transportation goals and avoid congestion, parking and pollution problems (De Luca & Di Pace, 2015).

According to Ferrero et al., (2018), Namazu and Dowlatabadi (2018), Shaheen, Cohen and Zohdy (2016) and Clewlow and Mishra, (2017), car-sharing can be classified into different business models:

- **Point-to-point:** vehicles are picked up and returned to pre-determined locations and rental is normally made by the hour. This station based service can be classified as: two-way (vehicle's journey must start and finish in the same pick up location) or as; one-way (the journey finish can be different from the parking lot in which it started). Some examples are: Autolib (Paris); Zipcar (France, Spain and the U.S.) and Hertz on Demand (across Europe and the U.S.).
- **Free-floating:** typically charged by the minute, in this business model cars are freely picked up and parked in public spaces within the operational area of the service provider. Companies such as DriveNow (BMW) and Car2Go (Daimler AG) are offering these services across Europe, United States and China.
- **Peer-to-peer:** within this business model, individuals can rent out their personal vehicles to others when not in use. Turo (formerly RelayRides) offers this service in more than 5,000 cities in the U.S., Canada, Germany, and the U.K. While their competitor GetAround offers their service across several American cities.

AVs might have a very interesting application on car-sharing schemes, especially on point-to-point and free-floating business models. As depicted by Jorge, Correia and Barnhart (2014), imbalances in spatial and temporal vehicle distribution are a common feature within these models, therefore relocation operations are required to maximize vehicle availability. With that, effective relocation strategies are essential these operations, which can be implemented without significant driver labor costs once self-driving technology is introduced to the vehicle fleet (Farhan & Chen, 2018, p.310).

At last, for low-mileage travelers, car-sharing provides a lower-cost alternative to owning a private vehicle as well as provides more flexibility than transit service while also being environmentally beneficial (Farhan & Chen, 2018; Nijland & van Meerkerk, 2017). On the other hand, although the number of car sharing users in the world has increased from 0.35 million in 2006 to approximately 5 million in 2016, it continues to represent a somewhat niche market - particularly compared to the rapid and widespread growth of ride-hailing services (Clewlow & Mishra, 2017; Prieto, Baltas & Stan, 2017).

Regarding car-sharing delivery, Volvo is already thinking along these lines. The company has developed a Volvo on-call app, which can give anyone access to a shared vehicle. The company plans to deploy its cars as mobile delivery stations. "A delivery company would buy the right to access the trunk of a car. It would put its parcels and other items into the trunk. Then they would check the required location and time of delivery with the customer. Once this was agreed, a human would drive the car to the agreed place. Using the Volvo on Call app, the customer would receive and use a digital key to open the trunk and collect their parcel (Heutger & Kückelhaus, 2014, p.32).

4.1.4. Last mile

The last mile issue is a recurring problem in large cities and it encompasses the difficulty in getting people from a transportation hub (railway, metro or bus stations, and ferry slips), to their final destination. Such problem can also happen in the beginning of a journey - that is: the "first mile issue".

As pointed out by Scheltes and Correia (2017) the last mile in a public transport trip is known to bring a large disutility for passengers, because the conventional transport modes for this stage of the trip can, in many cases, be rather slow, inflexible and not provide a seamless experience to passengers. Furthermore as pointed out by Cohen & Kietzmann (2014, p.282), "when the overall transit system fails to solve this so-called "first mile, last mile" problem, many residents in outlying areas opt for driving vehicles for the entire commute, thus reducing overall public transit usage and resource efficiencies." Hence, Autonomous Vehicles could act as a first mile/last mile connection to mass public transport modes (Scheltes & Correia, 2017).

The same goes for cargo, in fact, if we imagine all the delivery vans and drivers needed to satisfy demand for package delivery we can measure the issues faced by last mile logistics (Boysen, Schwerdfeger & Weidinger, 2018). In this context, one of the modes presented by this typology is a kind of delivery-assistance vehicle suited to support urban delivery processes. According to Heutger and Kückelhaus (2014, p.31), "the biggest advantage is its potential to increase the productivity of each delivery person, making their job easier and at the same time more attractive. On good example of this application would be the Support vehicles for letter and parcel deliveries".

These ideas may sound far-fetched, yet some companies have been working on solutions for this issue, just last January in San Mateo, autonomy startup Udelv used a custom-built package delivery van, bristling with rooftop cameras and lidar sensors, to make a roughly 3-mile run on public streets to deliver groceries from Draeger's Market (Robar, 2018). Meanwhile, companies such as: Waymo, Ford, Daimler and others are working on automating last-mile delivery systems (Hirsch, 2018).

In the present study, this typology can be offered to consumers in any of the three typologies described above (ride-haling; ride-sharing and; car-sharing) both via B2C or P2P business model. It is worth mentioning that any of the aforementioned typologies correspond to the seminal developments that can occur considering AVs' B2C and P2P business models as a starting point. From these initial typologies several unfoldings can arise, as well as hybrid typologies according to the later advance and development of AVs.

4.1.5. Microtransit

With no evidences found for cargo transport (to date), this typology is likely to initially be applied for passengers commute. As described by Jin et al. (2018) and Shaheen, Cohen and Zohdy (2016), the premise of microtransit is to provide a ride-sharing flexible shuttle service with small buses or vans, that would be bigger than traditional cars and smaller than traditional public transport buses.

This business models entails privately owned and operated shared transportation systems that can have fixed routes and schedules, as well as flexible routes and on-demand scheduling. It mainly provides commuting services that connect residential areas with urban and suburban working and commercial areas (Jin et al., 2018; Ganapati & Reddick 2018; Shaheen, Cohen & Zohdy, 2016).

Chariot (Transit Inc.) is an interesting ongoing example of this typology that currently operates in cities in the United States and Europe. The company's mobile-phone application allows passengers to ride a shuttle between home and work during commuting hours with new routes determined based on demographic information and crowdsourced data; the exact boundaries are flexible, depending on riders' demand, and could shift or expand according to rush hours (Cutler, 2014; Suzdaltsev, 2014; Cronkleton, 2016).

Therefore microtransit could be an interesting alternative for AVs. As stated by Mira-Bonnardel and Attias (2018), in cities that struggle to provide adequate public transport, autonomous shuttles could partially fill the gap by fulfilling the promise of personal rapid transit and offering a personalized point-to-point service without the hassle, congestion, or crashes involved in driving. Several newcomers companies such as Navya, EasyMiles, Auro Robotics and Local Motors are entering the domain of driverless shuttles and buses, with pilot projects being deployed in the U.S., Europe, Singapore, Taiwan, Japan and the Middle East (Mira-Bonnardel & Attias, 2018).

Regarding Navya, its autonomous shuttles are being implemented on full-scale demonstrations of urban transport automation in low- to medium-demand areas of four European demonstrator cities: Geneva, Lyon, Copenhagen and Luxembourg, and 3 replicator cities in a second phase, as part of the project AVENUE (*Autonomous Vehicles to Evolve to a*

New Urban Experience) - a consortium of 16 partners from 7 European countries (Mira-Bonnardel & Attias, 2018). According to the authors, AVENUE's ambition is to boost the adoption and acceptance of AVs for public transportation, accelerating their commercial deployment and European leadership in the domain, while stimulating international R&I cooperation.

Although these proposed typologies approach a product innovation that is still being tested and perfected to reach the market, the definition of some components of the business model is a hard task to accomplish - such as: possible revenue models and cost structures. Thus, one way to mitigate such uncertainties is by designing and determining Key Performance Indicators (KPIs), which as pointed out by Hein et al. (2018), by considering the particularities of AVs as a PSS, KPIs would serve as business models anchors for the proposed typologies as well as for the proper functioning of the models.

4.2 Key Performance Indicators for Autonomous Vehicles as a Product-Service System

In this section, we propose relevant KPIs found for AVs as a PSS. By the content analysis, we categorized all the information provided by the interviews and, guided by inflexion points, we were able to describe some Key Performance Indicators suggested by the specialists. After we were able to allocate them into the typologies of this study and also classify them in either economic-centered or user-centered KPIs (Table 1). We assumed that, economic centered dimensions are related to the best use of resources (e.g. money and time), and the user-centered KPIs are related to the user experience and expectations such as the flexibility, comfort and well-being inside the vehicle, as well as vehicle availability and so on.

It's worth highlighting that the listed KPIs where those that are more recurrent in the both academic and grey literature and that would have more direct / visible impact in each described business models typology. Table 1, describe such indicators, their possible metrics as well as highlights some other KPIs possibilities according to the described typologies.

KPI	Description	Category	Typologies Applied
Fuel autonomy (hybrid or electricity)	Number of kilometers driven per unit of fuel (being it gasoline or electricity)	Economic Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Trip costs	all the costs involved on operating and maintaining the car per mile traveled	Economic Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Safety	Number of accidents/incidents per miles traveled	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Vehicle miles traveled	Number of miles traveled per vehicle	Economic Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Trip travel time	Average time spent in the trip (considering the moment that you order the service until the final destonation)	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Trip Price	Average price (for the user) per mile traveled	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Trip length	Average time (minutes/hours) that the commute lasts.	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Waiting time	Average time (minutes) to get the transport	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile
Travel time reliability of origins/ destinations	Expected departure and arrival time.	User Centered	Passengers: ride-hailing; ride-sharing; car-sharing; last mile; microtransit Cargo: ride-hailing; ride-sharing; car-sharing; last mile

Table 1. Key Performance Indicators for AVs as PPS.
Source: prepared by the authors.

5. Concluding Remarks

This paper aimed at drawing a typology model for the uses of Autonomous Vehicles in the scope of a Product-Service System and propose relevant key performance indicators.

By outlining the typologies of use of AVs as a PSS as well as the main examples of the developments that may occur in each typology, the role that AVs will play in the near future is undeniable, acting as important catalysts in the process of transforming mobility. Thus, autonomous driving technology is a key competition area for TNCs as robots can work tirelessly, do not demand a salary, and don't care for employment status or benefits (Dudash, 2017). “Having fleets of driverless cars on the street will not only affect congestion and transportation accessibility and safety, but also have a strong impact on the livelihoods of ridesourcing drivers, and even drivers working for the traditional transportation and logistics industry” (Jin et al. 2018, p.102).

Models such as ride-hailing, ride-sharing and car-sharing, especially in passenger transport, are already a reality present in the daily lives of thousands of urban-dwellers. By considering the insertion of AVs in this equation, we see the potential for change / impact of these modes to increase even more, translating into new ways of "thinking" the traffic as we have today.

It is worth noting that when we consider AVs as a PSS, we have a shift focus from the vehicle as a privately owned asset to a service with a mobility function. In this sense, the dimensions of the business model for the AVs as a PSS need to be rethought, as well as we the new array of performance indicators, mainly related to the user experience.

Thus, in addition to dealing with economic aspects, fuel autonomy and maintenance costs, for example - which continue to have their space - we must think about aspects related to the flexibility offered, the comfort and well-being that the user will have inside the vehicle (in the case of passenger transport), connectivity and accessibility options as well as reliability and security issues.

As for research limitations, we point out the novelty of the theme, in a sense that since AVs are not yet a reality in the market, carrying out research on the topic is challenging due to lack of information as well as due to high speculations. Also noteworthy is the difficulty in obtaining answers to the questionnaires and contact of people involved in the industry, since discussions regarding AVs in the business environment are still mainly being kept confidential, therefore we were not able to get as many answers as we desired.

As for future studies, we suggest deeper research (both empirical and theoretical) on the proposed typologies as a way of testing and validating whether the KPIs are fit for each of them. Furthermore, we recommend analyses in dimensions of business models in a context of AVs as a PSS. We also suggest studies on other possible emerging hybrid typologies, such as the bundled offer of cargo and passengers services. At last, we suggest further studies coupling the product-service system approach with the business ecosystem theory, since, as pointed out by Kowalkowski (2011), PSS require ecosystem thinking to understand who and what are needed to keep the equipment working so that it supports the customer’s or end-user’s business.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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ARTICLE 3 - BUSINESS PLATFORMS FOR AUTONOMOUS VEHICLES WITHIN URBAN MOBILITY

Paper under evaluation on the Elsevier's journal "*Futures*"

ISSN: 0016-3287, JCR: 2.256.

Business Platforms for Autonomous Vehicles within Urban Mobility

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Highlights

- B2C and P2P ridesharing; B2C and B2C + P2P multimodal mobility are the 4 scenarios for Urban Mobility with AVs;
- P2P ridesharing and MaaS schemes will likely be prevailing in Urban Mobility Business Models;
- B2C multimodal mobility provided by a single firm is the most unlikely scenario to be consolidated;
- AVs may act as catalysts on accelerating the transitions towards servitization of Urban Mobility;
- Business Platforms and Ecosystems approaches are theories well suited to sustain Urban Mobility scenarios for AVs

Abstract: With mobility becoming a key factor affecting citizen's well-being and life-quality, innovative schemes such as P2P ridesharing business models and Mobility as a Service (MaaS) concepts can have significant impacts to existing urban transportation business models. Furthermore, one of the most disruptive technologies regarding the future of urban transportation, is the insertion of Autonomous Vehicles (AVs). In this sense, the present study aimed at creating future scenarios for Business Platforms for AVs in urban mobility contexts. We proposed 4 scenarios with real-word examples present in urban mobility today, extrapolated to a future reality in which AVs are seen as a transport mode; (A) B2C autonomous ridesharing; (B) P2P autonomous ridesharing; (C) B2C multimodal mobility and; (D) P2C + P2P multimodal mobility. For scenarios A and B the prevailing business model is autonomous ridesharing which can be explained by business platforms theory, meanwhile for scenarios C and D the underlying business model is sustained by MaaS schemes where business platforms theory is tied to business ecosystem theory to explain value creation and distribution. We conclude that, besides the unlikelihood of scenario C, any of the others three have potential to become a reality whether AVs become an urban transport mode.

Keywords: Autonomous Vehicles; Business Platforms; Urban Mobility; Scenario Planning.

1. Introduction

Over the course of the 20th century, automobility has become the world's dominant transport option, considering that among the wide range of transport modes, Internal Combustion Engine (ICE) vehicles have historically been placed within the central core (Urry, 2004). In turn, such mobility regime has been responsible for a variety of negative environmental impacts both on a global and local level (Epprecht et al., 2014). Thus, governments, OEMs, and society as a whole are aware that changes towards more efficient and sustainable mobility regimes are urgent (Fournier, 2017; Enoch, 2015; Afabuzzaman & Malzoumi, 2011).

The current mobility regimes based on fossil fuels and mainly individual mobility is reaching its environmental, economic and social limits, to a point where privately owned cars will be more and more challenged as a solution to satisfy mobility needs (Fournier, 2017). Thereby, this current traditional transport model could suffer an exponential decline in the coming decades, since we are moving away from a set-up that involves car-ownership, and towards transportation systems in which users want to choose mobility rather than being subjected to it (Attias, 2017; Cao & Wang, 2017).

With that, new economic models are emerging, since businesses are realizing that manufacturing and sales can no longer be the only source of competitive advantage and differentiation (De Zan et al., 2015). Companies are now combining bundled offerings of products and services in a market proposition where the emphasis is on the "sale of use" rather than "sale of products", being the millennials and generation Z very favorable to alternative mobility solutions (Johnson & Mena, 2008; Baines et al., 2007; Wong, 2004; Lasmar Junior et al. 2018).

Among the various emerging alternatives, solutions such as Peer-to-Peer (P2P) ridesharing business models (i.e.: Uber; Lyft; Didi Chuxing; and so on), have rapidly emerged and gained ground as alternative modes that would provide a partial solution to mobility issues presenting themselves as another transport mode (Amirkiaee & Evangelopoulos, 2018).

Another interesting emerging solution, attempting to provide an answer to these demands, is the concept of Mobility as a Service (MaaS), which is a model that deliver users' transport needs through a single interface of a service provider by combining different transport modes to offer tailor made mobility packages (Jittrapirom et al., 2017; Mulley, 2017; Kamagianni et al., 2016, Hietanen, 2014).

Still, regarding the future of urban mobility, one of the most disruptive technology are the Autonomous Vehicles (AVs). As Litman (2018) states, autonomous car-sharing/taxi schemes will become a reality in 2030-40s, suggesting a positive impact of AVs on urban mobility. Therefore, the implementation of innovative mobility schemes can have significant impacts to the existing business model of public transportation, especially when it comes to integration with private transport providers (Jittrapirom et al., 2017).

Such integration of services may be realized by using the so-called multi-sided business platform technology, which aims at creating value by orchestrating interactions between external producers and consumers (Parker, Van Alstyne & Choudary, 2016; Choudary, 2015), thus, facilitating interactions between travelers and suppliers of transport services in an improved or smarter way.

Given the aforementioned, this study is guided by the following question: what will be the future scenarios of urban mobility with the insertion of AVs as a mode of transportation? In this sense, by considering as study object business platforms for AVs in large centers where the need for mobility solutions are required, the present study aims at creating future scenarios for the Business Platforms of Autonomous Vehicles in urban mobility contexts.

2. Theoretical background

2.1. Urban Mobility - Challenges towards servitization

Mobility has become a key factor affecting citizen's well-being and life-quality, since it enables citizens to access their workplaces, hospitals, schools and other public services. Moreover, in cities, mobility plays a central role for ensuring prosperity and social cohesion as well as influencing urban geography by defining where people work and live and consequently, on how urban dwellers commute on a daily basis (Melis et al., 2016; ITF, 2015).

Yet, by considering our highly motorized and car-dependent society, mobility is also a source of major problems in urban areas, in a sense that cities are increasingly facing problems such as: congestion, air pollution, noise and other externalities associated with moving people and goods around. As pointed out by Fournier (2017) and Gao et al. (2017), in the 1950s there were approximately 50 million automobiles in the world, by 2017 that number ranged around 900 million and the estimates are of 1.3 billion by 2030 and 2 billion by 2050.

The reason for such growth in number of vehicles lies on the fact that private cars pose a clear advantage over other transport options: flexibility, comfort and availability; thus, these characteristics overshadow the advantages of other transport modes, leading to a bias in favor of the private car (ITF, 2015). Furthermore, Smith (2018) states that even with higher costs, cars users usually just compute the additional expenses to a trip (e.g. fuel, parking so on), and this makes them believe that taking the car seems cheaper than alternative transportations modes.

In this regard, contemporary transport practices are increasingly compromising the well-being of existing populations, perhaps most importantly, the way we travel today is constraining and compromising the environment of generations to come (Mulley, 2017).

One promising emerging solution for answering these demands is the concept of Mobility as a Service (MaaS), that besides being a very recent construct (with a first comprehensive reference dating back to Hietanen, 2014) - it presents a shift from the current ownership-based regime towards an access-based one (Jittrapirom et al., 2017). With the aim of offering customized transport services to fit individual traveler’s needs and requirements, MaaS delivers multimodal tailored-made mobility packages via a single interface of a service provider (Karlsson, Sochor & Strömberg, 2016; Hietanen, 2014). Table 1 depicts the underlying logic of MaaS.

Core feature	**Description**
1. Transport on demand	By using Information and Communication Technologies (ICTs), it offers an integration of transport modes with multiple actors (both public and private stakeholders) in order to meet consumers’ demand, arranging the most suitable routes and transport means.
2. Subscription service	By registering on the service, consumers can buy mobility packages that are offered by the same or different operators by using a single platform, providing the freedom of choice for an agreed time-period or even “pay-as-you-go” subscriptions.
3. New markets’ potential	For transport providers, MaaS can offer new sales channels, access to untapped consumer demands, simplified user account and payment management, as well as richer data on travel demand patterns and dynamics.

Table 1. Mobility as a Service core features.
Source: prepared by the authors based on Mulley (2017), Jittrapirom et al. (2017) and Kamargianni et al. (2016).

The effect of Autonomous Vehicles is another aspect that needs to be considered and that will ease relocation efforts on MaaS schemes. As Zhang et al. (2011) points out, AV are able to rebalance themselves in the network and coordinate their actions at a system-wide level. As pointed out by Litman (2018), automatic car-sharing/taxi schemes will become a reality in the next decades (2030-40s), suggesting a positive impact of automated vehicles on MaaS. Furthermore, according to Tasha Keeney, a researcher analyst on industrial innovation at ARK Invest, MaaS platforms in a context of AVs will be one of the most valuable investment opportunities in public equity markets, exceeding over than 10 trillion dollars in gross revenue by the early 2030s (Keeney, 2017).

2.2. Autonomous Vehicles - Disrupting cities' environments

Autonomous Vehicles (AVs) are cars with motion and action capabilities that do not require any sort of conductor (driver) or teleoperation control (Frazzoli, Dahleh & Feron, 2002). These vehicles are also known as Automated Driving Systems (ADS), which is a recommendation terminology adopted by the Society of Automotive Engineers (SAE, 2016) to refer to vehicles with different automation levels (Figure 1) and avoid multiples definitions with ambiguous meanings widely used in the literature (i.e.: autonomous vehicles/cars, self-driving vehicles/cars, car-like robots, intelligent vehicles/cars, driverless vehicles/cars, so on).

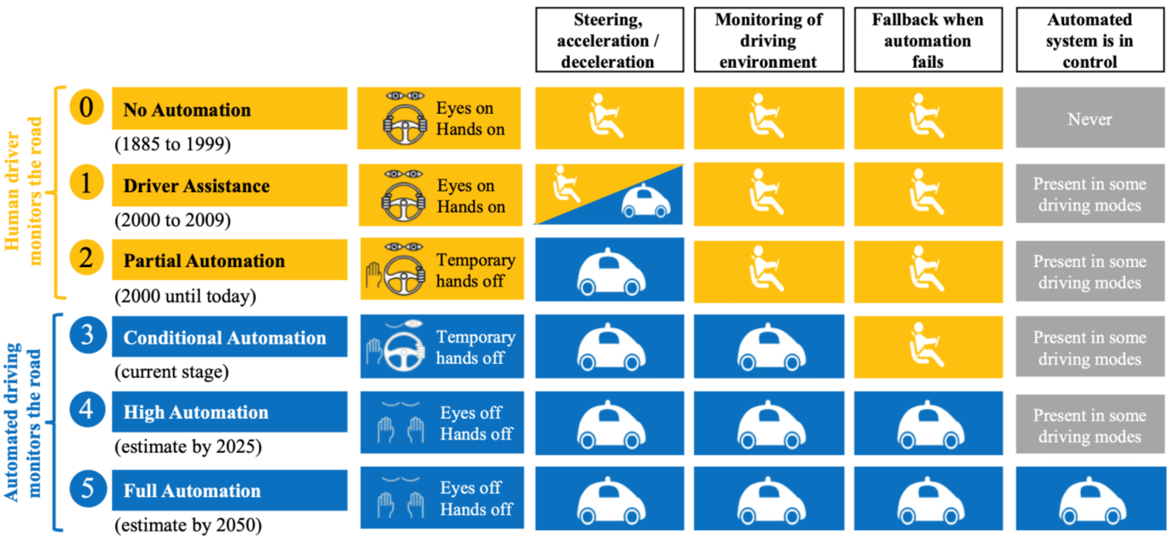

Figure 1. Summary of SAE's automation levels for automated driving systems.
Source: adapted from SAE (2016); Nascimento, Salvador & Vilici (2017); Hawes (2016).

According to Lang et al. (2016) and Mutz et al. (2016), there is a strong expectation that, in the future, AVs are most likely to fundamentally change - for the better - urban mobility in cities, bringing significant improvements on how people live, work, and get around. Far fewer accidents lower transportation costs and time, as well as higher traffic efficiency, improved productivity, social inclusion, and lower pollution rates are just some of the anticipated benefits. Nonetheless, there are relevant questions that still need to be addressed and taken seriously by governments and carmakers, such as: security and reliability issues; impacts on mobility behaviors and human-machine interactions; consumer acceptance; job losses; impacts on cities' revenues and costs; as well as regulatory, ethical and liability frameworks (Nascimento, Salvador & Vilicic, 2017; Scherurs & Steuwer, 2015; Schellekens, 2015).

Thus, the trend towards putting AVs on the road is rapidly gaining momentum across a broad front that encompasses OEMs, suppliers, mobility providers, technology companies, academic institutions, governments, and regulatory bodies (Lang et al., 2016). Being so, these new AV trends are concomitant with the generalization of the so-called "service economics" or "sharing economy" - where owning a car will no longer be seen as a priority. Thus, vehicles will increasingly be shared and the "mobility" function becomes the goal of market and business analysis.

In this context, OEMs find themselves obliged to form alliances with new entrants, often far removed from their core business, such as: Google, Uber, Lyft, among other tech-companies (Attias & Mira-Bonnardel, 2017). As Johnson and Mena (2008) states, manufacturers are combining products and services (concept known as Product-Service System - PSS; see: Tukker, 2004; Baines, 2007) in order to provide greater value to consumers and to facilitate longer, more profitable business relationships.

Such business model in which cars are offered as services is gaining strength and it is being tackled by many companies and scholars. Thus, making such PSSs models a reality will mean rethinking the way innovation process is organized, so that the chosen production model fits in with mobility requirements (Attias, 2017). As emphasized by Fournier (2017):

> "value propositions of mobility solutions will therefore deeply impact the future, since new vehicles and services will emerge; new players will reshape the value chain thus, challenging traditional OEMs' with new products and services; even customers will be part of the value chain and become prosumers" (Fournier, 2017, p.21).

As elucidated by Jittrapirom et al. (2017) such integration of products and services may be realized by using business platforms, in a sense that innovations on urban mobility are not only about the integration of mobility services, but also requires a complete restructuring of the supply chain for mobility service providers. The final section of this theoretical background better describes the main concepts of business platforms.

2.3. Multi-sided Business Platforms

Multi-sided Business Platforms (also known as Industry Platforms; see: Gawer & Cusomano, 2015; 2002; Sugano, 2005; Figueira, 2013) are responsible for a revolution that is affecting many industries across the globe. They are an important business phenomenon that have existed for a long time, but over the past 7-8 years proliferated with the widespread of Information and Communication Technologies (ICTs), (Parker, van Asltyne & Choudary, 2016; Choudary, 2015; Osterwalder & Pigneur, 2010).

Multi-sided Business platforms are such an expressive business phenomenon, that three of the world’s five largest firms as measured by market capitalization - Apple, Google and Microsoft (to date) all run platform business models (Parker, van Astyne & Choudary, 2016). Furthermore, the authors state that incumbent giants from Walmart and Nike to John Deere, General Electrics and Disney are all scrambling to adopt the platform approach to their businesses.

As Choudary (2015) states, if ICTs had not come up, we would still be stuck in “pipeline business models” which - until recent years - had been the prevailing dominant business model wherein value is created in a linear fashion, with centrally employed staff and owned assets. Unlike “pipes”, multi-sided platforms create value by orchestrating interactions between external producers and consumers (Evans & Gawer, 2016; Parker, van Asltyne & Choudary, 2016; Osterwalder & Pigneur, 2010). Therefore, the role of multi-sided platforms is to bring together two or more distinct but interdependent groups (people or entities), creating value by connecting such groups without necessarily having the possession of any transacted asset (Evans & Gawer, 2016; Osterwalder & Pigneur, 2010).

As represented on Figure 2, in the center we have the platform itself (here exemplified by several successful platform firms - with highlights to the second row that contains examples of platform firms within urban mobility). Taking Airbnb as an example: on the top we have the producers (the hosts - people who have rooms, apartments, etc., available for rent); on the bottom we have consumers (the guests - people looking for an accommodation to rent). The role of the platform operator (Airbnb) is to pull both sides together, by matching producers to consumers and facilitating the interactions, creating value for all involved stakeholders (Parker, van Asltyne & Choudary, 2016; Choudary, 2015).

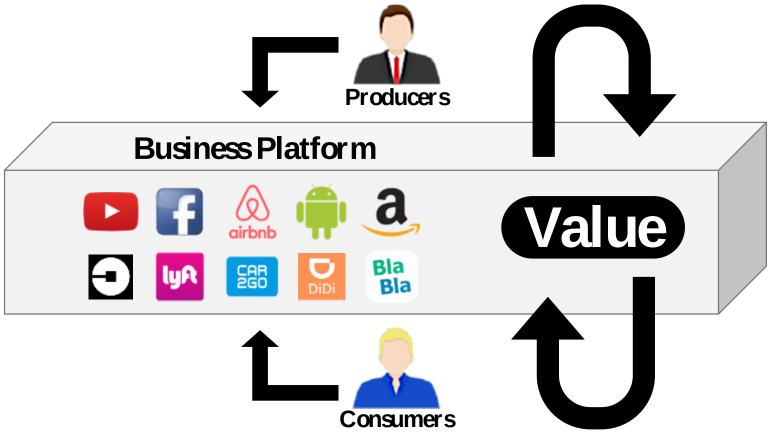

Figure 2. Multi-sided business platform design
Source: prepared by the authors based on Choudary (2015, p.47).

A platform must be built around a "core interaction", that is the "unit of value" to be exchanged must be clearly defined as well the involved participants and the desired algorithm filters (Tura, Kutvonen & Ritala, 2017; Parker, van Astyne & Choudary, 2016; Evans & Gawer, 2016; Eisenmann, Parker & van Alstyne, 2006; Evans, 2003). As stated by Choudary (2015), while "pipes" aim on 1) sourcing (inputs); 2) assembling and; 3) delivering, platforms must:

- **"Pull" the two sides together:** the platform's value for a particular user group depends substantially on the number of users on the platform's other side;
- **"Facilitate" interactions:** unlike "pipes", platforms do not control value creation; therefore, they must make it as easy as possible for producers to create and exchange valuable goods and services by reducing barriers to usage, but at the same time by building governance in order to encourage desirable interactions and discourage undesirable ones;
- **"Match" producers to consumers:** by constantly capturing data and better filtering the results a successful platform creates efficiencies by matching the right users with one another and ensuring that the most relevant goods and services are being exchanged.

Thus, a platform is nothing more than a huge network of relationships between organizations around a core technology (Carvalho, Dias & Sugano, 2016). It is a co-evolving system composed of three main key stakeholders: 1) the platform operator; 2) ecosystem of producers and 3) ecosystem of consumers, all connected by an interface that seamlessly link such complementors to the core (Parker, van Asltyne & Choudary, 2016).

With that, platforms are able to: 1) reduce inefficient gate keepers (letting the market decide what it wants); 2) unlock new sources of value (consumers can become producers: "prosumers"); 3) aggregate fragmented inefficient markets (similar to what TripAdvisor has done with small restaurants and hotels); 4) enable new production paradigms (taking a traditional supply chain and moving into a platform model) and 5) be easily scalable (due to zero marginal costs for expansion, positive feedback loops and network effects, platforms have the potential to scale exponentially) (Choudary, 2015).

Furthermore, as depicted by Casey and Valovirta (2016), smart mobility services are evolving from closed to more open structures, encompassing not only platform business models, but instead, an ecosystemic business approach - as stated by Moore (1993). On doing so, the authors make an analogy to the value system modeling framework proposed by Ali-Vehmas & Casey (2012) - described in Figure 3 - in which it is analyzed the evolution and transitions of GSM mobile networks and the Internet from closed to open ecosystems.

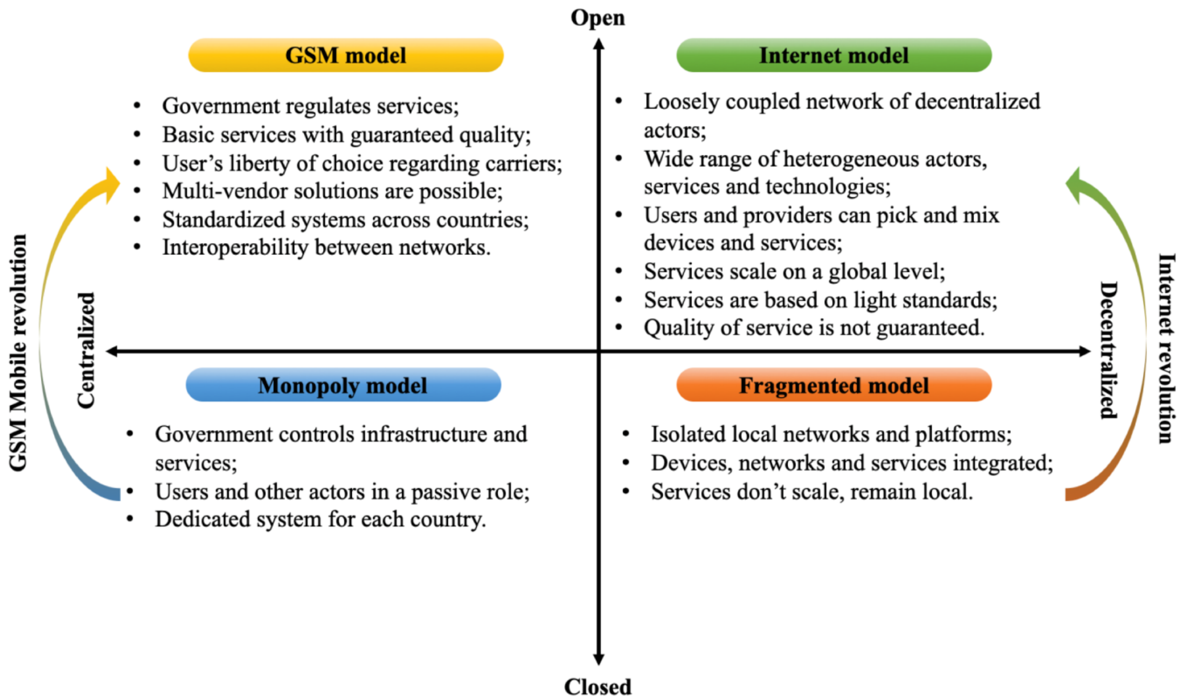

Figure 3. GSM mobile networks and Internet transitions from closed to open business ecosystems. Source: adapted from Casey and Valovirta (2016, p. 10).

By considering Choudary's (2015) assumption that business platforms companies have skyrocketed with the advent and democratization of internet-connected devices, it is suitable to think of multi-sided mobility platforms as belonging within the upper right quadrant of Figure 3, that is, as an internet model value system. Since, as stated by Casey and Valovirta (2016):

> "The Internet brought about a new paradigm and created a loosely coupled network of decentralized actors. The new model led to a wide range of

> heterogeneous interconnected actors, services and technologies where users and providers were able to pick and mix devices and services in a modular manner" (Casey & Valovirta, 2016, p. 11).

Therefore, as pointed out by Parente, Geleilateb and Rong (2018) the business ecosystem approach is a promising theoretical lens to assess smart urban mobility services. In a sense that modern businesses are viewed not as members of single industry, but rather part of a business ecosystem that crosses a variety of industries, which includes customers, suppliers, competitors, and other stakeholders, who coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies (Muegge, 2013; Moore, 1993).

3. Research methodology

With the aim of creating future scenarios for the business platforms for AVs in urban mobility contexts, the research design adopted in the present study was characterized as qualitative of exploratory-descriptive nature (Malhotra, 2001; Gil, 2008). The detailed research design carried out is shown in Figure 4.

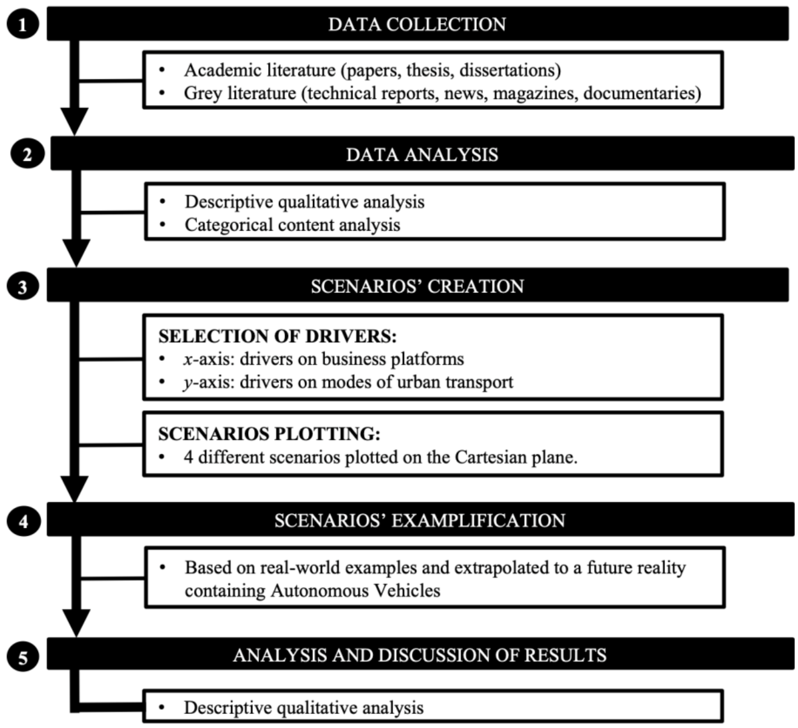

Figure 4. Research design for this proposed paper.
Source: prepared by the authors.

The first step carried out in this study was the collection of secondary data (from both academic and grey literature) in order to subsidize the creation and discussion of the scenarios. At this stage, saturation criteria was used as a stopping point (Fontanella, Ricas & Turato, 2008; Guerra, 2006). Next, on step 2, data was structured and analyzed via descriptive qualitative analysis (Sanderlowski, 2000; 2010; Kim, Sefcik & Bradway, 2016) and content categorical analysis (Bardin, 2010; Vergara, 2005).

After having structured the data, stage 3 was dedicated to scenarios' creation by applying scenario planning techniques (Pillkahn, 2008; Bradfield et al., 2005). As pointed out by Amer, Daim and Jeter (2013), there is no single approach to scenario planning, since in general, is a fairly practitioner driven approach. With that - we opted in this particular study - to apply Osterwalder and Pigneur's (2010 p. 186-189) scenario planning approach. For the authors, the first step is to define the drivers (*x*- and *y*-axis) for plotting the scenario matrix. After clearly defining and explaining each driver, step two consists on the effective plotting of four scenarios in a cartesian plane.

Next, on stage 4, in order to explain and detail each scenario, four hypothetical examples were drawn based on real word initiatives present on urban mobility today - such as the ones exemplified by Jittrapirom et al. (2017), Kamargianni et al. (2016) and Karlsson et al. (2016), however extrapolated to a future reality where Autonomous Vehicles might be seen as a transportation mode. It is worth highlighting that in the present study, we are considering for analysis SAE's levels 4 and 5 of automation, similarly to Schellekens (2015) on his study about the self-driving cars and the chilling effect of liability law.

In parallel, stage 5 consisted on analyzing and discussing the results obtained on stages 3 and 4 - based on secondary data in order to support the findings (academic and grey literature) - via descriptive qualitative analysis (Sanderlowski, 2000; 2010; Kim, Sefcik & Bradway, 2016).

4. Results and discussion

4.1. Scenarios' creation

Applying scenario planning techniques to business model innovation forces reflection on how a model might have to evolve under certain conditions, by: fostering strategic thinking, enhancing mental models of decision makers and reducing the negative effect of cognitive biases (Meissner & Wulf, 2013). Furthermore, scenario planning it is not simply a forecast of the most probable outcome but rather it creates a set of the plausible futures rendering the abstract tangible as well as, capturing a wide range of options, stimulating future thinking and challenging the prevailing mindset and *status quo* (Amer, Daim & Jeter, 2013; Wilkinson, 2009; Schoemaker, 1991).

Scenarios are a very useful technique to provide concrete future contexts for which one can invent appropriate business models. Therefore, for creating the scenarios for AVs' business platforms in urban mobility contexts, we opted to use as inspiration the pharmaceutical industry example given by Osterwalder and Pigneur (2010 p.186-189), as well as Helbig's et al. (2017, p.18-19) automotive value chain in 2025 plausible scenarios, Beiker's (2016) deployment scenarios for vehicles with higher-order automation and, Corwin's et al. (2016 p.4) future states of mobility, by plotting four different scenarios on a cartesian plane, guided by two main drivers (*x*- and *y*-axis).

Business platforms (*x*-axis):

Considering that multi-sided business platforms create value by orchestrating interactions between external producers and consumers (Evans & Gawer, 2016; Choudary, 2015), their success can be hindered by the so-called "chicken and egg dilemma" (Parker, van Asltyne & Choudary, 2016). Such dilemma is an issue that must be taken seriously, in a sense that value for users on one side of the platform (i.e.: producers side) depends substantially on the number of users on the other side (consumers), that is - in a platform without producers that are no consumers and vice-versa (Parker, van Asltyne & Choudary, 2016; Osterwalder & Pigneur, 2010). Therefore, finding a way around this dilemma is crucial for any multi-sided platform development and survival.

Parker, van Asltyne & Choudary (2016) ranked in their book eight possible ways for beating such dilemma. Among those, we highlight one solution that was also described by Osterwalder and Pigneur (2010) which is the so-called "one-way multi-sided platform". The premise behind this concept is to subsidize one side of the platform (normally the customer segment); by doing so the platform operator incurs costs to provide tools, products, services, or other benefits that will attract users (consumers) to the other side. Once there is a critical mass on one side, users will be attracted to the other, leading to an inflexion point - based on network effects and positive feedback loops - where "one-way platforms" become "two-way platforms" hindering mute the need for subsidies (Parker, van Asltyne & Choudary, 2016; Osterwalder & Pigneur, 2010; Shapiro & Varian, 1999). With that, the *x*-axis for our scenario creation is composed on one end by "one-way multi-sided platforms" (requiring subsidies) and on the other by "two-way multi-sided platforms" (no subsidies required).

Transportation modes (*y*-axis):

As stated by Attias (2017, p.10) “new behavior patterns, uses and mobility requirements are now emerging that no longer view vehicles as objects of pleasure, freedom and social mobility, in which usage can substitute ownership”. Hence, if this new understanding of transport solutions is to be achieved, policy-makers, urban and mobility planners as well as other public and private stakeholders must undertake strong initiatives by adopting a multimodal and integrated approach (Ambrosino et al., 2016). Then, the priority now is to improve mobility and accessibility while at the same time, reducing the major social/environmental/economic issues caused by our prevailing mobility regimes.

The realization of more environment-friendly transportation systems is now a worldwide goal (Cao & Wang, 2017). Efficient urban mobility is unlikely to be achieved without the provision of efficient, extensive and accessible transport options, since urban areas require robust mobility solutions which are well integrated in the overall urban planning system (Ambrosino et al., 2016).

In order to achieve that, it is not only necessary to improve vehicles’ technology and cities’ infrastructure but also to change people’s travel behaviors, with the aim of reducing private car dependency (Karlsson, Sochor & Strömberg, 2016) and towards a multiple transportation mode approach.

With that, the *y*-axis for our scenario matrix is composed on one-end by a single transport mode (i.e.: going from point A to point B using only an AV) and on the other by a multimodal solution (i.e.: going from A to B using a bundle of transport modes). Considering the value system modeling framework (Ali-Vehmas & Casey, 2012; Casey & Valovirta, 2016) and the assumption that business platforms are fit within the internet ecosystem model, Figure 5 depicts the complete scenario array based on the two created drivers.

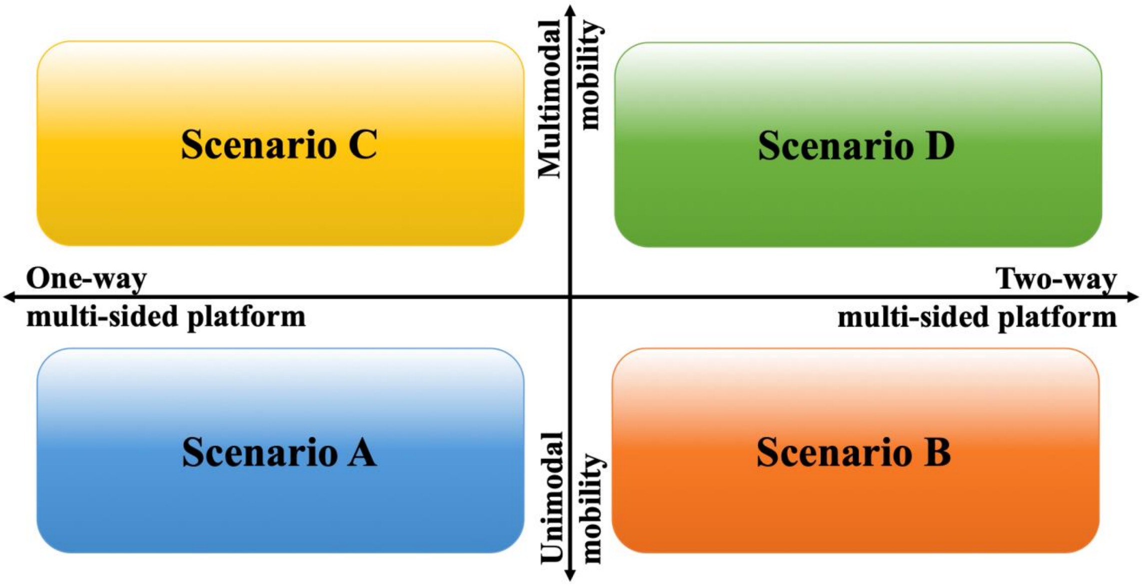

Figure 5. Autonomous vehicles business platforms scenarios.
Source: prepared by the authors.

Over the next subsection we better discuss and exemplify each of the proposed scenario with real-word examples present in urban mobility today, extrapolating them to a future reality in which AVs are seen as a transport mode.

4.2. Scenarios exemplification

4.2.1. Scenario A: Business-to-consumer autonomous ridesharing

This first scenario entails one-way multi-sided platforms offering a single transport mode solution. That is, one firm - by subsidizing the consumer segment - will offer complete journeys from point A to B in a single transport mode. Such scenario can be configured as a gateway for peer-to-peer ridesharing companies in the market of AVs. The examples in this scenario do not need to be extrapolated for a future AV reality since they already exist in urban mobility today.

On September 14, 2016, Uber launched in the city of Pittsburgh (Pennsylvania) its first self-driving car services to selected customers by using a fleet of Ford Fusion cars (SAE level 4 - Silver, 2018); just three months after, the company began using a fleet of self-driving Volvo XC90 SUVs in its hometown of San Francisco (California) (Tascarella, 2016; Della Cava, 2016). On yearly 2017, the company then moved the program to the city of Tempe (Arizona) (Hawkins, 2017; Wakabayashi, 2018).

Nonetheless, the company announced in November 2017 that it planned to buy up to 24,000 Volvo cars designed to accept autonomous technology between 2019 and 2021, on an ambitious plan that aims on moving from its current model of ride-sharing using freelance drivers to owning a fleet of AVs (Gibbs, 2017; Estes, 2017). According to Jeff Miller (Uber's head of automotive alliances): "it only becomes a commercial business when you can remove the vehicle operator from the equation" (Gibbs, 2017). Furthermore, as reporter Kevin Mccullagh (2017) points out:

> "Most driverless cars in urban areas will be provided as a service by the likes of Uber, and without a driver to pay, price per mile is likely to drop to $0.50 from $1 to $1.50 per mile. This will challenge the viability of buses and trams on many routes, and is likely to blur the boundaries between shared and public transport" (Mccullagh, 2017).

In the meantime, Lyft (Uber's main competitor in the U.S.) is also on the race towards self-driving P2P services. On January 4, 2016, the company announced a partnership with General Motors, which invested $500 million as part of a $1 billion fundraising effort to help both companies accelerate in the ride-sharing market, as well as in the AVs arena by using a self-driving fleet of Chevrolet Bolt (Kokalitcheva, 2016; Wayland, 2017).

Furthermore, in September 2017, Lyft announced a partnership with Ford adding the company to its list of self-driving car partners (Isaac, 2017). In March 2018, they partnered with GoMentum Station (an AVs testing site company) to test their self-driving technology, furthering the company's efforts toward making transportation safer and more accessible, later that month, they partnered with Magna (leading auto parts supplier in North America) with the aim of co-funding, developing, and manufacturing AV systems to foster production of self-driving technology to all car manufacturers (Crum, 2018; Kerr, 2018).

At last, it is also worth highlighting the giant efforts Google's sister company Waymo - leader on self-driving R&D with more than 4 million miles driven (Silver, 2018). In 2018, Waymo placed orders for up to 62,000 hybrid-drive Pacifica minivans and 20,000 Jaguar I-Pace electric sedans, with the aim of launching ride-hailing services in various U.S. cities, enough to accommodate hundreds of thousands of riders each day (Madrigal, 2018).

4.2.2. Scenario B: Peer-to-peer autonomous ridesharing

Similar to scenario A, the premise here is to offer full journeys from point A to B in a single transport mode, the main difference is that instead of a service provider subsidizing one side of the platform, neither side is subsidized. Such approach is the current primary revenue business model of traditional (human-driven) P2P ridesharing companies such as Uber, Lyft, Sidecar, Didi Chuxing, Go-Jek, Grab Taxi, Haxi, and so on.

The premise falls within the traditional definition of multi-sided business platforms (Parker; van Alstyne & Choudary, 2016; Choudary, 2015; Gawer & Cusomano, 2002), in which the firm (service provider) matches individuals with vehicles and extra time to drive them with people who need rides, taking a commission on each ride (Macmurdo, 2015). Differently from scenario A though, the company does not need to own the fleet, it simply connects supply with demand and create value in the process.

As highlighted by Park, Shin and Park (2006, p.121), "technological knowledge is accumulated and thus increased through R&D and innovation efforts, but it depreciates and becomes obsolete over time". Saracco (2017) exemplifies: "the cost of technology keeps decreasing at an amazing pace (…) in 1971 storing 1GB of data would have cost 250 million dollars, now storing a GB on a hard drive cost less than 0.03$, in less than 50 years the price went down 8 billion times." The same goes for many other technology consumer goods, as pointed out by the U.S. Bureau of Labor Statistics (2015), prices - for the last 18 years - have dropped dramatically in almost every tech sector.

In the automotive industry such phenomenon can already be seen with Electric Vehicles (EVs). According to Knupfer et al. (2017), in the three-year period from 2014 to 2016, battery production costs fell over 50% from process improvements and scale effects, bringing EVs significantly closer to parity with ICE costs. Furthermore, Jolley (2018) states that overall, electric car prices will drop significantly by 2023. However, the environmental cost caused by batteries should not be neglected, for which more detailed future studies are needed.

Regarding Autonomous Vehicles - which most likely will be electric or hybrids (Gandia et al., 2018), forecasts are similar. According to Delphi Automotive CEO, Kevin Clark: "while current estimates for AVs embedded technology range from $70,000 to $150,000, the cost of that autonomous driving stack by 2025 will come down to about $5,000 because of technology developments and higher volume" (Lienert, 2017). Additionaly, Litman (2018) states that shared AVs are predicted to cost less than human-driven taxis and ride-hailing services, but more than human-driven personal vehicles and public transit services; for the author:

> "In the future, personal AVs will continue to cost more than human-operated vehicles, but shared AVs will be cheaper than human-operated ride-hailing and taxi services" (Litman, 2018 p.9).

With that, a couple propositions can be drawn for this scenario, the first two based on ordinary people owning AVs (P1 and P2) while the last two are based on car-ownership on the hands of car rental companies (P3 and P4).

- **Proposition 1 (P1):** ordinary private AVs owners making their cars available to P2P ridesharing companies.
- **Proposition 2 (P2):** P2P car rental companies making their clients' AVs available to P2P ridesharing companies.

Whether and when AVs come on stream in volume (Hensher, 2017), more and more ordinary consumers would be able to afford one. Thus, for those who are interested, a new income opportunity may arise, given that a car remains on average 95% idle - being parked at home, work or elsewhere (Barter, 2013; Kappenechker et al. 2014), an **(P1)** AV owner could make his/her car available for third party usage by directly renting it to a P2P ridesharing company (i.e.: Uber; Lyft; etc) or **(P2)** by making it available on a P2P rental car platform (such as: Getaround, Turo, Drivy, Ouigo, Parpe, etc.) which - in turn - via partnerships, would provide the vehicle for P2P ridesharing companies.

From the AVs owner's perspective, there are (for now) no evident significant differences between one option or another, however from the P2P carsharing company standpoint, hiring someone's car from a P2P car rental company might bring advantages regarding strategic agreements on data and user's installed based exchange.

In either case, the central idea remains: put the AV to work and make money for its owner. This approach is similar to the currently existing P2P ridesharing business models, the difference being that today the car owner - which in most cases is also the driver - would no longer need to be a freelancer, being able to use his/her time with other tasks or jobs.
It is worth highlighting that these two hypotheses may prove unfeasible due to the relationship humans have with their cars. According to Belk (1988), some possessions (like cars) become the extension of someone's self; which makes it difficult for people to lend or even dispose of such goods. Furthermore, Steg (2005) enumerates three main motives for car use: instrumental; affective and symbolic, therefore depending on how high the last two are for individuals, it might hinder the possibility of this type of business.

- **Proposition 3 (P3):** traditional car rental companies making their AVs available to P2P ridesharing companies.

An interesting fact that is happening today in the context of P2P ridesharing is that there is a contingent of drivers willing to provide their services for these companies but who do not own a car. Aiming on tapping this unexplored market, car rental companies (i.e.: Unidas[2] and Localiza Hertz[3]) are forming partnerships with P2P ridesharing companies so these drivers can rent cars and start generating revenue - overall, it is a win-win situation for all three parties. Considering a future context in which **(P3)** AVs might also be available for rental by these companies, it is plausible to imagine that such kind of partnership will prevail, the difference would be the absence of the driver, but it would still be a win-win situation for both car rental and P2P companies.

- **Proposition 4 (P4):** traditional car rental companies becoming a P2P ridesharing company

At last, one can also imagine that instead of the proposition 3, **(P4)** car rental companies may seize the opportunity of becoming P2P ridesharing companies themselves (since they would already own the AVs fleet). In this case, these companies would become "one-way multi-sided platforms" which would place them within scenario A. Also worth highlight is that the aforementioned propositions might happen simultaneously, that is, not necessarily one at once, or one or the other.

4.2.3. Scenario C: Business-to-consumer multimodal mobility

Moving the analysis to the upper quadrants of Figure 5, we are now considering getting from point A to B by using a bundle of transport modes, therefore AVs would be seen as one of many transport options within urban centers. For this kind of scenarios (both C and D) an interesting premise posed by many scholars is that AVs could be very useful on helping solve the first- and last-mile issues (Chong et al., 2011; Scheltes & Correia, 2017; Ohnemus & Perl, 2016) which according to the authors are the most constraining parts on the urban commute since conventional transport modes for this stages of the trip can, in many cases, be rather slow, inflexible and not provide a seamless experience to passengers.

Scenario C entails one-way multi-sided platforms offering bundled transport solutions. That is, a single firm - by subsidizing the consumer segment - will offer complete journeys from point A to B via a combination of transport modes.

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[2] https://www.unidas.com.br/blog/facil/como-trabalhar-com-a-uber-de-carro-unidas/ Retrieved on November 23, 2018.

[3] https://www.localiza.com/uber/sobre Retrieved on November 23, 2018.

An attempt towards this type of business model was the one planned for Las Vegas during the years of 2013-2015, the project was called “SHIFT - Project 100”. According to Kamargianni et al. (2016), this approach, in which multiple modes are owned and operated by one company, is very unique.

By owning all vehicles in its fleet (most of them electric powered) and not by partnering with other service providers, SHIFT - Project 100 aimed at offering bundled mobility services including 100+ on-demand drivers, 100+ shared cars, 100+ shared bikes, and 100+ shared shuttle bus stops as well as a valet service (Loveday, 2015; Kamargianni, et al., 2016). The project was ICT integrated, therefore users could choose the destination in the journey planning tool and the app would automatically make a choice of transport modes for the user (Kamargianni et al., 2016; Jittrapirom et al., 2017). SHIFT also provided a variety of membership levels each with a designated amount of trip time each month, these pre-paid monthly packages allow customers to pay for all their usage beforehand at once (Kamargianni et al., 2016).

The project however, was cancelled before its operation even began. The major claim for the premature shutdown according to the company’s CEO Zach Ware, was that from the 100 Model S they ordered from Tesla Motors they only received 10 to 20 in June of 2014, and it never did take delivery of the full 100 (Loveday, 2015; Rothberg, 2015).

To date, no other real-life examples for scenario C were found neither on academic or grey literature. In such scenario, by owning and managing all the multimodal fleet, the service provider would have control of all user data, as well as bargaining power with other public and private stakeholders on its ecosystem.

4.2.4. Scenario D: Peer-to-peer multimodal mobility - MaaS rather than mess

By offering multimodal mobility via multi-sided platforms, scenario D is likely to be the most complete but also the most complex of all four. The claim is that the service operator - or: the platform firm (third party; public transport provider or public entity) would match producers (public and private suppliers of multimodal transport services) with consumers (demanders of mobility). The complexity lies on the bundled offering of private and public transport by multiple companies via a single user interface.

The premise falls within the definitions of Mobility as a Service (Hietanen, 2014; Karlsson, Sochor & Strömberg, 2016; Mulley, 2017), in which tailored-made mobility packages are created to fit individual traveler’s needs and requirements, delivering multimodal transport solutions via a single interface of a service provider. Thus, unlike scenario C, the platform firm does not need to own the multimodal fleet, even though such scenario also falls within MaaS definitions.

Jittrapirom et al. (2017) and Kamargianni et al. (2016) listed on their critical reviews several examples of MaaS schemes worldwide; the former authors listed 12 and the latter 15 all held in developed countries. The most integrated MaaS model listed by both groups of authors was the Swedish project UbiGo. It consisted on a pilot tested in the city of Gothenburg from 2012 to 2014 involving the cooperation between a public transport operator (Vasttrafik), car sharing, car rental, taxi and bike sharing companies - respectively: Sunfleet, Hertz, TaxiKurir and JCDecaux (Kamargianni et al. 2016; Holmberg et al., 2016). The ICT, payment and ticket integrated service combined everything into one application (provided by Ericsson AB).

For the pilot, 70 households subscribed for prepaid tailored monthly packages (determined in time or distance for each mode), such packages were created based on each household need and the package price was cheaper than paying for each individual service separately (Jittrapirom et al., 2017; Kamargianni et al. 2016). During each journey planning, users made their own travel choices regarding transport modes. If the subscription ran empty, additional trips were billed after. Further, electric cars and bikes were available and the user could get bonus points for such sustainable choices (Kamargianni et al. 2016). Based on the gained successful experiences, the project was thoroughly evaluated and on March 2018 relaunched in a larger scale in Stockholm (Kamargianni et al. 2016; Arby & Pichler, 2017).

Another interesting example came in 2016 from Helsinki (Finland) in which a group of eight investors lead by Transdev, have teamed up forming a MaaS operator named Whim (Goodall, et al., 2017; Holmberg et al., 2016). Similar to UbiGo, it offers a subscription of various transport modes (public transport; car-sharing; taxi and bike-sharing) under one contract. Several other similar examples are spreading worldwide, to name a few: Moovel in Germany; Smile in Vienna (Austria); My Cicero in Italy; TransitApp in North America, Europe and Australia (Jittrapirom, et al. 2017; Kamargianni et al. 2016), therefore MaaS is proven to be an interesting alternative for urban mobility issues.

Within MaaS literature, AVs are considered as an important future transport mode (Goodall et al. 2017; Keeney, 2017; Cao & Wang, 2017; Hensher, 2017; Jittrapirom et al., 2017; Mulley, 2017; Corwin et al., 2016). As pointed out by Mira-Bonnardel and Attias (2018), AVs open doors to new mobility business models embedded in the smart development of cities.

Furthermore, Keeney (2017) already stated: the global MaaS market will exceed $10 trillion in gross revenue by early 2030s while sales from AVs will total about $900 billion at that time, or roughly one tenth of the services market, which represents more than 30 times the size of the taxi industry today. In a benchmark study carried out for BMCP and Mo'Veo, Charlet and Chaufrein (2017) stated that just in 2017 alone, 64 programs involving experimentations with autonomous and connected vehicles were running worldwide (of which more than 50% were in Europe). As depicted by Corwin et al. (2016):

> "Frictionless, automated, personalized travel on demand: that's the dream of the future of mobility. And the future mobility ecosystem's various elements are coalescing to realize that dream sooner than expected, which means that incumbents and disruptors need to move at top speed to get on board" (Corwin et al., 2016 p.2).

At last, Keeney (2017) states that investors may be undervaluing MaaS severely today, and that in 5 years autonomous taxi networks could command a market capitalization of over $5 trillion. However, it is worth noting that governance is likely to be the most challenging aspect on scenario D, since, implementation of MaaS can have significant impacts to the existing business model of public transport, especially on the level of integration with private actors (Docherty, Marsden & Anable 2018, Jittrapirom et al., 2017), therefore deciding who will be the platform provider and how value is likely to be created and distributed will be some of the major challenges, since as pointed out by Kamargianni and Matyas (2017) MaaS in theory is much simpler than in practice.

4.3. Scenarios synthesis

Figure 6 summarizes the four created scenarios highlighting their prevailing business model as well as the most relevant explanatory managerial theories fit to explain them.

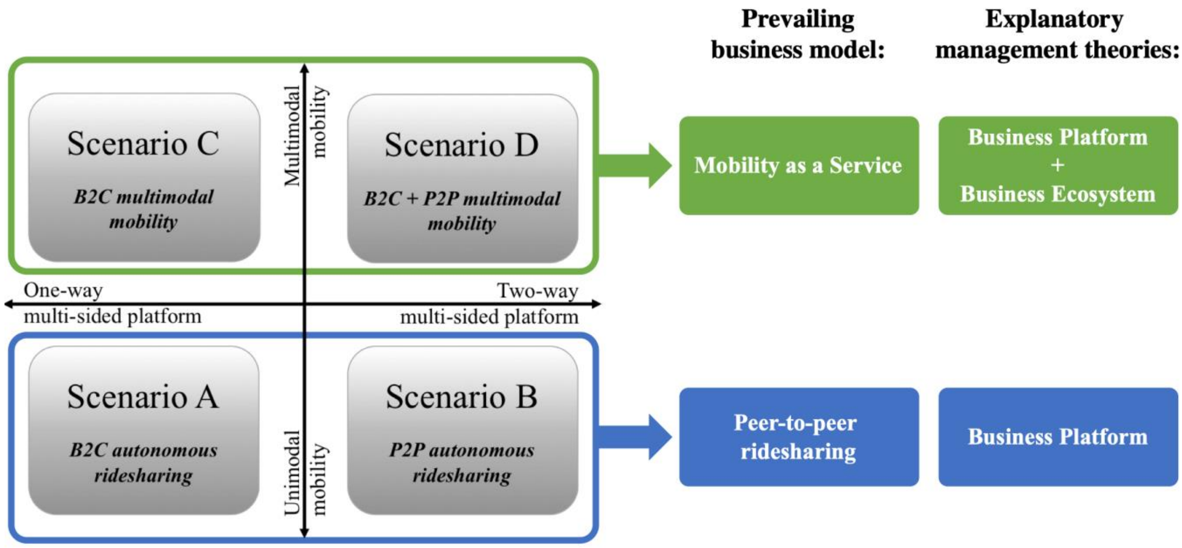

Figure 6. Business model and management theories for the created scenarios.
Source: prepared by the authors.

By observing Figure 6, it is possible to state that scenarios A and B will not be configured as MaaS schemes; given that an important premise within MaaS literature is the integration of multiple transport modes to deliver tailor-made mobility solutions to users. Thus, considering that such scenarios aim on delivering single transport mode solutions, the best business model to be applied is P2P ridesharing alongside the theory of business platforms.

On the other hand, scenarios C and D both fall within the MaaS definitions, which entails a complex network of stakeholders - both private and public actors delivering bundled tailor-made multimodal mobility for users. In this sense, the theory on business platforms is useful to some extent: understanding the underlaying logic of the core interactions to be carried out by the service provider while connecting producers (transport providers) to consumers (demanders of mobility).

However, such theory is limited on explaining the complexity of all stakeholders involved in MaaS schemes. In this sense, the theory on business ecosystems (Moore, 1998; 1993), as depicted by Kamargianni and Matyas (2017), Iivari (2016) and Corwin et al. (2016), might prove useful for this scenarios. As pointed out by Parente, Geleilateb and Rong (2018, p.52) “the business ecosystem approach is a promising theoretical lens to assess this phenomenon due to its more holistic view of multisided network effects and multiple stakeholders' participation.”

Considering that, “a business “ecosystem” is the wider network of firms that influences how a focal firm (MaaS provider), creates and captures value” Kamargianni and

Matyas (2017 p.6). That is, modern businesses are viewed not as members of single industry, but rather part of a business ecosystem that crosses a variety of industries, which includes customers, suppliers, competitors, and other stakeholders, who coevolve their capabilities and roles, and tend to align themselves with the directions set by one or more central companies (Muegge, 2013; Moore, 1993).

5. Concluding remarks

With the aim of creating future scenarios for the business platforms for AVs in urban mobility contexts, the present study sought to design and exemplify four distinct scenarios based on business platforms and transport modes. Scenario A encompasses unimodal mobility delivered by a single firm subsidizing the consumer segment - companies like Uber, Lift, and Waymo are already doing that by testing their AVs services in several American cities. Meanwhile, scenario B also delivers unimodal mobility, but no side of the platform is subsidized - this is the current business model of P2P ridesharing companies by hiring freelance drivers. Thus, if and when AVs come on stream in volume, such model might prevail generating revenue for AVs owners without the need for them to drive. Traditional car rental companies with their autonomous fleet could also benefit from scenario B, by renting their AVs directly to P2P ridesharing companies or by becoming a P2P ridesharing themselves.

By delivering multimodal mobility (having AVs one of the transport modes) provided by a single firm subsidizing the consumer segment, scenario C is the most unlikely to consolidate - this can be corroborated by the SHIFT - Project 100 in Las Vegas that was discontinued before it even started. At last, scenario D proves to be the most complete but also the most complex in execution among all. By delivering multimodal solutions via two-way multi-sided platforms, governance of this ecosystem might be its most constraining aspect, once orchestrating public and private transport offerings via a single platform service can be quite challenging, in a sense that: city governments should buy in, public-private partnerships are required to established and must be open, technology architecture may be agreed upon and, municipal transportation must be included.

Besides the unlikelihood depicted on scenario C, we believe that any of the others three have potential to become a reality. We also believe in the evolving aspect of urban mobility, in a sense that scenario A is already being test in small scale, it could grow and evolve towards scenario B (with the service provider suspending subsides) or even scenario

D, with P2P AVs companies becoming one among the many modals within MaaS schemes. The same goes for scenario B, that could also grow and evolve towards D.

We also conclude that for scenarios A and B, the prevailing business model will continue to be the current P2P ridesharing one, supported by the theory of business platforms. While for the upper quadrants scenarios, MaaS seems to be the most coherent business model to be applied, having both business platform and ecosystem theories as guidelines. In this sense, we infer that AVs may act as catalysts on accelerating the transition towards mobility "servitization", especially on scenarios C and D where AVs might be well fit as a transport mode for fist- and last-mile issues.

As for limitations, by being a prospective study based on secondary data, the present research lacks empirical evidence to test the scenarios. In this sense, further studies are needed to test such scenario's feasibility as well as to corroborate or refute our inferences. We also suggest deeper studies on whether one-way or two-way platforms is the best solution for inserting AVs in urban mobility contexts as well as to corroborate the evolutive aspects of the scenarios, identifying the main involved stakeholders and how value will be generated and distributed. At last, further studies are need to test the feasibility of MaaS schemes on developing countries as well as the viability of inserting AVs in such contexts.

Acknowledgments:

This paper would not have been possible without the support of the Post Graduate Program in Administration of Federal University of Lavras (UFLA - Brazil), Terrestrial Mobility Laboratory (LMT / UFLA - Brazil), and the Laboratoire Génie Industriel (LGI / Centrale Supélec - France). We also would like to thank the institutions that have been funding this project: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES - Brazil), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq - Brazil), Ecole Centrale Supélec (Université Paris-Saclay - France) and, Fundação de Amparo à Pesquisa de Minas Gerais (Fapemig - Brazil).

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ARTICLE 4 - GOVERNANCE OF AUTONOMOUS URBAN MOBILITY PLATFORMS: A CONCEPTUAL ANALYSIS WITHIN BIG DATA CONTEXT

Paper ready to be submitted to Elsevier's "*Research in Transportation Economics*"

ISSN: 0739-8859; JCR: 0.992.

Governance of autonomous urban mobility platforms: A conceptual analysis within big data context

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JEL Classification codes: R4; R42; K30; O30.

Abstract: With the widespread adoption and fast pace of smart innovations, data is playing an important role within transportation. Recent transformations in automobile culture led to significant changes on urban transport: away from personally-owned cars towards on-demand mobility, Autonomous Vehicles (AVs) and dynamic pricing. Therefore ownership and management of huge datasets are inherent for creating new business platform models within urban mobility, which brings up the need of proper governance mechanisms for data-based mobility solutions. Therefore, this study sought to conceptually explain how big data impacts on governance structures in four scenarios of autonomous urban mobility platforms. By gathering data on grey and academic literature, 24 assets were ranked to plot governance models for each proposed scenario. Scenarios were plotted and validated qualitatively with 12 mobility researchers and specialists in Brazil and France. Scenario A entails unimodal mobility by a single company that owns the AVs' fleet. Scenario B also provides unimodal mobility however AVs' are offered as a P2P platform. Scenario C consists on multimodal autonomous mobility with all fleet owned by the service provider. Scenario D provides multimodal mobility on both B2C and P2P fleet ownership. Results show that Scenarios C and A presented predominantly hierarchical governance structures, entailing on higher operational costs. Scenarios B and D are predominantly hybrid governance structures with higher transaction costs. Furthermore, the greater the number of transport modes, the greater the disturbances' frequency. Thus, for scenarios where platform providers owns the fleet (A; C) disturbances tends to be lower than in scenarios where providers do not own such assets (B; D).At last, Big data ownership delineates each scenario's governance mechanisms within mobility platforms. Furthermore, blockchain and smart contracts technologies may benefit all Scenarios, however Scenarios B and D are likely to benefit more from it, due to their hybrid governance models.

Keywords: Governance models; Urban mobility platforms; Big data; Scenarios plotting; Autonomous Vehicles.

1. Introduction

With the widespread adoption and fast pace of innovation on Information Communication Technologies (ICTs), data have been playing an important role within transportation systems (Birkin, 2018). Thus, urban centers could largely benefit from the usage of big data, since it could provide more sophisticated, wider-scale, finer-grained, real-time understanding and control of mobility, through "smart cities" (Kitchin, 2014).

Over the past decade, all changes in the automobile culture, via integration of technologies and digitalization have led to a significant shift away from personal car ownership. Thereby, transportation is on the verge of a revolution, since, on-demand mobility services, autonomous driving, dynamic pricing algorithms and vehicle electrification will change the way people experience mobility in urban environments (Glus, Rothman & Iacobucci, 2018; Alazzawi et al., 2018). Thus, urban mobility is increasingly relying in large amounts of multi-sourced data (big data), which in turn play an important role in route- and city-planning (Xia et al, 2018).

Big data is therefore, revolutionizing the way businesses operate in many industries (Lee, 2017). The automotive and mobility industries are not an exception, due to a great availability of real-time data on users as well as on transport modes. Therefore, two main service segments can be clearly distinguished in the growing connected vehicle market: integrated product services (to enhance driving experience) and mobility services; to offer alternative modes of transportation from traditional private car ownership (Graham et al, 2016). Furthermore, more recently, Shared and Self-driven Electric Vehicles (SAVs) are being seen as the main disruptive and innovative feature of the automotive industry (Ferràs-Hernández, Tarrats-Pons & Arimany-Serrat, 2017). For these authors, firms working on: self-driven technologies or Autonomous Vehicles (AV's) navigation and communication systems, sharing vehicles, and car dealer platforms are predominant in automotive innovations.

Given this transformative context, the ownership and management of huge datasets (big data) is inherent for the creation of new business models within the automotive industry as well as for describing new scenarios of urban mobility systems. In this sense Antonialli et al. (2018) proposed four future scenarios of business data platforms in which Autonomous Vehicles (AVs) are considered as a transport mode to help enhance mobility in urban environments. According to Stone et al. (2016), this is justified given that AVs and peer-to-peer (P2P) transportation services have the potential to eliminate vehicle ownership, promoting changes into public transportation systems.

These features bring up the need of choosing proper governance mechanisms for data-based transportation systems and mobility platforms (Veneeman et al 2018; Yap & Munizaga 2018). Governance mechanisms represent the study of relations between firms concerning its transactional features. These mechanisms could be established through market practices, hierarchical or internalized within firms, or mixed into contractual or hybrid mechanisms (Williamson, 2005; Crook, et al, 2013).

Considering all scenarios of mobility platforms proposed by Antonialli et al. (2018), in which AVs could be analyzed both within unimodal transport solutions (e.g., Peer-to-Peer or Business-to-Consumer platforms) as well as within multimodal P2P or B2C mobility platforms (e.g. mobility-as-a-service - MaaS schemes), considering a context of vehicular automation, the guiding question of this present research is: **How can governance mechanisms be improved via big data within the context of urban mobility platforms?**

Therefore, the present study aims to characterize distinct types of governance models in different scenarios of autonomous urban mobility platforms considering the big data context, in all of them. The research justifications are based on two main reasons: first, big data is increasingly present within the automotive industry and also in mobility platforms contexts (Seiberth & Gründinger, 2018; ITF, 2015). The second aspect relates to the contributions and characterization of the most appropriate governance mechanisms to analyze and enhance the usage of big data in mobility platforms (Veneeman et al., 2018; Yap & Munizaga, 2018).

Besides this introduction, this paper is composed of a theoretical background, encompassing the theories on urban mobility platforms, big data, and governance structures. Next the methodology is presented, followed by the results and discussions which is divided into asset's identification and governance plotting for each scenario proposed by Antonialli et al. (2018), and platforms' costs and the role of institutions towards regulations and standards. At last, the concluding remarks are presented followed by the list of bibliographical references.

2. Theoretical background

2.1. Urban mobility platforms

With the constant growth of the urban population (United Nations, 2018), mobility is becoming a constraining factor for urban dwellers. As a consequence, cities around the world are coming to the realization that they need to spearhead efforts to develop more sustainable transportation systems (Pancost, 2016; Rosenzweig et al., 2010). Thus, new shared mobility forms are gaining ground, such as car-, scooter- and bike-sharing platforms; Peer-to-Peer ride hailing platforms as well as Mobility-as-a-Service schemes (Amirkiaee & Evangelopoulos, 2018; Jittrapirom et al., 2017).

The majority of these new mobility on-demand services are enabled by the so-called "business platforms". According to Evans and Gawer (2016) and Parker, van Asltyne and Choudary (2016), they work by bringing together two or more distinct and interdependent groups (people or companies), creating value by connecting them via transacting data without necessarily having the possession of any physical asset.

As reported by Attias (2017), these new forms of mobility are likely to be catalyzed by the arrival of autonomous vehicles, minibuses and shuttles, thus building a new paradigm of urban mobility developing "smart-cities". Based on that, Antonialli et al. (2018) proposed four future scenarios for urban mobility platforms where Autonomous Vehicles- AVs (considering the levels 4 and 5 of automation proposed by SAE, 2016) are seen as one possible transport mode. Figure 1 displays the proposed scenarios, their prevailing business model as well as their respective explanatory management theories.

In this figure, Scenario A entails one-way multisided platforms offering a single transport mode solution. That is, one firm by subsidizing the consumer segment will offer complete journeys from point A to B on a single modal, in this case an AV. Regarding scenario B, the premise is also to offer journeys from point A to B in a single transport mode; however, the platform provider would not need to subsidize any side of the platform (Osterwalder & Pigneur, 2010). This scenario would entail ordinary peers offering their private AVS on P2P ridesharing platforms to other peers (commuters).

Moving to the upper quadrants of Figure 1, the authors considered a multimodal mobility solution for getting from point A to B. Thus, scenario C has a similar approach to scenario A, in a sense that the platform provider subsidizes the consumer segment - by owning the multimodal fleet - and offers complete journeys via bundled transport modes. Scenario D would entail a platform provider offering multimodal mobility by matching offerings (public and private transport firms) with demand (commuters) via a single user interface with unified payment system - however, without possession of any transport mode. Thus, the premise of Scenario D, falls within the definitions of Mobility as a Service schemes - MaaS (Mulley, 2017; Hietanen, 2014). According to Antonialli et al. (2018), this scenario is likely to be the most complete, however, the most complex to be executed, mainly due to governance and regulatory issues.

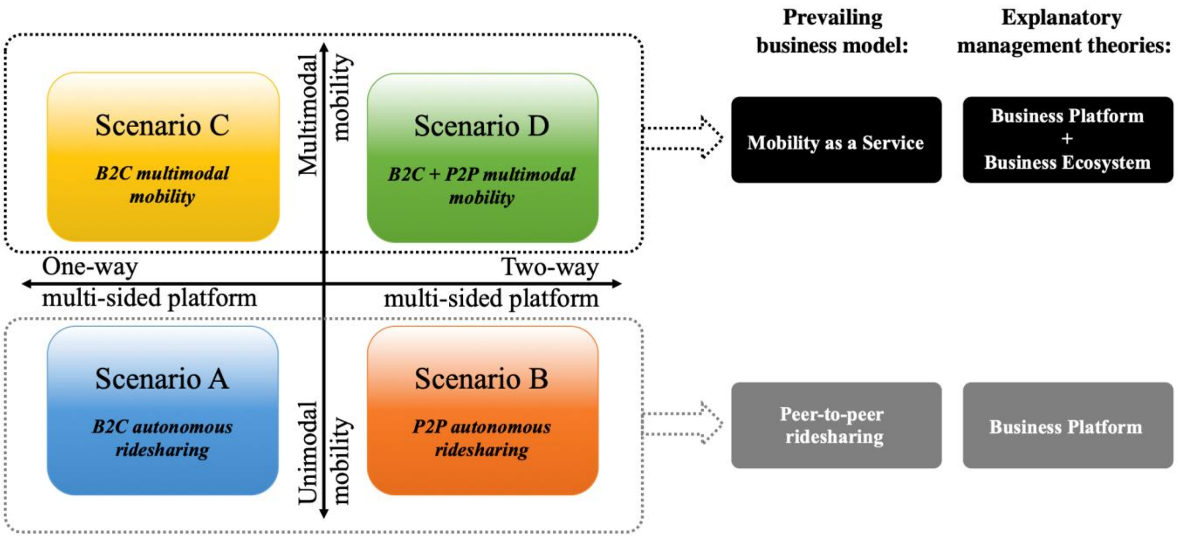

Figure 1. Future scenarios for urban mobility by considering AVs as a transport mode.
Source: Antonialli et al. (2018).

Nevertheless, a common feature among all scenarios is the role played by data. As pointed out by Redman (2015), data do not only enable strategies, they become the strategy; with that, it not only improves existing processes and functions, but enables entirely new business models. Thus, urban mobility is of the industries with the most data volume being generated (Seiberth & Gründiger, 2018), this growing volume of data both structured and unstructured has considerable potential to drive new opportunities and refine existing ones.

Thus, for transportation research, the availability of new sources of data about mobility, transport supply and usage, presents opportunities to analyze transportation infrastructure and behavior in new ways (Tranos & Mack, 2018). These dynamic strategies are aimed at better utilizing the limited resources in the urban mobility network, and are made possible by the availability of data and the widespread connectivity of individuals (Stone et al., 2016), which implies cross-domain sharing of information (Osman, 2018). Hence, data integration and analysis becomes increasingly important for urban mobility platforms.

2.2. Big data and mobility platforms

The subject of big data has emerged as a relevant research theme for the business and management field (Akoka, Comyn-Wattiau & Laoufi, 2017; Mesquita, Antonialli & Rezende, 2018). Within this field, data is modifying managerial and strategic movements in industries in a profound digital transformation (Seiberth & Gründiger, 2018). Therefore, for transportation and mobility sectors, big data can address issues more efficiently and in a real-time manner (Tranos & Mack, 2018).

Big data is represented by extremely large data sets able to be acquired, stored, and interpreted through analytics technology. It is composed both by structured and unstructured data (Gandomi & Haider, 2015; ITF, 2015), which impacts business operations and decision-making in real-time, through mining insightful information from data (Sheng, Amankwah-Amoah, & Wang. 2017). The main characteristics related to big data are summarized by the 3Vs: volume, variety, and velocity of data available for organizations and society (Davis, 2012; Seth et al., 2013).

Research in transport is strongly driven by data (Birkin, 2018). So, applying these new technologies to the transportation industry can bring new understanding to their infrastructures (Kemp et al, 2015). It is necessary for transport network and service operators to manage available, reliable, accurate, and true data. Therefore, data standards should be established and incoming data needs to be monitored, controlled, and refined (Clarke, 2016). In this sense, the potentials of big data are relevant for a wide array of applications within urban mobility (Knieps, 2018), besides the fact that big data is currently being applied for real-time sensing and traffic prediction, route calculations, peer-to-peer ridesharing as well as for self-driving vehicles trials (Stone et al., 2016).

Recent trends suggest that it is inevitable that, automatically recorded, digital data will come into mainstream usage for both academic studies and practical planning of transport systems (Milne & Watling, 2018). As vehicles become increasingly “connected”, they produce more data that can be used for management (West Oliver et al, 2014).

Considering that the current transportation infrastructures of urban centers are being pushed to their limits, they are urgently demanding for smart and adaptive means of transporting and routing policies to optimize the existing system’s growth; with that, mobility requires data analysis systems to be able to deal with mobile and real-time data sources. Thus, the role of big data in transport planning is that it will replace much of the information that has previously been collected manually (Milne, Watling, 2018; Osman 2018).

Therefore, new models of public-private partnership involving data-sharing may be necessary to leverage all the benefits of Big Data. These new arrangements should be based on the need for market tests, cost-benefit assessment, and public utility objectives (ITF, 2015).

It is possible to state that the current challenges to stimulate further and faster use of big data in practice - e.g., to improve the quality of transport for users - are predominantly institutional instead of technical (Veeneman et al., 2018). According to the authors, in a time of fast technological developments, technical challenges can be solved easier. Thus, Big Data is seen as both an opportunity and a challenge and this is especially true for the management and proper choice of a governance structure for transport-related data.

2.3. Governance models for mobility platforms

The studies of governance mechanisms have an applied orientation, with emphasis on the modes of contractual relations among firms (Williamson, 2005). Over the past three decades, numerous studies have examined transaction cost economics' directing managerial decisions and the resulting performance about whether to organize firms' activities via market (exchange of services), hybrid (mutual adjustment), or hierarchy (authority) (Crook et al., 2013; Veeneman et al., 2018).

The drive for greater efficiency and cost reductions has forced many organizations to specialize in a limited number of key areas (McIvor, 2009; Hamel & Prahalad, 1990). Regarding market governance mechanisms, they rely on price, and competition between firms, as for hierarchical mechanisms, those are controlled by the authorities of third parties and hybrid mechanisms of governance are based on contracts and networked structures.

Asset specificity and frequency are elements that drive the choice of governance mechanisms more suited to each economic context (Kupfer & Hasenclever, 2002; Mesquita et al., 2013). When an asset has low specificity, governance via market is the best coordination system for reducing opportunistic behaviors, uncertainty degree, and transaction costs. In a medium level of specificity, a hybrid mechanism is more adequate for reducing transaction costs. At last, when asset has a high specificity, hierarchy is the best alternative to minimize the degree of uncertainty, transaction costs and opportunistic behavior of economic agents (Antonialli; Antonialli & Santos, 2017). Figure 2 proposed by Williamson (1991), describes the governance mechanisms combined according to asset specificity and frequency of disturbance.

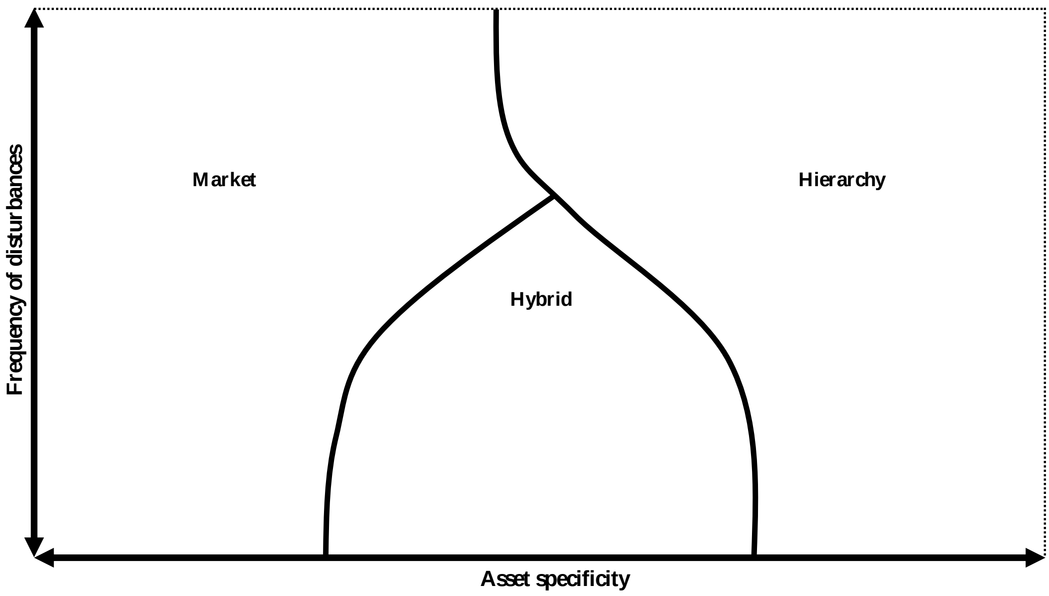

Figure 2. Governance responses to changes in disturbances frequency and asset specificity. Source: Adapted from Williamson (1991, p.292).

Summarizing the conceptual structure, governance mechanisms are analyzed and chosen under conditions of transactions' uncertainty between and within firms (Gibbons, 2010). As for mobility platforms contexts, governance mechanisms play an important role. According to Veeneman et al. (2018), governance arrangements are critical for the success of mobility data platforms. For instance, P2P mobility companies such as Uber, Lyft and Didi Chuxing are very good on efficiently selling reductions in transaction costs, via their data platform by connecting buyers (consumers demanding transportation) and nearby sellers -e.g., drivers- (Munger, 2018).

Hereupon, a proper governance model is considered a critical element for enhancing all possibilities that these new transportation data platforms could achieve. According to Yap & Munizaga (2018), in mobility data platforms, technical challenges can be solved easier, whereas institutional or governance challenges tend to be more complex. For the authors, this complexity is the result of the necessary coordination and cooperation between public and private stakeholders that are not always aligned. Thus, the greater the level of a mobility platform in relation to the number of goals and the number of stakeholders involved, the more difficult it is to define and reach consensus on the directions of the platform. This context elevates the need for a clear and efficient governance structure and coordination.

According to Veeneman et al. (2018), in this scenario of the mobility platforms three main questions emerges: 1) what kind of data is relevant and could be valuable in a mobility data platform? 2) what types of actors generate and own that data? and 3) what kind of relations do these actors have with a platform manager that could drive the governance? These questions will assist on conducting the analysis of the results of the present study.

3. Methodology

The present study proposes a qualitative approach, which adopted an exploratory and descriptive nature (Gil, 2008; Malhotra, 2001). Figure 3 details the adopted research design.

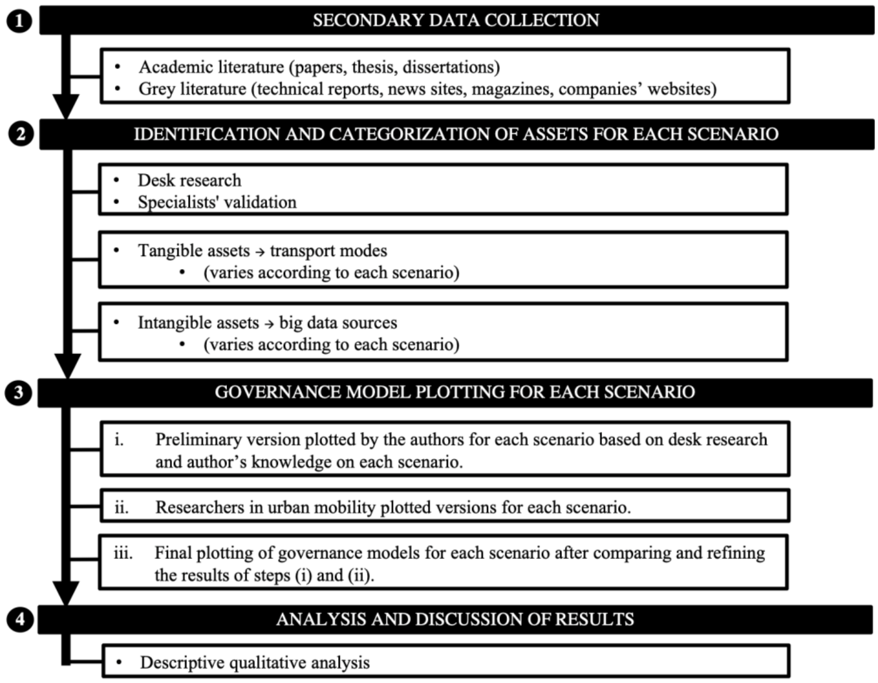

Figure 3. Research design for this proposed paper.
Source: Prepared by the authors.

The first stage carried out on this study was the collection of secondary data on both academic and grey literature as a way of subsidizing the identification of the big data sources for urban mobility platforms. After the gathering and categorization of secondary data, we proceeded with the identification of specific assets (tangible and intangible ones) for each scenario proposed by Antonialli et al. (2018). This stage was also carried out based on literature review and with the help of two researcher professors on urban mobility from the *Terrestrial Mobility Laboratory of Federal University of Lavras,* Brazil - LMT/UFLA.

We opted to take a single example for each scenario depicted by Antonialli et al. (2018) and extrapolate them to a future where autonomous vehicles are seen as a transport mode, and based on that, describe the correspondent governance model. For Scenario A, we considered Uber's operations with their current experimental fleet of AVs in the United States in the cities of Pittsburgh, San Francisco, and Tempe (Tascarella, 2016; Della Cava, 2016; Hawkins, 2017). Regarding Scenario B, we also considered Uber's business model, however, in this case, taking into account that the company does not own the fleet; AVs would belong to ordinary people that could make their cars available for other peers via the UBER platform - such premise is the current primary revenue business model of traditional (human-driven) peer-to-peer ridesharing companies such as Uber, Lyft, Sidecar, Didi Chuxing, Go-Jek, Grab Taxi, Haxi, and so on (Antonialli et al., 2018; Macmurdo, 2015).

In Scenario C, we considered the Las Vegas project "SHIFT - Project 100", which entailed a privately owned multimodal fleet (Kamargianni et al., 2016; Jittrapirom et al., 2017). Such fleet would encompass shared vehicles - here considered as autonomous on a scheme similar to Scenario A; shared bicycles and private shuttles - here also considered as autonomous - similar to Navya's and Easymile's automated shuttles.

At last, regarding Scenario D, we took as example the Swedish Mobility-as-a-Service (MaaS) scheme of UbiGo (Kamargianni et al. 2016; Jittrapirom et al., 2017), in which the available transport modes extrapolated to a future reality with AVs would be: peer-to-peer autonomous vehicles - on a scheme similar to Scenario B; business-to-consumer autonomous cabs - working similar to scenario A; shared bicycles and; public transport (encompassing: buses, trains, tramways and metro).

Inspired by Antonialli, Antonialli & Santos (2017) and Otto and Chobotová (2013), stage 3 consisted on conceptually plotting the specific assets for the given examples on each scenario based on Williamson's (1991) discrete structural analysis for governance models (depicted on Figure 2). This stage was subdivided in three sub-steps:

i) Based on literature review (methodology's stage 1), the authors plotted on Williamson's (1991) model a preliminary governance version for each scenario by ranking each asset (raised on methodology's stage 2) regarding how specific they are to the platform provider, that is: how difficult it is for the provider company to "produce" such assets? (ranging from 0 to 8 on the *x*-axis) and how uncertainty and disturbances regarding each asset influence on the platform's business model (ranging from 0 to 4 on the *y*-axis).
ii) With the aim of validating the aforementioned plotted governance models, each scenario's core characteristics were explained in details for 12 researchers in urban mobility both in France (*Laboratoire Génie Industriel - CentraleSupèlec*) and Brazil (LMT/UFLA) - this group of researchers was comprised of professionals both from technical and non-technical areas related to urban mobility, therefore following the premise posited by Gandia et al. (2018) of the importance of pluridisciplinarity for the advancement of research on vehicular automation. Thus, the researchers were split in pairs and were invited to plot their versions of the graphs (also ranking the assets on the *x*-axis from 0 to 8 and the *y*-axis from 0 to 4) for each scenario.

iii) At last, the results found on sub-steps (i) and (ii) were compared, discussed, and refined and a final governance graph for each scenario was plotted based on the arithmetic means and standard deviations.

After plotting the graphs, stage 4 was carried out with the analysis and discussion of the governance models for each scenario, via descriptive qualitative analysis (Sanderlowski, 2000; 2010; Kim, Sefcik & Bradway, 2016). Also, secondary data was used to subsidize the discussions as well as to support the findings.

4. Results and discussion

4.1 Assets' identification and governance plotting for each scenario

Before categorizing the governance models for each scenario, the first step taken in the present study was surveying the assets to be plotted in the charts. The assets were surveyed aiming to address the first question posed by Veeneman et al. (2018), in terms of mobility platforms.

Therefore, based on literature review and validation with urban mobility research professors, a total of 24 assets considered as valuables into mobility data platforms were listed. Such assets are depicted on Figure 4.

It is worth highlighting that the assets considered do not represent the totality of specific assets existent for each scenario. That is, the search for assets was not exhaustive, but rather it was carried out to provide a set of trivial components for the distinction between the governance models for each scenario.

	Tangible assets (transport modes)					Intangible assets (data)																							
Scenarios	a. Autonomous vehicles (AV)	b. Bicycles	c. Autonomous Shuttles	d. Autonomous Taxis	e. Public Transport (PT)	a_1. AV's location	a_2. AV's availability	b_1. Bicycle's location	b_2. Bicycle's availability	c_1. Shuttle's location	c_2. Shuttle's availability	d_1. Taxi's location	d_2. Taxi's availability	e_1. PT's location	e_2. PT's availability	f. Passenger's location	g. Trip's demand	h. User's evaluation	i. Trip's travel time	j. Modal's occupancy	k. Weather	l. Traffic	m. Trip's revenues	n. Trip's costs
A	✓					✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓
B	✓					✓	✓									✓	✓	✓	✓	✓	✓	✓	✓	✓
C	✓	✓	✓			✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
D	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 4. Surveyed assets for plotting the governance charts.
Source: prepared by the authors.

Of the 24 surveyed assets, five were tangible (**a**, **b**, **c**, **d**, and **e**); being those the transport modes present in each scenario. As for intangible assets, those accounted for 19 of the 24 assets, comprising the data required for the businesses platforms' proper functioning, as inquired by Veeneman et al. (2018), at the end of this study's theoretical background.

Regarding Scenarios A and B, eleven assets were used for plotting the governance models; being those: (**a**) autonomous vehicle; ($\mathbf{a_1}$) data on AV's location; ($\mathbf{a_2}$) data on AV's availability; (**f**) data on passenger's location; (**g**) data on trip's demands; (**h**) data on user's evaluation; (**i**) data on trip travel time; (**j**) data on modal's occupancy; (**k**) data on weather; (**l**) data on traffic; (**m**) data on trip's revenues, and (**n**) data on trip's costs.

Scenario C encompassed, in addition to these eleven previous assets, two other transport modes (**b** - bicycle and **c** - private autonomous shuttles) as well as their respective data on location and availability ($\mathbf{b_1}$, $\mathbf{b_2}$ and $\mathbf{c_1}$, $\mathbf{c_2}$), totaling 17 assets plotted.

Scenario D also holds the eleven assets from Scenarios A and B, in addition to the modal bicycle and its data on location and availability depicted in scenario C as well as two other transport modes (**d** - autonomous B2C taxis and **e** - public transport) and also their respective data on location and availability ($\mathbf{d_1}$, $\mathbf{d_2}$, $\mathbf{d_3}$, and $\mathbf{d_4}$), thus, totaling 21 assets plotted. Following all scenarios are described and respective governance mechanisms are analyzed.

Scenario A:

Uber B2C autonomous operations in Pittsburgh, San Francisco and Tempe.

As depicted in the lower-left quadrant of Figure 5, in this scenario, the platform provider subsidizes the consumers' segment by being responsible for all direct and indirect costs regarding both the fleet and the platform itself. The tangible asset - Autonomous Vehicle - presents a high specificity degree (7.65) and an intermediate frequency of disturbances (1.50). Thus, with the platform provider owning the fleet (B2C business model), the number of AVs available to commuters is likely to be smaller when compared to traditional peer-to-peer mobility platforms. This peculiarity could raise operational issues to both commuters and platform provider, which may raise opportunities for new market entrants. On the other hand however, by owning the fleet, the platform provider has more control over supply and reallocation of its vehicles in face of demand fluctuations.

As for intangible assets, most of the data are anchored within the hierarchical side of Williamson's model ($\mathbf{a_1}$, $\mathbf{a_2}$, **g**, **h**, **i**, **j**, **n**), since for one-way multi-sided platforms, producing such data internally may be considered strategical for the business model efficiency and success. The only two intangible assets acquired via market for this scenario, are data on weather (**k**) and on traffic (**l**) due to their low specificity degree.

At last, data on passenger's location (**f**) and on trip's revenues (**m**) are anchored on the hybrid portion of the graph. In both cases, the platform provider cannot produce this data internally nor acquire them directly on the market, thus contractual relations among the involved stakeholders are necessary. The user (commuter), by agreeing to Uber's terms of service, agrees to assign his/her location data to the company as well as to allow his/her credit card carrier to make financial transactions on each completed journey.

Regarding the frequency of disturbances, most of the assets in this scenario were plotted as having an intermediate disturbance frequency. Data on weather (**k**), traffic (**l**), modal's occupancy (**j**), vehicle's availability ($\mathbf{a_2}$), and user's evaluation (**h**), all displayed a frequency of disturbance around 2,00 units. Data on passenger's location (**f**), trip's revenue (**m**), trip's costs (**n**) and vehicle's location ($\mathbf{a_1}$) presented lower frequency of disturbance, while data on trip's demand (**g**) and trip's travel time (**i**) ranked higher on disturbances frequency.

Thus, the governance model for Scenario A is likely to be more hierarchical, because, by internalizing most of the data (72.8%), the number of transactions carried out via market or hybrid forms is likely to be minimized. Hence, it reduces the need of formal contracts as well as the odds of information asymmetry and opportunistic behavior by the involved stakeholders (Veeneman et al., 2018; Yap & Munizaga, 2018).

Scenario B:

Peer-to-peer autonomous Uber extrapolation.

Moving to the lower-right quadrant of Figure 5, Scenario B entails unimodal mobility were AVs (**a**) are seen as tangible assets of low specificity (1.17) and intermediate uncertainty (2.33), coordinated mainly by market mechanisms. As for intangible assets, since AVs' ownership now belongs to ordinary peers, vehicles' usage as well as their data, rely on contractual and consensual relationships among the vehicle's owners and the platform provider.

In this sense, the majority of these assets once anchored within hierarchical mechanisms in Scenario A, have now migrated towards hybrid structures - data on modal's occupancy (**j**), AVs' location ($\mathbf{a_1}$) and availability ($\mathbf{a_2}$) as well as trip's costs (**n**) being anchored within the hybrid governance structure alongside passenger's location (**f**) and trip's revenue (**m**) - while data on user's evaluation (**h**), trip's demand (**g**) and trip's travel time (**i**) are still plotted within hierarchy. However, leaning a bit towards hybrid governance, which, according to Sundararajan (2016), the reality of AVs brings up a more distributed or networked economic structure derived from the digitalization of economy. At last, data on weather (**k**) and traffic (**l**) continue to be acquired via the market (as in Scenario A).

As for disturbances' frequency, this scenario presented similar behavior to Scenario A, with most of the assets displaying intermediate uncertainty degree. However, it is worth highlighting that, by not owning the fleet, all assets presented a slight rise on disturbances when compared to the previous scenario, except for data on traffic, which remained basically unchanged.

Scenario C:

Multimodal B2C mobility - the SHIFT Project 100 autonomous extrapolation.

Moving to the upper-left quadrant of Figure 5, Scenario C offers a multimodal solution from point X to Y with SHIFT - the service provider - owning all multimodal fleet. With that, the tangible assets (**a**) autonomous vehicles, (**b**) bicycles and (**c**) autonomous shuttles are all anchored within hierarchy and presenting intermediate to low disturbances frequency, in a sense that by owing the fleet, SHIFT is likely to have more control over its tangible assets, where through preventive maintenance, scheduled fleet's cleaning, among other factors, may reduce the frequency of problems with its fleet.

Overall, the business model logic behind this scenario is very similar to Scenario A. However, due to a higher number of modals, asset specificity tends to move further into hierarchy and intangible assets' frequency of disturbances also tends to be somewhat higher. Therefore, the governance structure of this scenario is the most hierarchical among the analyzed scenarios, confirming Van den Broek & Van Veenstra's, (2018) argument that the more closed or sensitive the data is, the more centralized or hierarchical approaches of governance is needed.

Scenario D:

Multimodal Mobility-as-a-Service - the UBIGO autonomous extrapolation.

By offering a bundled public-private multimodal mobility solution via a unified platform, Scenario D perfectly fits the definitions of Mobility-as-a-Service as proposed by Jittrapirom et al. (2017), Mulley (2017), and Hietanen (2014). Furthermore, in the same way that Scenario C resembles Scenario A, the present scenario is very similar to B regarding its business model operation. By analyzing the upper-left quadrant of Figure 5, one can notice that the multimodal fleet composed of (**a**) P2P autonomous cars, (**b**) B2C bicycles, (**d**) B2C autonomous taxis and (**e**) B2C public transport are all plotted within the market governance structure with intermediate to high disturbances frequency.

Because UBIGO does not own the fleet, the company relies on third parties to carry out its operations. thus, much of the data required (62.5%) for the correct functioning of its business model are anchored in the hybrid governance structure, those being: data on AVs' location ($\mathbf{a_1}$) and availability ($\mathbf{a_2}$), bicycles location ($\mathbf{b_1}$), autonomous taxis' location ($\mathbf{d_1}$) and availability ($\mathbf{d_2}$), public transport location ($\mathbf{e_1}$), passengers' location (**f**), trip's demand (**g**), trip's travel time (**i**), modals' availability (**j**) and trip's costs (**n**).

In this sense, the frequency of disturbances tends to be from intermediate to high. Therefore, well-defined contracts and trust relationships among the involved stakeholders are fundamental for reducing information asymmetry and thereby reducing opportunistic behaviors, as well as for value to be generated and distributed fairly among all actors in the platform ecosystem. As this platform became more digitalized, not only transactions costs are likely to be reduced, but also value creation might be enhanced (Munger, 2018; Souza et al, 2018).

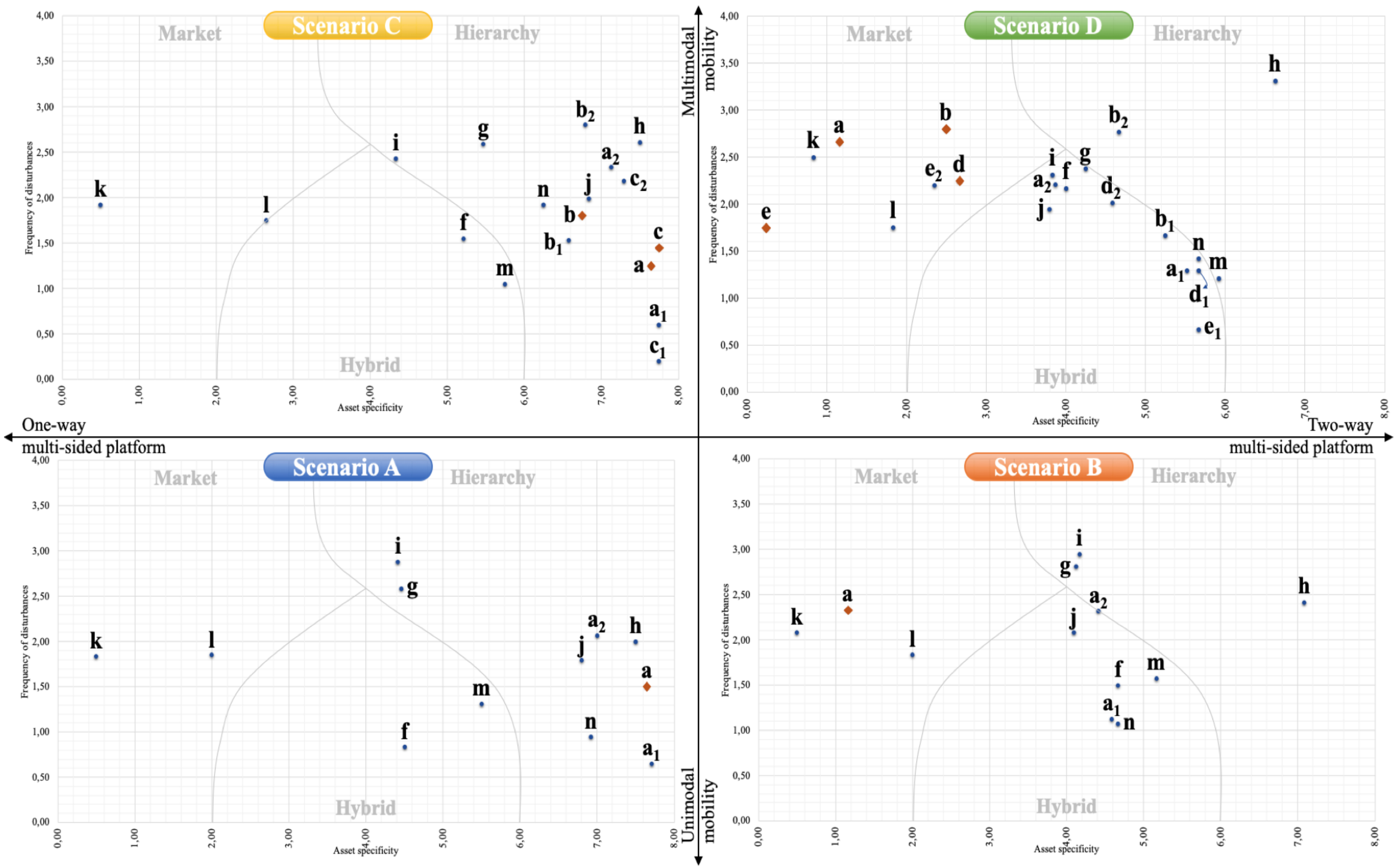

Figure 5. Scenarios' assets distribution towards specificity and disturbance frequency.
Source: prepared by the authors.

For purposes of better visualization, Figure 5 depicted only the averages obtained for the plotted assets in each scenario. Therefore, complementing Figure 5, Table 1 presents in detail the averages of each asset plotted in each scenario as well as their respective standard deviations.

Scenario A

		AVERAGE		STD. DEVIATION	
		x axis	*y* axis	*x* axis	*y* axis
Autonomous vehicles (AVs)	a	7,65	1,50	0,36	0,13
AV's location	a_1	7,71	0,65	0,10	0,26
AV's availability	a_2	7,00	2,07	1,50	0,40
Passenger's location	f	4,50	0,83	1,26	0,32
Trip's demand	g	4,46	2,58	1,89	0,46
User's evaluation	h	7,50	2,00	0,34	0,72
Trip's travel time	i	4,42	2,88	1,88	0,20
Modal's occupancy	j	6,80	1,79	1,39	0,69
Weather	k	0,50	1,83	0,72	0,79
Traffic	l	2,00	1,85	1,05	0,82
Trip's revenues	m	5,50	1,31	1,45	0,23
Trip's costs	n	6,92	0,95	0,66	0,27

Scenario B

		AVERAGE		STD. DEVIATION	
		x axis	*y* axis	*x* axis	*y* axis
Autonomous vehicles (AVs)	a	1,17	2,33	0,48	0,87
AV's location	a_1	4,58	1,13	2,54	0,62
AV's availability	a_2	4,42	2,32	1,19	0,65
Passenger's location	f	4,67	1,50	2,30	0,91
Trip's demand	g	4,13	2,81	1,77	0,72
User's evaluation	h	7,08	2,42	1,51	1,19
Trip's travel time	i	4,17	2,95	1,88	0,35
Modal's occupancy	j	4,09	2,08	1,04	0,77
Weather	k	0,50	2,08	0,72	0,61
Traffic	l	2,00	1,83	1,05	0,83
Trip's revenues	m	5,17	1,58	1,71	0,58
Trip's costs	n	4,67	1,08	1,47	0,09

Scenario C

		AVERAGE		STD. DEVIATION	
		x axis	*y* axis	*x* axis	*y* axis
Autonomous vehicles (AVs)	a	7,65	1,25	0,36	0,38
AV's location	a_1	7,74	0,60	0,11	0,21
AV's availability	a_2	7,13	2,33	1,52	0,73
Bicycles	b	6,75	1,80	1,44	0,73
Bicycle's location	b_1	6,58	1,53	2,30	0,94
Bicycle's availability	b_2	6,79	2,80	2,34	0,94
Private shuttles	c	7,75	1,45	0,11	0,11
Shuttle's location	c_1	7,74	0,20	0,11	0,04
Shuttle's availability	c_2	7,29	2,18	1,12	0,72
Passenger's location	f	5,21	1,55	1,02	0,28
Trip's demand	g	5,47	2,59	1,18	0,53
User's evaluation	h	7,50	2,61	0,72	0,86
Trip's travel time	i	4,33	2,43	1,90	0,27
Modal's occupancy	j	6,83	1,99	1,41	0,56
Weather	k	0,50	1,92	0,72	0,93
Traffic	l	2,65	1,75	1,81	0,67
Trip's revenues	m	5,75	1,05	1,31	0,31
Trip's costs	n	6,25	1,92	0,79	0,47

Scenario D

		AVERAGE		STD. DEVIATION	
		x axis	*y* axis	*x* axis	*y* axis
Autonomous vehicles (AVs)	a	1,17	2,67	0,48	0,32
AV's location	a1	5,53	1,29	2,45	0,71
AV's availability	a2	3,87	2,21	1,45	0,21
Bicycles	b	2,50	2,80	1,50	0,92
Bicycle's location	b_1	5,25	1,67	2,90	1,19
Bicycle's availability	b_2	4,67	2,77	2,19	1,04
Taxis	d	2,67	2,25	1,66	0,63
Taxi's location	d_1	5,67	1,29	2,32	0,71
Taxi's availability	d_2	4,58	2,02	1,85	0,15
Publict transport (PT)	e	0,25	1,75	0,11	0,83
PT's location	e_1	5,67	0,67	2,70	0,38
PT's availability	e_2	2,35	2,20	1,87	0,68
Passenger's location	f	4,00	2,17	1,78	0,94
Trip's demand	g	4,25	2,38	2,14	0,55
User's evaluation	h	6,63	3,31	2,28	0,89
Trip's travel time	i	3,83	2,31	2,04	1,22
Modal's occupancy	j	3,79	1,95	0,69	0,61
Weather	k	0,83	2,50	1,10	0,88
Traffic	l	1,83	1,75	0,87	1,31
Trip's revenues	m	5,92	1,21	1,41	0,51
Trip's costs	n	5,67	1,42	1,75	0,96

Table 1. Averages and standard deviations for all plotted assets in each scenario.
Source: prepared by the authors.

4.2. Platforms' costs and the role of institutions towards regulations and standards

By analyzing Figure 5, it is in fact clear the governance similarity between scenarios A and C and Scenarios B and D. However, regarding operation and transaction costs, a mirror-like behavior was observed. As depicted in Figure 6, the evolution of transaction costs among the scenarios presents a N-type curve behavior starting on Scenario A and ending in Scenario D with the highest transaction costs, while operational costs tend to evolve in the opposite trajectory, starting on B, moving up to D and them to A and finally being the highest on Scenario C.

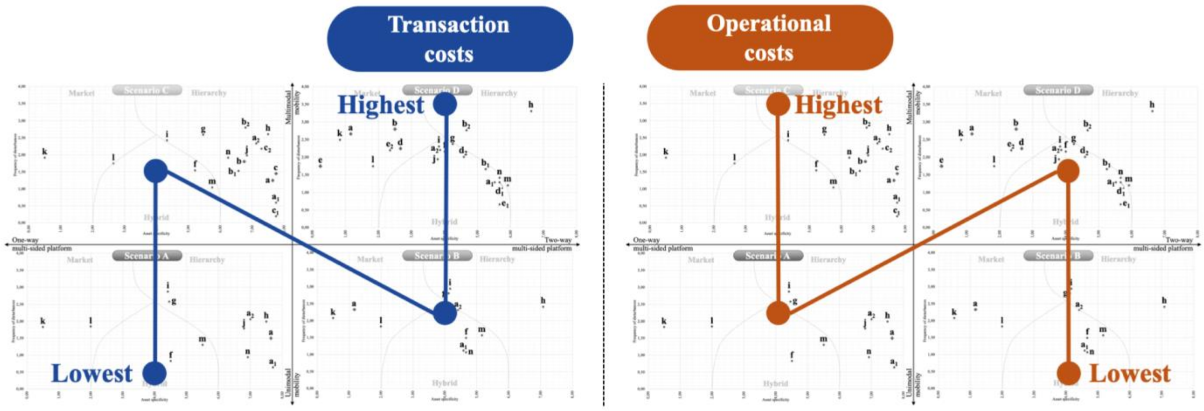

Figure 6. Operational and transaction costs among the plotted scenarios.
Source: prepared by the authors.

By offering a subsidized unimodal commute between two points, the market dependence of Scenario A is restricted to commoditized data, such as weather (**k**) and traffic (**l**), hybrid governance is limited to contracts on user's location data (**f**) and data on trip's revenue (**m**), resulting in all other tangible and intangible assets being produced internally. These assets, in turn, lead to reductions in transaction costs and tends to mitigate opportunistic behavior among the stakeholders in the platform ecosystem (Williamson, 2005; Crook et al., 2013). This same analysis can be applied to Scenario C, but, since the platform provider owns a multimodal fleet, the frequency of disturbances affecting the assets tends to be higher, which causes transaction costs to slightly rise as well.

As for Scenario B, by also offering a unimodal solution between two points, its operation logic resembles Scenario A. However, by not owning the fleet, the platform provider becomes more dependent on market transactions (assets: **k**, **a** and **l**) and hybrid transactions (assets: **j**, $\mathbf{a_1}$, $\mathbf{a_2}$**,** **f**, **n,** and **m**). Thus making transaction costs higher than the two previous scenarios and corroborating with Williamson's (2005) premises.

At last, Scenario D presents the highest transaction costs among all; by not owning the multimodal fleet, the platform provider is at the mercy of several market transactions (assets: **e**, **k**, **a**, **l**, $\mathbf{e_2}$, **b,** and **d**) and a wide range of hybrid relations with the most varied stakeholders in its ecosystem (assets: **j**, $\mathbf{a_2}$, **i**, **f**, **g**, $\mathbf{d_2}$, $\mathbf{b_1}$, $\mathbf{a_1}$, **n**, $\mathbf{d_1}$, and $\mathbf{e_1}$) such peculiarities also make the frequency of disturbances higher in this scenario for a large part of the assets. Such results corroborate the assertive proposed by Souza et al. (2018) that, within the digital economy, hybrid governance structures on data platforms are likely to prevail. Sundararajan (2016) also confirms this argument highlighting that generally, platform structures of digital economy such as Uber entails hybrid governance between pure market and hierarchy.

Notwithstanding, with regard to direct and indirect operating costs, the results on Figure 6 show an opposite behavior to the evolution of transaction costs. By executing its business via a single transport mode and by not owning the fleet, Scenario B presents the lowest operating costs among all scenarios; having to bear only the costs related to the platform maintenance and the data needed to its functioning. The same goes for Scenario D, however, due to its multimodal approach more data needs to be managed, which in turn slightly raises the operating costs.

With tangible assets belonging to the platform provider, operating costs go beyond maintaining the platform and data; direct and indirect costs with the fleet (such as maintenance, insurance, cleaning, recharging, relocation, etc.) become crucial to the platform’s governance structure. In this sense, Scenario A presents higher operating costs to Scenarios D and B. In addition, Scenario C, presents the highest operating costs among all models, which can lead to the failure of the business model if management is not well planned and implemented - which in fact happened to SHIFT's operations in Las Vegas (Loveday, 2015; Rothberg, 2015).

Such findings are aligned with Veeneman et al. (2018). Where were studied 10 mobility platforms and pilot projects aiming on identifying key governance mechanisms that affect the success of mobility platforms using big data. They reached a conclusion that more ambitions a mobility platform has, more governance challenges arise due to several mechanisms. In this sense, as stated by Yap and Munizaga (2018), a higher ambition level of a mobility platform and the number of stakeholders to get involved makes it more difficult to define and realize consensus about the platform directions, increasing the need for a clear governance structure and coordination.

Ergo, the latter authors conclude that in times of fast technological developments, technical challenges can be solved more easily when compared to solving institutional challenges, which tend to be much more complex. This complexity results from required coordination and cooperation among public and private entities that are not always aligned. As Provan and Kenis (2008) state, this is relevant because data have to cross several institutional borders, including organizational ones, between departments, public-private borders and the barrier between supply and demand, hence, governance is believed to contribute to the efficiency and effectiveness of arrangements over all those borders.

With that, as depicted by Yap and Munizaga (2018), another important element for the governance of mobility data platforms is the role of the institutional environment and the respective local transport authorities. These entities play a fundamental role in directing the governance structures to be adopted by the platforms. As IET (2017) point out local authorities nowadays plays a part in a wider technological ecosystem.

As highlighted by Veeneman et al. (2018) and Yap and Munizaga (2018), the institutional context should mainly be considered an ‘as-is’ state. That is, to successfully institutionalize the use of big data in mobility platforms, the technical ambitions should be aligned with the given institutional environment that the platform is positioned in.

Furthermore, efforts towards enabling and easing the use of big data by transport authorities are fundamental for the success of platforms (Yap & Munizaga, 2018). According to the authors, it is important to develop common definitions and standard data formats, together with the industry, but not neglecting to consider the challenges and peculiarities of the IT industry. Thus, reaching an agreement on common data formats also eases consolidation of data sources and can support the stakeholders to get more value from big data.

In this context, in addition to the definition of standards, it is important to highlight some issues related to data ownership and transparency. The recent Facebook data scandal which granted Cambridge Analytica access to data on 87 million people (Yuieff, 2018; Solon, 2018) and the new European Union General Data Protection Regulation (EU - 2016/679) coming into force at the end of May 2018, not only brought up the discussion on data privacy, transparency, and ownership, but also prompted several platform companies to update their terms of service (Biersdorfer, 2018; Riley, 2018).

In response to these issues, the blockchain technology - that emerged in 2009 with the cryptocurrency Bitcoin - is proving to be a viable alternative to ensure a more ethical, decentralized and transparent usage of data (Geiregat, 2018). As simply put by Macrinici, Cartofeanu and Gao (2018, p.2337):

> “Traditionally, within our society, we have created trust through intermediaries. We use these third party entities because we trust that they will store and protect our goods and send the right amount when we request it, and to the right person. Blockchain replaces the need for intermediaries by redirecting the trust to decentralized systems.”

Thus, blockchain provides a viable method of coordination of parties that do not trust each other by offering a decentralized network of “verifiers” to clear transactions, rendering mute the need of a central authority (Sundararajan, 2016). In their master’s thesis Andersson and Torstensson (2017) explore the role of blockchain technology in Mobility-as-a-Service schemes. For the authors, by the use of blockchain, MaaS schemes would have all stakeholders participating on the network in equal terms. Furthermore, by using the so-called "smart contracts", rules can be specified between multiple parties in a transaction within a MaaS platform:

> "The user sends the contract to the blockchain network, and all interested participants can see it. Participants that want to provide the service make counteroffers to the initial contract. The user accepts the offer that it prefers. Both parties now have more certainty about the outcome of the agreement. If the service is fulfilled, the provider will be guaranteed to get a payment and, with the accepted contract, the user knows that the provider is very likely to deliver the service" (Andersson & Torstensson 2017, p.45).

Unlike traditional contracts that require a court and law system to be negotiated, ratified and enforced, smart contracts are guaranteed to execute as coded without any manipulation from the parties, such contracts essentially are containers of code that encode and mirror the real-world contractual agreements in the cyber realm (Macrinici, Cartofeanu & Gao, 2018; Geiregat, 2018). Once a smart contract has been created it cannot be changed, this gives its participants a guarantee of what will happen (Andersson & Torstensson, 2017).

Thus, blockchain and smart contracts may therefore benefit all the scenarios here studied. However, due to the inherent characteristics of this technology, we believe that Scenario B and mainly D are likely to benefit the most from it, due to their hybrid governance models. In addition, future studies are needed to identify the best way to ensure the insertion and usage of smart contracts within the proposed scenarios.

At last, Table 2 summarizes the main results found in the present conceptual study as well as it answers the two remaining questions posited by Veeneman et al. (2018) in the end of the present study theoretical background.

Scenario	Main features	Prevailing governance model	Big Data ownership	Regulations
A	B2C unimodal mobility	Hierarchy	Centralized on Platform provider	Centralized on Transport Authorities
B	P2P unimodal mobility	Hybrid	Spread among different stakeholders	Smart contracts via Blockchain
C	B2C multimodal mobility	Hierarchy	Centralized on Platform provider	Centralized on Transport Authorities
D	B2C + P2P multimodal mobility (Mobility-as-a-Service)	Hybrid	Spread among different stakeholders	Smart contracts via Blockchain

Table 2. Governance of autonomous urban mobility platforms via big data.
Source: Prepared by the authors.

According to Table 2, Scenario C is the most hierarchical in terms of governance structure, closely followed by Scenario A. In this sense, their regulation structure could be more centralized on transport authorities since both these mobility platforms have their assets less dispersed and distributed among its respective business ecosystems, as corroborated by IET (2017).

Scenarios B and D have a predominance of hybrid governance structure, noting that Scenario D relies on a greater number of market transactions due to the inherent characteristic of its tangible assets. In this sense, Sundararajan (2016) points out that the business platforms which are into sharing economy features, present more networked-based relations instead of traditional centralized ones. Yap & Munizaga, (2018) confirm this argument by stating that when it comes to data-based mobility platform,s which entails public and private organizations, it is necessary to build up trustworthy relations among the involved stakeholders as well as it is relevant to secure data sharing among them via contracts and standards. Ménard (2013) also highlights that adequate contracts are the underlying hybrid structures of governance.

Therefore, among the studied scenarios, Scenario D deals with greater complexity, bringing up the need of improved hybrid arrangements, bringing to light technologies such as blockchain and smart contracts. As Veeneman et al. (2018) point out the more complex a mobility platform is on a technical level, higher governance challenges.

5. Concluding remarks

Big data represents a massive change within transportation systems yielding direct implications to urban mobility platforms. Therefore, this paper sought to conceptually explain how big data impacts on governance structures of future autonomous urban mobility platforms. In sum, this paper, pointed out that the level of big data ownership is related to each scenarios features (mobility platforms characteristics and all its respective assets) which therefore, delineates the most proper governance mechanism for autonomous mobility platforms. One contribution of this present study, is to address conceptually, issues related both on big data as well on governance within mobility platforms as described by Yap & Munizaga, (2018) and Veeneman et al. (2018).

In this sense, Scenarios C and A (respectively) presented governance structures predominantly hierarchical, and, due to that, such scenarios displayed the highest operational costs among all four. That is - by owning the fleet - the platform provider not only has to bear the costs of maintaining the platform itself, but also has to bear all direct and indirect costs of its fleet.

Meanwhile, Scenarios D and B (respectively) presented more hybrid governance modes, which, in turn, reduces the operating costs, but raises transaction costs. By not owning the fleet, such platforms rely on contractual and trust relations with other parties, hence, given margin to information asymmetry, which might lead to opportunistic behaviors and therefore raising transaction costs. In order to circumvent this situation, contracts and control mechanisms must be very clear and previously established in order to generate value for all parties involved.

As for frequency of disturbances, findings showed that the greater the number of transport modes are, the greater is the frequency of disturbances. Thus, for those scenarios, which the platform provider is also the owner of the vehicles' fleet (A and C), the frequency of disturbances tends to be smaller than in scenarios where the platform provider does not own such tangible assets (B and D). By owning the tangible assets, the platform provider also owns several data generated by such assets, thus reducing the need to acquire them via market or via partnerships, which, in turn, gives greater control and, consequently, tends to reduce the frequency of disturbances, but, on the other hand, significantly increases operating costs.

Generally, within the four scenarios analyzed, it was possible to characterize different governance modes, according to the types and ownership degree of tangible (transport modes) and intangible assets (big data) in each mobility platform analyzed. Therefore, the findings of this conceptual paper allow elaborating the following propositions to be tested in future studies: **1) the tangible assets' (transport modes) ownership degree determines both specificity and the level of disturbance frequencies of the intangible assets (data), which consequently determines the governance structure each mobility platform.**

Furthermore, another propositions to be tested in future might be: **2) As scenarios gain complexity (by incorporating more transport modes), more big data is generated.** At last; **3) As more big data is generated there is an increased need of more complex regulations via smart contracts on blockchain for reducing opportunistic behavior and, consequently, its transaction costs** (as seen on scenario D).

Moreover, future studies based on this paper could provide modelling strategies via computational and statistical methods to confirm or refute each governance scenario features and the propositions described on this paper via hypothesis tests.

As for research limitations, data collection with mobility researchers instead of industry members could bring up subjective aspects into the research method performed.

However, due to the difficulty of access to professionals of the urban mobility market, conducting the present study with urban mobility researchers was the most viable option. In the same way, the adopted methodology (by itself) presents subjective biases, so the conceptual and exploratory character of the present study requires validation through computational modeling and more robust databases. Therefore, future studies with urban mobility industry professionals are recommended. Also, this recommendation would imply in a larger variation specifically of intangible assets (big data), since it would be collected not only via researchers, and literature review.

In summary, governance mechanisms will always be imperfect. There will always be a certain degree of information asymmetry and externalities. However, the more sophisticated the governance is, more it will encourage the ecosystem's stakeholders to take action. Thus, the governance cannot be static; in contrast, it must be adjusted according to the future scenarios in the market, new user behaviors, conflicts, and risks, allowing the whole ecosystem to be flexible to take decisions quickly (Parker, Van Alstyne & Choudary, 2016). Therefore, within big data contexts, complex platform structures bring up the need for more sophisticated governance structures (e.g., hybrid modes with smart contracts), and a more dynamic behavior of all involved stakeholders.

Acknowledgments

This paper would not have been possible without the support of the Post Graduate Program in Administration of Federal University of Lavras (UFLA - Brazil), Terrestrial Mobility Laboratory (LMT / UFLA - Brazil), and the Laboratoire Génie Industriel (LGI / Centrale Supélec - France). We also would like to thank the institutions that have been funding this project: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES - Brazil), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq - Brazil), Ecole Centrale Supélec (Université Paris-Saclay - France).

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