RODRIGO MARÇAL GANDIA

**INNOVATION IN ECOSYSTEM BUSINESS MODELS:**
AN APPLICATION TO MAAS AND AUTONOMOUS VEHICLES IN URBAN MOBILITY SYSTEM.

**LAVRAS – MG**
**2020**

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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 Gestão Estratégica, Marketing e Inovação, para obtenção do título de Doutor.

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**2020**

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

Gandia, Rodrigo Marçal.
Innovation in Ecosystem Business Model: An application to MaaS and Autonomous Vehicles in Urban Mobility System. / Rodrigo Marçal Gandia. - 2020.
195 p. : il.

Orientador(a): Joel Yutaka Sugano.
Coorientador(a): Isabelle Nicolaï.
Tese (doutorado) - Universidade Federal de Lavras, 2020.
Bibliografia.

1. Mobility as a Service. 2. Autonomous Vehicles. 3. Urban Mobility. I. Sugano, Joel Yutaka. II. Nicolaï, Isabelle. III. Título.

**RODRIGO MARÇAL GANDIA**

# INNOVATION IN ECOSYSTEM BUSINESS MODELS:
AN APPLICATION TO MAAS AND AUTONOMOUS VEHICLES IN URBAN MOBILITY SYSTEM.

# INOVAÇÃO EM MODELOS ECOSSISTÊMICOS DE NEGÓCIOS:
UMA APLICAÇÃO DO MAAS E A INTEGRAGRAÇÃO DOS VEICULOS AUTONOMOS EM UM SISTEMA DE MOBILIDADE URBANA.

# INNOVATION DANS LES MODÈLES D'AFFAIRES D'ÉCO-SYSTÈMES:
UNE APPLICATION AU MAAS ET À L'INTÉGRATION DES VÉHICULES AUTONOMES DANS UN SYSTÈME DE MOBILITÉ URBAINE.

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

Approved on 23th April, 2020

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**LAVRAS – MG**
**2020**

*For my parents, my cornerstone, my everything, Marta and Lourenço.*

*To my brother, my friend, my inspiration, Rômulo.*

*To my love, my safe place, Andréia.*

***I Dedicate***

**_Acknowledgements_**

*It is a little bit funny to stop and write "acknowledgments" when in fact, thanking should be a daily habit of our journey... Unfortunately, we cannot always say thank you; sometimes, it passes… the rush of everyday life often tries to justify a thank you' forgotten hug.*

*However, this is the time to externalize in words - at least to try - a bit of the gratitude' feeling for each of the essential people to complete this journey named "doctorate".*

*First and foremost, I thank God and my family, my father Albany Lourenço Godoy Gandia and my mother Marta Lúcia Perujo Marçal Gandia, examples of determination, inspiration, and life; and my brother Rômulo Marçal Gandia, who has always been in my side given support, encouragement, and plenty of laughs, love you all!*

*To my loving fiancée, Andréia Nunes Campos, for the belief, complicity, friendship, and patience, always being there for me.*

*To my advisors, professor Joel Yutaka Sugano and professor Isabelle Nicolaï, who have always been by my side, helping to make possible the moments when everything seemed impossible. To professor Arthur, responsible for the beginning of this incredible journey looking for solutions on urban mobility in Brazil and - why not - the world.*

*In the "UFLA world" many friends were present. To the professors and researchers of the Laboratório de Mobilidade Terrestre - LMT and to the Grupo de Estudos em Redes e Estratégia - GEREI, especially to the professors Daniel Rezende, Grützmann, Antonialli, Danilo Alves, Zambalde, and Luiz Henrique. To Deila and the entire staff of the Programa de Pós-Graduação do DAE.*

*To my statistical friends, who helped me so much in my journey through the world of numbers, professor Izabela and Julia, thank you.*

*To my siblings by choice, Fabio and Bruna, without words to thank you for everything. To the great friends that the academy gave me - and became for life - Thais, Daniel Leite, Guilherme, Dudu, Elisa, Cassiano, Ricardo, and Zé Willer. You all made this journey lighter.*

*To PH, who introduced me to the academic world back in the master's degree and, since then, more than a professor, I have a friend for life.*

*There are too many people to "remercie" in France too! To the professors and staff of École CentraleSupélec, in particular the members of Laboratoire Génie Industriel - LGI, especially professors Bernard, Pascal, Jakob, Flore, and Danielle. To my friends of LGI Abood, Hichem, Haythem, Tasneem, Selmen, Ouaïl, Islam, Bassem, Gustavo, Ikaro, Rongyan, and Hoang-Phuong (FonkTronk). Besides, of course, to the dears' Delphine, Sylvie, Corrine, Carol, Mathieu, and Suzanne Thuron.*

*To the whole deuxième étage from Maison du Brésil and my friends Jeferson, Lucio, and Fillipo.*

*To Fapemig and CAPEs for the scholarships granted to me for the accomplishment of this thesis.*

**_Thank You Very Much | Muito Obrigado | Merci Beaucoup_**

*"If I have seen further, it is by standing on the shoulders of Giants."*
*Isaac Newton*

## GENERAL ABSTRACT

Given existing environmental pressures, the importance of traffic safety, and increasing regulatory constraints, mobility in cities is a significant concern for communities and citizens. In this con-text, technological innovations based on the widespread use of connected and shared vehicles, the emergence of Autonomous Vehicles (AVs), impose a reflection on the definition of sustainable urban mobility in the cities of the future. In addition to traditional transport, individual solutions are being developed (car sharing, soft mobility, autonomous shuttle, son on), which must be part of a global urban mobility system. In this sense, the concept of Mobility as a Service (MaaS) has gained ground and has become a concrete market option ensuring a transition from the existing property-based transport system to a use-based system. MaaS meets the transport needs of users through a single interface of a service provider by combining different modes of transport to provide a tailor-made mobility offer. This approach places the user at the center of mobility issues. The innovations involved in urban mobility are technological but also social and organizational. They are multi-actor and require coordination of each actor involved in the value chain to develop and disseminate these innovations. We are thus talking about innovation in a business ecosystem. To date, like any innovation, MaaS is a source of uncertainty for markets and sur-rounded by ambiguities. Moreover, MaaS deployments are mainly concentrated in developed countries with efficient public transport systems. However, we believe that MaaS is modular, adaptable, and applicable to a variety of realities (including a wide variety of public-private transport systems). Based on this research, this Ph.D. thesis aims to analyze the concept of MaaS in order to identify its implementation and acceptance within an urban mobility system. The results of our work indicate that the MaaS system can be based on the theoretical tripod of “Product-Service System (PSS),” "business ecosystem", and "eco-innovation." Also, we propose that MaaS can be thought of not only as a transport concept, phenomenon, or solution but also as a business model. Therefore, we propose that MaaS should be oriented towards the value proposition of users, within addition, a reflection based on the successful dissemination of MaaS in southern countries. In order to take its place in the urban mobility of the future, MaaS must be considered as a modular and adaptable economic model, applicable to all contexts (the efficiency - or inefficiency - of public transport must not be limited). To this end, the MaaS business model must be established as part of a systemic rethinking around the mobility ecosystem, and sustainability should not be considered as an intrinsic characteristic of a MaaS model. This innovative ecosystem business model is oriented towards consumer acceptance (user-centric innovation) and acceptance of existing transport modes that fit the specific context established. We will broaden our analysis of the conditions of development and diffusion of the autonomous vehicle within a MaaS at the socio-political level. In this sense, shared and connected AVs must be considered as one among several elements of the urban mobility ecosystem.

**Keywords:** Mobility as a Service; Autonomous Vehicles; Urban Mobility.

## RESUMO GERAL

Dadas as pressões ambientais existentes, a importância da segurança no trânsito e o aumento das restrições regulatórias, a mobilidade nas cidades é uma preocupação para a sociedade. Nesse contexto, inovações tecnológicas baseadas no uso difundido de veículos conectados e compartilhados assim como o surgimento de Veículos Autônomos (VAs) impõem uma reflexão sobre a definição de mobilidade urbana sustentável nas cidades do futuro. Além do transporte tradicional, estão sendo desenvolvidas soluções individuais (compartilhamento de veículos, mobilidade leve, vans autônomas, dentre outros), que devem fazer parte de um sistema global de mobilidade urbana. Neste sentido, o conceito de Mobilidade como Serviço (MaaS) vem ganhando espaço e se tornando uma opção concreta de mercado, apresentando uma transição entre o sistema de transporte baseado na posse de um produto para o acesso a sua utilização. O MaaS tem como proposta oferecer diversas opções de transporte à usuários através de um provedor de serviços com interface única, combinando diferentes modos de transporte de modo a proporcionar um pacote de mobilidade personalizado. Essa abordagem coloca o usuário como central à aspectos relacionados a mobilidade urbana. As inovações envolvidas na mobilidade urbana são tecnológicas, mas também sociais e organizacionais. Elas são multi-atores e requerem a coordenação de cada ator envolvido na cadeia de valor para desenvolver e disseminar essas inovações. Assim, esta inovação pode ser analisada sob a perspectiva do ecossistema de negócios. Até o momento, como qualquer inovação, o MaaS é uma fonte de incerteza para os mercados e cercada de ambiguidades. Além disso, as implantações de MaaS estão concentradas principalmente em países desenvolvidos com sistemas de transporte público eficientes. No entanto, acreditamos que o MaaS é modular, adaptável e aplicável a uma variedade de realidades (incluindo uma ampla variedade de sistemas de transporte público-privado). Com base nesses preceitos, esta tese de doutorado tem como objetivo geral analisar o conceito de MaaS, de modo a identificar sua implementação e aceitação dentro de um sistema de mobilidade urbana. Os resultados indicam que o conceito de Mobilidade como Serviço pode ter como base o tripé teórico de Sistemas de Produtos e Serviços (PSS), Ecossistema de Negócios e Eco-inovação. Além disso, este trabalho propõe que o MaaS pode ser pensada não apenas como um conceito, fenômeno ou solução de transporte, mas também como um modelo de negócios. Portanto, o MaaS deve ser orientado à proposta de valor dos usuários, além de uma reflexão baseada na disseminação bem-sucedida do MaaS nos países do sul. Para ocupar seu lugar na mobilidade urbana do futuro, o MaaS deve ser considerado como um modelo econômico modular e adaptável, aplicável a todos os contextos (a eficiência - ou ineficiência - do transporte público não deve ser limitada). Para esse fim, o modelo de negócios MaaS deve ser estabelecido como parte de uma reflexão sistêmica em torno do ecossistema de mobilidade, e a sustentabilidade não deve ser considerada como uma característica intrínseca. Esse modelo inovador de ecossistema de negócios é orientado para a aceitação do consumidor (inovação centrada no usuário) bem como à adaptação aos modos de transporte existentes de um contexto específico. Ampliaremos nossa análise das condições de desenvolvimento e difusão do Veículo Autônomo dentro de um MaaS no nível sócio-político. Nesse sentido, VAs compartilhados e conectados devem ser considerados como um, entre vários elementos do ecossistema de mobilidade urbana.


**Palavras Chave:** Mobilidade como um Serviço; Veículos Autônomos; Mobilidade Urbana.

## RÉSUMÉ GÉNÉRAL

Compte tenu des pressions environnementales existantes, de l'importance de la sécurité routière et des contraintes réglementaires croissantes, la mobilité dans les villes est une préoccupation majeure pour les collectivités et les citoyens. Dans ce contexte, les innovations technologiques basées sur l'utilisation généralisée de véhicules connectés et partagés, l'émergence des Véhicules Autonomes (VA) imposent une réflexion sur la définition de la mobilité urbaine durable dans les villes du futur. A coté des transports traditionnels se développe des solutions individuelles (autopartage, mobilité douce, navette autonome…) qui doivent s'insérer dans un système global de mobilité urbaine. En ce sens, le concept de Mobilité comme Service (MaaS) a gagné du terrain et est devenu une option de marché concrète assurant une transition du système de transport basé sur la propriété existant vers un système basé sur l'usage. MaaS répond aux besoins de transport des utilisateurs via une interface unique d'un fournisseur de services en combinant différents modes de transport pour proposer une offre de mobilité sur mesure. Cette approche place l'utilisateur au centre des questions liées à la mobilité. Les innovations engagées dans la mobilité urbaine sont technologiques mais aussi sociales et organisationnelles. Elles sont multi-acteurs et nécessitent une coordination de chaque acteur impliqué dans la chaine de valeur pour développer et diffuser ces innovations. Nous parlons ainsi d'innovation dans un écosystème d'affaires. A ce jour, comme toute innovation, le MaaS est source d'incertitudes pour les marchés et entouré d'ambiguïtés. De plus, les déploiements MaaS sont principalement concentrés dans les pays développés dotés de systèmes de transport public efficaces. Or, nous pensons que le MaaS est modulaire, adaptable et applicable à plusieurs réalités (dont des systèmes public-privé de transport très variés). Sur la base de ces recherches, cette thèse de doctorat vise à analyser le concept de MaaS pour identifier sa mise en œuvre et son acceptation au sein d'un système de mobilité urbaine. Les résultats de nos travaux indiquent que le concept de MaaS peut avoir comme fondement le trépied théorique de système produit-service (PSS), de « l'écosystème d'affaires » et de « l'éco-innovation ». Aussi, nous proposons que le MaaS puisse être pensé non seulement comme un concept, un phénomène ou une solution de transport, mais aussi comme un modèle d'affaires. Nous proposons alors que le MaaS soit orienté vers la proposition de valeur des utilisateurs, avec une réflexion appuyée sur les modalités de diffusion réussie du MaaS dans les pays du sud. Afin de prendre place dans la mobilité urbaine du futur, le MaaS doit être considéré comme un modèle économique modulaire et adaptable, applicable à tous les contextes (l'efficacité - ou l'inefficacité - des transports publics ne doit pas être limitative). Pour cela, le modèle commercial du MaaS doit être établi dans le cadre d'une réflexion systémique autour de l'écosystème mobilité, et la durabilité ne doit pas être considérée comme une caractéristique intrinsèque d'un modèle MaaS. Ce modèle économique d'écosystème innovant est orienté vers l'acceptation des consommateurs (innovation centrée-usagers) et des modes de transport existant qui correspondent au contexte spécifique établi. Nous élargirons notre analyse des conditions de développement et diffusion du véhicule autonome au sein d'un MaaS au niveau socio-politique. En ce sens, les VA partagés et connectés doivent être considérés comme un, parmi plusieurs éléments de l'écosystème de la mobilité urbaine.


**Mots clés :** Mobilité comme Service ; Véhicules Autonomes ; Mobilité Urbaine.

## SUMMARY

## FIRST PART

*“We can't solve problems by using the same kind of thinking we used when we created them.”*
*(Albert Einstein)*

# 1. GENERAL INTRODUCTION

The present study addresses the issue of the Future of Urban Mobility in the context of Autonomous Vehicles and Mobility as a Service (MaaS) as an Innovative Ecosystemic Business Model. This introductory section is composed of the contextualization and motivation to the study, the research question, the objectives and the justifications of research. Finally, the doctoral thesis structure is discussed.

## 1.1 Research contextualization and motivation

Nowadays, around 54 percent of the world's population is currently living in urban areas (Population Reference Bureau, 2016), with estimates of a 66 percent by 2050 when the world's population expects to reach nine billion people (Fournier, 2017; EEA, 2013). In this sense, with the continuing global trend of urbanization and the growing demand for transportation, urban mobility poses significant challenges for the future.

To address these challenges is essential to look closely at the transportation sector, which, for most of its history, has remained mostly unchanged (Karlsson et al. 2016; Kamargianni and Matyas, 2016). It is predicted that the need for transportation will rise, resulting in a more significant increase in noise and air pollution, overloaded infrastructure, and congestion. Furthermore, contemporary transport practices are increasingly compromising the well-being of existing populations. Hence, there is a consensus among authors in the study-field that changes are needed (Mulley, 2017; Kamargianni et al., 2016).'

Among the many changes foreseen for the transport paradigm (Mulley, 2017), the arrival of new information and communication technologies (ICTs) increasingly promote the development of business concepts for more efficient use of vehicles, optimization of the transport network, better use of infrastructure and seamless commute (Kamargianni and Matyas, 2016).

Therefore, it is held that technology changes will make the future of mobility occur. For Saddi (2018), three factors must be considered: 1) data collection, 2) autonomous (and electric) vehicles, and 3) multimodal transport. Also, Kuhnert & Stirmer (2017), states that the car of the future will be EASCY, that is: Electrified, Autonomous, Shared, Connected, and Yearly updated. For the relations established among these factors, we understand that they have to be analyzed together as part of a unique ecosystem. Thus, we believe that these new mobility 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.

In this sense, the concept of Mobility as a Service (MaaS) has been gaining ground in recent years and becoming a solid market option, by presenting a shift away from the existing ownership-based transport system toward an access-based one (Jittrapirom et al., 2017; Ambrosino et al. 2016; Mulley, 2017; Kamargianni et al., 2016).

At its core, MaaS delivers users' transport needs through a single interface of a service provider by combining different transport modes to offer a tailored mobility package (Hietanen, 2019). This approach places the user as central to aspects related to mobility, as pointed out by Hannon et al. (2016), the individual traveler is at the heart of this evolution, so consumers need to be open to adopting new technologies and services.

Furthermore, most of the current MaaS deployments are mainly centered in developed countries with efficient public transport systems (Jittrapirom et al., 2017; Kamargianni et al., 2016). On the other hand, we believe that MaaS is modular, adaptable and applicable to several realities, including developing countries where public transport systems are lacking and inefficient – and where the population craves for better solutions.

Another aspect that must be considered in the future of urban mobility is the arrival of Autonomous Vehicles (AVs). There is an expectation that AVs will be a catalyzer of traditional transportation modes (Enoch, 2015) by solving some of the possible system-level problems of car-sharing, suggesting a positive impact in MaaS ecosystem (Jittrapirom, 2017). For instance, from the possibilities of using other complementary sensor technologies, such as communication capabilities, an AV can be part of a shared multimodal transport system and source of data collection, connecting vehicle-vehicle (V2V) and vehicle-infrastructure (V2I) to improve performance and contribute to the entire urban mobility ecosystem (V2X).

In this context, it is essential to understand the relationships and how AVs could influence the MaaS ecosystem, as long as it must be capable of integrating new technologies as they become available (Strömberg et al., 2016). At last, it is worth highlighting a recent study by the consulting firm ARK (, which states that autonomous mobility as a service market presents an opportunity much more significant than investors appreciate, which will exceed $10 trillion in gross revenue by the early 2030s (Keeney, 2017).

However, we believe that the implementation of AVs in a MaaS system will not necessarily imply benefits for the overall outcome of mobility ecosystems. To put AVs on the road is needed much more than technology. Aspects such as consumer acceptance, regulations, and the socio-economic perspective are also pivotal. Thus, these factors should be analyzed as a unique ecosystem like a Business Model.

## 1.2 Research question and objectives

The context of technological innovation with the widespread use of connected objects and the development of AVs imposes a reflection on the definition of sustainable urban mobility in the cities of the future. According to experts, this mobility will be multimodal, such as the development of MaaS systems. However, despite the growing number of studies regarding MaaS in the past years two years (see: Utriainen & Pöllänen, 2018), it is still not possible to define which are the theoretical field underlying this concept (Hünewaldt, 2018), phenomenon, transport solution (Jittrapirom et al., 2017), or anything else that MaaS could be classified.

Furthermore, the Society of Automotive Engineers (SAE, 2018) states that MaaS is an evolving concept that could be defined by them in future revisions of the J3163 standard. Also, there are still some misunderstandings related to which kind of mobility service is or is not MaaS. In this sense, the following question emerged to study: How can a MaaS system be implemented in the future of urban mobility?

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

**Analyze the concept of MaaS in order to identify its implementation and acceptance within an urban mobility system.**

To achieve this objective, this doctoral thesis is subdivided into the following specific objectives, each one extrapolated to a scientific article, aiming to:

**1) Analyze MaaS as a Product-Service System and as an Eco-innovation under the Business Ecosystem concept, as well as propose a schematic model for different mobility services;**

**2) Identify the main characteristics of the AV field, as well as its evolution and to highlight the potential trends for prospective studies;**

**3) Examine the perception of different transport models among students and to find a profile that can predict respondents' willingness to use MaaS in a developing country;**

**4) Identify the motivating factors of the practice of casual carpooling and propose a strategy to implement it in a MaaS System;**

**5) Analyze the insertion of AVs in urban mobility based in the Quintuple Helix Model and discuss this dynamic in the Brazilian context.**

The investigations of this thesis are based on MaaS systems' perspective as a disruptive innovation inserted into a business ecosystem that has the option to have autonomous vehicles as modes of transport. As disruptive innovations, MaaS systems must deliver value to the user in some way, which can go beyond the mobility function. In turn, autonomous vehicles are considered disruptive technologies due to their technological advances condensed in the need for a motorist to drive a vehicle. Thus, within business ecosystems, autonomous vehicles deliver the same value as a traditional vehicle to a user, albeit with a different technological approach.

Thus, in order to achieve the general objective of this doctoral thesis, it is necessary to understand the theoretical foundations of a MaaS system (paper 1) as well as the technological evolution of the autonomous vehicles (paper 2) considering its as one of the possible modes of the MaaS ecosystem. In order to observe MaaS systems through the theoretical lens of consumer behavior, their willingness to use, and strategies for implementation in developing countries, we propose papers 3 and 4. Finally, we understand that the spread of autonomous vehicles goes beyond the user perspective, determining broader socio-economic concepts, which can be guided by the five-helix model (paper 5).

## 1.3 Research justifications

The research justification for this doctoral thesis is guided by common sense that the concept of MaaS is one of the most promising initiatives in the field of mobility and has been gaining full recognition in the field of transportation. MaaS is growing fast, and many cities and countries around the world have stated their intentions to introduce this new service model, which restructures the mobility distribution (Kamargianni and Matyas, 2017; Flügge 2017; Hensher, 2017).

The key concept behind MaaS is to offer travelers mobility solutions based on their tailored needs (Hensher, 2017). However, according to Matyas and Kamargianni (2017), travelers' needs are immensely heterogeneous, and there is still a vast gap in knowledge about the ideal design of mobility plans. In this sense, MaaS has the very real opportunity to match customer needs more closely to service supply and to reveal the real contribution of conventional public transport services (Hensher, 2017).

Thus, MaaS opens up opportunities for higher customer service and potential reductions in public subsidy for public transport services, many of which are currently inefficient in terms of cost and network effectiveness (Hensher, 2017). In this sense, Keeney (2017) states that the traditional automotive industry may be subsumed by MaaS platforms that could become one of the most valuable investment opportunities in public equity markets.

Additionally, MaaS concepts are still incipient in the literature (Kamargianni and Matyas, 2017; Strömberg et al., 2016; Ambrosino et al., 2016) and even more uncertain and unexplored when we consider autonomous vehicles in the mobility ecosystem context (Lamotte, 2017). According to Ambrosino et al. (2016), there is not yet quantifiable evidence on the costs and benefits of MaaS, as well as on its influence on travel patterns and behavior of the end-users and this is an urgent area for further research.

Thereby, it is worth highlighting that all current studied MaaS systems take place in developed countries (Jittrapirom, 2017; Kamargianni et al., 2017), and the advances in MaaS are being constructed, especially in Europe (Hensher, 2017). In this sense, analyze different contexts (i.e., in a small city of a developing country) that MaaS can be inserted could provide better conditions to understand the concept's applicability. As far as it is known that local conditions, such as population density, wealth, infrastructure, pollution and congestion levels, and local governance capabilities, will determine what changes and how quickly they will occur in the future of mobility (McKinsey & Company, 2016).

It is worth mentioning that business and management research on the field of vehicular automation is still incipient (Cavazza et al., 2019). Therefore, this doctoral thesis helps to contribute to adding in the development and consolidation of the thematic in the field of studies of social sciences as well as helps on the advancement of Mobility as a Ser-vice concept and Business Ecosystem models.

Also, it is worth highlighting four main contributions addressed by this doctoral the-sis: academical, management, public policies, and social. As an academic contribution, we can name the knowledge fields studied by this doctoral thesis. The concept of MaaS will be analyzed through distinct fields of knowledge such as; Product-Service System (PSS), business model, eco-innovation. From the PSS perspective, MaaS presents a user-centric approach. Therefore, we extended our contribution to cultural aspects, consumer behavior, and socio-economic perspective. Besides, concepts such as eco-innovation and business model lead us to analyze MaaS as disruptive innovation and AVs as a disruptive technology.

As a managerial contribution, we will examine the conditions for the diffusion of a MaaS: the supply side (condition of the diffusion of innovation) and the demand side (condition of acceptability). In the case of public policies, the indicators inherent to this project may contribute to public actions in favor of improvements in urban mobility.

Last but not least, social impacts will be addressed by this doctoral thesis. The development of a business model such as MaaS can bring positive impacts to the future of urban mobility. The promise to offer commuters with a smooth, flexible, reliable, price-worthy, and environmentally sustainable, everyday travel solution, will positively impact the urban mobility scenario. This doctoral thesis develops a specific vision of urban mobility in Brazil so that it could be useful for the development of sustainable cities in developing countries.

### 1.4 Doctoral thesis structure

This doctoral thesis was adapted from the thesis structure written in the form of scientific articles, provided on the “Manual of standards and structure of academic works” from *Universidade Federal de Lavras*[1]. In this sense, this doctoral thesis was composed of three main parts:

**First Part:** The Introduction composed by the sections: Research contextualization and motivation; Research question and objectives; Research justifications, and this final subsection; Doctoral thesis structure. The Theoretical Background composed of the main concepts needed for the development and understanding of the research topic proposed in this project. Next, it is presented the Methodology specifying and describing the stages of the research, each one for each article that composed the doctoral thesis.

**Part Two:** Presents the scientific articles that composed the doctoral thesis. It is worth highlighting that each scientific article was presented in a full version with its own abstract and references.

**Part Three:** General Considerations, considering a prospective synthesis of what we achieve with this doctoral thesis. At last, the Bibliographical References are presented.

[1] Available at: < http://repositorio.ufla.br/jspui/bitstream/1/11017/5/NOVA%20VERSÃO%20DO%20MANUAL%20DE%20NORMALIZAÇÃO%20E%20ESTRUTURA%20DE%20TRABALHOS%20ACADÊMICOS.pdf> Accessed on January 5th, 2020.

# 2. THEORETICAL FOUNDATIONS

This section aims to present the theoretical foundation that underpins this doctoral thesis as a way to provide 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 Mobility as a Service (MaaS) and Autonomous Vehicles

Mobility as a Service (MaaS) was born in Finland, and Hietanen offered the first comprehensive definition of MaaS. The author describes MaaS as a distribution model of mobility that delivers 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 (Hietanen, 2014).

Recently, the concept of Mobility as a Service (MaaS) has been gaining ground and becoming a solid market option, by presenting a shift away from the existing ownership-based transport system toward an access-based one (Jittrapirom et al., 2017; Ambrosino et al. 2016; Mulley, 2017; Kamargianni et al., 2016).

MaaS is a very recent mobility construct surrounded by ambiguities and uncertainties, especially related to its main characteristics and use (Caiati et al., 2017). Besides of this, Jittrapirom et al. (2017, p.14) affirm that MaaS can be thought 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)".

Many of MaaS initiatives are not new and are similar in intent to flexible transport services, including demand-responsive transit. What is different today is the ability to bring such flexible options direct to any interested user via the digital app capability available on smartphones. These mobility options could be delivered for the customers similar to mobile phone plans, where users pay for a specific amount of services (calls, texts, and data) each month, offering to the customers' option to buy monthly mobility plans (Hietanen, 2014).

This customization provides a more efficient way to service mobility needs that is available to all, albeit under special pricing and service level conditions (Hensher, 2017).

For this, the essential idea of MaaS is to see transport or mobility not as a physical asset to purchase (i.e., a car) but as a single service available on-demand and incorporating all transport services from cars to buses to rail (Transport Systems Catapult, 2015). Complementary, Hans Arby, the CEO of UbiGo (one of MaaS systems from Sweden) affirms that:

> *"My perspective on mobility is not to focus on overcoming a distance from location A to location B. It is more the complete need for mobility from morning to evening, from Monday to Sunday, from January to December – this is what makes you decide to own a car or not. It is a long-term decision with respect to deciding on a car. The car ownership, not car use, is the key to rethink the mix of mobility offerings (bus, public transport, bike, taxi, etc.). Car ownership is one kind of 'mobility insurance' and therefore it represents flexibility and availability. When going into new kinds of mobility offerings reliability needs to be offered. Hence, you need to make very good promises so that mobility works for people on the road without owning a car"* (Flügge, 2016 p. 245).

In this sense, it is necessary a cultural shift, away from personal car ownership and reliance, towards the multiple, often shared, and unrestricted mobility offerings (Mulley, 2017). Some evidence points out that consumers, in all age groups but particularly the Millennials, are increasingly expecting their experiences in transport and other sectors, to be delivered as a service, and to get more value as a result. Additionally, changes in mobility consumption mean more significant adoption of new mobility models, and this may lead to a move away from car ownership (Datson, 2016; Mulley, 2017; Shaheen & Cohen, 2016; Karlsson et al., 2016).

According to Kamargianni and Matyas (2017), MaaS is a user-centric, intelligent mobility distribution model in which all mobility service providers' offerings are aggregated by a sole mobility provider (the MaaS provider) and supplied to users through a single digital platform. This user-centric business model contributes to the task of moving away from car ownership because of the value proposition added to the individuals. Corroborating of this, Datson (2016) point out that there are two core strengths to the MaaS systems: servitization, whereby the MaaS Provider creates a value proposition that comprises a 'bundle' of different mobility services; and Data Sharing, whereby the MaaS Provider shares data on the mobility needs of customers, to help Transport Operators improve their service.

In a quest to put user, people, and goods, as the core of transport services, Mulley (2017) defines three mains concepts of MaaS;

> *"**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.*
> ***A Subscription Service:** users have no 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.*
> ***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"* (Mulley, 2017 p. 248-249).

Many authors are working on understanding and provides a more comprehensive definition for MaaS. Jittrapirom et al. (2017) carried out a critical literature review to identify, among others, the core characteristics of MaaS (Table 1).

**Table 1.** Description of MaaS' core characteristics

| 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, ridesharing, 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 | An 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, 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, LTE); GPS; e-ticketing and e-payment system; database management system and integrated infrastructure of technologies (i.e. IoT). |

| | |
|---|---|
| 6. Demand orientation | Seeks to offer a transport solution that is best from the 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. The 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).

In another perspective, the Autonomous Vehicles (AVs) emerged as a disruptive and beneficial technological change to the intelligent transportation systems business model (Milakis et al., 2017). There is a consensus that AVs are bound to change the future of urban mobility, and such transformation will affect not only the means of transport but also society as a whole (Attias, 2017; Mutz et al., 2016; Schreurs & Steuwer, 2016; Enoch, 2015).

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 general, AVs use a procedural design called "feel-plan-act," in which, understanding the environment, employ a combination of sensors (Anderson et al., 2016), driver assistance, geolocation, among others. Those features will also include a completely new opening to the commercial and advertising dimension perfectly suited to the occupants of the vehicle.

Preventive systems will monitor occupant health, predict vehicle maintenance, propose entertainment alternatives, or sell new and original products. Numerous innovations are to come, such as the creation of new demands, including the inclusion of specific audiences, which are currently absent from this market, such as the disabled or the elderly, ensuring for them an entirely new perspective in terms of mobility (Mutz et al., 2016; Schreurs & Steuwer, 2016).

On the other hand, AVs' proliferation is far from guaranteed. As Fagnant and Kockelman (2015, p. 168) state, "complex questions related to legal aspects, liability, privacy, licensing, security, and insurance regulation remain to be solved." Further, AVs may introduce new risks, such as system failures that would make these vehicles less safe under certain situations and conditions due to being connected to the cloud and operated by a central unit system, also meaning there will be security and privacy concerns related to cybersecurity.

At last, it is worth to mention the growing number of AVs in the world. This increase is a very significant point, given that today there are just a couple of 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). In this sense, consider this disruptive technology as part of MaaS as disruptive innovation is crucial.

### 2.1.1 MaaS as a Disruptive Innovation and AVs as a Disruptive Technology

Christensen (1997) states – in his seminal work: *"The Innovator's Dilemma"* – that disruptive technologies bring to market a very different value proposition than those previously available; which generally by being technologically straightforward, offer different packages of attributes that are not often considered essential to mainstream customers.

According to the author, technological innovations generally come in two types: 1) incremental (sustaining) technologies and 2) radical (disruptive) technologies. In the former, products are made better overtime to meet the demands of costumers who are willing to pay more for better products, in this sense, most technological advances in a given industry are sustaining in character; on the latter, the introduced products bring to market a very different value proposition than had been previously available (Markides & Geroski, 2005; Christensen & Raynor, 2003).

As depicted in Figure 1, every market has an expected performance rate demanded by its customers; the dotted grey arrows represent such performance rates over time (for high-end, low-end, and average consumers). In every market, there is a different trajectory of improvement that companies provide as they introduce new and improved products, the blue solid upward arrow represents such pace of technological progress (incremental innovations) that almost always surpasses the customers' ability to use them. Thus, a company whose products are squarely positioned on mainstream customers' current needs will probably overshoot what those same customers can utilize in the future. This happens because companies keep striving to make better products that they can sell for higher profit margins to not-yet-satisfied customers in more demanding tiers of the market (Christensen, 2013).

Disruptive innovations (red arrow) do not attempt to bring better products to established customers in existing markets; instead, they disrupt and redefine such trajectory by introducing new products (and services) that are not as good as currently available products. However, once the disruptive product gains a foothold in new or low-end markets, the improvement cycle begins.

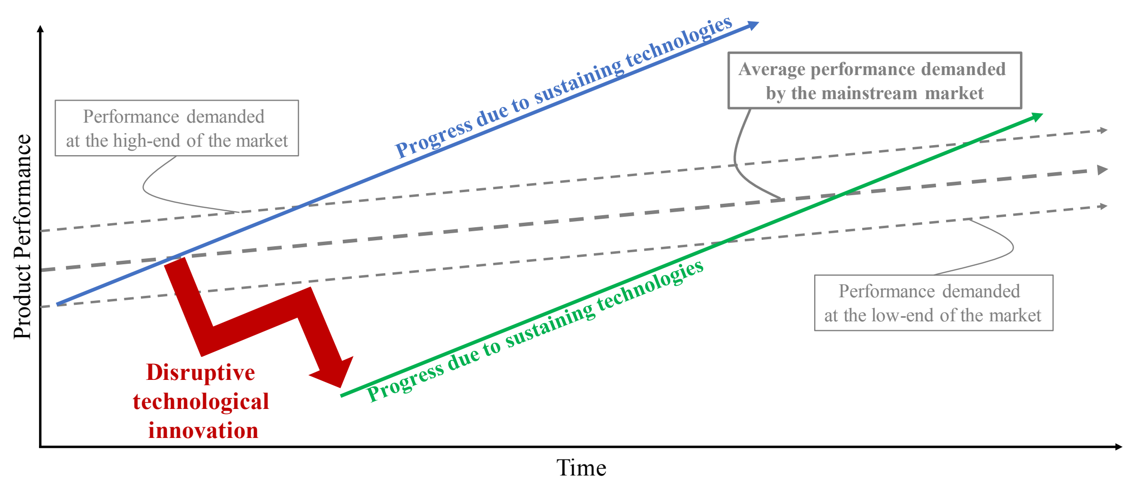


**Figure 1:** The Disruptive innovation model.
Source: Christensen (1997).

Disruptive innovations can come in two general types; 1) low-end disruption – those that attack the least-profitable and most overserved customers at the low end of the original value network and; 2) new-market disruption – which enables a whole new population of people to begin owning and/or using the product (service) in a more convening setting (Christensen and Raynor, 2003).

As shown in Figure 2, a new dimension (dotted green arrow) has been added to the model, it represents new contexts of consumption and competition; therefore, new value networks. According to Christensen and Raynor (2003), it entails a new market in which the product/service offers a different value proposition than the primary market, that is, customers who previously lacked the money or skills to buy and use the product (service), or different situations in which a product (service) can be used-enabled by improvements in simplicity, portability, and cost.

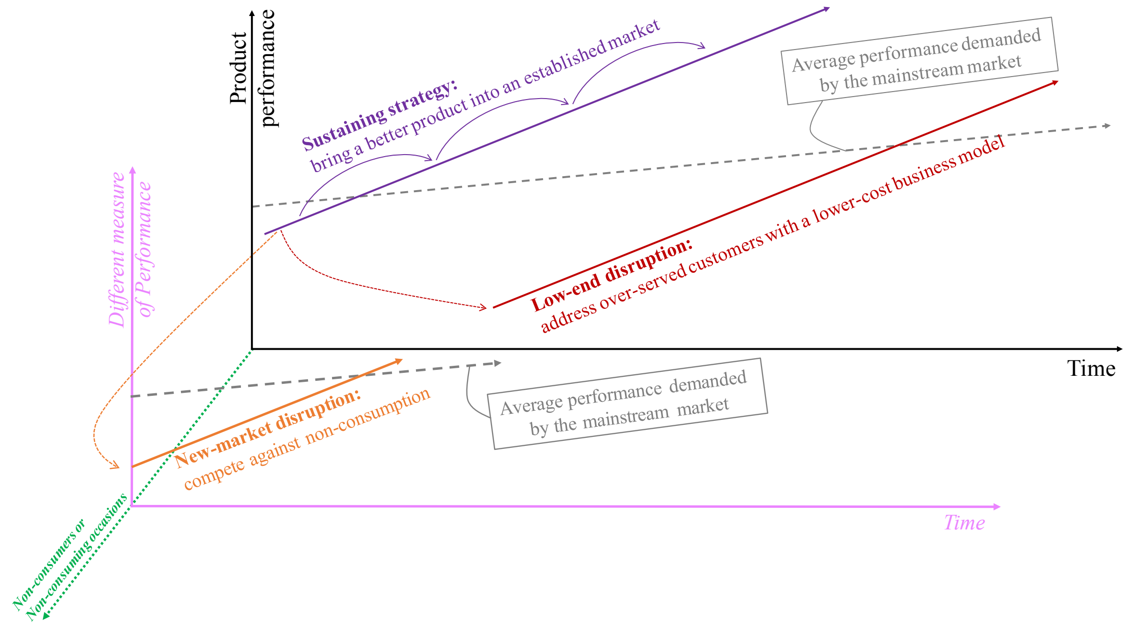


**Figure 2:** New market disruption model.
Source: Adapted from Christensen and Raynor (2003).

According to Sprei (2018), the private-owned vehicle is still holding its dominant position, and shared mobility per se might not be attractive enough to disrupt the transportation system. In this sense, MaaS and AVs will not be per se, the disruptive solution for urban mobility. We believe that they should be analyzed in a complementary way to achieve a disruption in mobility.

However, we understand that MaaS and AVs present distinctions concerning disruptive concepts. The first can be considered a disruptive innovation, because of the possibility to create new markets without the need to deliver a breakthrough technology. According to Flügge (2017), all the solutions for MaaS are here, and we just need to orchestrate them. For the latter, we understand it as a disruptive technology for the utterly advance in technology of AVs regarding the traditional automotive industry. Sprei (2018) state that AVs will be disruptive, even with all the major car manufacturers are being proactive and investing in technology.

The MaaS' potential to create new markets (Mulley, 2017) is closer to the new market disruption concepts proposed by Christensen and Raynor (2003). Corroborating with this, Sprei (2018) states that to be genuinely disruptive shared mobility has to have the potential to grow beyond niches, and one way to improve this attractiveness is combining different services, such as MaaS. However, the technological disruption of AVs not necessarily deliver the creation of new markets. For instance, if autonomous taxis just replace the driver, they will be like other taxis. Complementary, Sprei (2018) points out that we cannot rely on those technological innovations alone will lead to a desirable disruption from society's point of view.

### 2.1.2 MaaS and AVs as a Product Service System (PSS)

The concept of a PSS can be defined as an integrated bundle of products and services which aims at creating customer utility and generating value (Boehm & Thomas, 2013). In the same way, Annarelli et al. (2016) state that a PSS is a business model focused on the provision of a marketable set of products and services designed to be economically, socially, and environmentally sustainable, with the final aim of fulfilling customer's needs. Also, according to Centenera and Hasan (2014), a PSS is an integrated combination of products and services for optimal consumption. Besides the multiple definitions, we observed that a PSS aims to create value for users by setting in joint offer products and services.

Tukker (2004) drew a categorization of PSS by creating eight different types of Product- Service Systems that, according to the author, exist with quite diverging economic and environmental characteristics. As displayed in Figure 4, it can be noted that types of PSSs vary on a spectrum in which, on one end, the primary value rests on product content (tangible) and the other on service content (intangible).

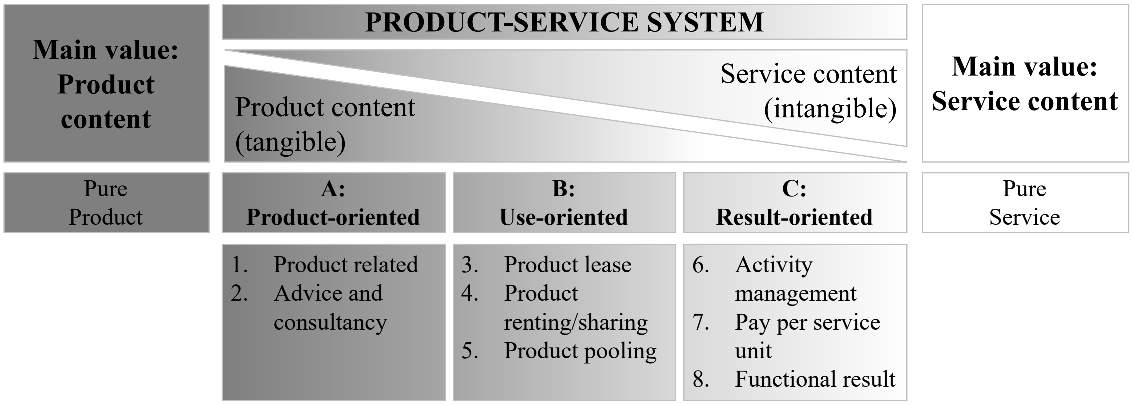


**Figure 4:** Archetypical Product-Service System models.
Source: Adapted from (Tukker, 2004, p. 248).

According to the author, the classification makes a distinction between three macro-categories: **A: Product-oriented service** - the business model is still mainly geared towards sales of products, but some extra services are added; **B: Use-oriented service** - 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 several users; **C: Result-oriented services** - the client and provider in principle agree on a result, and there is no pre-determined product involved (Tukker, 2004, p. 248).

In an initial effort, Antonialli et al. (2018) analyzed the disruptive technology of Autonomous Vehicles into Tukker's PSS and state that AVs better fit within use-oriented category. Autonomous vehicles will have a shifting focus from the vehicle as a privately-owned asset to a service with a mobility function. In the same perspective, Blomsma et al. (2018) affirm that Riversimple, a company that sells hydrogen cars' miles instead of traditional car ownership, presents a user-oriented service. For the authors, product ownership remains with the service provider, but the customer has access to the product. This project follows the same perspective regarding AVs as a use-oriented PSS (Antonialli, 2018), and the example of Riversimple can help to reinforce it.

Regarding MaaS, we no longer found any efforts to classify it as PSS. Given MaaS' concepts (Kamargianni et al., 2018; Hietanen, 2019; Ambrosino et al., 2016; Jittrapirom et al., 2017; Mulley, 2017), and core characteristics like the ones mentioned by Jittrapirom et al., 2017, such as the possibility of integration of transport modes, diverse tariff options, using just one platform to connect multiple actors, intense utilization of technologies for the management of big data to personalize and customize services, and being demand-oriented, MaaS is likely to be positioned on category C - Result-oriented service of Tukker's PSS archetypical.

MaaS may offer options for payment, which mainly includes "pay-as-you-go" or "monthly packages" pre-established between operator and consumer (Jittrapirom, 2017). These options are respectively related to the pay-per-service unit and functional results' PSS (Tukker, 2004). In the former, the user buys the output of the product according to the level of use. Meanwhile, in the latter, the provider is entirely free as to how to deliver the result, which, in theory, offers the highest potential to design a low-impact system (Tukker, 2004).

Thus, to be established as a result-oriented PSS, a MaaS must have several stakeholders (e.g., the AVs' use-oriented PSS can be part of this perspective as stakeholders). In practice, this necessitates multi-stakeholder approaches that can overcome the various barriers and obstacles to integration (Spickerman et al. 2014). For this, Datson (2016) suggests that understand the MaaS architecture (relations among stakeholders, technologies, and capabilities) should be a good starting point. In this context, the ecosystem concept should be applied.

Corroborating with this, Kamargianni & Matyas (2016) affirms that the necessary changes for MaaS and most of the new mobility services are of a systemic nature and require a business ecosystem where multiple organizations act in collaboration, mixing the traditional boundaries of business sectors and companies, and involving users in the co-creation (Kamargianni & Matyas, 2017p. 3). In this way, the perspective of the business ecosystem can help in understanding a MaaS system.

## 2.2 Business Ecosystem

With rapid global advances and organizational complexity, significant changes are taking place in the business environment, especially concerning technology, physical environment, market forces, consumer behavior, and finance (Chesbrough 2011). In this sense, the notion of ecosystems has gained increasing attention in academic literature as a concept to understand and explain the complexity of the interconnected nature of the modern business environment (Lehto et al. 2013; Durst & Poutanen 2013).

The business ecosystem approach comes from a seminal work by James Moore (1993). The author stated that are parallels with business and natural ecosystems when environmental conditions change too radically. In a business ecosystem, companies coevolve capabilities toward innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations (Moore, 1993 p. 76).

Since then, several authors agree that the definition and concept of an ecosystem are unclear, and there still much work to be done to establish it (Tsujimoto et al., 2017; Iivari, 2016; Koenig, 2012; Daidji, 2011; Peltomiemi & Vuori, 2004).

In this way, many different definitions of the business ecosystem emerge. Iivari (2016) affirms that a business ecosystem refers to a network of organizations involved in the development and delivery of a specific product/service through both competition and cooperation. However, for Peltoniemi & Vuori (2004), there is no need for government interventions to a business ecosystem survivor because they are self-sustaining.

Toward an ecosystem approach Peltoniemi (2004) observed distinct differences between cluster, value network and ecosystem in 5 key aspects: 1) geographic dimension; 2) role of competition and co-operation; 3) concept of industry; 4) knowledge creation and knowledge transfer issue and; 5) control or power. Different from other models, a business ecosystem is characterized by not presenting geographical boundaries, evidencing a "coopetition" role, and putting the concept of industry obsolete. On the other hand, Daidiji (2011) claim that these affirmations are not categorical, and, in some case, other arrangements can present similar behaviors to the ecosystems and vice-versa.

Also, Daidji (2011) states that other factors should be considered in business ecosystems, such as the existence of leader companies (keystones), the decentralized business ecosystem control notion, and the business platform concept. According to the author above, although the business ecosystem presents decentralized control, a company leader exists to coordinate other companies immersed in the same system Daidji (2011) through business platforms that act centrally bridging the ecosystem innovation (Evans et al., 2008; Gawer and Cusumano, 2013).

In a MaaS context, corroborating with this, Jittrapirom (2017) states that MaaS ecosystem is built on interactions between different groups of actors through a digital platform: demanders of mobility (i.e., private customer or business customer), a supplier of transport services (i.e., public or private) and platform owners (i.e., third party, PT provider, public authorities). Other actors can also cooperate to enable the functioning of the service and improve its efficiency: local authorities, payment clearing, telecommunication, and data management companies.

On the other hand, platforms are considered one within the four types of business ecosystems (Koenig, 2012). This author claims that there are specific mechanisms to each type of business ecosystem, suggesting a typology based on key resource control (centralized or decentralized) and type of interdependency (reciprocal or clustering). Thus, four typologies are proposed (Figure 5).

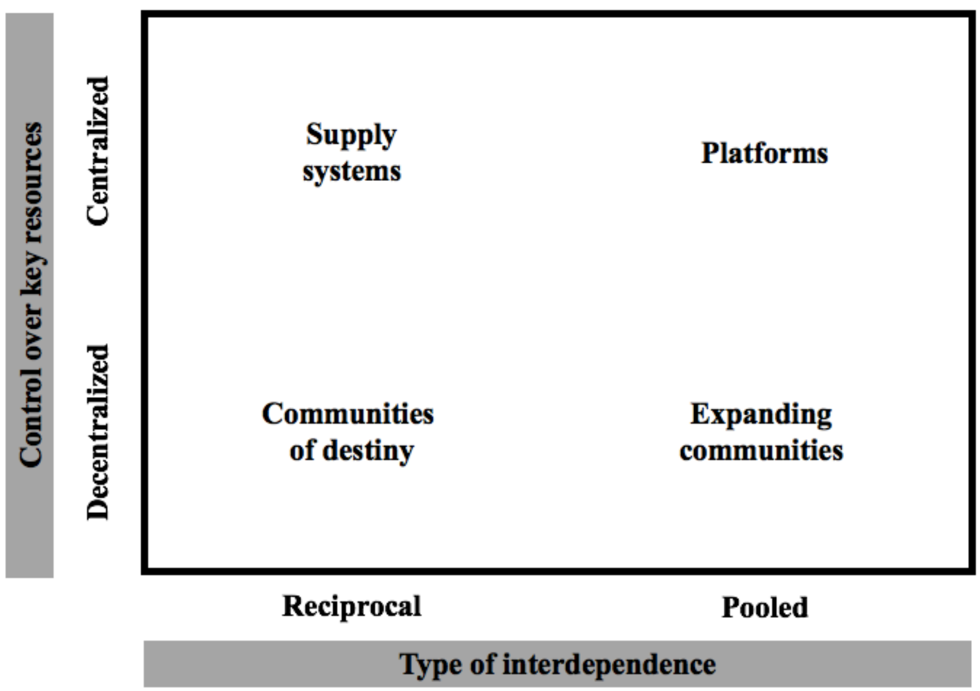


**Figure 5:** Typologies for a Business Ecosystem
Source: Adapted from Koenig (2012).

Regarding the control upon the centralized key resource, two typologies emerge, Supply systems and platforms. In the former, the interdependency type is reciprocal, and in this case, a central actor controls the business ecosystem and determines the partner tasks.

As for the latter, the interdependency is pooled, and in this case, the central actor establishes only the platform use rules, not defining the players' tasks neither its contribution.

When the control of the key resource is decentralized, two typologies emerge: communities of destiny and expanding communities. On the former the interdependence is reciprocal, and in this case, it does not rely on a central actor, instead of on existential solidarity. As for the latter, the interdependency is pooled, congregating a large number of players around a common essential resource.

It is essential to highlight that the reciprocal interdependence supports qualitative development, deepening the individual relationship. As for the pooled, there is a propensity to a quantitative development corresponding to the expansion process, which the technological development favored its dissemination (Koenig, 2012). In the same way, technological development was also favorable for the development and evolution of MaaS, allowing the stakeholders' integration and the users (Lyons et al., 2018).

Given the aforementioned, it is essential to briefly present some concepts of the platform to understand the relation to the typologies of the business ecosystem proposed by Koenig (2015) and MaaS.

According to Gawer and Cussomano (2015), platforms create value for innovative ecosystem participants by structuring the innovation process around the core and complementary elements and by creating the network effects that accelerate the adoption and use of platforms. Therefore, a platform is nothing more than a vast network of relationships between organizations around a core technology (Carvalho; Dias; Sugano, 2016).

In this sense, we understand that the MaaS operator (Kamargianni et al., 2018) is a central actor from a network that establishes platform rules but does not determine the tasks and contributions of each stakeholder (Koenig, 2015).

Another contribution is the proposition of MaaS ecosystem by Kamargianni & Matyas (2017). Based on the business ecosystem precepts suggested by Moore (1993), the authors classified different actors based on the relationships with MaaS providers under layers (Figure 6). According to the authors, a business ecosystem is composed of several layers, which correspond to differing levels of commitment to the MaaS providers (core, 1, 2, 3 layers – which 3 has the lowest commitment). Also, they suggest that regulators and researchers are positioned in the third layer, which corresponds to the less committed to the business ecosystem, “even though they are perhaps not directly involved in the business operations, these parties may have a significant effect on the success of the MaaS model.”

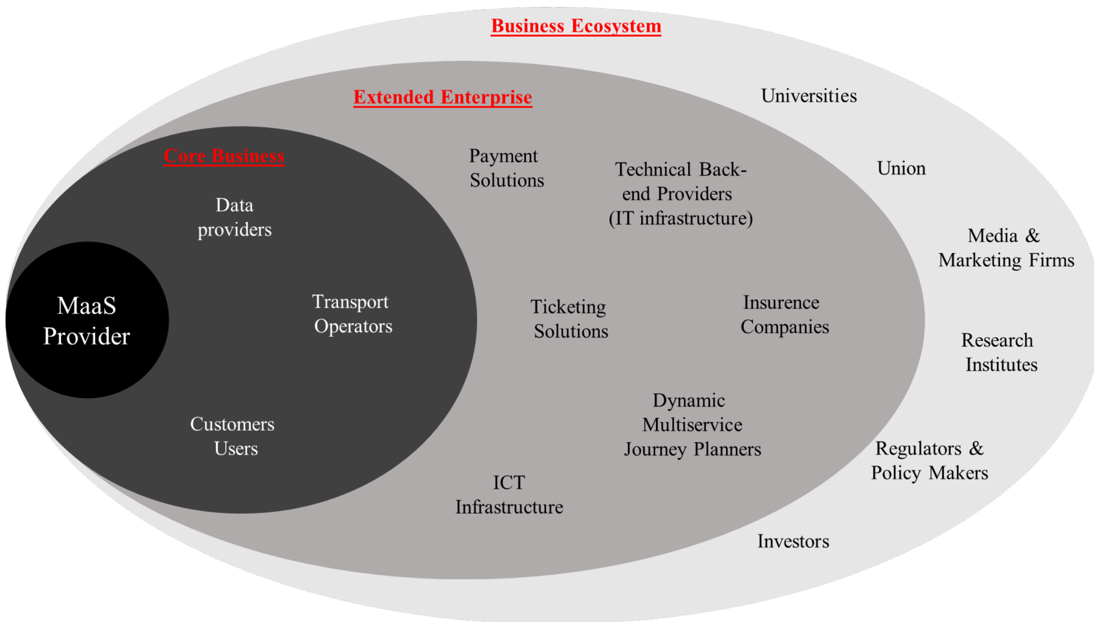


**Figure 6:** The proposal of Mobility as a Service Ecosystem
Source: Adapted from Kamargianni & Matyas (2017).

The ecosystem’s core business layer consists of the MaaS provider (the focal firm) and the parties forming the heart of the business: the business network actors such as suppliers and customers. In the case of the MaaS provider, the core business parties are the transport operators, the data providers, and the customers. The next layer, the extended enterprise, widens the view of the business supply chain to include the complementors and second-layer suppliers. In the MaaS ecosystem, these are the technical back-end providers (IT infrastructure providers), firms offering ticketing and payment solutions, ICT infrastructure, and insurance companies. The outermost layer, the business ecosystem, adds regulators, unions, universities, and other research bodies, investors, and stakeholders to the business ecosystem. Even though they are perhaps not directly involved in the business operations, these parties may have a significant effect on the success of the MaaS model (Kamargianni & Matyas, 2017, p. 6).

The authors conclude that MaaS providers aggregate the offering services by mobility providers and, for this, MaaS is not only about the integration of mobility services, but also requires a complete restructuring of the supply chain of mobility service providers. Also, they suggest that regulators and researchers, although positioned in the third layer, have vital importance at this early stage, because researchers could provide quantified evidence regarding the model in order to regulators could enable the market. At last, the authors assumed that this is just grazing in the surface of the intricate MaaS ecosystem, and this model needs more research and development (Kamargianni & Matyas, 2017), for instance, the insertion of AVs in this ecosystem.

In the same way, Jittrapirom (2017) states that a step forward needed to be considered in the MaaS ecosystem is the effect of the disruptive technology of autonomous vehicles and how their insertion will change the MaaS operator tasks (Jittrapirom, 2017; Flügge, 2016). In this context, having a shared AV can result in significant benefits for the ecosystem: 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.

In this perspective, a new way to define value creation conditions is created, and we should consider this ecosystem as a business model. Business models offer strategists a new way to consider their options in uncertain and fast-moving environments because it entails insights, experimentation, and organizational learning (McGrath, 2010). Since the proposition of Business Model Canvas (Ostewalder & Pigneur, 2010), some authors propose distinct approaches such as sustainable business models (Baldassarre et al., 2017; Geissdoerfer et al., 2018) and business model innovation for the sharing economy (Ciulli & Kolk, 2019).

In this perspective we can infer that a business model can be applied in any context and the failure of a product (or service) is not always due to its inherent flaws, but due to the used business model, which does not add the correct value proposition (Chesbrough, 2003; Ballon and Hawkins, 2009; Magretta 2002). We will then focus our study on the possibility of characterizing MaaS as an ecosystemic business model.

In order to explore the emergence of ecosystemic business models, Iivari (2016) conduct a study analyzing open innovation and business model theories. The author concludes that in a complex, multileveled configuration of ecosystems, striving for synergy within the ecosystem is a prerequisite for the successful building of eco-systemic value and competitive advantage as a whole. Furthermore, business models are valid not only at the organizational level but at the ecosystemic level as well, as ecosystem synergy and successful orchestration can be achieved through utilizing the ecosystemic business model.

Given the aforementioned, the ecosystem of MaaS (as a complex business model), and influences of Autonomous Vehicles (as a disruptive technology), in a synergistic view between the approaches inherent in the Business Ecosystem Models, seems to fit in the theoretical streams and corroborate to the field.

### 2.3 Consumer Behavior

In terms of mobility, the choice for a given mode of transport is an indicator of an individual's commute consumption pattern, which is mainly guided by the following three factors: cost, time and, comfort. Private cars are the best choice to fulfill the "comfort" requirement and, to some extent, "time," which makes it one the most suitable options for those who can afford it (Kamau et al., 2016). Complementary, as stated by Hans Arby (CEO of UbiGo – Swedish MaaS company), car ownership is a kind of "mobility insurance" and therefore represents flexibility and availability for its owners (Flügge, 2017). On the other hand, as pointed out by Schuppan et al. (2014), some people instead use their cars due to poorly city infrastructures or inappropriate offers of alternatives modes of transport. Furthermore, as elucidated by Steg (2005), historically, car usage could be explained by instrumental factors such as speed, flexibility, and convenience. However, the author states that symbolic and affective aspects also significantly influence the use of cars.

Nevertheless, younger generation cohorts (such as millennials and gen-z) seem to prefer alternative modes of transport when compared to previous generations. They are owning fewer cars, driving less, and, therefore, making more use of other transport modes (Delbosc et al., 2019), and sharing more their transport modes, seems to be congruent with these generations (Ambrosino et al., 2016). Historically, the concept of sharing was restricted to people from the same social circle, making it a tendency not to share with strangers (Frenken & Schor, 2017). However, the emergence of digital platforms has facilitated the exchange of underutilized assets by strangers (Böcker & Meelen 2017) in such a way that platforms facilitate building trust (Frenken & Schor, 2017; Ballús-Armet et al., 2014;

Botsman and Rogers, 2011). Thus, with an expectation that younger generations will firstly adopt MaaS, it has the potential to disrupt the mobility industry on the same as the aforementioned new business platforms entrants disrupted traditional business models (Utriainen & Pöllänen, 2018; Jittrapirom et al., 2018).

In this sense, dematerialization practices (Magaudda, 2011) seem to be aligned with the consumption practices proposed by MaaS, with some evidence of this phenomenon already being observed. For instance, the results from UbiGo (MaaS operator in Stockholm) indicate an increase in usage of sustainable transport modes while private car usage reduced by 50% (Strömberg et al., 2016; Utriainen & Pöllänen, 2018). It is worth mentioning, however, that such positive MaaS results are derived from experiments carried out in developed countries and regions.

According to Delbosc et al. (2019), travels behaviors are location-based, which is the context in which mobility offerings are inserted matters. With that, it is not reasonable to believe that a given MaaS implementation will be useful in another reality without any adaptation. For this, it is necessary to understand MaaS as a modular and adaptable model in order to implement it based in the context where it will be established and consider not only the consumer acceptance (micro perspective) but also the socio-economic context (macro perspective).

### 2.4 Socio-economic perspective (Quintuple Helix Model)

The evolution of AVs as a disruptive technology, as well as MaaS as an ecosystemic business model, will be determined due to the context in which they are inserted. Factors such as infrastructure, consumer acceptance, regulation, and technology will affect their development. Thus, an analysis from the construct of the Quintuple Helix Model (QHM) from the perspective of Brazil can help the unfolding of this modal and future paths for non-implementation or implementation - outside or within a MaaS business ecosystem.

Created by Carayannis and Campbell (2009) the QHM presents the three original helices operating in a complex urban environment, where market demand, governance and citizens' characteristics, along with cultural and social capital endowments, shape the relationships among the traditional helices of university, industry, and government (Lombard et al., 2012). The most crucial element of the QHM is the "knowledge" feature, which encompasses the entire system. This model, which can be used both in theory and practice, highlights the exchange of knowledge resources based on five social subsystems to promote the sustainable development of society (Carayannis, Barth & Campbell, 2012). The quest to reduce uncertainties has motivated several countries to take significant steps to be at the forefront of AVs research (Cavazza et al., 2019). Universities, industries, and governments worldwide (especially in the USA, China, and the European Union) are studying AVs to determine how this innovation may affect cities and be implemented as part of urban mobility solutions.

Therefore, the AVs analyzed by the helix approach seek to pivot considering not only technological development but also the social-political context. At this point, instead of considering only the acceptance of consumption as a motivator in the implementation of a MaaS ecosystem, this project also expands the analyzes to a macro perspective, including socio-political aspects.

## 2.5 Theoretical key constructs

In order to align with the general objective of this doctoral thesis, the formulation of the key constructs is based on a distinct analysis of two promises for the future of urban mobility; the concept of MaaS and the development of AVs. Figure 7 provides an overview of the theoretical construct that is being carried out in this doctoral project.

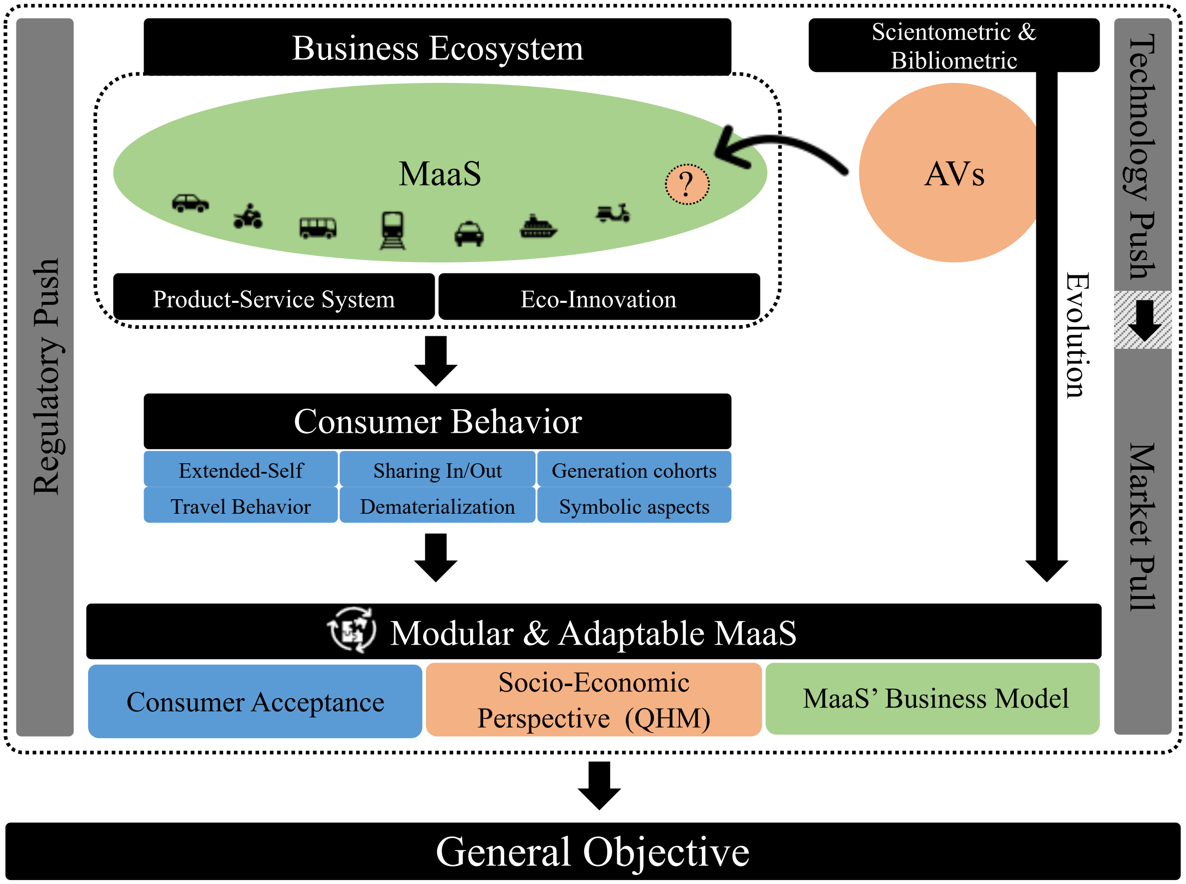


**Figure 7:** Doctoral thesis' theoretical key construct.
Source: Prepared by author.

Regarding the concept of MaaS, we observed in preliminary studies that the systems analyzed are mainly carried out in developed countries, which can generate conceptual ambiguities and myopia. Thus, an analysis of the concepts of Business Ecosystem, Eco-innovation and Product-Service System (PSS), seeks to collaborate with a theoretical foundation and critical approach to MaaS, which is still permeated by uncertainties. Also, to bring another perspective to MaaS - as a disruptive innovation - we seek to analyze the consumer acceptance of this business model in a developing country, without efficient public transportation. For this, consumer behavior constructs and their theoretical developments were utilized.

Besides, as one of several possible modes of transport within a MaaS business ecosystem, AVs were also analyzed. As a disruptive technology, its evolution towards the introduction into a MaaS ecosystem was considered and socio-political aspects from the Quintuple Helix Model (QHM) perspective.

Given the previous constructs, we can analyze MaaS as a modular and adaptive model. Based on the variables derived from the consumer acceptance of MaaS (micro perspective), socio-economic context of AVs (macro perspective), the idea is to consider MaaS as a business model based on the characteristics of consumption, the supply of transport modal, and the context in which the Business Model of MaaS will be deployed

## 3. METHODOLOGY

With a constructivist epistemological foundation, the present doctoral thesis is classified as descriptive and exploratory, with a qualitative and quantitative approach. Data collection was based on both primary and secondary sources, such as academic literature, grey literature, and online surveys. Regarding analysis, content analyzes, descriptive qualitative analyzes, descriptive, and multivariate analyses were used.

Figure 8 provides an overview of the research methodology that had been carried out in this doctoral thesis. It’s worth highlighting that each scientific paper has a specific methodology presented in each article in part two.

**RESEARCH QUESTION**
**How can a MaaS system be implemented the future of urban mobility?**

**GENERAL OBJECTIVE**
**Analyze the concept of MaaS in order to identify its implementation and acceptance within an urban mobility system.**

| Main Objective | Research type | Research method | Data collection | Data analysis | Publication Status |
|---|---|---|---|---|---|
| Article 1<br>Analyze MaaS as a Product-Service System and as an Eco-innovation under the Business Ecosystem concept. | Qualitative, Exploratory, and Descriptive research | Secondary data | Academic & Grey literature | Content analyzes and Descriptive qualitative analyzes | Ready to be submitted to Journal of Cleaner. Production.<br>JCR: 6.395<br>Qualis Capes: A1 |
| Article 2<br>Identify the main characteristics of the AV field, as well as its evolution and to highlight the potential trends for prospective studies. | Qualitative, Exploratory, and Descriptive research | Secondary data | Academic & Grey literature | Content analyzes and Descriptive qualitative analyzes | Full Paper published on Transport Reviews Journal.<br>JCR: 6.648<br>Qualis Capes: A1 |
| Article 3<br>Examine the perception of different transport models among students and to find the profile that can predict respondents' willingness to use MaaS in a developing country. | Quantitative, Exploratory, and Descriptive research | Primary and Secondary data | Academic & Grey literature<br>Online Survey | Descriptive and Multivariate analyzes | Full Paper accepted on International Journal of Transport Development and Integration. |
| Article 4<br>Identify the motivating factors of the practice of casual carpooling and propose a strategy to implement it in a MaaS system. | | | Academic & Grey literature<br>Online Survey<br>Web Scraping | Descriptive and Multivariate analyzes | Full Paper under review on Technological Forecasting and Social Change.<br>JCR: 3.815<br>Qualis Capes: A1 |
| Article 5<br>Analyze the insertion of AVs in urban mobility based in the Quintuple Helix Model and discuss this dynamic in the Brazilian context. | Qualitative, Exploratory, and Descriptive research | Secondary data | Academic & Grey literature | Content analyzes and Descriptive qualitative analyzes | Full Paper published on RASI Journal.<br>Qualis Capes: B3 |

**Figure 8:** Summary of the research methodology – Methodological Mooring Matrix (MMM).
Source: Prepared by the author inspired by Costa et al. (2019).

## PART TWO

*"Success is the sum of small efforts - repeated day in and day out."*

*(Robert Collier)*

## 4. ARTICLES

### ARTICLE 1: The business ecosystem of Mobility as a Service as a product-service system: An eco-innovation.

**Extended abstract of the paper published on the proceedings of the 15th Biannual Nectar Conference: Towards human scale cities – open and happy, Helsinki, 2019.**

Gandia, R. M.; Antonialli, F.; Sugano, J. Y.; Nicolaï, I. (2019). Mobility as a Service Ecosystem: An Eco-Innovative Business Model of Mobility. In: 15th Biannual Nectar Conference, 2019, Helsinki. Proceedings of the 15th Biannual Nectar Conference: Towards human scale cities – open and happy.

**Preliminary version of the paper presented in the Paper Development Workshop for the *Revista Brasileira de Gestão de Negócios*, Madrid, 2019.**

Gandia, R. M.; Antonialli, F.; Sugano, J. Y.; Nicolaï, I. (2019). The Business Ecosystem of Mobility as a Service as a Product-Service System: An Eco-Innovation. In: Paper Development Workshop – RBGN, Madrid.

**Preliminary version of the paper published on the proceedings of the 22th *Seminários em Administração* - SemeAd, São Paulo, 2019.**

Gandia, R. M.; Antonialli, F.; Pinto, G. A.; Sugano, J. Y.; Nicolaï, I. (2019). The Business Ecosystem of Mobility as a Service as a Product-Service System: an Eco-Innovation. In: SemeAd, São Paulo. XXII SemeAd.

**Full paper being prepared to be submitted on Journal of Cleaner Production**
**ISSN: 0959-6526, JCR: 6.395, Qualis Capes: A1**

# The business ecosystem of Mobility as a Service as a product-service system: An eco-innovation.

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**Abstract:** By presenting a shift away from the existing ownership-based transport systems and towards access-based ones, Mobility as a Service (MaaS) is gaining ground in recent years and is becoming a concrete market option, however, the construct is still surrounded by ambiguities and uncertainties among academics and mobility experts. We advocate that MaaS as a PSS should create value from a range of distinct actors and thus be aligned with the theories on business ecosystems and eco-innovation. In this sense, this paper aims to analyzed MaaS as a Product-Service System and as an Eco-innovation under the Business Ecosystem concept, as well as propose a schematic model for different mobility services. We observed that the theoretical approaches of PSS, Eco-Innovation, and Business Ecosystem, presents density to support the concept of MaaS. As a PSS, the mobility function is what should be considered as a result of a MaaS. The business ecosystem contributes by the concept of coopetition with distinct stakeholders creating value for users in terms of mobility. Also, MaaS would not be characterize as an eco-innovation if private car users not find the value needed to replace their vehicles. In this way, we propose an evolution of the current MaaS concept: MaaS 2.0. This level is the most promising in environmental terms, however, it comes with higher risks and governance and operationalization challenges.

**Keywords:** Mobility as a Service; Product-service system; Business ecosystem; Eco-innovation.

## Introduction

By presenting a shift away from the existing ownership-based transport system and towards an access-based one, the concept of Mobility as a Service (MaaS) has been gaining ground in recent years and becoming a market option (Ambrosino, Nelson, Boero, & Pettinelli, 2016; Jittrapirom et al., 2017; Mulley, 2017). The essential idea of MaaS 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 and incorporating all transport services from cars to buses to rail (Ambrosino et al., 2016).

Despite the growing number of studies regarding MaaS in the past years (2017 and 2018 see Utriainen & Pöllänen (2018)), it still not possible to define which are the theoretical field underlying this concept (Hünewaldt, 2018), phenomenon, transport solution (Jittrapirom et al., 2017), or anything else MaaS could be fitted and we still don't know. Furthermore, SAE (Society of Automotive Engineers) International states that MaaS is an evolving concept that could be defined by them in future revisions of the J3163 standard (SAE International, 2018). Also, there are still some misunderstood related to which kind of mobility service is or not a MaaS.

In preliminary analyses, we observe that the concept behind MaaS relates to Product-Service System (PSS) approach. A PSS can be defined 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 (Manzini & Vezzoli, 2003). In this sense, if MaaS is able to fulfil users' needs it will not be necessary, for example, cars' ownership. In fact "for many, owning a car to commute will make as much sense as owning a cell tower to scroll Instagram" (Neff, 2019, p.1).

However, some studies illustrate the eventual negative implications of the rebound effects caused by a PSS (Manzini & Vezzoli, 2003; Tukker, 2015), that might also affect MaaS systems. For instance, the promise of not owning a vehicle proposed by peer-to-peer (P2P) companies brought unexpected impacts to urban mobility. Thus, the migration of public transportation users toward P2P services negatively impacted bus companies (Marques, 2018), that had to disable bus schedules in the outskirt's neighborhoods, notwithstanding the environmental impacts due to the insertion of more automobiles on the roads instead of collective solutions.

Therefore, sustainability is not an intrinsic characteristic in a PSS (Doualle et al., 2016). In this sense, the eco-innovation concept can be inserted in MaaS approach as a PSS, as long as it represents an innovation that brings a reduction on the environmental impacts. According to Fussler & James (1996), eco-innovation consists of new products and processes which provide customer and business value and mainly a significantly decrease in environmental impacts.

Furthermore, as a complex and integrated model, MaaS should be analyzed in a business ecosystem perspective (Kamargianni and Matyas, 2017; Jittrapirom et al., 2017).

Business ecosystems bring together multiple players of different types and sizes in order to create and capture value in a synergic and networked way, resulting in new sources of employment and growth (Mulas, Minges & Applebaum, 2016).

Considering the aforementioned, this study purposes at answering the following research question: Do MaaS fit the PSS model? Which are the main concepts behind MaaS? Can MaaS be considered an eco-innovation? What is the main difference between mobility levels and MaaS systems? In this sense, this paper aims **to analyze MaaS as a Product-Service System and as an Eco-innovation under the Business Ecosystem concept, as well as propose a schematic model for different mobility services**.

This paper addressed three main contributions. First, by analyzing MaaS via the theoretical tripod of PSS, Eco-Innovation and Business Ecosystem, we sought to contribute to the state-of-the-art of these knowledge fields. Second, by comparing different mobility offerings (including MaaS), we attempted to improve the proper use of MaaS. Third, we endeavored to find trends for MaaS by proposing an evolution on its typology based on the integration of the aforementioned theoretical tripod.

## Literature Review

### Mobility as a Service as a Product-Service System

According to Boehm & Thomas (2013), a PSS is an integrated bundle of products and services which aims at creating customer utility and generating value. In the same way, Annarelli et al. (2016) states that a PSS is a business model focused toward the provision of a marketable set of products and services, designed to be economically, socially and environmentally sustainable, with the final aim of fulfilling customer's needs. Also, according to Centenera and Hasan (2014) a PSS is an integrated combination of products and services for optimal consumption.

In order to establish relations among MaaS and the PSS concept, we choose the archetypical PSS from Tukker, (2004). The author drew a categorization of eight PSS models that vary on a spectrum in which on one end the man value rests on products content and on the other service content (Figure 1).

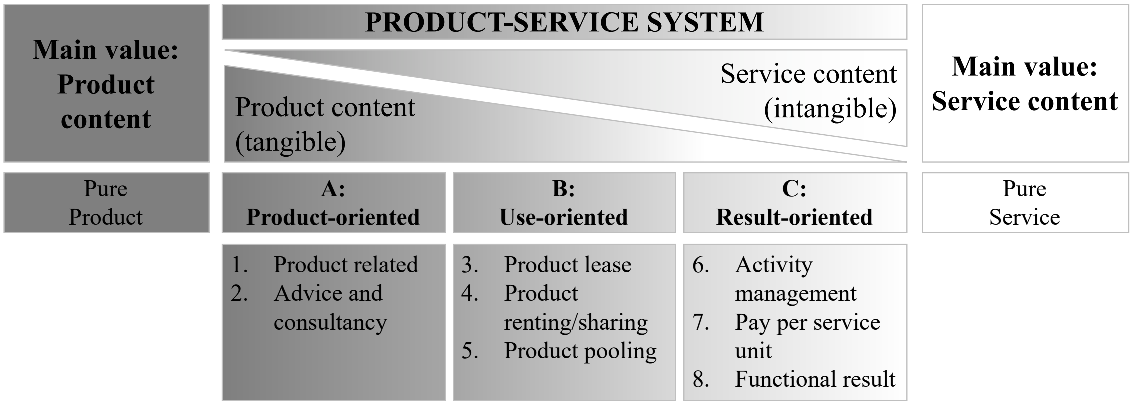


**Fig. 1**: Archetypical Product-Service System models.
Source: Adapted from (Tukker, 2004, p. 248).

According to the author the classification makes a distinction between three macro-categories; **A: Product-oriented service** - the business model is still mainly geared towards sales of products, but some extra services are added; **B: Use-oriented service** - 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 provide, and is made available in a different form, and sometimes shared by a number of users; **C: Result-oriented services** - the client and provider in principle agree on a result, and there is no pre-determined product involved (Tukker, 2004, p. 248).

Given the MaaS concepts (Kamargianni et al., 2018; Hietanen, 2019; Ambrosino et al., 2016; Jittrapirom et al., 2017; Mulley, 2017), and core characteristics (see Jittrapirom et al., 2017) and based on the PSS' macro categories we propose that MaaS are likely to be positioned on category C: Result-oriented service. According to Tukker (2004) this category is composed of three different PSSs: i) **Activity management/outsourcing**: Here a part of an activity of a company is outsourced to a third party; ii) **Pay per service unit**: The PSS still has a fairly common product as a basis, but the user no longer buys the product, only the *output* of the product according to the level of use; iii) **Functional result**: Here, the provider agrees with the client the delivery of a result (Tukker, 2004, p. 249). The analyzes and discussion section will go further on this topic.

Still, in the mobility context, new consumption trends have emerged in past years (e.g. short-term hire models of use for cars, bicycle, and scooters, ride-hailing service, and ridesharing). However, these cannot be classified as result-oriented services since they present a user-oriented business mode, when specifying a modal. On the other hand, they still present environmental characteristics which characterize some of them as an innovation that regards with environmental aspects, since the asset use is optimized varying the necessity and usage of some transport modals in the urban environment. This sort of innovation can be named as eco-innovation (Aloise & Macke, 2017).

**Eco-innovation**

The concept of eco-innovation was proposed by Rennings (2000) after his analysis of the innovation definition by the Oslo-Manual of the OECD (2005). According to the manual, eco-innovation cannot be conceived because it does not provide information on the difference between environmental and non-environmental innovation, and, hence, the challenges of sustainable development, innovation household, and institutional changes are not considered. Thus, in a nutshell, by including these elements, eco-innovation can be conceived as a conventional innovation when they are concerned with the environment and sustainability (Aloise & Macke, 2017).

According to Rennings (2000), eco-innovation can be developed by companies or by non-profit organizations with technological, social or institutional nature. Thus, eco-innovation has the attribute to reduce environmental burdens related to, at least, one type of natural resource. In consequence, the technological focus is changed from the economic efficiency of the productive systems toward the technological innovation seeking environmental protection in a preventive and corrective manner (Rennings, 2000).

Hence, eco-innovation encompasses broad aspects of organizational elements such as "product, process, marketing, and organizational innovations, leading to a noticeable reduction in environmental burdens" (Horbach et al. 2012, p., 119). As a result, explicit positive or collateral effects of innovation can occur with: (i) the companies involved or; (ii) customers, through better use of products and services (Horbach et al., 2012).

Therefore, eco-innovation asks from actors throughout the whole product/service lifecycle seeking to optimize the assets use, reducing environmental risks, pollution, negative impacts of resources use (including energy use) comparing to other alternatives (Kemp and Pearson, 2007 p.16). To achieve this, effort from relevant actors (firms, politicians, unions, associations, private households), to develop new ideas, behavior, products and processes, apply or introduce them contribute to a reduction of environmental burdens or to ecologically specified sustainability targets (Klemmer, Leher, & Löbbe, 1999; Rennings, 2000).

Correlated, the Eco-Innovation Observatory (2012) states that eco-innovation is the "introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water, and land) and decreases the release of harmful substances across the whole life-cycle" (p.8).

Besides of these multiples' definitions, according to (Hojnik & Ruzzier, 2016, p. 32) "eco-innovation reflects two main consequences: fewer adverse effects on the environment and more efficient use of resources". However, to orchestrate these effects several stakeholders are involved toward an environmental approach. Thus, a Business Ecosystem perspective is also needed.

**Business Ecosystem**

The business ecosystem approach comes from a seminal work by James Moore (1993). The author stated that are parallels with business and natural ecosystem, when environmental conditions change too radically. "In a business ecosystem, companies coevolve capabilities toward innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations" (Moore, 1993 p. 76).

Since then, several authors agree that the definition and concept of ecosystem are unclear and there still a lot of work to be done to establish it (Iivari, 2016; Koenig, 2012; Daidji, 2011; Peltomiemi & Vuori, 2004).

In this way, many different definitions of business ecosystem emerge. Iivari et al. (2016) affirms that business ecosystem refers to a network of organizations, involved in the development and delivery of a specific product/service through both competition and cooperation. However, for Peltoniemi & Vuori (2004) there is no need for government interventions in order to a business ecosystem survivor because they are self-sustaining.

Also, Daidji (2011) states that other factors should be considered in business ecosystems such as the existence of leader companies (keystones), the decentralized business ecosystem control notion and the business platform concept. According to the aforementioned author, although the business ecosystem presents decentralized control, a company leader exists in order to coordinate other companies immersed in the same system Daidji (2011) through business platforms that acts centrally bridging the ecosystem innovation (Evans et al., 2008; Gawer and Cusumano, 2013).

On the other hand, platforms are considered one within the 4 types of business ecosystems (Koenig, 2012). The author proposes that there are specific mechanisms to each type of business ecosystem suggesting a typology based on key resource control (centralized or decentralized) and type of interdependency (reciprocal or clustering). With reference to the control upon the centralized key resource, 2 typologies emerge; supply systems and platforms, respectively reciprocal and pooled interdependency. When the control of the key resource is decentralized, 2 typologies emerge; communities of destiny and expanding communities. On the former the interdependence is reciprocal, for the latter, the interdependency is pooled.

It is important to highlight that the reciprocal interdependence supports qualitative development, deepening the individual relationship. As for the pooled, there is a propensity to a quantitative development corresponding to the expansion process, which the technological development favored its dissemination (Koenig, 2012). In the same way, the technological development was also favorable for the development and evolution of MaaS allowing the stakeholders' integration and the users (Lyons et al., 2019).

In this sense, Jittrapirom (2017) states that MaaS ecosystem is built on interactions between different groups of actors through a digital platform: demanders of mobility (i.e. private customer or business customer), a supplier of transport services (i.e. public or private) and platform owners (i.e. third party, PT provider, public authorities). Other actors can also cooperate to enable the functioning of the service and improve its efficiency: local authorities, payment clearing, telecommunication and data management companies.

Based on business ecosystem precepts suggested by Moore (1993), Kamargianni & Matyas (2017) classified different actors based on the relationships with MaaS providers under layers. According to the authors a business ecosystem is composed of several layers, which correspond to differing levels of commitment to the MaaS providers (core, 1, 2, 3 layers – which 3 has the lowest commitment). Also, they suggest that regulators and researchers are positioned in the third layer, which corresponds to the less commitment to the business ecosystem, "even though they are perhaps not directly involved in the business operations, these parties may have a significant effect on the success of the MaaS model” (Kamargianni & Matyas, 2017 p. 6).

**Methodological Approach**

With the aim of analyze MaaS as a Product-Service System and as an Eco-innovation under the Business Ecosystem concept, as well as propose a schematic model for different mobility services this study is characterized as a qualitative approach of exploratory-descriptive nature. Figure 2 presents the research design.

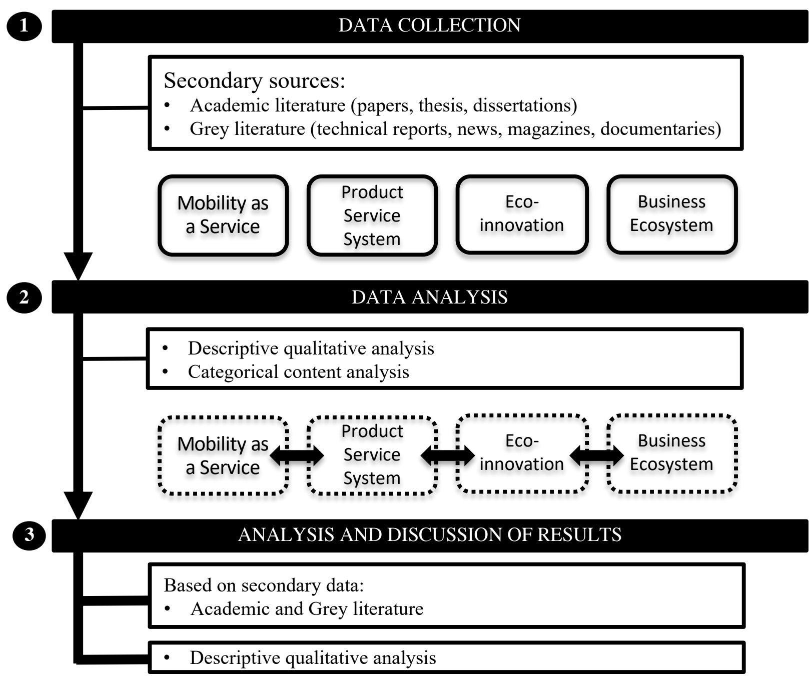


**Fig. 2** Research design.
Source: Prepared by the authors.

The first step carried out in this study was the collection of secondary data (from both on academic and grey literature) from the topics of; Mobility as a Service (MaaS), Product Service System (PSS), Eco-innovation and, Business Ecosystem. At this stage, saturation criteria were used as a stopping point (Fontanella, Ricas & Turato, 2008).

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). At this point, the fields of knowledge were analyzed not only isolated but also considering relations among them. It is worth to highlight that, in this study, the analysis of content was used qualitatively and not quantification through frequency distribution and other statistical techniques.

At last, stage 3 consisted on analyzing and discussing the results 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).

**Analyses and discussion**

First, we present relations among MaaS and the concepts of PSS, Business Ecosystem and Eco-innovation. Next, we propose a comparison between mobility service levels, taking as a starting point the relations found in the literature. Finally, based on the PSS, Business Ecosystem and Eco-innovation approaches found in the literature, we suggest an evolution of the MaaS concept.

**Business Ecosystem of MaaS as a PSS: An Eco-innovation**

As depicted by Figure 3, the theoretical approaches of PSS, Eco-Innovation, and Business Ecosystem, presents density to support the concept of MaaS. In this sense, we unveiled MaaS under the theoretical tripod of each field of knowledge above mentioned, considering them as MaaS pillars. Also, it's worth to highlighted that the connections between some of those fields of knowledge are close enough to suggest other concepts. These new concepts may be also used in the construction of theoretical frame of MaaS, however there were not considered in this study (e.g. PSS and Eco-innovation present the concept of Sustainable PSS (Roy, 2000)).

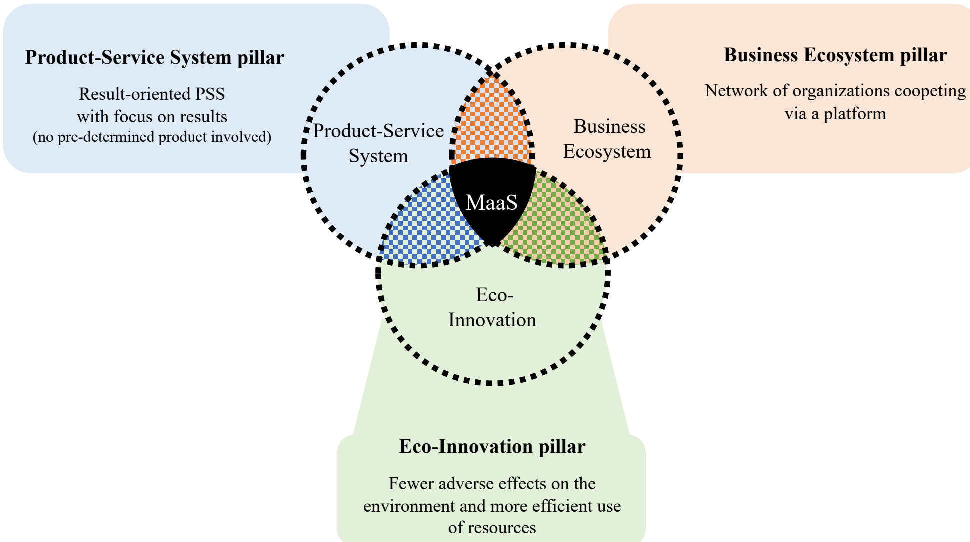


**Fig. 3** MaaS under the theoretical tripod of PSS, Business Ecosystem, and Eco-Innovation. Source: Prepared by the authors.

### Unveiling MaaS: Product-Service System pillar

Besides the multiple definitions, we observed that a PSS aims to create value for users by setting products and services. In the same way, the main idea of MaaS is to integrating transport modes (i.g. combine multiples products/services) in a unique platform to fulfill customer needs. Corroborating with this, Hietanen (2019) describes MaaS as a distribution model of mobility that delivers users' transport needs through a single interface of a service provider by combining different transport modes to offer a tailored mobility package.

Hence, by combining/integrating the transportation modes, a MaaS operator delivers "mobility" as a result of their business. As opposed to a unique transport mode (product) pre-established, there are a bunch of options for the customer. Corroborating with this, Melis et al. (2018) affirms that in MaaS, instead of passengers be committed on specific means they will enjoy a broad spectrum of alternatives from which to choose, taking into account their current needs.

Therefore, MaaS as a PSS can be understood as result-oriented (Tukker, 2004). More specifically, MaaS may offer options for payment which mainly includes "pay-as-you-go" or "monthly packages" pre-established between operator and consumer (Jittrapirom, 2017). These options are respectively related to pay-per-service unit and functional results' PSS (Tukker, 2004). In the former, the user buys the output of the product according to the level of use. Meanwhile, in the latter, the provider is completely free as how to deliver the result, which, in theory, offers the highest potential to design a low-impact system (Tukker, 2004).

Also, we observe that stakeholder behavior is different inside and outside a MaaS system. When analyzed isolated, some of these stakeholders may be positioned in different categories from Tukker's PSS model. According to Kamargianni & Matyas (2017) to establish a MaaS model, it is necessary several stakeholders, such as: transport operators, data providers, technology and platform providers, ICT infrastructure, insurance companies, regulatory organizations, universities, and research institutions. Some of these stakeholders may offer a pure product, product-oriented' PSS, use-oriented' PSS or a pure service (Tukker, 2004).

For instance, in a future scenario, Antonialli et al. (2018) states that autonomous vehicles better fit within Tukker's PPS use-oriented category. Autonomous vehicles will have a shifting focus from the vehicle as a privately-owned asset to a service with a mobility function Antonialli et al., 2018). In the same way, Blomsma et al. (2018) affirms that Riversimple, a company that sells hydrogen cars' miles instead of traditional car ownership, presents a user-oriented service. For the authors, product ownership remains with the service provider, but the customer has access to the product (Blomsma et al., 2018).

However, when those stakeholders are inserted in a MaaS system, this sum changes their behavior to a result-oriented PSS. We suggest that the result-oriented characteristics in MaaS occur due to its Business Ecosystem aspect (Figure 4).

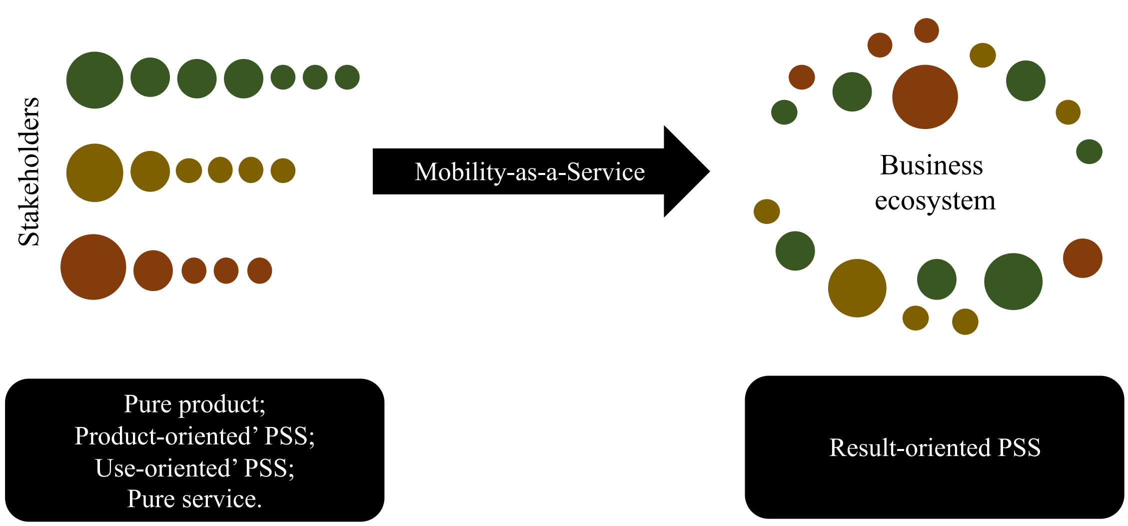


**Fig. 4** Stakeholders' ecosystem transition in Mobility as a Service context.
Source: Prepared by the authors.

Therefore, in a “business ecosystem, multiple organizations act in collaboration, mixing the traditional boundaries of business sectors and companies, and involving users in the co-creation” (Kamargianni & Matyas, 2017 p. 3). In the same way, from a customer perspective, being offered an integrated solution allows for ‘one-stop-shopping’ and thus enhanced efficiency and effectiveness (Kuijken, Gemser & Wijnberg, 2017).

**Unveiling MaaS: Business Ecosystem pillar**

The main idea of MaaS is to offer a unique and seamless interface to its users, aggregating heterogeneous transport options offered by different mobility providers handling the whole experience of traveling, from providing information, to travel planning, and payments (Callegati et al., 2016). However, the more stakeholders a MaaS platform comprises, the more complex the business ecosystem becomes. According to Mäntymäki et al. (2018), one of the main tensions related to the concept of business ecosystem is the regulation by one actor of a complex and interconnected system.

In the same way, Tukker (2004) states that the function-oriented PSS needs attention concerning operationalization. Corroborating with this, in research concerning implementation hurdles of MaaS around experts and academics, the higher level (49%) is related to the difficult to integrate different players (Hünewaldt, 2018). Thus, in our perspective, the first step to solve this concern is to clearly understand how the MaaS business ecosystem as a result-oriented PSS can be structured.

Many authors point out that MaaS has to be established as a platform (Jittrapirom, 2017; Kamargianni et al., 2017; Utriainen & Pöllänen, 2018). Also, some advanced level MaaS systems (e.g., UbiGo and Whim) already use digital platforms to integrate mobility operators and customers. We did not find in the literature the reasons that leads a MaaS system to be integrated in a platform, but we think that the concept of business ecosystem found in Koenig (2012) may explain this.

According to Hensher (2017), MaaS initiatives are not new and are similar in intent makes transport services flexible including demand-responsive transit. What is different today is the ability to bring such flexible options direct to any interested user via the digital app capability available on smartphones (Lyons et al., 2019; Hensher, 2017). In the same way, the concept of Business Ecosystem is not radically new and the key factor that brings the innovator aspect is the platform utilization, which was enabled by the technological progress (Koenig, 2012; Daidji, 2011).

Thus, Mäntymäki et al. (2018) affirms that the ecosystem concept appears to fit particularly well to situations where there is a focal firm or platform leading the network. Also, Koenig (2012) states that a platform in a business ecosystem presents a centralized control of key resources and interdependence pooled. This means that the central actor establishes only the platform use rules not defining players' tasks neither its contribution. In this sense, we understand that the MaaS operator (see Kamargianni et al., 2018) is a central actor from a network that establishes platform rules but does not determine tasks and contributions of each stakeholder (Figure 5).

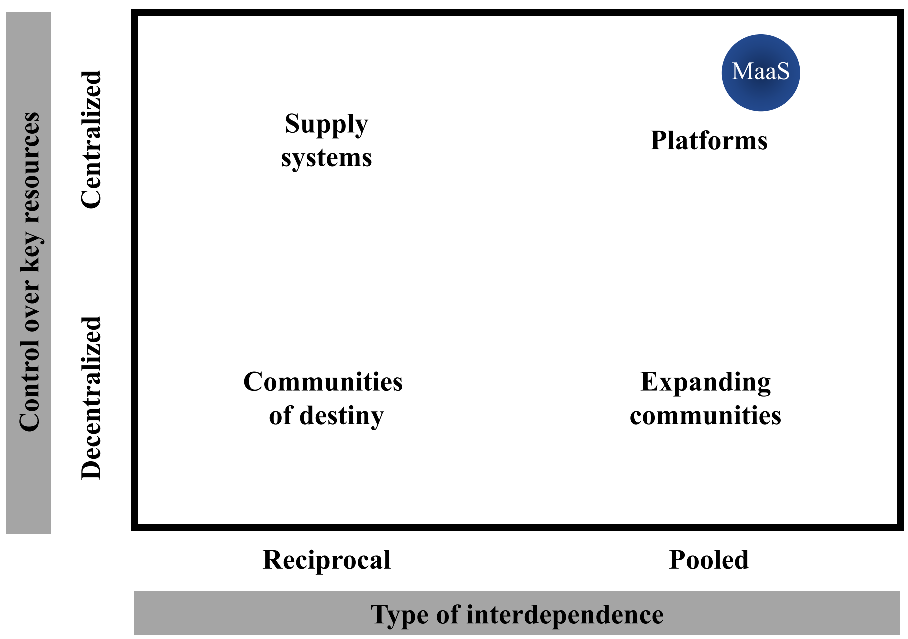


**Fig. 5** Typologies for a MaaS' Business Ecosystem
Source: Adapted from Koenig (2012).

Bring the result-oriented PSS perspective for the Business Ecosystem lead by platforms, we understand that the MaaS operator should provide mobility for the commuters, and build an ecosystem guided by rules to deliverer it, but not determining tasks for the stakeholders.

**Unveiling MaaS: Eco-innovation pillar**

In the current mobility paradigm private car ownership and usage contributes with significant issues in our transport system being responsible for a variety of negative environmental impacts, both on a global and local level (Utriainen & Pöllänen, 2018; 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.

In this sense, MaaS aims to move away from car ownership by using alternative bundles of sustainable transport modes (Utriainen & Pöllänen, 2018) which are aligned with the eco-innovation approach. Even though, sustainability is not an intrinsic characteristic in a PSS (Doualle et al., 2016). Thus, the eco-innovation concept can be inserted in MaaS approach as a PSS, as long as it represents an innovation that brings a reduction on the environmental impacts (OECD, 2009).

In the same way, eco-innovations are alternatives that can be used in PSS mixing sustainability and business (Jesus Pacheco, D. A.et al., 2019). Specifically, result-oriented PSS is the most promising in environmental terms (Tukker, 2004), which fits the approach that MaaS is sustained. However, it's important highlight that our eco-innovation approach for MaaS systems is only applicable in optimal scenarios. In other words, if the shift from private car user to MaaS occurs, as theoretical assumed by MaaS concepts, we understand that the eco-innovation pillar is not part of MaaS.

For this, is important to consider the rebound effect in a PSS (Manzini & Vezzoli, 2003). For instance, P2P services can be a good option to users, even though in the urban mobility ecosystem context, it might have as much negative impacts as the car ownership, or even bigger in certain cases. A user that owns a car could opt to sell it and use exclusively P2P services. Hence, a car that would not need to be on the road, still there with two users (service provider and commuter), still presenting idle capacity.

In another situation, which is more serious in urban mobility ecosystem context, is when a commuter change from PT (bus or trains) to P2P services. In this case, the commuter changes to a less eco-efficient modal, increasing idle capacity, disabling bus lines, hence losing capillarity in the urban mobility.

Thus, we argue that a successful MaaS system is one that not only integrates transport modals, but one that considers the eco-innovation concept by attracting to its platform both PT users and car owners. Mainly for MaaS we consider eco-innovation as the reduction of car ownership or more efficiently use of it by user and "not-sharing" P2P commuters

## The Distinct Levels of Urban Mobility Services

In order to promote a bird’s-eye view of our findings, we drew a framework that aimed to compare distinct urban mobility services (Figure 6). For doing so, we took into account the compilation of main MaaS features (Jittrapirom et al., 2017; Stopka, Pessier & Günther, 2018) supported by our theoretical tripod model (Figure 3). By considering MaaS as a result-oriented PSS, from an ecosystemic perspective, we assumed that the more stakeholders, the higher the managerial complexity. As for Eco-Innovation, the greater the need to own a vehicle (or less efficient usage of it), the lower the levels of Eco-Innovation.

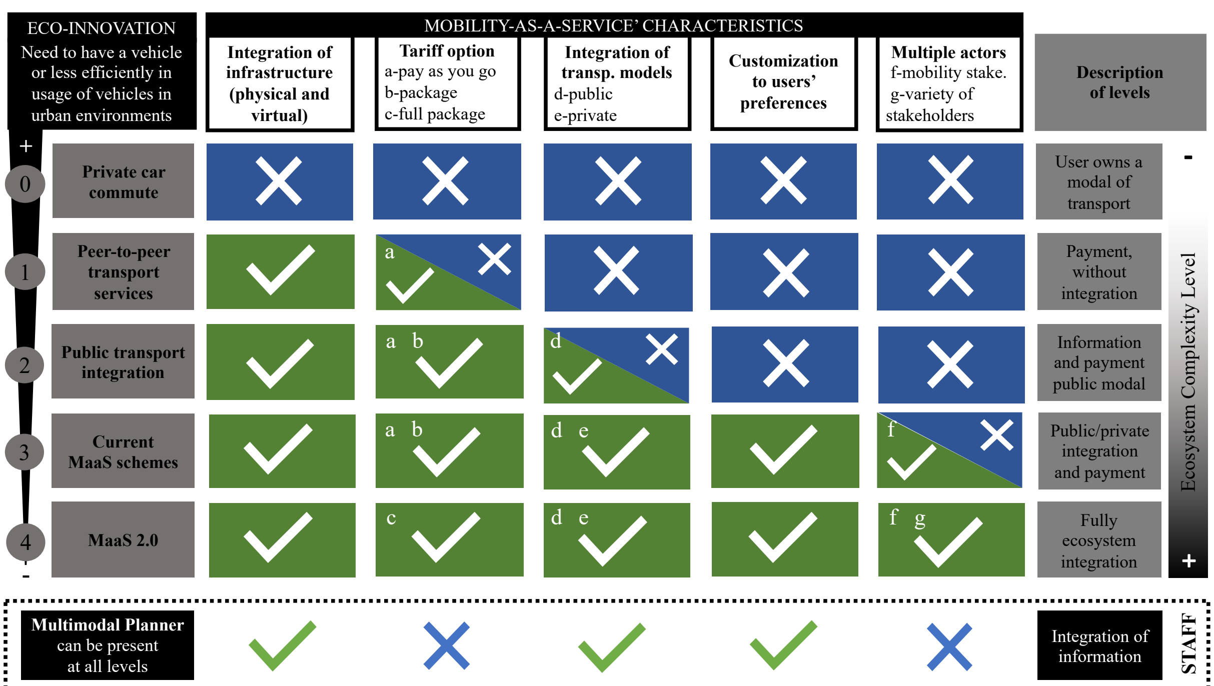


**Fig. 6** Comparison of distinct levels of urban mobility services.
Source: Prepared by the authors.

The first MaaS characteristic is the integration of infrastructure (physical and virtual): it corresponds to the level sync level among the real conditions of transportation modals and how the users know about it (app, website, so on). For instance, a bus is 5 minutes late; Uber is 3 minutes from user's location; to arrive from point to B take the bus and the train, so on.

Another MaaS characteristic is the tariff option: (a) pay-as-you-go: the option to one-way trip (e.g. Uber, individual bus or metro ticket); (b) package: daily/monthly/annual plans (e.g. Navigo in France, Oyster Card in London; UbiGo in Stockholm); (c) full package: we understand that in advanced levels of MaaS (full MaaS) the ecosystem can add stakeholders different from the mobility context. Therefore, the tariff may vary according to the included options besides of mobility, like restaurants, food or even rent (e.g. app WeChat in China; and DenCity project).

More than integrating the infrastructure, MaaS also integrates transport means, such as: (d) public: integration among PT operators, only (e.g. Navigo in France; Oyster card in London); (e) private: integration with private transport means such as taxis, P2P services.

Also, MaaS allows customization to user's preferences. When a user is allowed to modify the offered service option according to their preference and the level has a demanding orientation. For instance, a user doesn’t like to bicycle, and the MaaS operator never bike-sharing’s models for them.

Finally, MaaS comprises multiple actors: (f) mobility stakeholders: interaction between mobility stakeholders, only; and (g) variety of stakeholders: which corresponds to the interactions between different actors, not only related to transport, but also from another industries (e.g. food, retailers, entertainment industry, so on).

As depicted in Figure X, five comparative mobility services levels are proposed: 0) Private car commute; 1) Peer-to-peer transport service; 2) Public transport integration; 3) Current MaaS systems and; 4) MaaS 2.0. Also, we found a Multimodal planner category, which we believe that act as staff for other levels, especial for the level 2 "public transport integration".

The multimodal planner is not considered as a level, but a staff to other levels. Google Maps, City Mapper and Moovit are examples of multimodal planner which integrated information in physical and virtual environment regarding best routes, public and private transport schedules and disturbs in its routes. It makes easier the utilization of other mobility services by commuters. However, this staff is useless without physical infrastructure.

Therefore, we opt to not consider this category as a service level, but as a support to other levels.

In Level 0 (private car commuter) we assume that users own a transportation modal, thus no characteristic of MaaS is found. This category is the biggest the since user have not access to the same convenience to commute in the other levels. In this level we consider the PT presence without integration. That is, it might exist bus routes operating in parallel with bike-sharing, train and/or taxi, however, they operate isolated. In our perspective this scenario is more able to occurs in fewer inhabitant cities, where the PT is poorly, and P2P services still haven't appeared. In this sense, the private car needed is higher, and the ecosystem is less complex than other.

The Level 1 (peer-to-peer transport services) user can have access to the information of a physical transportation modal in a digital platform (app). For instance, user is able to call an Uber through the app and; visualize the real time location, waiting time, license plate, model, driver, rating, run price, among other information that integrate physical and virtual infrastructure through the platform.

With respect to the pricing model, in, general P2P apps offer pay-as-you-go option, which charges commuters according to their utilization. At this level, the need to use exclusively a is slightly reduced when compared to Level 0. However, the choice for single trips payment, besides monthly plans may decrease the trips because the liberty to may recur to P2P options just in case, while seeking other mobility options whenever is possible. Another factor that should be considered is the pool option which fosters better vehicle utilization providing better prices for commuters. Also, pool option provides reduction of idle capacity and positive environmental implications (e.g. less traffic on the road, less emission of pollutants). However, presents a disadvantage if compared to PT. Also, rebound effects are detected in this level. The ecosystem in Level 1 is more complex than Level 0. Number of stakeholders and infrastructure' integration is responsible for this complexity.

Level 2 considers the infrastructure integration between PT players offering to commuters different transport modals information. Multimodal planners (e.g. Google Maps, City Mapper, and Moovit) aid this integration by establishing routes and presenting modal schedules. Tariff options are presented as pay-as-you-go or package. With respect to the former user buy a single ticket and uses several means of transportation for a limited time.

As for the latter, a monthly payment enables unlimited access to all modals (e.g. Oyster Card in London or Navigo in Paris).

Still with reference to Level 2, ecosystem complexity is higher than previous levels due to the high numbers of players integrating the same system. Also, large cities that present railway options such as train, are more likely to develop this level. We suggest that in places that Level 2 are inserted, the necessity to use exclusively a vehicle are fewer than previous levels due to the integration of PT improve the mobility seamless.

Level 3 presents current MaaS systems. At this level, all fundamental MaaS features are present. Users get known about the physical world being able to choose between public and/or private transport, being charged by pay-as-you-go or periodic packages (weekly/monthly/etc.). Comparing to other levels, current MaaS systems add a customization layer according to user's preferences. For instance, in a rainy day, commuters might avoid PT, or to pay for a faster modal in case of hurry or a user can avoid bike or sharing a vehicle. Some real examples are already operating in Finland (Whim) and Sweden (UbiGo).

With respect to the mobility multiple actors, the ones evolved are the only needed to make MaaS works. Hence, this is the second more complex ecosystem. In fact, according to Hünewald (2018), MaaS implementation is not easy due to the necessity to integrate different players. As public transportation represents the backbone of MaaS (Pangbourne et al., 2018) to implement it is necessary an efficient PT.

In addition, previous studies show MaaS applied only in developed countries (Figure 7). However, we propose that MaaS is adaptive and modular, suiting also in cities that PT is not efficient (e.g. being replaced for other transport solutions like hitchhiking, bus shuttles or other transport solutions). Also, emergent countries, claimed for transportation solutions and an adaptive and modular MaaS can be well fitted in, though there are no preliminary tests. Corroborating with this, Hietanen (2019) states that MaaS is a viable answer in most places, because the modal split can be adjustable.

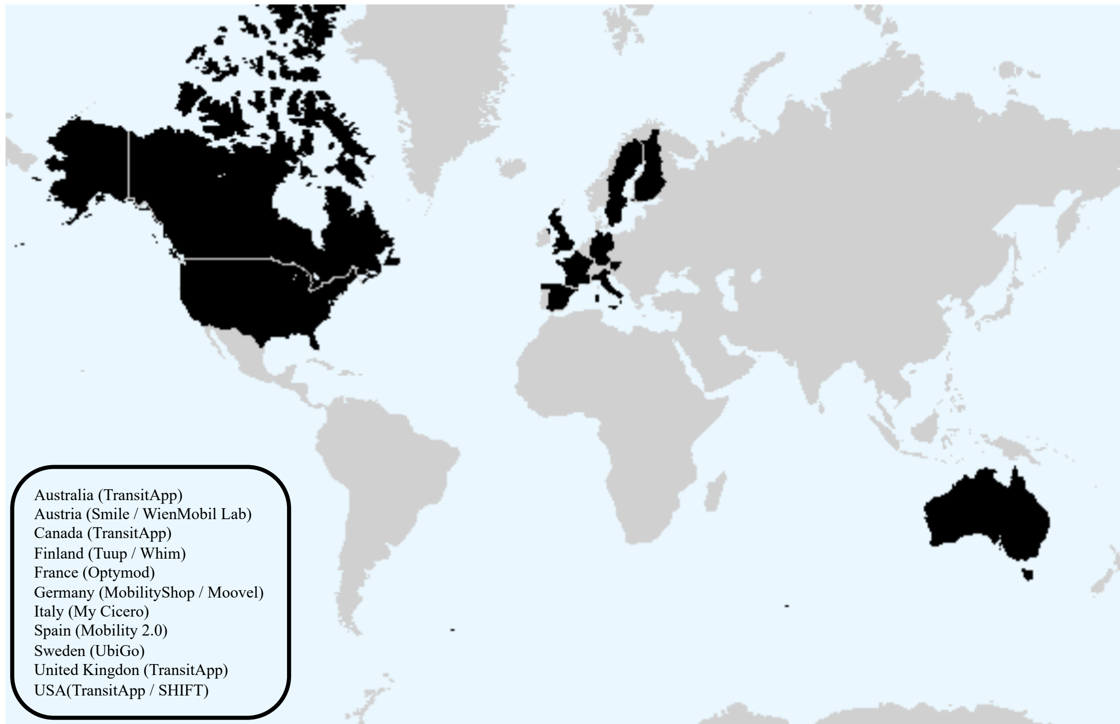


**Fig. 7** Current MaaS systems worldwide
Source: Adapted from Jittrapirom et al. (2017).

Finally, we proposed a Level 4 named MaaS 2.0. We understand that this current MaaS' evolution must not only seek sharing and integration of transport modes but also integrate other stakeholders (not directly related to mobility). Also, we suggest a full package payment mode, bringing private-car users to into their ecosystem (with aims to solve not only their mobility problems but also creates higher value propositions, trying to mitigate their car dependency). For this, other industries such as; entertainment, retailers, food service, and even housing can be a part of MaaS 2.0. At this level, the need to own a car could be drastically reduced while the ecosystem complexity would increase.

For instance, a MaaS 2.0 system could include housing, which could be built without garages, and the rent could be part of the full package. In other words, user would pay a single and monthly fee for rent and transport. Likewise, DenCity project (being tested in Stockholm and Gothenburg) suggest a collaborative form between academy, industry and society building integrated smart cities as an alternative of car use (Closer, 2019).

Another example that sustains this broaden ecosystem, is the app WeChat, which has almost 1 billion users in China. In this app is possible to order food, seek for medical advice, book a trip, flirt, buy any kind of product, call a cab, see friends posts, check fan pages, pay and be possibly work as official identification in Chinese government (Silveira, 2018). The future belongs to ecosystem, the users don't want to have this information spreads in apps, but condensed in one (Hietanem, 2019).

Hence, we consider that the necessity to own a car could reduce drastically while the ecosystem complexity would increase, proportionally. Corroborating, Tukker (2004) states while the result-oriented PSS is the most promising in environmental terms, this system is also the one that demands most risk and attention regarding its operationalization.

In addition, it is important to be alert to factors like regulation and consumption behavior. As pointed by Hojnik & Ruzzier (2016) those factors are critical drivers for an eco-innovation. Some evidences point out that consumers, in all age groups but special the Millennials, are increasingly expecting their experiences in transport and other sectors, to be delivered as a service, and to get more value as a result. Also, changes in mobility consumption means greater adoption of new mobility models and this may lead to a move away from car ownership (Mulley, 2017).

Thus, we propose MaaS 2.0 as “a business model that should, via a single platform, integrate result-oriented services among different stakeholders in an ecosystem with a value proposition sufficiently greater for private car users to switch to the platform or use their vehicles more efficiently”.

## Concluding remarks

The theoretical tripod of Product-Service System, Business Ecosystem, and Eco-Innovation may be a used as foundation to Mobility as a Service. We observe that all of those knowledge fields present relation with body of MaaS founded in literature.

MaaS can be considered a result-oriented PSS. From this perspective, the mobility function is what should be considered as a result of a MaaS. To this end, the business ecosystem contributes by the concept of coopetition with distinct stakeholders creating value for users in terms of mobility through a platform. In this sense, Mobility as a Service can be thought not only as a concept, phenomenon or transportation solution (Jittrapirom et al., 2017) but also as a business model. More specifically, MaaS as a PSS can be named as a result-oriented business model.

Nevertheless, as a PSS we observe that the environmental issue should not be considered as an intrinsic factor. Thus, an analysis from the eco-innovation perspective has made us reflect upon the real need for vehicle ownership and its efficient use. However, from such perspective, current MaaS systems are subject to rebound effects. Private car users may not find the value needed to replace their vehicles, which, in consequence, would not characterize MaaS as an eco-innovation.

Through the lens of eco-innovation, the main drivers of MaaS are regulations and the market pull. In this sense, assumed that MaaS will replace private car ownership in any context, designed in the same way as current MaaS systems would neglect the legal and cultural specificities of each place. We assumed that this perspective occurs because all current MaaS systems still take place in developed countries with efficient public transport.

We believe that MaaS is a modular and adaptive and should create value from a range of distinct actors and thus be compatible with eco-innovation concepts, due to its sustainable essence. In this way, we propose an evolution of the current MaaS concept: MaaS 2.0. This level is the most promising in environmental terms, however, it comes with higher risks and governance and operationalization challenges. In fact, all of mobility services levels analyzed may succeed or not, with has to take account is the risks to implement and environmental concerns of each locality.

Although this study needs more in-depth analysis, we have brought initial toughs about Maas through a theoretical perspective not yet addressed in the literature. As a future agenda, we suggest analyzes pillar on each of the theoretical tripod. Also, we believe it is worth to look at consumer behavior and regulatory approach of MaaS in developing countries. In addition, understand whether the perspective of a results-oriented PSS is related to the configuration of a business ecosystem could aid in theoretical advances in this field. Finally, we assume that a MaaS business model is only configured as disruptive if it is eco-innovative, however this proposition still requires future analysis.

## Acknowledgements

This paper would not have been possible without the support of the *Laboratoire Génie Industriel* (LGI / *CentraleSupélec – Université Paris-Saclay /* France), the Post-Graduate

Program in Administration of *Universidade Federal de Lavras* (PPGA/UFLA - Brazil), and the Statistics Department of *Universidade Federal de Lavras* (DES/UFLA – Brazil). We also would like to thank the founding institutions: *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES - Brazil) and *Fundação de Amparo de Pesquisa de Minas Gerais* (Fapemig - Brazil).

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**ARTICLE 2: Autonomous vehicles: Scientometric and bibliometric review.**

**Preliminary version of the paper published on the proceedings of 25th International Colloquium of Gerpisa, Paris, 2017.**

Gandia, R. M.; Antonialli, F.; Cavazza, B. H.; Neto, A. M.; Lima, D. A.; Sugano, J. Y.; Nicolaï, I.; Zambalde, A. L. (2017). Autonomous vehicles: Scientometric and bibliometric studies. In: 25th Gerpisa International Colloquium, 2017, Paris. R/Evolutions. New technologies and services in the automotive industry, 2017.

**Full Paper published on Transport Reviews Journal.**
**ISSN: 1464-5327, JCR: 6.648, Qualis Capes: A1**

**doi. https://doi.org/10.1080/01441647.2018.1518937**

Gandia, R. M.; Antonialli, F.; Cavazza, B. H.; Neto, A. M.; Lima, D. A.; Sugano, J. Y.; Nicolaï, I.; Zambalde, A. L. (2018). Autonomous vehicles: scientometric and bibliometric review. Transport Reviews, v. 38, p. 1-20.

# Autonomous Vehicles: Scientometric and Bibliometric Review

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**Abstract**: This paper presents a scientometric and bibliometric review of the research on autonomous vehicles (AVs) to identify its main characteristics, evolution, and potential trends for future studies. Relevant articles were searched on WoS, yielding a research corpus of 10,580 papers, and the software CiteSpace was subsequently used for analysis. The results showed that AV research is heterogeneous and registered a growing demand over time. Multidisciplinarity is present, with 96 science fields being identified. As in any other sector, it is necessary to understand broader aspects of this industry such as the market factors surrounding it, as well as other economic and managerial issues. In this sense, we observed a migration of the research field from multidisciplinarity to pluridisciplinarity with a greater number of studies focusing on the latter. We understand that terminology standardization contributes to achieving pluridisciplinarity. As such, it is important to highlight that sustainability, public policies, liability, and safety, as well as business issues such as performance and business models are some of the tendencies in the field of AVs. For future studies, we suggest a more in-depth analysis of publications in terms of individual search terms, as well as the sub-areas identified as trends in this paper.

**Keywords** Autonomous Vehicles • Bibliometrics • Scientometrics • Review • CiteSpace

## Introduction

The robotics industry has been contributing to many everyday aspects for over five decades. Further, several IT-related industries based on mobile information technology are emerging due to the second information revolution, which is also called the fourth industrial revolution (Rifkin, 2011; Schwab, 2017). In this context, the first vehicle equipped with an automated driving system appeared in the mid-1980s at Carnegie Mellon University, the Navlab 5 (Pomerleau & Jochem, 1996). Since then, several advances have been made in this area, and numerous major companies and research organizations have developed autonomous vehicle (AV) prototypes.

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

The automated driving technology is changing rapidly due to road safety concerns, potential cost savings, and technology innovations (McKinsey & Company, 2016). The current technology state, along with expected improvements and the already-announced plans of several large Original Equipment Manufacturers (OEMs) and others, make it likely that AVs will be available by the mid-2020s. In the business context, AVs have been gaining increasing attention, as numerous companies have been standing out in the “race” for leadership in this innovation process.

Although the AV theoretical field has been established, its main aspects, conceptual base, tendencies, and characteristics have not been fully identified yet. Consequently, the following questions emerged as a framework for this paper: (i) how does the field of studies regarding AVs perform; (ii) what is the historical evolution of the field (science branches and fields of knowledge); and (iii) what are the thematic of the technological evolution and the main research trends?

In this sense, we carry out a scientometric and bibliometric review **to identify the main characteristics of the AV field, as well as its evolution and to highlight the potential trends for prospective studies**.

Our paper is structured as follows. Section 1 provides an overview of AVs with respect to their concept and terminologies, assumed benefits/implications, as well as the efforts of different stakeholders to promote these vehicles. Section 2 presents the research methodology, explaining the necessary steps to perform the scientometric technique. Section 3 presents the results and discusses the proposed analysis in two stages: a descriptive analysis of the papers, seeking to delineate the field of study, and insights to researchers in the field of AVs by an in-depth analysis of the conceptual base, trends, directions, and changes that are influencing this research area. Finally, in Section 4, we present concluding remarks, summarizing the main findings and highlighting the possibilities for future research.

**Autonomous Vehicles Overview**

AVs are cars with motion and action capabilities that do not require any sort of conductor (driver) or teleoperation control (Frazzoli, Dahleh & Feron, 2002). The Society of Automotive Engineers (SAE, 2016) has recommended the term "automated driving systems (ADS)" to refer to vehicles with different automation levels to avoid multiple definitions with ambiguous meanings. The aim of this terminology is to encompass several terms widely used in the literature, such as: autonomous vehicles/cars, self-driving cars, car-like robots, intelligent vehicles, driverless cars.

AVs represent a potentially disruptive and beneficial change to the intelligent transportation systems business model, as pointed out by Milakis, Van Arem, and Van Wee (2017), as automated driving might bring several interrelated effects to mobility and society. The authors refer to such implications such as the "ripple effect," in which AVs are placed in the center and surrounded by a first layer of implications, such as traffic, travel cost, and travel choices, while a second layer implies changes in vehicle ownership and sharing, location choices and land use, and transport infrastructure. Finally, the third layer refers to wider societal implications due to the introduction of AVs, such as energy consumption, air pollution, safety, social equity, economy, and public health.

On the other hand, AV proliferation is far from guaranteed. As Fagnant and Kockelman (2015, p. 168) state, "complex questions related to legal aspects, liability, privacy, licensing, security, and insurance regulation still remain to be solved." Further, AVs may introduce new risks, such as system failures that would make these vehicles less safe under certain situations and conditions due to being connected to the cloud and operated by a central unit system, also meaning there will be security and privacy concerns related to cyber security.

Further, Hucko (2017) highlights that the abuse of vulnerable information, tracking, and data sharing could violate passengers' privacy, and that such cars could be used for terrorist activities. The high costs related to additional car equipment services and maintenance, as well as further investments in roadway infrastructure, would hamper large-scale production and mass consumer availability (KPMG & CAR, 2012; Grau, 2012; Hickey, 2012).

Autonomous technology is now the greatest bet of large automakers, led in the United States by Ford, GM, and Tesla and in Europe by Audi, Mercedes, and Volvo, as well as 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, while Uber's AVs have also reached over 1.5 million driven kilometers in their testing cities of Pittsburgh, Phoenix, and Toronto.

Meanwhile, numerous carmakers, such as Audi, BMW, Cadillac, Ford, GM, Mercedes-Benz, Nissan, Toyota, Volkswagen, and Volvo, are already testing AVs (Fagnant & Kockelman, 2015), not to mention that vehicles with semi-autonomous capabilities at the Society of Automotive Engineers' (SAE, 2016) level 2 and 3 of automation are already being marketed (e.g., Tesla's Roadster, Model S, Model X, Mercedes-Benz's S65, Infiniti's Q50S, BMW's 750i xDriv for SAE's level 2 and 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).

Also worth mentioning are the partnerships among companies, which have been a common method for the development and advance 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.

The governments of several countries have also become interested in the possible benefits of vehicular automation. The United States was the first country to introduce legislation allowing the testing of AVs on their streets and roads. The same goes for several European countries (e.g., Finland, France, Germany, Italy, the Netherlands, Spain, Sweden, and the UK), where lawmakers are already allowing the development and testing of AV technologies on their roads as well (Patel, 2018). Similarly, Asian countries such as Japan, Singapore, China, and South Korea are interested in international regulations being updated to allow for the development of automated vehicle technologies (Schoitsch, 2016; U.K. Department for Transport, 2015).

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

According to Yun et al. (2016), the advancement of technological innovations in the AV field is part of the dynamic relationship established between technology, business model, and market. In this context, the possibility of changes in the dynamic relationships between these three factors to obtain the expected results is evident. This change may be part of a process inherent to the role of a business model not yet established. However, in the future, it will be necessary to develop dynamic system models and more concrete simulation research on political leverage, including the market's growth pattern and the implications it will have on multiple sectors.

There are several contributions on the subject, and the transition from a long-established industry (automotive) to a new configuration (mobility eco-system) is still surrounded by uncertainties as to the inherent aspects of regulatory factors, technology, business models, and market. Through the investigation and map of this field's main features, a bird's eye view of the current research can contribute to the field.

**Research Methodology**

This study was conducted from November 2016 to February 2017 and updated during May–July 2018. It is descriptive and also employs a quantitative approach to identify the main characteristics of the AV field, as well as its evolution to highlight potential trends for future studies. The research is characterized as scientometric and bibliometric, based on articles indexed in the Thomson Reuters' Web of Science (WoS) database.

The scientometric technique, which is a method that refers to knowledge domain visualization or mapping (Pollack & Adler, 2015) and a quantitative technique that applies bibliometrics to published literature (Börner, Chen & Boyack, 2003) is used to map the structure and evolution of numerous subjects based on a large-scale scholarly dataset through network modeling and visualization. Scientometric research aims to analyze the intellectual landscape of a knowledge domain and perceive questions that researchers have been attempting to answer, as well as the methods they have developed to achieve their research goals (Chen and Paul, 2001).

Bibliometric analysis must be systematic and stem from primary studies; it must also comprise the aims, as well as clearly expressed materials and methods and be conducted through a clear and reproducible methodology (Greenhalgh, 1997). In this sense, the results of bibliometric analysis are useful for: 1) measuring and understanding the study field of a given subject; 2) providing a solid view of the field's historical evolution; 3) presenting a thematic and technological analysis; and 4) providing evidence and a basis for future research.

Based on these methodological procedures, the present study proposes four steps, which are described in the following and illustrated in Figure 1.

- **Step 1 – Delimitation of analysis scope and article selection:** the articles were searched on the WoS database in a single search, from 1945 to 2018, using the Boolean operator[2] "OR." Because of the multiples definitions still used in this field, the papers were selected using the following terms in the title, abstract, or keyword fields: *autonomous_car; autonomous_vehicle; autonomous_automobile; automated_car; automated_vehicle; automated_automobile; driverless_car; driverless_vehicle; driverless_automobile; self-driving_car; self-driving_vehicle; self-driving_automobile; intelligent_car; intelligent_vehicle; intelligent_automobile;* and *automated_driving_system*. This search resulted in 10,580 results, which constitute the corpus of the present study.
- **Step 2 – Descriptive analysis of papers:** the following analyses were performed: 1) number of papers published per searched term; 2) number of papers per year; 3) most published authors; 4) most published sources; and 5) countries analyzed.
- **Step 3 – In-depth analysis of papers:** we carried out on CiteSpace the following in-depth analysis of the 10,580 articles: 1) dual-map overlay; 2) analysis of the main

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[2] The Boolean operator underline '_' was used to ensure the search yielded only the results in which the pair of words appeared together. Terms were only searched in the singular form, as this would find both singular and plural terms.

WoS categories in which the articles were published; and 3) analysis of the most relevant keywords.

- **Step 4 - Interpretation and discussion of results:** we carried out a joint interpretation and discussion of the results in steps 2 and 3, to identify the main research trends and gaps within the fields of study.

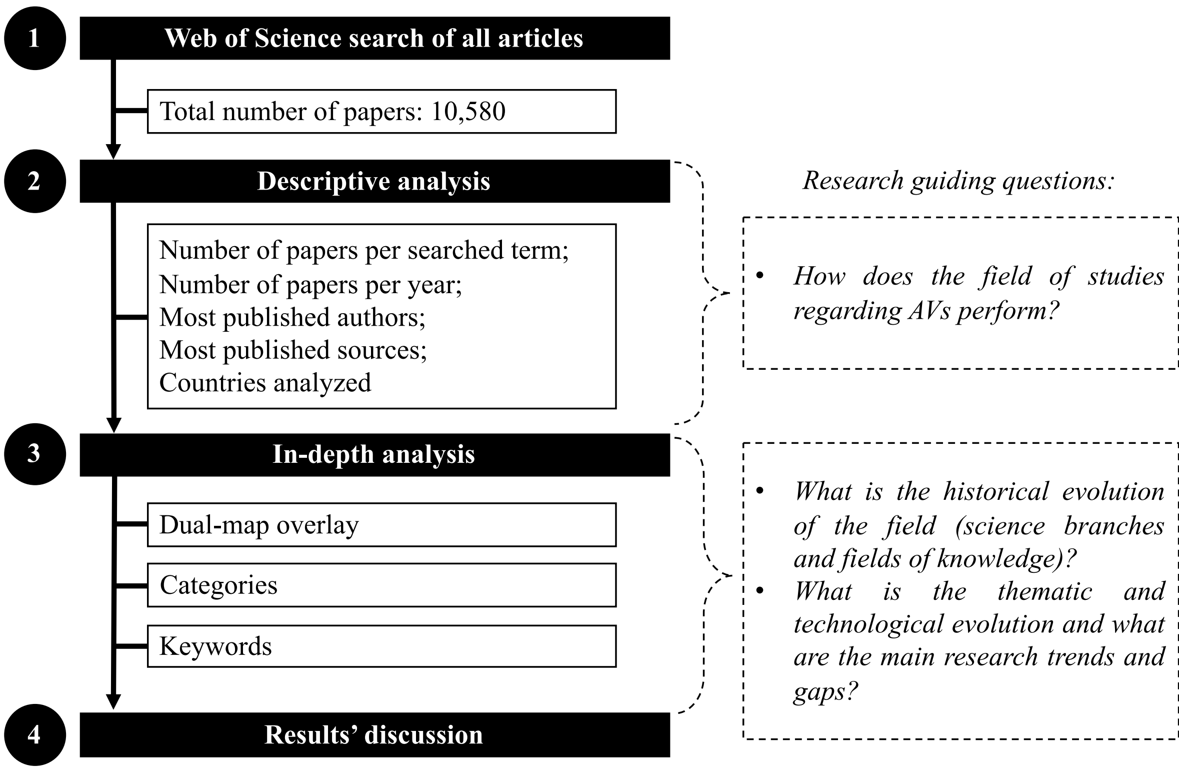



**Fig. 1:** Methodological research design.
Source: prepared by the authors.

## Results and discussion

The results and discussion of the proposed analysis are presented in two stages. The first one presents a descriptive analysis of the papers, seeking to delineate this field of study. The second stage is characterized by an in-depth analysis of the theme to draw a thematical and technological evolution of the field, as well as point out the main research trends and gaps.

## Descriptive analysis

To separately observe the contribution of each searched term used to create the sample for this study, Figure 2 illustrates the number of papers, as well as the year of publication of the first paper by each searched term.
The terms "autonomous_vehicle" and "intelligent_vehicle" were the most representative, yielding 6,087 and 2,310 papers, respectively. In this sense, it is possible to infer the relevance of the term "autonomous_vehicle" to the research field in detriment to the other possible terminologies. On the other hand, the term "driverless_car" yielded the oldest record in the sample, having the first paper published in 1969.

In 2014, SAE adopted the terminology of ADS to refer to vehicles with different automation levels and avoid multiple definitions with ambiguous meanings (SAE, 2014, 2016). The term "automated_driving_system" was first used in a publication in 1997; however, it is important to highlight its evolution in terms of publication number, in that the average until 2014 was 2.2 papers per year and increased to 31.6 papers per year from 2015. It is worth noting that, although being the official recommendation of SAE, the term ADS represents only 1.12% (118 papers) of the total sample (10,580 papers).

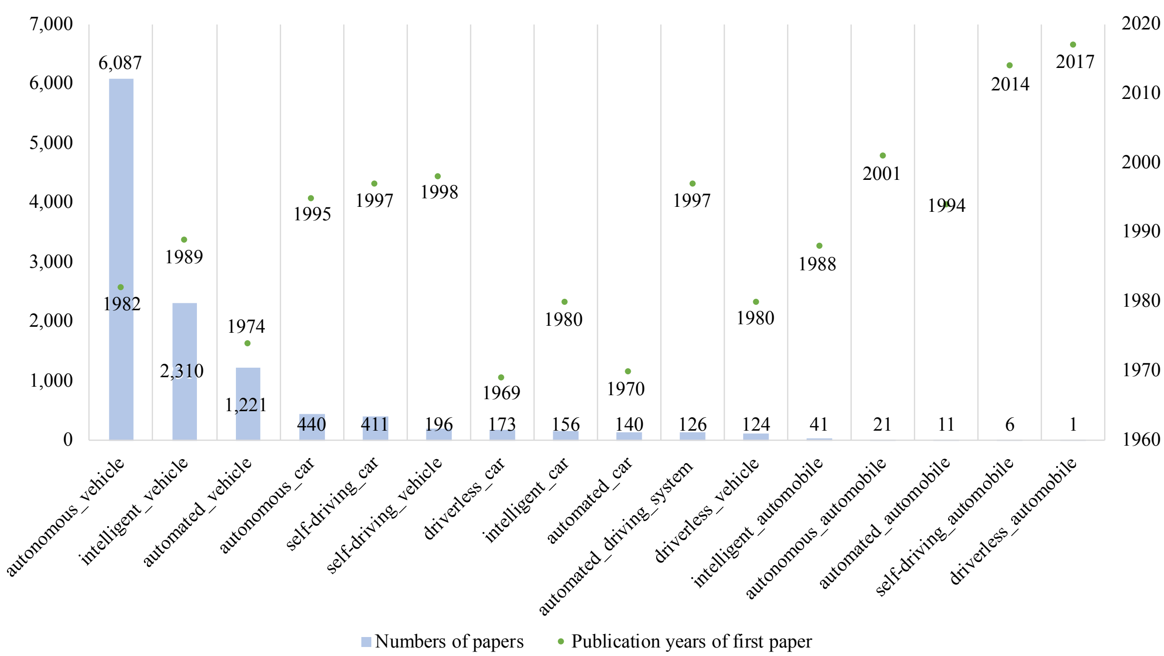
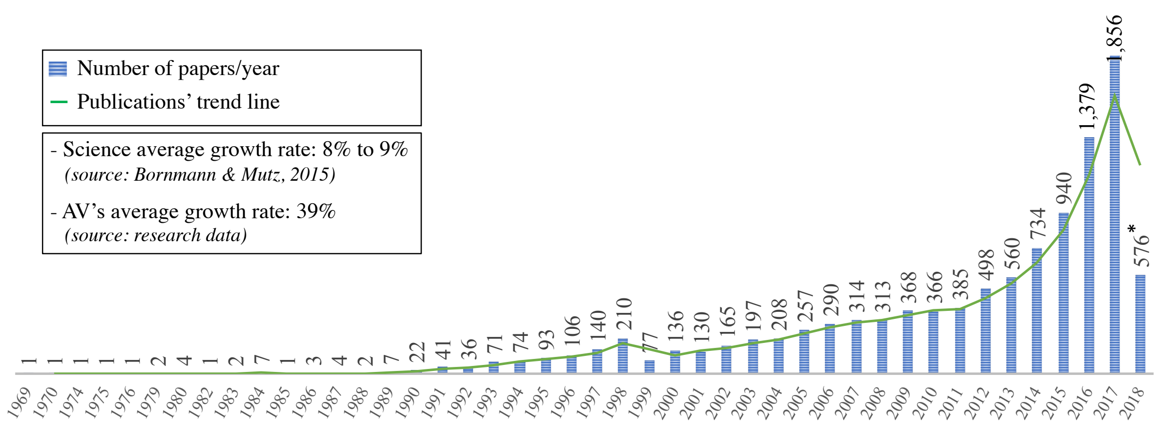



**Fig. 2:** Number of papers per searched term
Source: prepared by the authors

The temporal distribution of the 10,580 papers published on the subject of AVs began in 1969 with Palatnick and Inhelder's work. The uninterrupted evolution of AV publications began in 1982 with the work of Roberts and Mathews (1982) and, from there, it followed an exponential curve (Figure 3), the years 2016 and 2017 registering the greatest number of publications of 1,379 and 1,856 papers, respectively.

Figure 3 also shows the publication trend line for the AV field, in which from 1969 to 2011, the number of publications followed the trend line with slight ups and downs (except for 1999, which showed a larger decline). However, from 2012, the number of publications exceeded the trend line, showing an exponential growth of the field in recent years. Compared to the average science growth rate, which is around 8–9% per year according to Bornmann and Mutz (2015), the related average growth rate of publications on AVs was 39% over the analyzed period.

This growth may indicate the publications in several AV related areas as its introduction to the market approaches, with several implications for all sectors of the economy.




* when data was collected, the year 2018 had not yet finished.
**Fig. 3:** Number of papers per year based on WoS data.
Source: prepared by the authors.

The top five authors with most publications are Junsoo Kim (49), Vicente Milanes (46), Umit Ozguner (46), Javier Perez (45), and Alberto Broggi (44). Nonetheless, there is significant heterogeneity when it comes to the most published authors. Based on WoS results, we observed 20,314 authors were responsible for the 10,580 papers.

From this result, a parallel with Price's Elitism Law (1976) can also be made. We observe that the elite corresponds to 143 authors ($\sqrt{10{,}580}$), who are responsible for 3,157 out of the total 10,580 identified papers. This value is below the minimum considered by the elitism law, assuming that for being considered a productive elite, these 143 authors should have published approximately 5,290 papers (half of the total number of publications). In this sense, we infer that the AV field is still incipient, considering the reduced number of works-per-author, with no existence of a considerable productive elite.

As for the number of publications, we carried out Bradford's Dispersion Law (1934) analysis. In this analysis, there are three distinct zones (nucleus) papers could fit in, each one containing 1/3 of the total of relevant articles.

The first nucleus (described in Table 1) contains 25 distinct sources with a total of 3,526 publications. The second nucleus (larger number of less productive journals) contains 259 different sources, which are responsible for 3,499 publications and, at last, the third nucleus (includes more journals, but each with less productivity), has 3,269 sources, responsible for 3,555 publications. Therefore, we observed that from the 3,553 sources responsible for AV publications, only 25 (0.70%) were responsible for approximately 33% (3,526) of the field's publications.

**Table 1:** Top 25 higher publications (first nucleus) of sources in numbers of papers

| | |
|---|---|
| IEEE Intelligent Vehicles Symposium | 670 |
| IEEE International Conference on Intelligent Transportation Systems (ITSC) | 498 |
| Proceedings of The Society of Photo Optical Instrumentation Engineers (SPIE) | 322 |
| IEEE Transactions on Intelligent Transportation Systems | 288 |
| Lecture Notes in Computer Science | 169 |
| Proceedings of The American Control Conference | 164 |
| IEEE International Conference on Robotics and Automation (ICRA) | 119 |
| IFAC Papersonline | 111 |
| IEEE Conference on Decision and Control | 104 |
| Transportation Research Record | 98 |
| IEEE International Conference on Intelligent Robots and Systems (IROS) | 92 |
| Transportation Research Part C: Emerging Technologies | 90 |
| IEEE Transactions on Vehicular Technology | 89 |
| Oceans IEEE | 83 |
| IEEE International Conference on Systems Man and Cybernetics Conference Proceedings | 81 |
| Sensors | 79 |
| Robotics and Autonomous Systems | 65 |
| Lecture Notes in Mobility | 59 |
| Lecture Notes in Artificial Intelligence | 58 |
| Control Engineering Practice | 55 |
| Advances in Intelligent Systems and Computing | 50 |
| IEEE Transactions on Control Systems Technology | 50 |

| | |
|---|---|
| Applied Mechanics and Materials | 44 |
| IEEE Industrial Electronics Society | 43 |
| International Conference on Connected Vehicles and Expo | 43 |

Source: prepared by the authors.

Table 1 also shows the concentration of sources in the first nucleus that belong to congresses or conferences (62%). This can be explained by the distribution of works related to AVs, where approximately 66% are proceedings papers, whereas 34% are journal articles, which may explain the recent recurrence of AVs in academia. This result also demonstrates that the discussion on AVs is far from being exhausted, characterizing this subject as a trending topic among researchers. It is worth mentioning the Institute of Electrical and Electronics Engineers' (IEEE) eloquence in this field, with 19 occurrences among the components of the first nucleus (51%). We also highlight that the outputs of this analysis are important to signal the most prominent sources (journals and conferences) that publish studies in this field.

As for countries, Table 2 presents—based on CiteSpace's analysis—the results of the top 20 (of 91) countries that published papers on AVs regarding number of publications, year of first publication, total papers, and centrality. The centrality metric indicates the importance of a given node and its collaboration in a network (Chen et al., 2010; Vasudevan et al., 2016). In other words, the more central the country, the greater the number of publications with other countries. It is important to highlight that a country with high centrality may not necessarily have a high number of publications. For instance, the USA has the highest number of publications (3,078) and a low centrality index (0.11), which indicates that it does not partner with as many countries for publications. On the other hand, England, Spain, Sweden, and others have higher centrality levels than the US although they have significantly fewer papers published.

Table 2 also presents the position of each country based on the KPMG (2018) ranking, which measures the countries' degree of openness and preparedness for AVs on 26 different variables within four pillars (policy and legislation, technology and innovation, infrastructure, consumer acceptance).

**Table 2:** Countries analyzed by CiteSpace and KPMG rankings

| Countries | CiteSpace Ranking | KPMG Ranking | First publication | Total papers | Centrality |
|---|---|---|---|---|---|
| United States | 1 | 3 | 1986 | 3.078 | 0.11 |
| China | 2 | 16 | 1993 | 1.484 | 0.08 |
| Germany | 3 | 6 | 1992 | 897 | 0.09 |
| France | 4 | 13 | 1994 | 612 | 0.11 |
| South Korea | 5 | 10 | 1998 | 527 | 0.00 |
| Japan | 6 | n/a | 1988 | 477 | 0.00 |
| Spain | 7 | 15 | 1993 | 476 | 0.35 |
| England | 8 | 5 | 1993 | 465 | 0.42 |
| Italy | 9 | n/a | 1992 | 411 | 0.11 |
| Canada | 10 | 7 | 1993 | 325 | 0.05 |
| Australia | 11 | 14 | 1995 | 302 | 0.05 |
| India | 12 | 20 | 1995 | 231 | 0.03 |
| Netherlands | 13 | 1 | 1994 | 229 | 0.05 |
| Sweden | 14 | 4 | 1993 | 216 | 0.31 |
| Portugal | 15 | n/a | 1993 | 182 | 0.08 |
| Singapore | 16 | 2 | 1998 | 167 | 0.00 |
| Brazil | 17 | 17 | 1998 | 163 | 0.09 |
| Taiwan | 18 | n/a | 1993 | 162 | 0.02 |
| Switzerland | 19 | n/a | 1997 | 97 | 0.00 |
| Turkey | 20 | n/a | 2005 | 96 | 0.00 |

Source: prepared by the authors.

Note that the United States ranks first in number of publications and third in the KPMG analysis, which could be explained by the synergies of numerous stakeholders (e.g., academia, public organizations, automotive companies, technology companies), since according to the KPMG report, the US is ranked at the top of the technology and innovation pillar. It scored maximum or near-maximum ratings on industry partnerships, research and development hubs, AV technology company headquarters, investment, and world economic forum ratings for technology availability and capacity for innovation. Besides the highest number of publications (3,078) and having the oldest publication in the analysis, the country has by far the greatest number of AV-related companies, with 163 headquarters (KPMG, 2018).

It is not only large companies driving the discussion on AVs in the USA, but startups like Faraday Future are also playing a role in imagining the applications of these vehicles (Gleave et al., 2016). Additionally, universities are contributing significantly to AV R&D; for instance, Uber has collaborated with two institutions, the College of Optical Sciences at the University of Arizona and the University of Michigan (NBC, 2015). It is also important to highlight DARPA’s Grand Challenge, which may also be a booster for American publications.

China, which ranked second in the number of publications (1,484), aims to lead the race in terms of electric vehicles and AVs by 2030. In fact, the country has ambitious plans for AVs, expecting vehicles with "driver assistance" and “partial driving automation” to account for 50% of sales by 2020, "conditional driving automation" cars 15% of sales by 2025, and, “high and full driving automation” vehicles 10% of sales by 2030 (Dunne, 2016). Contrarily, China ranks 16th in KPMG’s report. In this context, the government could be one of the main stakeholders to develop the AVs in the country, although more accurate public mapping would help achieve AVs readiness (KPMG, 2018).

Although the Netherlands ranks 13th in number of publications (229), the country is the indisputable leader in KPMG Index. The Dutch ecosystem for AVs is complete, providing the infrastructure, as well as a supportive government AV readiness model for other countries to follow, with excellent road and an already enthusiastic adoption of electric vehicles (KPMG, 2018).

Singapore holds the second position in KPMG report but ranks 16th regarding publications (167). Singapore’s 2017 amendment to its Road Traffic Act allowing self-driving vehicles to be tested on public roads has helped the city state gain its high level of AV readiness and could explain the country’s good position in KPMG’s report. Moreover, the country tops two pillars of this index, “policy and legislation” and “consumer acceptance,” and is second to the Netherlands in infrastructure (KPMG, 2018).

Besides the Netherlands, several European countries are taking significant steps to be at the forefront of this field’s research, with nine out of the 20 countries that have published the most papers on the subject (Germany, France, Spain, the UK, Italy, Portugal, Sweden, the Netherlands, and Switzerland). The European Commission and other European bodies have demonstrated great interest in vehicle automation by funding a variety of research and innovation. One of the main areas was the development and implementation of driver assistance systems to improve driving safety (Gleave et al., 2016).

Particularly, German manufacturers are promoting full driving automation vehicles and are currently undertaking tests. OEMs’ such as Audi, BMW, and Mercedes-Benz are active in this sector, leading experiments worldwide. The country ranks third when it comes to publications (643) and sixth in KPMG's readiness index.

When it comes to publication centrality, the UK has a predominant score (0.42), followed by Spain (0.35), and Sweden (0.31). While USA and China, the most signified countries in number of publications, present a low influence in centrality score (0.11 and 0.08, respectively). The European Union influence could be responsible for the high centrality score of European countries. According to the European Commission (2017), it is time to put into practice the possibilities of AVs in real traffic conditions. The experience from some member states shall be used and test data should be exchanged. The use of other languages except English can explain the low centrality score in countries with higher publication numbers, such as China, South Korea, and Japan.

## In-depth analysis

### Dual-map overlays

For a broader view of the field's evolution, we carried out the CiteSpace dual-map overlay analysis. These interactive maps allow the exploration of how disciplines are related and how individual publications from an organization are distributed across a landscape (Chen & Leydesdorff, 2014). The initial appearance of the user interface simultaneously shows citing and cited journal base maps. Each dot represents a journal, where the base map of 10,330 citing journals is on the left and the 10,253 cited journals are on the right. This layout reflects the similarity among journals based on data in Thomson Reuters' Journal Citation Report (Chen, 2016).

In this paper, two dual-maps overlays were drawn in Figure 4 (A) and (B). The methodological procedures for the construction of the dual-map overlay (A) use the same database as all other analyses in this paper (AVs), separating the curves by distinct colors. To contrast the results, we use the *z-score* option that converts the raw scores into a standard. As for the dual-map overlay (B), we use the AVs research database (highlighted in red);

however, to draw a comparative analysis, we carried out a new database search, here named *electric vehicles*[3] (highlighted in cyan), therefore adding a new overlay.

In Figure 4 (A), the evolutions in the field of the AVs can be observed. It is worth noting the predominant field of mathematics, system, and mathematical (MSM) evolves strongly (see the thickness of the curve indicated by this field) in terms of references cited, for the most part, in systems computing, computer (SCC). Further, the MSM field evolves discreetly to economics, economic, and political (EEP), indicating that this field (EEP) within the AVs theme makes use of MSM in its publications. In addition, we noticed influences (even on a small scale) of publications in all other fields, corroborating with the assertion of the heterogeneity of publications on AVs.

As for Figure 4 (B), which includes the electric vehicles database (over the AVs database), we can see an alignment between the two themes. An overlap of the electric vehicles curve (cyan) over the AVs curve (red) of the publications on MSM is strongly evolving to SCC, as well as influences EEP. This fact shows that electric vehicles and AVs are aligned when it comes to academic influence. In other words, AV technologies can help enable a transition to electric and other alternative fuel vehicles (Anderson et al., 2016). These vehicles, fully or partially powered by electricity, would be able to travel the same range using smaller and cheaper batteries.

Additionally, Figure 4 (B) shows that electric vehicles have strong influence also from physics, material, and chemistry (PMC), with a strong evolution curve for PMC. This may indicate that the evolution of PMC within the theme of electric vehicles is still making significant use of the knowledge generated by the field itself. Furthermore, the Earth, geology, and geophysics field (EGG, on the right side) currently shows influences from different knowledge areas and is marked by an increasing number of publications (denoted by the large circle around it). This may be related to the growing trend towards cleaner and more sustainable energy, as well as environmental issues regarding electric vehicles and their positive impacts on the oil industry.

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[3] For electric vehicle data, the articles were searched on the WoS database in a single search using the Boolean operator "AND" and were selected by the following terms in the title, abstract, or keywords: *electric_vehicle** AND *car*, for a total of 4,148 papers.

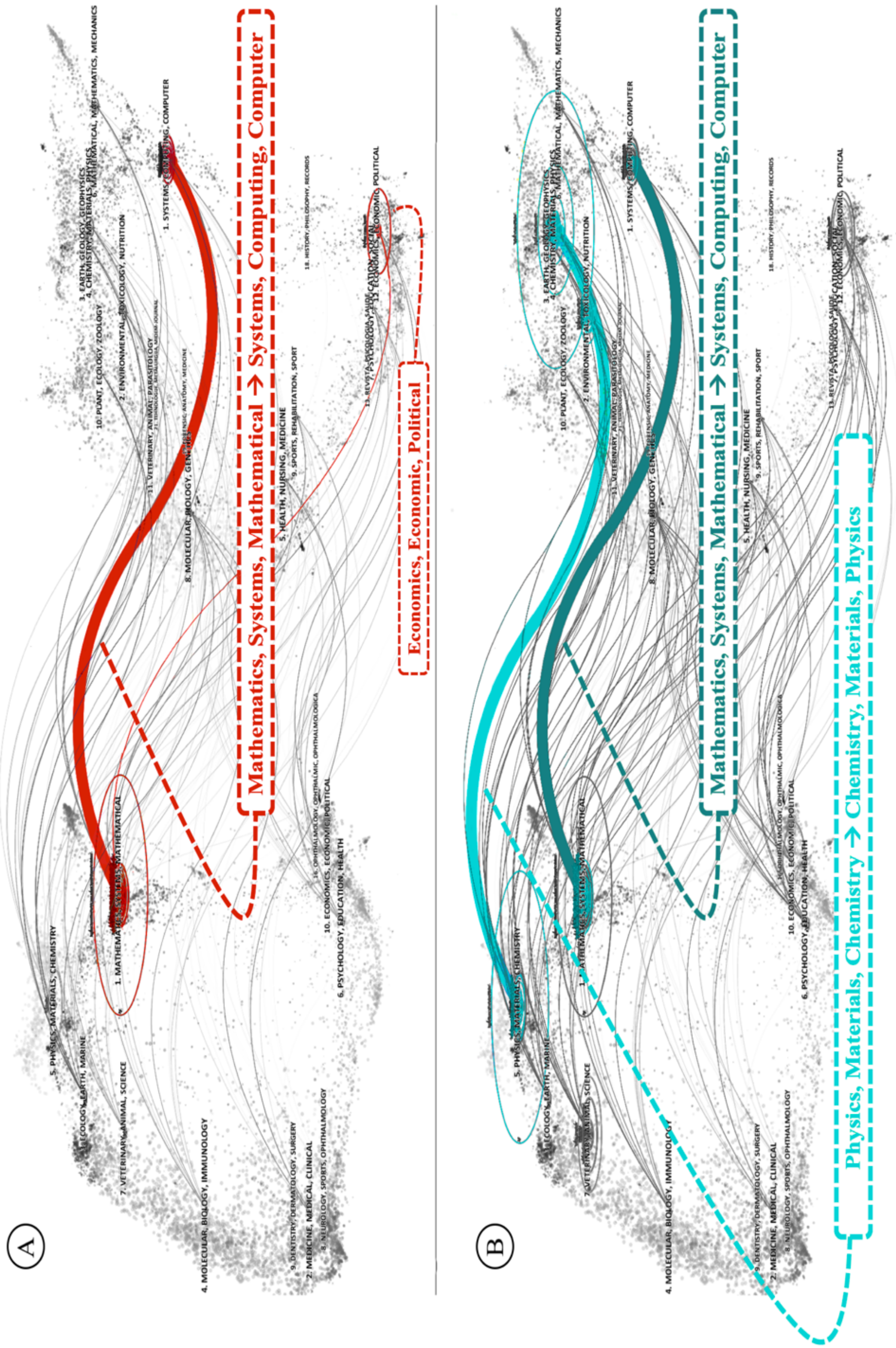



**Fig. 4:** Citation dual-map overlays of AVs and electric vehicles.
Source: prepared by the authors on CiteSpace.

**Web of Science category analysis**

Figure 5 presents the top 20 categories from the total 96 in which the studies on AVs are anchored (demonstrating a multidisciplinarity in the field's knowledge development). However, more than half of the sampled papers (53.49%) fit within the engineering category, 41.14% within computer science, 23.51% within transportation and automation control systems, and 16.26% within robotics, evidencing the technical aspects of the studies in this field. We highlight that each article can be listed within one or more WoS category, explaining why the total exceeds 100%.

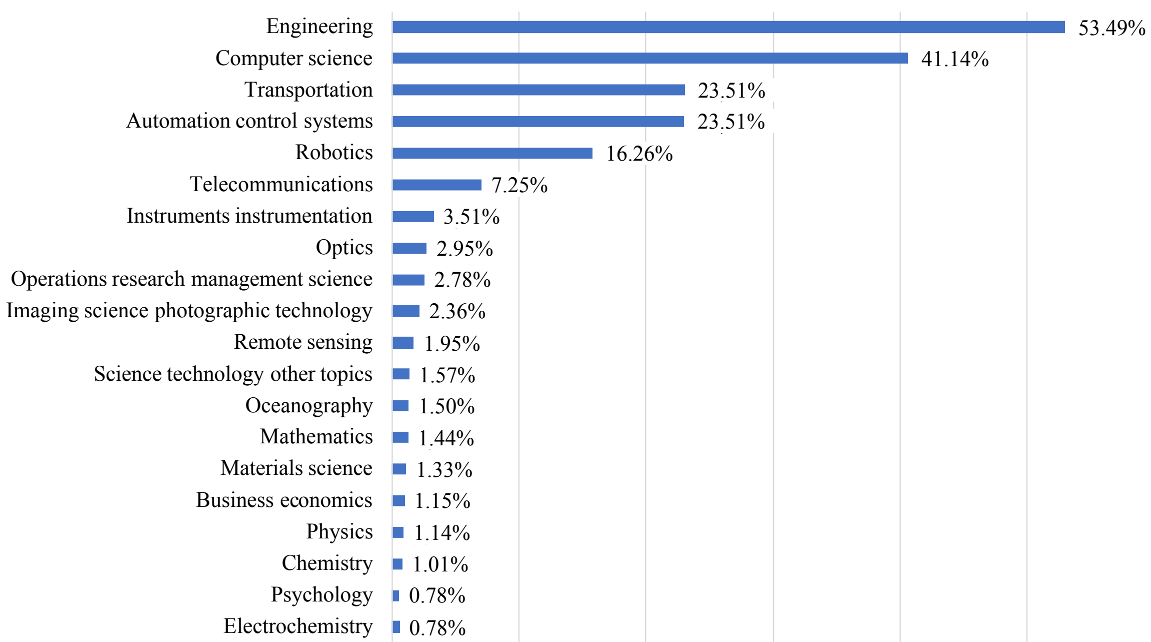



**Fig. 5:** Top 20 research categories
Source: prepared by the authors.

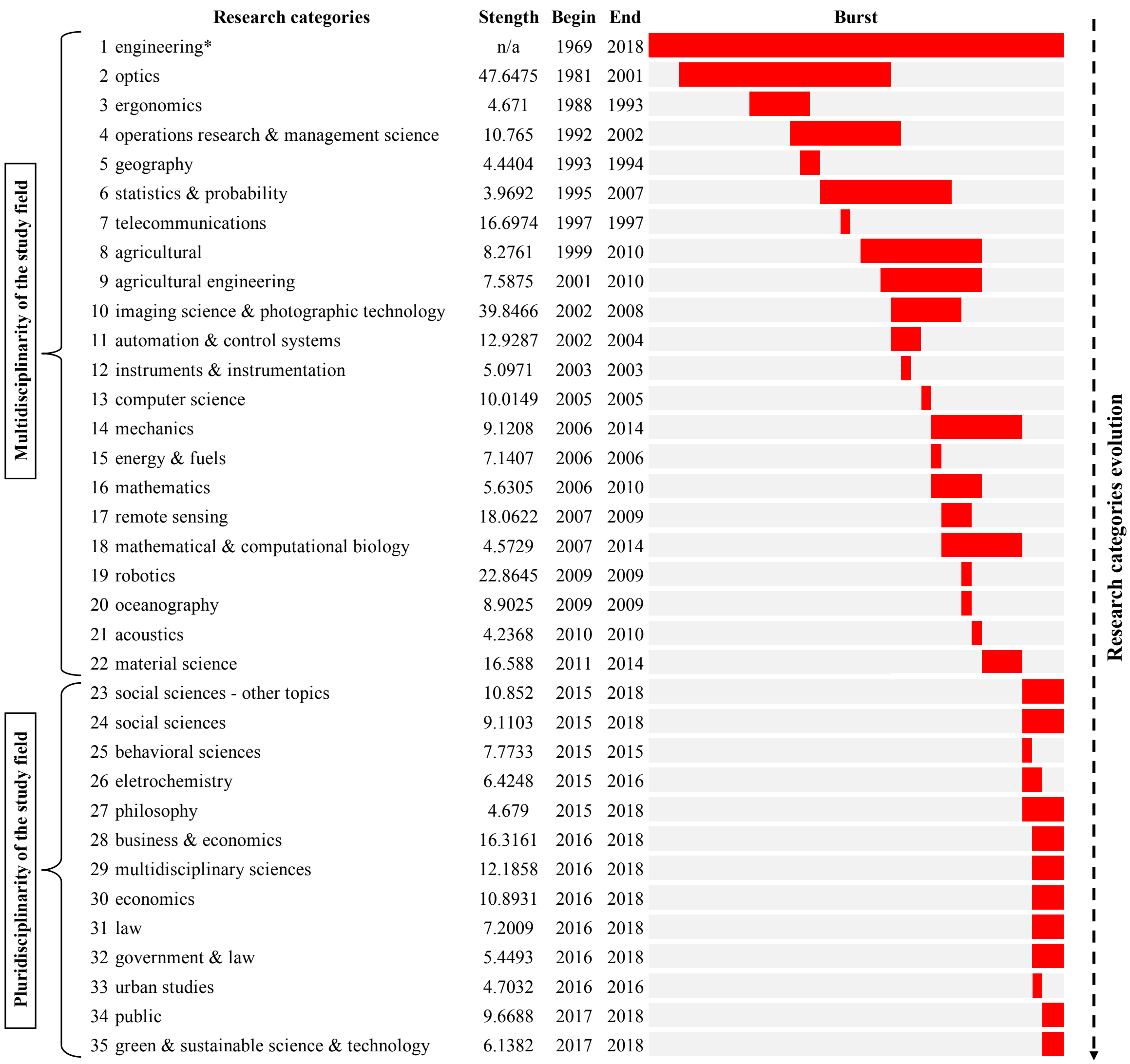
Furthermore, only three of the top twenty categories are non-technical—operational research management science (2.72%), business economics (1.08%), and psychology (0.78%)—which corroborates the aforementioned predominance of technical studies in the AV field.

Such a low incidence of business-related categories in relation to the other areas of knowledge demonstrates a possible mismatch between the technological evolution of the field and the businesses models and platforms necessary for the presence and consolidation of such vehicles on the market. As pointed out by Yun et al. (2016), the business model plays an extremely important role in the events that precede the advancement of AVs in society. Therefore, by increasing the level of the business model, even if the level of technology is not high, the size of the market increases through positive feedback (Yun et al., 2016; Shapiro & Varian, 1999). This development can be achieved by the adoption of standards that organize innovations diffusion (Shapiro & Varian, 1999) or by clusters of formed innovation (Zimmerman, 1995; Kokshagina, 2014).

Therefore, it is expected that the studies in business-related categories, as well as the social-related fields, are going to increase as the introduction of AV really becomes reality in the near future.

To analyze these, Figure 6 shows the categories' bursts, according to Kleinberg's burst-detection algorithm (Kleinberg, 2002). Chen (2006) reinforces that such an algorithm is adapted to identify emergent research-front concepts. To elucidate the use of such algorithms for the above categories, it is worth highlighting that "the burst-detection algorithm can be adapted for detecting sharp increases of interest in a specialty" (Chen, 2006, p. 364). Although Kleinberg (2002) states that the original algorithm was developed to detect the bursts of single words, "the algorithm is generic enough to be applied to a time series of multiword terms or citations of articles" (Chen, 2006, p. 364).

We notice that this scenario has been changing recently, since it is possible to observe, from 2015 onwards, a burst of categories that concern to non-technical aspects of AVs (Figure 6). These are social sciences, management, philosophy, business and economics, law, and urban studies, among others. That is, among the 35 categories that presented a burst of publications, 12 (~35%) were characterized by areas of applied social sciences and humanities. Rather than showing the evolution of the field, this analysis explains the main trends for future studies in the AV field.




*Because of its relevance, the category of Engineering presents an uninterrupted burst.
**Fig. 6** Categories' burst-detection based on WoS data.
Source: prepared by the authors on CiteSpace.

As observed from the number of papers per year analysis, there was an explosion of publications after 2012. During this period, there was a migration of common areas from multidisciplinary (common theme without relation nor cooperation among categories) to pluridisciplinary (common theme with relation and cooperation among categories). Thus, one can hypothesize that technical areas, such as engineering, computer science, and automation, seem to have reached a certain degree of maturity and present a constant variation in the number of publications. On the other hand, the discussions and studies extrapolating AVs technical aspects, by inserting them in a dynamic environment with several agents and implications, are far from being exhausted.

## Keywords analysis

The keyword search on the 10,580 articles aimed at elucidating the main approaches in the field's evolution. In this sense, Figure 7 shows, chronologically, the 46 keywords with greater burst strength, according to Kleinberg's (2002) burst-detection algorithm. The first column displays the keywords; the second column shows the burst strength found by the algorithm, followed by the initial and final burst period; and finally, the corresponding burst time interval is highlighted by the red dashes.

To contextualize the observed results among keyword bursts, it is worth highlighting the historical moment at which DARPA's Grand Challenge was inserted in AV studies. We sought here to bring the discussion on bursts as close to reality as possible to consider DARPA as a watershed on AVs. As pointed out by Lima (2015), the 2004 and 2007 DARPA's Grand Challenges were responsible for leveraging the tests and advancements on AV R&D.

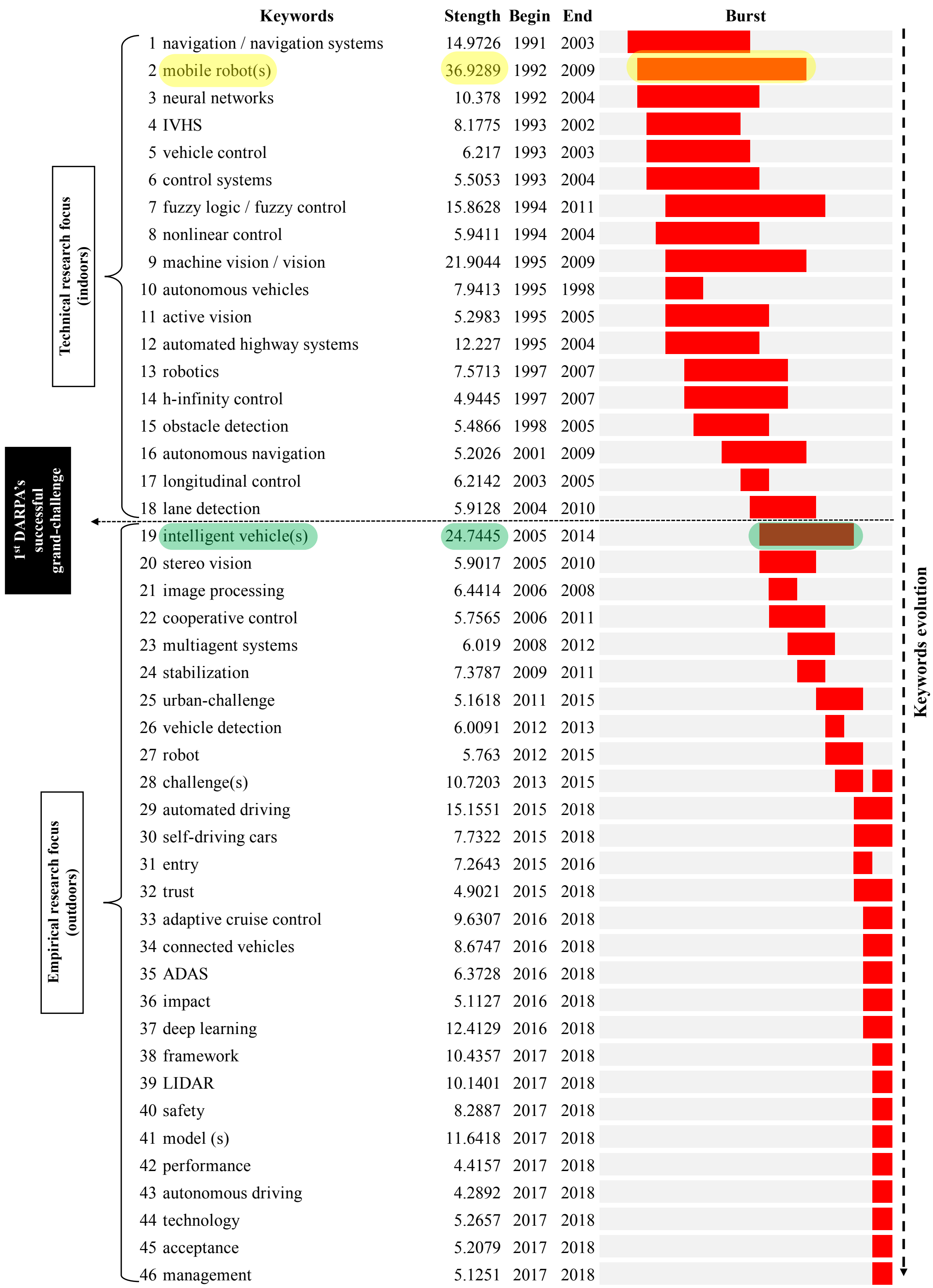



**Fig. 7:** Keywords' burst-detection based on WoS data.
Source: prepared by the authors on CiteSpace.

As per Figure 7, in the years before the challenges, there was a concentration of terms featured as more basic technical-focused regarding the conception of mobile robots, including AV based vehicles. Here, they are denominated as *Technical Indoors Research Focus*, with focus on the keyword “mobile robot(s)” (yellow griffins)—the term showed a strength of 36,9289 from 1992 to 2009, where, for approximately 17 years, the articles related to AVs sought to understand/relate to mobile robots.

Regarding the period after DARPA, here named *Empirical Outdoors Research Focus*, we observed a concern not only centered on the technical characteristics of AVs but also an approach to the systematization and empirical operationalization of vehicles beyond the laboratories. Highlighting (in green griffins) the term “intelligent vehicle(s)” with greater strength (24.7445) and time-span (2005 to 2014). The term “challenge(s)” also has significant strength (10.7203) and a five-year burst (from 2013 to 2015 and then from 2017 to 2018). This shows a strong relation between the publications and the challenges related to AV implementation, including the DARPA challenge.

It is also worth highlighting the terms with the most recent bursts (2017–2018), namely “framework,” “LIDAR,” “safety,” “model(s),” “performance,” “autonomous driving,” “technology,” “acceptance,” and “management,” which demonstrate AVs’ exposure to reality. Finally, note the relationship between “management” and the studied topic, which is the most recent burst. Although the research field is almost 50 years old, only recently studies started focusing on the business impacts that AVs will have on the market.

## Concluding Remarks

This work aimed at conducting a scientometric and bibliometric review to identify the main characteristics of the AV field, as well as its evolution, to highlight potential trends for future studies.

As for the descriptive analysis, there has been a great heterogeneity and a growing demand for this topic over the years. We observed, by the dispersion of authorship in the field, a non-fully constructed science, that a consolidated state-of-the-art on this subject has not yet been identified. This fact is also evidenced by the analysis of Price’s elitism law. After 2012, the number of publications exceeded the trend line, showing an exponential growth of the field in recent years. This fact can be corroborated by analyzing the average science growth rate of around 8–9% per year, while the average growth rate of publications on AV in the analyzed period was 39%. Regarding the higher number of publication sources, it was observed that only 0.70% of the sources are responsible for approximately 33% of the publications on the theme. Therefore, it is worth noting that the scope of AVs is still being widely discussed in congresses and conferences, showing that such research subject is far from being exhausted in academia.

It is worth noting that the academic production country ranking is far from KPMG's Readiness Index ranking (Table 2), due to the analyzed key performance factors. This also implies that the introduction of AVs on the market is highly locally oriented, indicating that many adaptations in technology as well as in business models must be addressed. The country analysis also demonstrates that the number of papers in the field is more representative in areas where public administration stimulated and attracted stakeholders, setting the conditions to undertake tests and authorizing the use of AVs on road infrastructures (e.g., USA, China, and the EU).

As for the in-depth analysis, the dual-map overlay analysis emphasizes the predominant evolution from MSM to SCC, but also indicates performance in all other emergent areas of the AVs field. The dual-map overlay has also demonstrated an alignment between the studies related to AV and electric vehicles, evidencing the industry paths for AVs cross those for electric vehicles. In 2018, there is a trend of exponential advances in electric vehicles, resulting in immediate advantages over traditional fossil fuel vehicles in mobility services. Consequently, there is a tendency that AVs might use electric powertrain technology as one of the possible sustainable engine sources in the future.

The multidisciplinarity is present in 96 areas of research (categories). Although there is a predominance of areas related to the technical evolution of AVs, we noted a growing presence of fields that include these vehicles. We believe that the maturity reached by the studies in technical fields, such as engineering, computer science, and automation, raised new questions about the insertion of this technology on the market, possible involved agents, and main impacts and implications that such vehicles will have on urban mobility.

Although there are studies on business, economics, and management, there is a slight evolution of these domains related to AVs. In this sense, the technological evolution of the area is evident. However, as in any other sector, it is necessary to understand broader aspects of this industry, such as the market factors surrounding them and other economic and managerial issues. The burst analysis of keywords corroborates the recent requirements of the field to extrapolate the technological areas, indicating market plans (e.g., “management” is the most recent keyword burst term). The historical moment at which DARPA’s challenges were created, indicates that the publications post-DARPA move closer to the reality outside laboratories. Further, there is a consensus that technological factors are essential for the fields’ evolution and should not be neglected. However, the other areas are also essential for the dissemination of the field and must follow the opportunities and requirements of this emerging issue.

To sum up, we observed a migration of the field from a multidisciplinary approach to pluridisciplinary one, with a greater number of studies converging to the latter. Additionally, we understand that the efforts regarding standardization of the term ADS (SAE, 2014, 2016) might contribute to achieve this pluridisciplinarity, since the unification of the theme will avoid misunderstandings and may enable clearer and more collaborative exchanges. However, there must be an impulse from academy on the use of this term.

Regarding trending topics, the results of the analysis of categories and keywords related to sustainability, public polices, liability and safety, as well as business issues, such as performance and business models, are characterized as relevant tendencies in AV research. As limitations of this study, it is important to mention the use of the WoS as the only source for data collection, a fact that may not have considered other possible related works in this area. It is also worth mentioning that the terms used in the search could correspond to other types of vehicles (e.g., in chemistry, intelligent vehicles are used as a tool for medical research; in business, we found records of the terms being used for warehouses and logistics). We also highlight that, although the term ADS could solve these limitations, its use is still incipient (yielding in only 118 papers in our search).

The results of this study could contribute with useful insights and inputs to the emerging study areas on AVs. In-depth integrative studies are suggested to investigate what has been done in terms of public policies and law (e.g., government measures, tax incentives, regulatory aspects, liability), cyber-security (e.g., data privacy, data security, hacker attacks), car safety (e.g., analysis of probable crashes and accidents, probability of accidents on different automation levels), sustainability (e.g., environmental impact, ecological footprint, analysis of different fuel types and powertrains, AVs and responsible innovation approach), business-related issues (e.g., consumer acceptance, new market niches, new business models and platforms, impact of shared economy, emergency of MaaS systems). Additionally, as an agenda for future studies, we suggest a more in-depth analysis of the individual publications per searched terms, as well as the sub-areas identified as trends in this paper.

**Acknowledgements**

This paper would not have been possible without the support of the Post-Graduate Program in Administration of *Universidade Federal de Lavras* (PPGA/UFLA - Brazil) and the *Laboratoire Génie Industriel* (LGI / *CentraleSupélec – Université Paris-Saclay /* France). We also would like to thank the founding institutions: *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES - Brazil) and *Fundação de Amparo de Pesquisa de Minas Gerais* (Fapemig - Brazil).

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**ARTICLE 3: Willingness to use Mobility as a Service in a developing country.**

**Preliminary version of the paper <u>published</u> on the proceedings of 25th International Conference on Urban Transport and the Environment, Aveiro, 2019.**

Gandia, R. M.; Oliveira, J. R.; Antonialli, F.; Sugano, J. Y.; Nicolaï, I.; Oliveira, I. R. C. (2019). Predisposition and Consumer: Behavior Towards Mobility as a Service among University Students in a Developing Country. In: 25th International Conference on Urban Transport and the Environment, 2019, Aveiro (Portugal). Proceedings of the 25th International Conference on Urban Transport and the Environment.

**Full Paper accepted on**
**International Journal of Transport Development and Integration**
**ISSN: 2058-8313**

# Willingness to use MaaS in a developing country

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**Abstract:** Mobility as a Service (MaaS) presents a shift from existing ownership-based transports and towards access-based ones and it has been recently gaining ground in urban mobility. MaaS is still surrounded by uncertainties and, its development and applicability are mainly centered in developed countries. However, we believe that MaaS is modular, adaptable and applicable to several realities. In this sense, this study aims to examine the perception of different transport models among students and to find the profile that can predict respondents' willingness to use MaaS in a developing country. This survey was applied to over 300 university students in a Brazilian city (Lavras). Using the CART algorithm, we obtained classification trees to predict favorable responses related to MaaS use, based on several predictor variables (socio-economic characteristics, means of transport used, distance and other). We observed that, car users are a little less sensitive to cost than non-car users. For car users, commute alternatives that take longer, with less flexibility and availability – even when offered at lower costs – are not appealing, while non-car users accept and spend more time whether lower costs are available. Also, in general, the tree-based classification model predicted a positive adherence possibility for a MaaS system for both car users and non-car users (69%). As conclusions, this study suggests a predisposition to MaaS model for creating value for commuters in a developing country. We found that many MaaS' characteristics (e.g. app payment, transport integration, monthly plan, customization, son on.) presented a positive predicted possibility of substitution, especially for millennials. Also, we found that bicycle may be a modal that can be explored for MaaS systems worldwide, and casual carpooling could be used as strategy to apply MaaS in places where the public transport lacks efficiency.

**Keywords:** Mobility as a Service; Consumer behavior; Travel behavior; Urban mobility; Tree-based classification model.

## Introduction

Urban mobility worldwide is suffering due to the crescent number of vehicles. In the course of the 20$^{th}$ century, the private car has become the dominant mode of transportation, fulfilling the growing needs of individuality, independence and flexibility (Urry, 2004; Shuppan et al., 2014). At the same time, car-based transportation systems are responsible for a variety of negative environmental impacts, both on a global and local level such as; noise and air pollution, emission of greenhouse gases, traffic jams, road accidents, fragmentation of ecologically valuable land, increased health costs and hence contributes to climate change (Epprecht et al., 2014; Stern, 2007). Thereby, urban mobility is suffering due to this rapid increase on vehicles' numbers, hence, the challenge now is to enhance mobility and accessibility while, at the same time, reducing congestion, road accidents, and pollution in cities.

In this sense, the challenge is 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). As alternative, shared mobility has the potential to reduce the private vehicle use and their negative environmental effects (Fishman et al., 2014; Martin et al., 2010; Wong et al., 2017). In this sense, the concept of Mobility as a Service (MaaS) has been gaining ground in recent years and becoming a concrete market option, by presenting a shift away from the existing ownership-based transport system toward an access-based one (Jittrapirom et al., 2017; Ambrosino et al. 2016; Mulley, 2017; Kamargianni et al., 2016).

The MaaS concept is fairly recent (Hietanen, 2014) and brings an innovative approach to traditional transport practices. However, MaaS is still surrounded by ambiguities and uncertainties, especially related to its main characteristics and use (Jittrapirom et al., 2017). Furthermore, most of MaaS deployments are mainly centered in developed countries with efficient transport systems (Jittrapirom et al., 2017; Kamargianni, Matyas & Schäfer, 2016). On the other hand, we believe that MaaS is modular, adaptable and applicable to several realities. In this sense, an eventual MaaS user (in any given context) should perceive a level of value that surpasses vehicle ownership or any other utilized transport mode.

Although there are still gaps in its theoretical field, there is a consensus related to its key concept, which is to offer tailored-made on-demand integrated mobility solutions based on users' needs (Hensher, 2017; Ambrosino et al., 2016; Matyas and Kamargianni, 2017; Jittrapirom et al., 2017; Datson et al., 2016). This approach places the user as central to aspects related to mobility, as pointed out by Hannon et al. (2016), the individual traveler is at the heart of this evolution, so consumers need to be open to adopting new technologies and services. Nevertheless, "there is very limited insight to date in terms of the behavioral impact of MaaS or its future potential" (Lyons et al., 2019, p. 26). In addition, studies on consumer behavior and MaaS usage are still incipient as well as the fact that research on MaaS in developing countries have not yet been found in the literature (Antonialli, 2018).

Early adopters of MaaS are expected to be comprised of younger generations (Gen-Z and Millennials) because of their commute patterns – flexible travelers, who combine different modes of transport to make their trips (Jittrapirom & Marchau, 2018). Mostly of university and college students can be comprehended as belonging to Gen-Z or Millennials, in this sense, it is important to understand the willingness to use MaaS from this group in order to comprehend whether MaaS can be achieved, by the consumer perspective, in a developing country.

Given the aforementioned the following questions were raised as guidelines for the present study: Which are the main characteristics of transport modes valued by university students? Is there demand predisposition for MaaS among university students from a developing country? Which are the profiles more susceptible to use a MaaS system among those students? In this sense, this study aims **to examine the perception of different transport models among students and to find the profile that can predict respondents' willingness to use MaaS in a developing country**. We understand that this paper provides as a first step, some insights to implement a MaaS system in a developing country, considerate the user-perspective.

## Background

In terms of mobility, the choice for a given mode of transport is an indicator of an individual's commute pattern, which is mainly guided by the following factors: cost, time, and comfort. Private cars are very good at fulfilling the "comfort" requirement and to some extent "time", which makes it one the most suitable options for those who can afford it (Kamau et al., 2016). Complementary, as stated by Hans Arby (CEO of UbiGo) car ownership is a kind of "mobility insurance" and therefore represents flexibility and availability for its owners (Flügge, 2017).

On the other hand, as pointed out by (Schuppan et al., 2014), some people rather use their cars due to poorly city infrastructures or inappropriate offers of alternatives modes of transport. Furthermore, as elucidated by (Steg, 2005), historically car usage could be explained by instrumental factors such as speed, flexibility and convenience. However, the author states that symbolic and affective aspects also significantly influence the use cars.

Nevertheless, younger generation cohorts (such as millennials and gen-z) seems to prefer alternative modes of transport when compared to previous generations; they are owning fewer cars, driving less and, making more use of other transport modes (Delbosc et al., 2019). In this sense, perceive mobility not as a “product” (a physical asset to be purchased – e.g., a car) but as a “service” (available on-demand and with bundled transport offerings) seems to be congruent with these generations (Ambrosino et al., 2016).

Even an industry as robust and consolidated as the automotive one, could suffer from a change of habits of a generation – as the example of several consolidated industries that were disrupted by digitalization: Kodak vs. digital cameras; Blockbuster vs. Netflix; encyclopedia Britannica vs. Wikipedia; hotels vs. Airbnb, and so on (Parker et al., 2016).

With an expectation that MaaS will be firstly adopted by younger generations, it has the potential to disrupt the mobility industry on the same as the aforementioned new business platforms entrants disrupted traditional business models (Utriainen & Pöllänen, 2018; Jittrapirom et al., 2018).

In this sense, dematerialization practices (Magaudda, 2011) seem to be aligned with the consumption practices proposed by MaaS, with some evidences of this phenomenon already being observed. For instance, the results from UbiGo (MaaS operator in Stockholm) indicate an increase in usage of sustainable transport modes while private cars usage was reduced in 50% (Utriainen & Pöllänen, 2018; Strömberg et al., 2016).

It is worth mentioning however, that such positive MaaS results are derived from experiments carried out in developed countries and regions (with good city infrastructure and efficient transportation modes), thus differing dramatically from the scope for implementation of MaaS proposed in this study. According to Delbosc et al. (2019) travels’ behaviors are location-based, that is the context in which mobility offerings are inserted matters. With that, it is not reasonable to believe that a given MaaS implementation will be effective in another reality, in a sense that, as stated by Datson (2016, p.7) "there will be no one model of MaaS that fits all".

## Research methodology

With the aim of identifying the perception of different transport modes among students and to find the profile that can predict respondents' willingness to use MaaS in a developing country, this study is characterized as quantitative of descriptive and exploratory nature. Figure 1 presents the detailed research carried out.

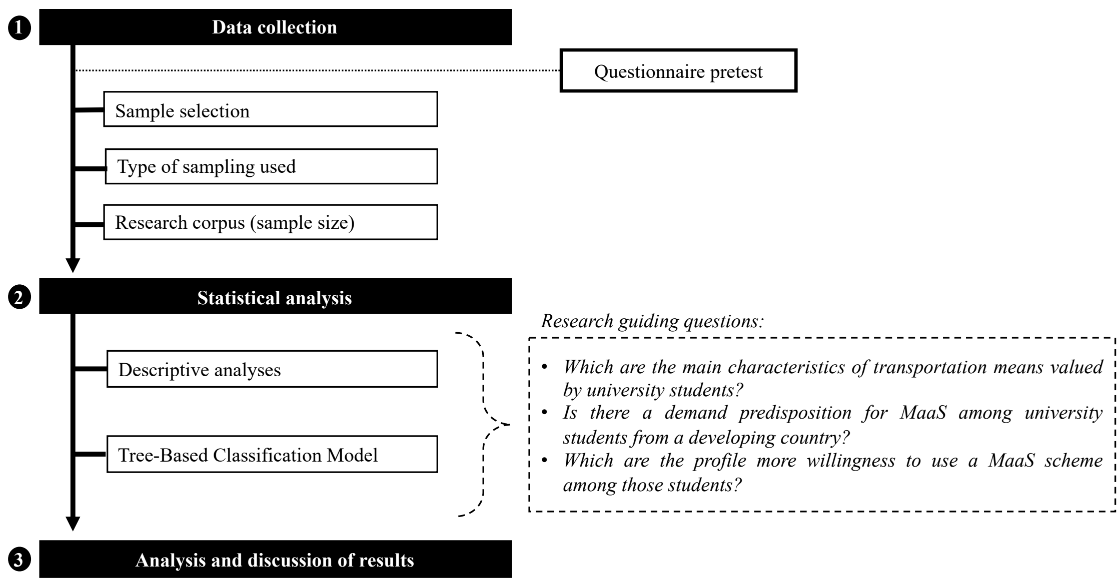



**Fig. 1:** Research design.
Source: prepared by the authors.

The first step referred to data collection. The survey was applied to 307 university students in Lavras - Brazil, enrolled in the second academic semester of 2018. This city of approximately 100,000 inhabitants was chosen as a study object given its peculiar mobility features. Due to the high number of university students the act of casual carpooling is common practice on their daily commute, especially in the public university which institutionalized this practice. Casual carpooling consists in the act of informal carpools for purposes of commuting and can be understood as a variation of hitchhiking for urban areas (Shaheen, Chan & Gaynor, 2016; Maltzman & Beroldo, 1987; Chan & Shaheen, 2012). Their essential idea is to provide a free ride for a passenger in order to complete idles seats in the car. The campus of public university counts with five stops for casual carpooling, which all have different destinations in the city.

Data collection was done by a cross-sectional study (survey) with application of a questionnaire among students of the four Higher Education Institutions (HEI) of the city (1 public and 3 private institutions). The selection of participants was done by non-probabilistic sampling (Aaker, Kumar & Day, 2001; Malhotra, 2001; Hair, 2005). The questionnaire used in data collection consisted mainly of qualitative questions. In addition to the characteristics of the individual, their motivations for choosing some transportation means and predisposition for sharing were investigated.

After, step 2 consisted in statistical analyzes. Descriptive statistics and tree-based classification models were used. We use the CART algorithm (Breiman et al., 1984) as implemented in the rpart R package followed by the plots obtained through the rpart.plot package. Also, it's important to highlight that we considered two distinct groups within the transport modes commute, 1) with car ownership, and 2) without car ownership.

In order to answer our first guideline question (which are the main characteristics of transportation means valued by university students) descriptive analyzes was used. Furthermore, the other guidelines questions (is there a demand predisposition for MaaS among university students from a developing country?; and which are the profile more willingness to use a MaaS system among those students?) we used descriptive and tree-based classification models.

Classification trees model a categorical response variable (in our case, a binary variable with answers Yes and No), as a function of one or more predictor variables, which can be both categorical and numerical. This technique (Classification trees) is particularly useful when there are a large number of predictor variables involved in the analysis.

The tree is constructed by repeatedly subdividing the data into two distinct paths per variable. Those divisions are dichotomic, splitting data into two mutually exclusive groups. The division procedure starts with the "root node" - a variable which explains most of the variability in the data. In the sequence the same procedure is applied to the subsequent nodes until the tree remains reasonably small. To interpret it, the partitions are read from top to bottom, where the left paths indicate that the condition on each partition (for each variable) has been fulfilled.

In order to understand the predisposition to use MaaS and the profiles more willingness to use MaaS from both the perspective of users with and without car ownership, two tree-based classification models were built (one for each group). Considering that MaaS is a fairly recent concept (Hietanen, 2014), many of the sampled users might not have been familiar with it. Thus, for the trees' construction we used in single statements (that were presented to the respondents) a compilation of features inherent from a MaaS platforms. In both cases we considered predictor variables; age, sex, income, marital status, study day- time, driver's license possession, distance from the institution, monthly expenses with transportation, commute weekly frequency and, type of institution (public or private). At last, step 3 consisted of the analysis and discussion of results.

**Analyzes and results**

The average age range for car users were 25 years- old while for non-users was 22. As for gender, numbers were similar for men and woman (141 and 166 responses, respectively). As our sample comprised of university students, the majority of respondents were single (282), with only 22 married and 2 divorced.

**Importance of transport mode choice**

Table 1 depicts the benefits perceived by the users regarding the choice of a transport mode – which they are depicted as columns and the independent variables as lines in the table. Such variables were analyzed in 5-point scales (ranging from 0 – less important, to 4 – most important) for each transport mode.

Compared to other transport modes, vehicle owners pointed out that they opted for this modal mostly because of its agility (3.83), flexibility (3.82), availability (3.73), security (3.60) and comfort (3.28) and, such results are congruent with the ones found by Kamau et al. (2016) and Flügge (2017).

Although the cost per trip for car owners is the factor with the least repercussion among the other transport modes (2.38), it was observed the such average is not much higher than the ones of other transport modes such as: bicycles, buses, or even walking. This may be explained because, in general, car owners tend to consider only fuel costs when questioned about their commute costs and, forget to include the fixed costs and other additional expenses like insurances, taxes, depreciation (Lyons et al., 2019).

Thus, this can be a complicating factor in attracting car owners to participate as a transport mode in MaaS systems. For instance, Lyons et al. (2019) concluded that the installment purchase of a Ford Fiesta and the monthly subscription of Whim (MaaS system in Helsinki) would have very similar cost values.

Regarding status, we observed that car owners do not value the fact of "being seen driving an automobile" as something important to them (0.47). This goes against the symbolic and affective propositions in the choice of modal proposed by Steg (2005). Such result may be explained due to profile of the sample – millennials or gen-Z university student – and their unique commute patterns regarding transport modes (Delbosc et al., 2019), which may lead to their motives to use a car being more instrumental than affective and / or symbolic.

On the other hand, the modal that presented the highest averages attributed to status was bicycle (1.00), that may be linked to the assumption that bicycles incite health and sustainability-related benefits – which may be influencers of this perception of status. This can be supported by the fact that this modal presented the highest averages regarding care for health and sustainability (both 3.00), in this way, bicycle is a modal still neglected in MaaS studies (Utriainen & Pöllänen, 2018) but it is a one that holds great potential (specially for the first- and last-miles of the daily commute). Corroborating with this, Mulley (2017) states that the recognition of active travel commute (e.g., cycling) can play a fundamental role on pushing this modal towards MaaS.

The search for parking spaces stimulated by high urban density is another factor that may influence the predisposition towards MaaS (Mulley, 2017). We observed that motorcycle users are the most concerned about parking difficulties (3.43). In this sense, it is important to highlight that, just as the lack of infrastructure can discourage the deployment of MaaS systems, the opposite can also serve as a stimulus (as in the case of the provision of parking spaces). In a study carried out in Sweden on corporate MaaS (CMaaS) it was observed that while drivers had their cars parked outside the company, many potential users have never used the CMaaS system (Hesselgren, Sjöman & Pernestål, 2019).

**Table 1:** Variables importance on the choice of transport mode by the participants

| | Car (driver) | | Without car ownership | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Car (passenger) | | Walking | | Bus/Shuttle | | Motorcycle | | Bicycle | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Agility** | 3.83 | 0.494 | 3.69 | 0.467 | 2.73 | 1.423 | 2.89 | 1.191 | 3.86 | 0.434 | 3.00 | 0.816 |
| **Availability** | 3.73 | 0.617 | 2.97 | 1.206 | 3.10 | 1.287 | 2.77 | 1.310 | 3.66 | 0.802 | 3.00 | 0.816 |
| **Care for health** | 2.82 | 1.276 | 2.75 | 1.380 | 2.82 | 1.289 | 2.47 | 1.521 | 2.53 | 1.502 | 3.00 | 0.816 |
| **Comfort** | 3.28 | 0.992 | 2.69 | 1.369 | 2.01 | 1.557 | 2.56 | 1.382 | 2.40 | 1.354 | 1.50 | 0.577 |
| **Cost** | 2.38 | 1.350 | 3.16 | 1.183 | 3.08 | 1.531 | 3.13 | 1.036 | 3.53 | 1.041 | 3.50 | 0.577 |
| **Flexibility** | 3.82 | 0.418 | 2.88 | 1.326 | 3.22 | 1.151 | 2.46 | 1.531 | 3.66 | 0.711 | 3.00 | 0.816 |
| **Parking difficulties** | 2.80 | 1.280 | ----- | ----- | ----- | ----- | ----- | ----- | 3.43 | 1.040 | 2.75 | 0.957 |
| **Safety** | 3.60 | 0.761 | 3.22 | 1.244 | 2.55 | 1.579 | 3.13 | 1.148 | 2.66 | 1.268 | 1.75 | 0.500 |
| **Status** | 0.47 | 0.893 | 0.36 | 0.833 | 0.53 | 1.140 | 0.62 | 1.119 | 0.76 | 1.250 | 1.00 | 1.154 |
| **Sustainability** | 1.78 | 1.438 | 2.19 | 1.489 | 2.85 | 1.149 | 2.72 | 1.247 | 2.13 | 1.547 | 3.00 | 0.816 |
| **Traffic avoidance** | 2.70 | 1.030 | 2.36 | 1.220 | 2.38 | 1.629 | 2.28 | 1.400 | 3.40 | 0.968 | 3.00 | 0.816 |

For public transportation users (Bus) "costs" and "safety" were the determining factors for the modal choice (both 3.13). In a similar way, we observed that the profile of users using cars as passengers presented averages very similar to public transport users (except for the "agility" factor that is most valued by car passengers - 3.69 compared to 2.89). This may represent an eventual migration of public transport users towards casual carpooling as a transport mode (thus balancing the deficiency presented by the latter) which could contribute to MaaS implementation in any given locality.

## Multimodality instead of ownership

Table 2 presents the predisposition to change vehicle ownership (with car ownership) or unwillingness to own a vehicle (without car ownership) in detriment of cost. Percentages of "yes" answers for each statement were analyzed.

**Table 2**: Willingness to use other transport modes instead of cars in detriment of cost

| | With car ownership | Without car ownership |
|---|---|---|
| **Lower Cost, but…** | | |
| …Longer travel times | 33,33% | 52,97% |

| | | |
|---|---|---|
| …Less comfort | 55,13% | 66,21% |
| …Less avaliability | 23,08% | 25,57% |
| …Less flexibility | 16,67% | 28,31% |
| …Less convenience | 25,64% | 21,46% |
| …Shared commute | 67,95% | 89,50% |
| …Change of transport mode | 61,54% | 72,15% |

It was observed that, except for the affirmative "cost over travel time" - for the non-drivers group, all other assertions pointed out that cost is not the predominant factor for both groups. The fact that non-drivers are slightly more vulnerable to price as a result of travel time, may have a relationship with the waiting habit inherent to other transport means (e.g., bus) rather than the car. Thus, in general, users who own vehicles are somewhat less cost-influenced than non-drivers.

When asked about a reduction in flexibility, convenience and availability (although this would also lead to a reduction in cost), both groups were not willing to the change, and the acceptance rate was low for all categories. The increase in convenience – when there was an increase in cost – presented similar average results, that is, lower acceptance. In this way, we observe that flexibility, availability and comfort are variables not only valued by car users (Kamau et al., 2016) but also valued by users of other transport modes.

However, the statements involving sharing and exchange of transport modes showed opposite results. Acceptance was high for both groups and categories, especially regarding vehicle sharing for non-drivers, which achieved 89.50% acceptance linked to reduced costs. This may corroborate the strategy of including casual carpooling as a transport mode (especially with regards to users without car ownership), as a way to complement a possible bottleneck in public transportation. In addition, the willingness to transport mode exchange for reduced costs is in agreement with the proposal of modal integration within MaaS systems.

**Tree-based classification models**

MaaS is still a incipient concept, which many users might not be familiar with. Thus, for the construction of the trees we use a compilation of characteristics present in a MaaS system, in the same statement. Thus, users were asked if they would change their private vehicle (tree model #1) or would no longer purchase a private vehicle (tree model # 2) for a "means of transport that would integrate multiple transport modals on a single platform (mobile app) and charge a monthly plan for it". Still, it is noteworthy that, in order to reach greater assertiveness, characteristics such as; "payment via app", "monthly plan", "transport integration", and, "customized" were analyzed separately for users with and without car ownership (Table 3).

**Table 3**: Willingness to use MaaS system based on their characteristics

| | **With car ownership** | **Without car ownership** |
|---|---|---|
| **MaaS Characteristics** | | |
| Payment via App | 71,79% | 68,04% |
| Monthly plan | 69,23% | 69,41% |
| Transport integration | 79,49% | 85,39% |
| Customized | 79,49% | 84,93% |

We observed that all MaaS' characteristics presented positive results regarding the willingness to use. The analyzes were performed as in Table 2 and the results, although not part of the tree construction, were used to support the discussion.

**Tree #1: Willingness to use MaaS from user with car ownership**

As depicted by Figure 2, in general, 69% of car owners were willing to use a MaaS system. Five splitting variables were identified: 1) income, 2) weekly commute frequency, 3) lone commutes, 4) day/night study-shift and, 5) transportation expenses.

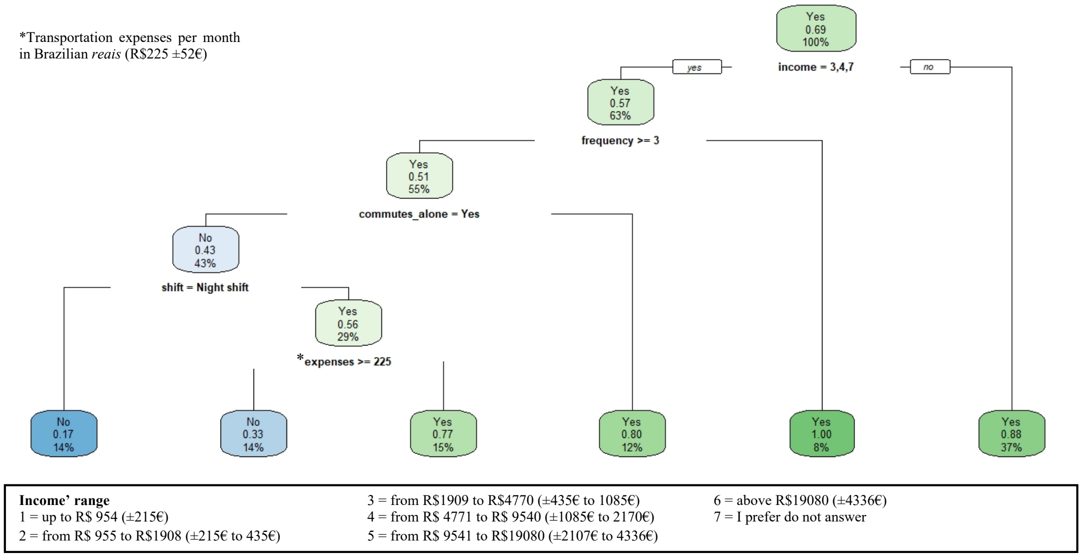
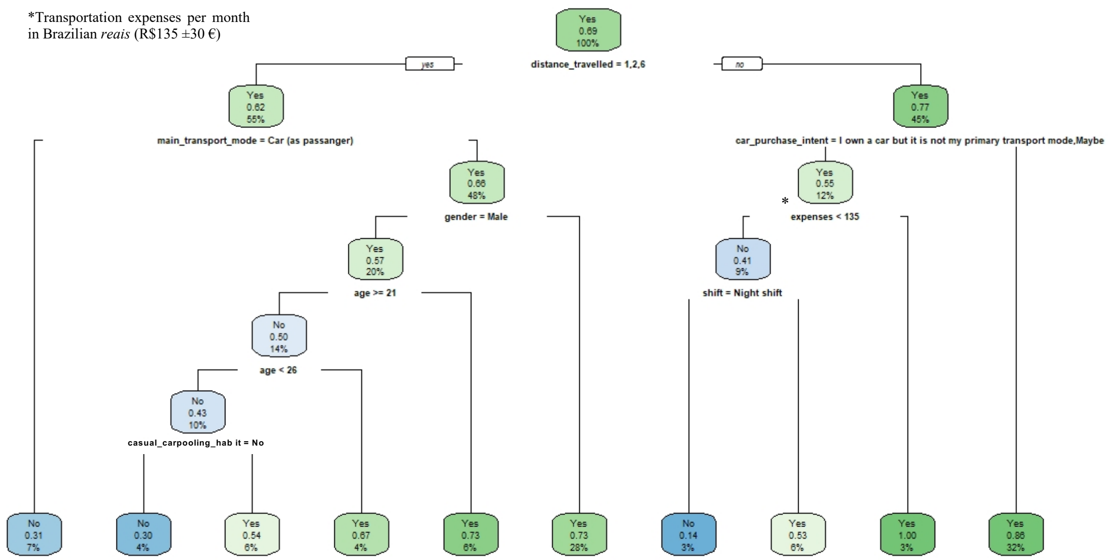



**Fig. 2:** Willingness to use Mobility as a Service from users with car ownership
Source: prepared by the authors.

We observed that the profile most likely to use MaaS systems are commuters with intermediate income rates that use their cars 3 times or less per week (100% of cases). On the other hand, we observed that commuters with intermediate income rates, with higher frequencies of car usage (superior than 3 times a week) and that are used to commute alone (especially in the night-shift) present lower adherence and less predisposition towards MaaS systems (only 17% of cases).

**Tree #2: Willingness to use MaaS from users without car ownership**

As observed on Figure 3, similarly to results obtained on Tree #1 in general, users without car ownership have also presented a high predisposition to use MaaS systems (69% of respondents). For this second model, eight splitting variables were identified: 1) distance travelled [daily average], 2) main transport mode, 3) car purchase intent, 4) gender, 5) age, 6) casual carpooling habit, 7) day/night study- shift and, 8) transportation expenses.




| Distance travel | 1 = up to 500m<br>2 = from 500m to 1km | 3 = from 1km to 2 km<br>4 = from 2km to 3 km | 5 = from 3 km to 4 km<br>6 = above 4 km |
|---|---|---|---|

**Fig. 2** Willingness to use MaaS from users without car ownership
Source: prepared by the authors.

In the case of users without car ownership, we observed that those who travel daily between 1km and 4km (3, 4, 5), who already own a car (but not as the main means of transport) or those who intend of buying a car and that have monthly transport expenses of more than 30 euros present 100% of predisposition to MaaS models. On the other hand, users with monthly transport costs of less than 30 euros, intermediate commute distances, who already own a car (or those who intend to buy one) and with predominant commuting habits during the night shift, presented only 14% of predisposition towards models of MaaS (most negative profile among the sampled users).

## Discussion

A MaaS system consists of different modes of transport to provide an integrated mobility service for the user. (Jittrapirom et al., 2017; Kamargianni, Matyas & Schäfer, 2016). In this sense, map the motivating factors and barriers to the use of transport mode by users is to understand the specificities to be eventually inserted in a MaaS system.

From our analysis, we identified two categories of transport modes: users who own cars and those who do not. In the first category, the driver may choose not to share his vehicle or to do so (as a driver). In the second category, 5 options were identified, car (as a passenger), motorcycle, bus / shuttle, walking, and bicycle. It’s worth highlighting that a car owner, may also opt to use any of the categories identified for the non-drivers.

For each mode the main benefits and barriers to their use were identified from the users' reports. We identified that there are distinct behaviors between whether or not to share a vehicle. We consider that environmental factors and personal motivations may be responsible for this transition, as well as other unknown factors. In addition, sharing a car (as a driver) has motivations and demotivation that were not analyzed because it is not part of the scope of this work.

At last, we understand that it is necessary to analyze the impact of each transport mode in a MaaS model based on urban mobility issues that such given a mode entail. Thus, we consider that car ownership presents higher issues for urban mobility than non-ownership. Among the alternatives, the worst scenario for urban mobility is a given user that owns a car and is not open to share it. In this sense, users who own the car but are open to sharing, and those who do not own the car, and use any of the other alternatives, present less harmful measures for urban transport.

Given the aforementioned and based on the importance of choice of the transport mode (Table 1), we plotted the higher and lower factor indicated in our results for each mode of transport based in a spectrum indicating the urban mobility issues (Figure 4).

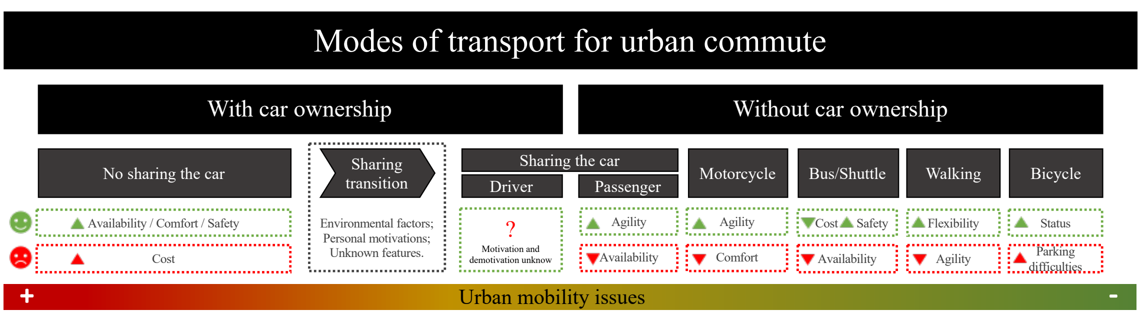



**Fig. 4**: Impact of transport modes on urban mobility
Source: prepared by the authors.

Looking at Figure 4, we understand that the real challenge is to implement a solution that better satisfies the mobility needs than the usage of a private car. The factors that discourage users from using transport modes with less impact on urban mobility (carsharing, motorcycle, bus/shuttle, walking, bicycle) are mostly related to availability, agility and parking difficulties. A MaaS system seeks to contribute exactly with solutions in optimizing the availability and agility of the search for the most appropriate transport mode with the aid of ICTs.

According to Kamau et al. (2016), on public transport – despite of more being affordable – users face less comfort and more time constraints than private car users. Thus, even with individual car ownership being one of the most comfortable options for those who can afford it, MaaS systems will help to contribute by minimizing the shortcomings of using other transport modes.

However, as postulated by Hitenan (2019), we agree that a MaaS system is not suited for all user groups. Thus, it is important to understand exactly the predisposed profile to use MaaS in order to start implementing a model from the most suitable users. Thus, we mapped the determinant variables for the use of MaaS and the profile of users with greater predisposition to its use, both for users with and without car ownership (Figure 5).

| | Determinant variables in the willingness to use MaaS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Income | Commute Frequency | Sharing commute habit | Day/night shift | Transport expenses | Distance travelled | Car purchase intent | Gender | Age | Casual carpooling habit |
| With car ownership | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | |
| Without car ownership | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

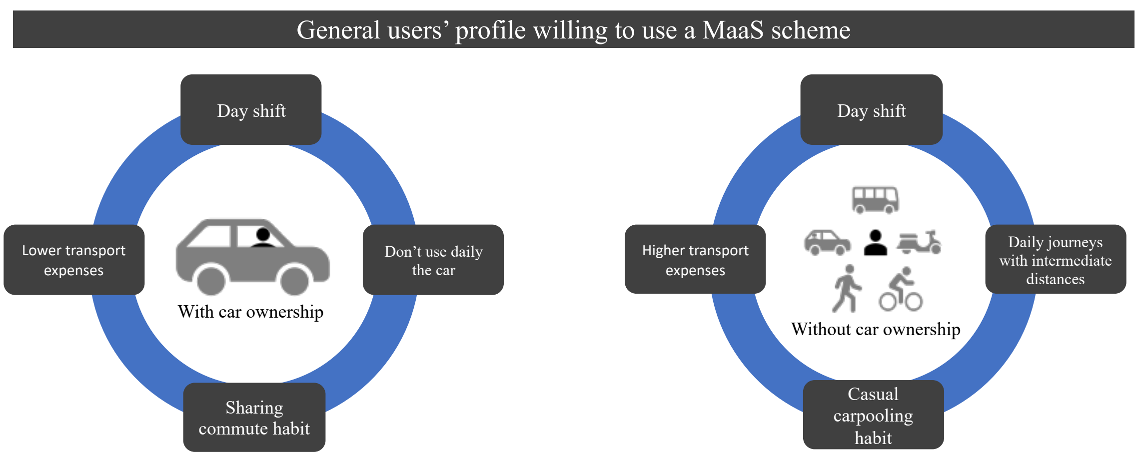



**Fig. 5**: Determinant variables for a MaaS system for the selected user groups
Source: prepared by the authors.

When it comes to adherence to a MaaS model, we observed that the night shift of studies had negative influences for both groups of commuters. In the same way, transport expenses influenced both profiles, while higher commute expenses negatively reflected the model for drivers, lower transport expenditures positively influenced the MaaS adherence regarding non-drivers.

This reinforces the greater sensitivity to the price of non-drivers (as previously depicted on the descriptive analyzes). Also, shared travel habits of users for both groups influence the predisposition to MaaS. At last, we observerd that car owners that do not use their cars on a daily basis, are more willing to take part in a MaaS system, as well as for those users that do not own vehicles, and that have a daily commute of intermediate distances, are also more prone to MaaS systems.

**Concluding remarks**

MaaS seeks to integrate on-demand commute via bundled offerings of public and private transportation on a single platform. However, as far as we know, MaaS studies have only been carried out in developed countries – with efficient public transport networks (Gandia et al, 2019). Consequently, we observed a gap with regards to both academic studies and practical deployment of MaaS systems in developing countries.

By the results obtained in this study, we observed the willingness to use MaaS systems among commuters in a developing country. In fact, there is a big challenge to offer seamless transportation in a country where public transport is inefficient. Nevertheless, we believe that MaaS is modular and adaptable and can be implemented to any context as long as users (commuters) perceive value.

The results pointed out by trees #1 and #2 displayed a general 69% of adherence rate from both car users and non-car users towards MaaS. Considering that the average age of our sample was between 22 and 25 years-old, we can infer that MaaS in a developing country has a positive acceptance from Millenialls, corroborating with (Jittrapirom & Marchau, 2018). Furthermore, we also found that, when we analyzed isolated characteristics such as: app payment, transport integration, monthly plan and customization, results presented a positive probability of substitution for car users and non-car users.

Thus, while income has a predictive impact on car users, the daily distance traveled is the variable that exerts most influence on non-car users. Factors such as day/night study-shift, transportation expenses, vehicle ownership, gender, age, hitchhiking habit and main transport mode used, had positive and negative impacts on the prediction of predisposition towards MaaS.

We observed that, among car users, the commute alternatives that take longer, with less flexibility and availability – even when offered at lower costs – were not appealing. Corroborating with this, car users pointed out flexibility, availability and agility as the most important characteristics in the choice of car. Also, the status was not signalized as representative for the car's choice. In this sense, we believe that a MaaS model that delivers more flexibility, availability and agility may be an option for car users in a developing country.

Regarding non-car users, we observed a relationship among car as a passengers' users and public transport' users. In general, the importance given to the choice of modal hitchhiking (except for the variable "agility"), is similar to the public transport' user (e.g. comfort, cost, safety, availability). Thus, we believe that MaaS' hitchhiking modal can be a strategic alternative to address the lack of public transportation efficiency in developing countries. It is worth mentioning that models such as Wazecarpool are already in operation in Brazil and adopt the hitchhiking in search of efficiency of cars users in urban transportation.

In addition, another modal for MaaS systems that could be explored in a developing country is the bicycle, especially when considering that this modal is an important part of MaaS system, especially as a solution for first- and last-mile (Nikitas, 2018), such transport mode is still neglected by most of MaaS studies (Utriainen & Pöllänen, 2018). We observed that users of bicycles believe that this modal deliver status, in addition to a perception of care with health and sustainability. In this sense, we believe that bicycles can strengthen MaaS models not only in developing countries but in MaaS systems worldwide.

We have also found that the dematerialization phenomena are perceived as positive for urban mobility users in our sample. The fact that transport is dematerialized, and it is presented as a mobile app, shows real perceived value in a considerable group of car users and non-car users. Peer to peer business models, such as Uber, Cabify and others are already playing an important role towards transport dematerialization, and this can a reshaping effect on the way commuter relate to transportation means – similarly to what has occurred to the music dematerialization phenomenon (Magaudda, 2011). However, is worth highlighting that transport modes, specifically in MaaS systems, present complex distinctions that were not analyzed in this study.

The MaaS concept is still recent and incipient. Therefore, further studies should analyze aspects related to the integration of actors and the Maas ecosystem. We believed that the specificities of each MaaS operator will impact its use. However, this study provides, as far as we know, a first step to understand the predisposition to use MaaS in a developing country.

**Acknowledgements**

This paper would not have been possible without the support of the *Laboratoire Génie Industriel* (LGI / *CentraleSupélec – Université Paris-Saclay /* France), the Post-Graduate Program in Administration of *Universidade Federal de Lavras* (PPGA/UFLA - Brazil), and the Statistics Department of *Universidade Federal de Lavras* (DES/UFLA – Brazil). We also would like to thank the founding institutions: *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES - Brazil) and *Fundação de Amparo de Pesquisa de Minas Gerais* (Fapemig - Brazil).

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**ARTICLE 4: Casual carpooling as a strategy to implement Mobility as a Service systems in a developing country.**

**Extended abstract of the paper published on the proceedings of the *XXVIII Congresso de Pós Graduação da UFLA*, Lavras, 2019.**

Gandia, R. M.; Oliveira, J. R.; Antonialli, F.; Sugano, J. Y.; Patricio, L. B.; Nicolaï, I.; Oliveira, I. R. C. (2019). Casual Carpooling as a Strategy to Implement Mobility as a Service (MaaS) in a Developing Country. In: Congresso de Pós-Graduação da Universidade Federal de Lavras, Lavras. XXVIII Congresso de Pós-Graduação da UFLA.

**Preliminary version of the paper published on the proceedings of 27th International Colloquium of Gerpisa, Paris, 2019.**

Gandia, R. M.; Oliveira, J. R.; Antonialli, F.; Sugano, J. Y.; Patricio, L. B.; Nicolaï, I.; Oliveira, I. R. C. (2019). Casual Carpooling as a Strategy to Implement Mobility as a Service (MaaS) in a Developing Country. In: 27th International Colloquium of Gerpisa, Paris. The Automotive Industry in Transition.

**Full Paper under review on Technological Forecasting and Social Change.**
**ISSN: 0040-1625, JCR: 3.815, Qualis Capes: A1**

# Casual Carpooling as a Strategy to Implement Mobility as a Service systems in a Developing Country

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**Abstract:** Mobility as a Service (MaaS) goal is to offer tailored-made on-demand mobility solutions by integrating on a single service, public and private transport modes. However, the concept is still uncertain, and its current development and applicability is centered on developed countries. On the other hand, we advocate that MaaS is modular, adaptable and applicable to several realities. In developing countries where public transport is mostly inefficient and insufficient, MaaS systems could help to "balance the scale" with private transportation offerings, such as: rides (casual carpooling). Thereby, our general objective was to identify the motivating factors of the practice of casual carpooling and propose a strategy to implement it in a MaaS system. The survey was applied to 307 university students in the city Lavras – Brazil. Data were analyzed using descriptive statistical techniques and Web Scraping. We assumed that the casual carpooling is sustained by solidarity; simplicity and agility; no costs to passengers; and pick-up points. As strategy to implement it, 4 pillars were identified: unified drop-off points; modal customization; remuneration for credit; and no costs for passengers. We concluded that casual carpooling may be a supplement mode on MaaS systems in last-miles commutes or in places with inefficient public transport.
**Keywords:** Mobility as a Service; Casual carpooling; Consumer behavior.

## Highlights

- MaaS is modular, adaptative and applicable to any context;
- The act of sharing a car may be used as a transport modal in a MaaS system;
- MaaS can be implemented in places without an efficient public transport;
- Casual carpooling may be a solution to implement MaaS in developing countries.

## Introduction

Mobility as a Service (MaaS) has the aim to offer tailored-made on-demand mobility solutions by integrating on a single service via a single user interface, public and private transport modes (Hensher, 2017). However, the concept is still surrounded by uncertainties and its current development and deployments are mainly centered in developed countries (Jittrapirom et al., 2017; Kamargianni et al., 2016). In addition, as Public Transport (PT) entails the backbone of MaaS systems (Pangbourne et al., 2018; Sochor et al., 2017; Karlsson et al., 2016), it is understood that in order to efficiently implement MaaS services, capable offerings of PT are pivotal.

On the other hand, we advocate that MaaS is modular, adaptable and applicable to several realities. Corroborating with this, Hietanen (2019) states that MaaS is a viable answer in most places because the modal split can be adaptable. For this, in places where PT is inefficient and mostly insufficient (e.g. developing countries), MaaS could help to "balance the scales" with private transportation offerings, for instance, by increasing private car efficiency with casual carpooling.

Casual carpooling is an informal, ad-hoc, user-run type of ridesharing that provides a high-occupancy rate on private vehicles (Shaheen, Chan & Gaynor, 2016; Chan and Shaheen, 2012). In this type of "free commute", the passenger occupies an idle seat that would not be used by the driver on his/her daily routine from point A to B anyway (Frenken & Schor, 2017; Beroldo, 1999). In this sense, by occupying the idle capacity of a vehicle, casual carpooling is aligned with the concepts advocated by the sharing economy (Benkler, 2004; Shaheen, Chan & Gaynor, 2016).

The sharing economy provides positive environmental effects (Acquier, Daudigeos & Pinkse, 2017; Botsman & Rogers, 2011). Thus, having casual carpooling as a transport mode inserted in a MaaS system could help in the construction of a service in favor of eco-innovation, in a sense that such access-based business models are pivotal to foster innovation on developing countries and frontier markets (Wiprächtiger et al., 2019). Gandia et al. (2019) state that MaaS should only be characterized as an eco-innovation if private car users either replace the usage of their vehicles for other transport modes or make more efficient use of their vehicles, that is, by reducing the idle capacity.

However, several factors can influence on casual carpooling, due to its consonant aspects to the sharing economy, such as trust and reputation (Ert, Fleischer & Magen, 2016; Wu, Ma & Xie, 2017), governance in collaborative consumption (Hartl, Hofmann & Kirchler, 2016), and generational cohorts influence (Godelnik, 2017; Lasmar et al., 2018).

Given the aforementioned, the present paper sought to focus on such issues in the context a small city (Lavras) in a developing country (Brazil), since this city holds several universities and therefore many students, who – on their daily commute – routinely practice casual carpooling (whether as passengers or as drivers).

Our research problem can be summarized in the following guiding questions: Which are the motivating factors of casual carpooling? And, how can casual carpooling be implemented in a MaaS system? Thereby, our general objective was **to identify the motivating factors of the practice of casual carpooling and propose a strategy to implement it in a MaaS System.**

This paper addresses three main contributions. First, by understanding MaaS as adaptative and modular, its business model could be conceived without having public transport as a backbone. In this sense, solutions aimed on reducing car-occupancy inefficiency while additionally complementing PT would be a feasible MaaS alternative in developing countries that struggle with public transport offerings. Given that, from the relations between casual carpooling and MaaS, our second contribution sought to analyze the possibility of this modal to be inserted in a MaaS system, which, to the extent of our literature review, such approach has not yet been taken into account, neither in the academia nor in real-world deployments. At last, our final contribution seeks to add to the state-of-the-art in a sense that there is a lack in studies on casual carpooling, when it comes to behavioral trends and user motivations (Shaheen, Chan & Gaynor, 2016).

## Literature review

### Mobility as a Service (MaaS) an overview

The first comprehensive definition of MaaS emerged in 2014 in Finland, where Hietanen (2014) described MaaS as a mobility solution offered by a single interface of a service provider that combines different transport modes to offer tailored mobility packages.

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). According to Callegati et al. (2016), the main idea of MaaS is to offer a unique and seamless interface to its users, aggregating heterogeneous transport options offered by different mobility providers handling the whole experience of traveling, from providing information, to travel planning, and payments.

Also, Matyas and Kamargianni (2017) point out that MaaS is a user-centric, intelligent mobility distribution model in which all mobility service providers' offerings are aggregated by a sole mobility provider (the MaaS provider) and supplied to users through a single digital platform. According to Mulley (2017, p. 248-249), there are three main concepts of MaaS;

1) **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;
2) **Subscription service:** users have no 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 and;
3) **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.

Thus, by this multiple definitions, Jittrapirom et al. (2017, p.14) affirms that MaaS can be thought 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)". In an effort to reduce that uncertainness, the authors also carried out a critical literature review to identify, among others, the core characteristics of MaaS (Table 1).

**Table 1**: Description of MaaS' core characteristics

| 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 | An 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, 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, LTE); GPS; e-ticketing and e-payment system; database management system and integrated infrastructure of technologies (i.e. IoT). |
| 6. Demand orientation | Seeks to offer a transport solution that is best from the 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. The 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 according to their preferences. This can increase MaaS' attractiveness among travelers and its customers' satisfaction and loyalty. |

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

Besides these multiple definitions, it is possible to observe that the main idea behind MaaS is to combine multiples products and services (integrating transportation modes) in a unique platform customized for passengers to fulfill their needs.

Utriainen & Pöllänen (2018) states that the transport modes analyzed in most MaaS studies are restricted to cars (privately owned vehicles, car-sharing, car rental, and taxis), public transport, and cycling. However, we understand that the possibilities for MaaS are wider and other kinds of transport modes could be used in a MaaS system, such as casual carpooling.

**Casual carpooling and sharing**

Casual carpooling, also known as "slugging", consists in the act of informal carpools for purposes of commuting and can be understood as a variation of hitchhiking for urban areas (Shaheen, Chan & Gaynor, 2016; Maltzman & Beroldo, 1987; Chan & Shaheen, 2012).

The concept was born in communities north and east of San Francisco (USA) and spread to other states in America (Shaheen, Chan & Gaynor, 2016). The essential idea is to provide a free ride for a passenger in order to complete idles seats in the car. By doing this, the driver gets access to benefits provided for high-occupancy vehicles (HOV) such as access to dedicated lanes and discount in tolls.

According to Chan & Shaheen (2012), for casual carpooling to be successful - in the context of USA – it should present the following features: (1) time savings incentive for drivers; (2) monetary savings for passengers; (3) pick-up locations near freeways, residences, parking, or public transit stops; (4) a common drop-off location; (5) convenient public transit for the evening commute; and (6) an high occupancy vehicle requirement of three or more persons to ease personal safety concerns (Beroldo, 1990; Reno et al., 1989 apud Chan & Shaheen, 2012).

Casual carpooling can also occur by solidarity, that is, without time and costs benefits, just for the act of sharing. In fact, Belk (2014) states that it is necessary to move from the old wisdom mindset of "you are what you own" towards "you are what you can access".

Over the past years, several different business models have emerged with similar characteristics related to the act of sharing (Acquier, Daudigeos & Pinkse, 2017; Cohen & Kietzmann, 2014; Botsman & Rogers, 2011). Despite the fact that sharing economy or collaborative consumption is a recent phenomenon – boosted by the widespread popularization of the internet (Casprini, Di Minin & Paraboschi, 2019), the act of "sharing is as old as humankind and has been essential for our survival" (Belk, 2017 p. 249).

According to Belk (2007, p. 126), "sharing is the act and process of distributing what is ours to others for their use as well as the act and process of receiving something from others for our use." Historically, the concept of sharing was restricted to people from the same social circle, making it a tendency not to share with strangers (Frenken & Schor, 2017). However, the emergence of peer-to-peer digital platforms has facilitated the exchange of underutilized assets by strangers (Böcker & Meelen 2017) in such a way that such platforms facilitate building trust (Frenken & Schor, 2017; Ballús-Armet et al., 2014; Botsman and Rogers, 2011).

However, Belk (2010) states that are imprecise lines between sharing and two other acquisition and distribution mechanisms: 1) gift exchange and, 2) commodity exchange.

According to the author, gift exchange aims at a desire for connection, often imposed by the need for reciprocity, while the economic exchange is characterized by calculability. Nevertheless, sharing tends to be a communal act that links us to other people. Sharing is linked to ideas about ownership and self, which are learned during childhood in the sense that sharing options refer to individual choices subject to individual and cultural differences (Belk, 2010).

Still, according to Belk (2010), sharing may have interesting social and theoretical implications when analyzed outside of the immediate family circle. Thereby the author brings the definitions of “sharing in” and “sharing out”. The former expands the sphere of the extended-self and the domain of common property. It is closer to the archetype of sharing within the family, because it involves ownership as common so that others are included in the extended self. The latter, however, deals with dividing a resource between different interests. It preserves the self / other boundary and does not involve expanding the aggregate sphere of the extended self by expanding the domain of common property. It involves giving others outside the boundaries that separate self and the other and is closer to the gift and commodity exchange (Belk, 2010).

In this way, sharing a car with family, friends or acquaintances would be closer to the concept of “sharing in”, while large P2P sharing services may be more related to “sharing out” (Belk, 2010). However, in between these two, other means of sharing (such as casual carpooling) could be inserted.

**Methodological approach**

This study is characterized as quantitative of exploratory and descriptive nature. The survey was applied to 307 university students in the city of Lavras - Brazil enrolled from the second academic semester of 2018. The research design is depicted in Figure 1.

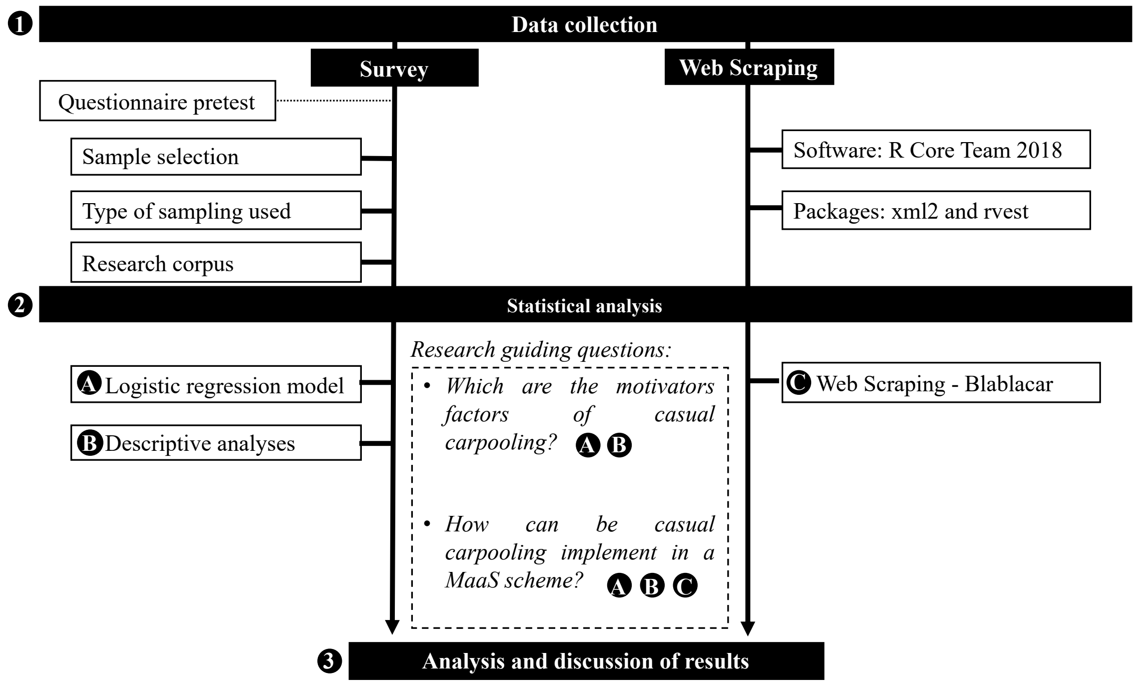


**Fig. 1.** Research design
Source: Prepared by the authors.

Step 1 referred to data collection. Data collection was carried out in two distinctive ways. The first one was done by a cross-sectional study (survey) with 307 students of the four Higher Education Institutions (HEI) of the city. The selection of participants was done by non-probabilistic sampling (Aaker, Kumar & Day, 2001; Hair, 2005; Malhotra, 2001). The second stage on data collection was done via web scraping. For this, we used software R version 3.5.1 (R Core Team, 2018) and the packages xml2 (Wickham; Hester; Ooms, 2018) e rvest (Wickham, 2016).

Step 2 consisted of statistical analyses. Our paper aimed to answer two main research problems. In order to answer our first research problem (Which are the motivating factors of casual carpooling?) survey data were analyzed using logistic regression models (A) fitted via software R. Also, descriptive statistical techniques (B) as a way of understanding the socioeconomic factors associated with the habit of offering and picking up rides (casual carpooling) were used.

After data pre-processing, logistic models were fitted separately for the groups of drivers ($n_c = 78$) and non-drivers ($n_{nc} = 204$), considering as response variable the habit of offering or taking a ride (Y = 1, for the answers "yes" or "occasionally", and Y=0 for the answer "no"). At first, full models were fitted considering the predictors age, sex, income, marital status, type of institution (public or private), day/night shift, and distance to the institution. The best models were then selected by stepwise based on AIC values. The final models are presented for each of the groups and interpreted in terms of odds ratios.

In order to understand the second research problem (How can casual carpooling be implemented in a MaaS system?) we also carried out a web scraping on the platform Blablacar from 9th to 27th March 2019. 290 users were analyzed on 298 trips, of which 97 were interstate journeys. Descriptive statistics were obtained for these data.

Web scraping consists of scraping data from internet sites to turn it into a simpler format to be analyzed. The Blablacar platform was chosen because it offers a service with characteristics close to what a MaaS model can be (since MaaS does not exist yet in the context in which this work was done). Although we are aware that distinctions between a MaaS model and Blablacar exists, both models have similar characteristics (such as one online platform, customization, personalization, registration requirement, and use of technologies). At last, step 3 consisted of the analysis and discussion of results.

**Research context**

The city of Lavras-MG with a population of around 100.000 inhabitants is located in the south of the state of Minas Gerais, 425 km from Rio de Janeiro, 380 km from São Paulo and 240 km from Belo Horizonte. The city holds four higher education institutions, being one public (Federal University of Lavras - UFLA) and 3 privates (Unilavras, Fagammon, and Fadminas).

UFLA currently holds 31 undergraduate courses and 33 lato-sensu and stricto-sensu graduate programs, totaling more than 16,000 people among students, faculty, and staff. Due to its extension and peripheral location regarding the city of Lavras, the campus counts with five stops for casual carpooling, which all have different destinations in the city. Today, the practice of casual carpooling is already institutionalized in the local culture. In addition, the university provides a free internal articulated shuttle which is intermittent at peak times and periodic during weekdays.

As for the private institutions, although significantly smaller than UFLA, they also represent a significant portion of the academic population of Lavras. Together, they hold 10 lato-sensu graduate programs and 17 undergraduate courses. However, unlike UFLA, they do not have physical stops for casual carpool (mainly due to the fact that they are all located within the city and not in the vicinities as UFLA).

## Analyzes and results

Results are displayed in 3 steps. Initially the results from the logistic models are presented, followed by their descriptive analyzes and. At last, the results obtained by web scraping in the Blablacar platform are shown.

## Logistic regression model

In order to understand the habit of casual carpooling, the first analysis we carried out was the logistic regression model (Table 2).

**Table 2**: Estimates and Wald tests for the effects in logistic regressions, odds ratios estimates and confidence intervals.

| Group | Effect | Estimate | s.e. | p-value | $\widehat{OR}$ | $IC_{95\%}(OR)$ |
|---|---|---|---|---|---|---|
| Drivers | Intercept | -1.192 | 1.451 | 0.411 | - | - |
| | Age | 0.071 | 0.056 | 0.203 | 1.074 | [0.977; 1.221] |
| | **Institution=Public** | **1.501** | **0.609** | **0.014** | **4.486** | **[1.427; 16.129]** |
| Non-Drivers | Intercept | 0.688 | 0.457 | 0.132 | - | - |
| | Institution=Public | 0.601 | 0.334 | 0.072 | 1.824 | [0.944; 3.513] |
| | Distance = 500m and 1km | 0.125 | 0.551 | 0.820 | 1.134 | [0.376; 3.339] |
| | Distance = 1km and 2km | -0.201 | 0.540 | 0.709 | 0.818 | [0.276; 2.334] |
| | Distance = 2km and 3km | -0.751 | 0.549 | 0.172 | 0.472 | [0.156; 1.364] |
| | **Distance = 3km and 4km** | **-1.756** | **0.685** | **0.010** | **0.173** | **[0.042; 0.631]** |
| | **Distance = 4km** | **-1.320** | **0.549** | **0.016** | **0.267** | **[0.087; 0.763]** |

For drivers, a significant effect was found regarding the type of institution they belong to. When belonging to the public institution, the estimated chances of him/her offering a ride are approximately 5 times higher than those of students from private institutions ($\widehat{OR} = 4.486$). This result was already expected due to the strong and structured sharing culture in the public university studied.

For non-drivers, we observed that the type of institution is also an important variable in the model, but not significant at a 5% significance level. For this group, we noticed a significant effect of the distance that the student lives from the institution. If this distance is greater than 3 km, the odds of the student to seek for a ride are reduced ($\widehat{OR} = 0.173$ and $\widehat{OR} = 0.267$) compared to students who live within a walking distance of (up to 500m) from the institution.

**Descriptive analyses**

Based on the logistic regression model, the only predictor variable that had an effect on the question "do you offer a ride?" was a type of institution (public or private). In this way, stratified analyses were performed in relation to the nature of the institution (public and private). Analyses were done separately for drivers and passengers.

Table 3 presents the predisposition and offer of casual carpooling stratified by type of institution. In general, we observed that there is a greater predisposition to offer a casual carpooling in the public institution over private ones (62.3% and 26.7%, respectively). The number of users who offers rides to strangers is also much higher in the public institution (45.9%). On the other hand, in the private institution, the largest offer leans towards family, friends, and acquaintances (62.1%).

**Table 3**: Predisposition for casual carpooling by institution type.

| **Do you offer a ride?** | **Higher Education Institutions** | |
|---|---|---|
| | **Public** | **Private** |
| Yes | 62,3% | 26,7% |
| No | 11,6% | 35,6% |
| Occasionally | 26,1% | 37,8% |
| **Usually, for who do you offer a ride?** | | |
| Family | 3,3% | 24,1% |
| Family or friends | 16,4% | 3,4% |
| Family, friends or acquaintances | 34,4% | 62,1% |
| Anyone | 45,9% | 10,3% |

For those drivers who do not offer rides, they were asked why they did not do so and what could make them change their minds (Table 4). While the greatest concern among respondents from the public institution was the loss of freedom (50%), in the private institution the fear of robbery was the biggest cause (43.8%). We observed that 48.8% of drivers would offer a ride to anyone if they were paid financially, but in the private institution, for most respondents, no sort of reward would make them change their minds (54.8%).

**Table 4**: Reasons to not offer rides and possible incentives.

| **Why do you not offer a ride?** | **Higher Education Institutions** | |
|---|---|---|
| | **Public** | **Private** |
| Loosing my freedom | 50,0% | 12,5% |
| Fear of theft | 25,0% | 43,8% |
| Routes without riders | 0,0% | 37,5% |
| Other | 25,0% | 6,3% |
| **What type of reward would make you offer rides to strangers?** | | |
| Tax exemption | 2,4% | 4,8% |
| Crypto-coins | 7,3% | 2,4% |
| Rewards program | 4,9% | 4,8% |
| Paid rides | 48,8% | 26,2% |
| Nothing | 34,1% | 54,8% |
| Would offer whithout reward | 2,4% | 7,1% |

Given that the celebration of casual carpooling should be mutual and have acceptance of both drivers and passengers, we also sought to understand the habits of casual carpooling among non-drivers (Table 5). It was noticed that the acceptance was greater in the public institution in which 62.6% of the respondents say they are carpooling fans, while in private the number was 44.4%.

Still distinguishing between UFLA and private institutions, when comparing the proportion of respondents who are willing to take rides with strangers, we also found a greater predisposition among UFLA's students (81.2%) while for the private universities this number drops to only 12.5%.

**Table 5:** Casual carpooling habits among non-drivers

| Do you get a ride? | Higher Education Institutions | |
|---|---|---|
| | Public | Private |
| Yes | 62,6% | 44,4% |
| No | 37,4% | 55,6% |
| **Usually, from who do you get a ride?** | | |
| Family | 2,6% | 15,3% |
| Family or friends | 2,6% | 26,8% |
| Family, friends or acquaintances | 13,7% | 44,6% |
| Anyone | 81,2% | 12,5% |

The analyses were also made under the MaaS perspective (Table 6). Considering that MaaS is a fairly recent concept (Hietanem, 2014); most of the respondents might not have been familiar with it. Thus, in order to analyze the results we presented a compilation of MaaS central features as a single statement to the respondents.

Overall, 53.2% of those who answered "yes" to the question regarding MaaS have already offer carpool rides. This number rises to 65.9% from the standpoint of UFLA's respondents and drops to 38.2% among the private schools' respondents.

**Table 6:** Willingness to offer rides within a MaaS context

| Adept at MaaS | Do you offer a ride? | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | General | | | Public | | | Private | | |
| | Yes | No | Occasionally | Yes | No | Occasionally | Yes | No | Occasionally |
| Yes | 29,1% | 16,5% | 53,2% | 27,3% | 6,8% | 65,9% | 32,4% | 29,4% | 38,2% |
| No | 20,0% | 28,6% | 51,4% | 24,0% | 20,0% | 56,0% | 10,0% | 50,0% | 40,0% |

## Web scraping Blablacar

The results obtained with the application of the web scraping technique on BlaBlaCar are presented in the sequence. As elucidated by Casprini, Di Minin and Paraboschi (2019), Blablacar is an online market platform whose business model is to offer peer-to-peer intercity shared mobility. According to the authors, today, the company operates in 22 countries, has over 600 employees, over 35 million members and an estimated value of over 1.5 billion USD.

Out of 290 users, 18.34% are female, while 81.66% are men. The ages range from 18 to 72 with averages of 30. Regarding users' profiles Blablacar offers the possibility (for both drivers and passengers) to express preferences for their trips (such as willingness to chat, listen to music, smoke, and carry pets). By subscribing to the platform, the user may (non-mandatory) tick one of three options related to each of these topics, the percentage of drivers who expressed preferences regarding these items is presented in Table 7.

Chattiness had the highest incidence of responses (39.34%), followed by smoking (22.58%). The highest percentage of responses from chattiness is neutral compared to openness to conversations (27.24%), indicating that the conversations may occur according to people's state of mind (mood). About 20% of drivers do not allow smoking. About the same percentage as to listen to music during the trip (19.53%). When it comes to the transport of pets, there is a duality between being welcome or not, and there is no neutrality.

**Table 7:** Carpooling preferences among users on Blablacar.

| Carpooling preferences | | Reponses | Total | Carpooling preferences | | Reponses | Total |
|---|---|---|---|---|---|---|---|
| **Chattiness** | I'm the quiet type | 0,96% | **39,34%** | **Smoking** | No smoking in the car please | 20,22% | **22,28%** |
| | I'm chatty when I feel like it | 27,24% | | | Smoking in the car is OK sometimes | 0,00% | |
| | I love to chat! | 11,14% | | | Smoking in the car doesn't bother me | 2,06% | |
| **Pets** | No pets in the car | 10,04% | **18,02%** | **Music** | Silence is golden | 0,83% | **20,36%** |
| | Depends on the animal | 0,00% | | | I listen to music if I fance it | 0,00% | |
| | Pets are fine. Woof! | 7,98% | | | It's all about the playlist! | 19,53% | |

In order to analyze the relationship between price and distance traveled, we also analyzed the most frequent origins for the city of Lavras on the platform (Table 8). For each of these routes, it is highlighted the average prices practiced in the platform, the standard deviation, as well as maximum and minimum values. For comparison, we also present the prices usually practiced by road transport companies for these same routes and a price/km ratio traveled regarding both Blablacar and road transport companies.

**Table 8:** Relation price/km from 10 most frequently departures to Lavras in Blablacar.

| Leaving from | Distance (km) | Frequence | Average prices | SD | Min – Max | Road transport (coach) | Price/Km Blablacar | Price/Km Road transport |
|---|---|---|---|---|---|---|---|---|
| Belo Horizonte | 240 | 73 | € 9,78 | ± 6,84 | 35 - 63 | € 17,99 | € 0,04 | € 0,07 |
| São Paulo* | 378 | 48 | € 14,13 | ± 9,65 | 56 - 97 | € 19,84 | € 0,04 | € 0,05 |
| S. J. Del Rey | 94 | 25 | € 3,96 | ± 2,75 | 14 - 20 | € 7,70 | € 0,04 | € 0,08 |
| Barbacena | 149 | 15 | € 6,25 | ± 4,89 | 22 – 35 | € 11,40 | € 0,04 | € 0,08 |
| Varginha | 107 | 10 | € 5,27 | ± 3,77 | 15 - 28 | € 9,49 | € 0,05 | € 0,09 |
| Pouso Alegre | 186 | 9 | € 6,94 | ± 3,49 | 28 - 37 | € 14,44 | € 0,04 | € 0,08 |
| Juiz de Fora | 244 | 8 | € 10,58 | ± 7,37 | 35 - 55 | € 17,99 | € 0,04 | € 0,07 |
| Piracicaba* | 484 | 8 | € 16,19 | ± 4,82 | 68 - 80 | € 22,19 | € 0,03 | € 0,05 |
| Três Corações | 87 | 7 | € 3,40 | ± 3,55 | 10 - 20 | € 7,47 | € 0,04 | € 0,09 |
| Uberlândia | 531 | 7 | € 22,54 | ± 10,69 | 80 - 110 | € 40,56 | € 0,04 | € 0,08 |

* Interstate routes

In general, we observe that the prices on the platform are approximately 50% lower when compared to the road transport companies, in this way, we realize that passengers are price sensitive (interstate transports showed a slightly lower difference). It is worth mentioning that the prices of these companies are also subject to changes, through high demand.

## Discussion

### Motivating factors of casual carpooling practices

The linear regression model showed that the type of institution (public or private) was the only influential variable in offering casual carpooling. It is worth mentioning that other variables such as sex, age and income were not representative to explain differences in the habit of offering rides.

We observe that this happens due to a culture established in the city, especially by UFLA, which encourages the habit of casual carpooling. In this sense lessons thought by the institutional theory can be used, mainly regarding the role of normative isomorphism (Dimaggio & Powell, 2005). As pointed out by Assis (2010), normative isomorphism occurs when there is a demarcation of conditions, methods and practices common to the exercise of an activity, defined through a sharing of norms and knowledge with other individuals, generating a similarity among them.

We verified that UFLA has institutionalized the practice of casual carpooling by installing physical pick-up points in avenues within the campus (Figure 2). The pick-up points indicate the region where the riders in the queue wish as a final destination.


**Fig. 2.** Casual Carpool Pick-up point at Federal University of Lavras

Although there are no explicit signboards outside UFLA’s campus indicating pick-up points, there are "informal" sites scattered throughout the city that lead to UFLA. These sites are generally close to public transportation bus-stops (Figure 3), similar to those observed in metropolitan areas in the USA (Shaheen, Chan & Gaynor, 2016).


**Fig. 3.** Informal Casual Carpool Pickup point in the city of Lavras, near to a bus stop

In the USA, there are policies put in place to stimulate the practice of casual carpooling. Several types of incentives are offered to drivers, such as access to dedicated lanes and discount in tolls (Shaheen, Chan & Gaynor, 2016). However, contrary to one of the factors of success of the casual North American carpooling; "time-saving incentives for drivers" (Chan & Shaheen, 2012), there is no municipal or institutional incentive for drivers to offer these rides in the city of Lavras. In addition, rides have no cost to passengers as well. In this way, 91.1% of the drivers do it out of benevolence and solidarity.

We believe that one of the factors that encourage this solidarity is the simplicity and agility in offering rides in Lavras. Passengers make a self-organized queue without any outside intervention. In this queue, whenever a car stops, visual communication or few words are enough to consummate the act of the ride. The driver indicates how many passengers can enter the car, while the queue order is generally respected. It is worth noting that eventually, whenever a driver sees someone, he/she knows in the queue, he/she stop a little ahead of the pick-up point and that given person in the queue (regardless of their position) goes to the car.

Differently, in the case of private universities, there are no carpooling pick-up points on their campuses nor in the city. Such a fact may explain the discrepancy between the percentage of rides to strangers offered by drivers from UFLA compared to drivers from private institutions (45.9% and 10.3%). Such a lack of "physical infrastructure" can act as a motivator to not offer a ride.

We observed that levels of trust are greater in the public institution than in the private ones (e.g., not offering a ride for fear of theft or robbery: respectively 25% and 43.8%). In addition, in private institutions, 37.5% of drivers claimed that they do not offer rides, because they usually do not encounter riders on their way to university, which may be explained due to the lack of "carpool pick-up points" aimed towards those institutions.

Thereby, we understand that the casual carpooling in Lavras is mainly sustained by the following motivating factors:

- **Solidarity:** drivers do not have financial rewards or municipal incentives to offer a ride;
- **Simplicity and agility:** casual carpooling is simple and intuitive with the pick-up points at the public university - drivers do not gain, but also do not waste time;
- **No costs to passengers:** riders accept and trust to carpool with unknown drivers;
- **Pick-up points:** bring legitimacy and practicality to casual carpooling.

A relevant factor to be highlighted is the role of solidarity as a fundamental pillar of the practices of casual carpooling. We observed that this solidarity rides are inherent to the public institution, due to the instituted normative isomorphism (Assis, 2010; Dimaggio & Powell, 2005) in the university due to the several carpool pickup points as well as due to the institutionalized culture. Thus, we consider that the act of casual carpooling in the public institution – by not seeking repayment in exchange (e.g., Belk, 2010 p. 721 "Money is irrelevant") – does indeed present features of "sharing".

However, the act of providing shared rides is not suited for everyone. Thereby, it is important to outline the user groups identified in our sample: 1) supporters of casual carpooling for acquaintances; 2) supporters of solidary casual carpooling for anyone; 3) supporters of casual carpooling for anyone given some sort of incentives are provided; and 4) non casual carpooling supporters.

Be being a relation that mitigates interpersonal boundaries posed by materialism and possession (by private car sharing), we believe that within the "sharing in – sharing out" spectrum proposed by Belk (2010), the practice of group 2 (supporters of solidary casual carpooling for everybody) is closer to the concept of "sharing in". Figure X demonstrates the identified groups plotted in Belk's (2010) spectrum of sharing in-out.

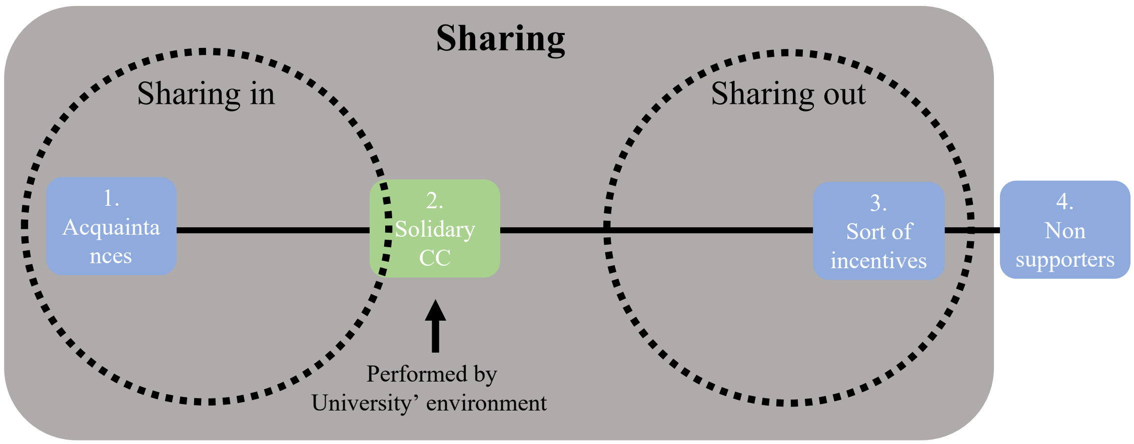


**Fig. 4:** Conceptual framework for casual carpooling supporters under Belk's (2010) sharing archetypes.
Source: Prepared by the authors.

By analyzing Figure 4, we advocate that group 1 should be placed on left-end of the spectrum, within the sharing in concept as proposed by Belk (2010). Group 2, suggests a level of openness which enables the self-extension (Belk, 2010). In contrast, group 3 is placed in opposite right-end of the spectrum.

Carpooling enabled by incentives resembles the rental of a vehicle by a car-sharing company, as suggested by Belk (2010). The distinction is that, in the case of the carpool, the activity is not configured as a business.

The presence of group 2 in the spectrum is only possible due to the peculiar institutional environment of the analyzed context. However, this does not mean that such group cannot exist in other contexts, or even be stimulated. In addition, as we advocate towards a context adaptive MaaS, this group can and should be used as a carpool catalyst in the insertion of a MaaS business model.

The group of non-casual carpooling supporters (4) is outside of the sharing spectrum. For this group motivating rewards would hardly be accepted. Also, due to their resistance to sharing, this group would have a certain aversion to MaaS. According to Hietanen (2019), MaaS is not meant to serve all, there will always be a demand that will not be fulfilled.

However, for the other groups (1, 2, and 3) certain stimuli can make drivers to give rides to other passengers besides acquaintances.

**Strategies to implement casual carpooling in a MaaS System**

Although we consider public transport to be a key actor for MaaS systems, it cannot be generalized as MaaS backbone. That being true, MaaS could not be adaptable to places in which public transport is inefficient (and that desperately need mobility solutions). Thus, in an analysis prior to the context in which this study was conducted, we observed that casual carpooling practices may be a viable alternative for the implementation of MaaS.

We observed that in general drivers predisposed to use MaaS offer rides in most cases (82.3%). This number rises to 93.2% when stratified for the public institution. In this way, we suggest that possible users of a MaaS model in the context of this study are already somewhat familiar with the casual carpooling and can make use of it as a modal.

However, it is still necessary to find a way to implement casual carpooling in a MaaS model, considering that the literature has not yet addressed this possibility. Our first thought is that casual carpooling should not be made available to all MaaS' users. This strategy is based in the customization option offered by the service provider. In a MaaS system, transport options are offered to the users based on their personal preferences. For instance, a user who is not open for physical exercise may not have bike-sharing among his/her transportation options. Likewise, MaaS users should only have the option of accessing casual carpooling as a transport if they are part of specific interest groups (e.g., universities or enterprises).

That is, the customization offered by the MaaS platform could provide casual carpooling as a transport mode for users of the same company or university. For instance, users (e.g. a student, professor, administrative staff, so on) from the same institution would have access to the casual carpooling among their MaaS transport modes, whereas this option would not be available to other users who are not part of this given university.

Also, based in logistic features, universities and big companies are places that have common drop-off locations (Chan & Shaheen, 2012). In addition, the institution as a unit can encourage the act of sharing due to the safety and the possible inherent social links established among its members (Belk, 2010).

Although the solidarity profile exists, we observed that some reward would motivate a greater commitment to casual carpooling for anyone (48.8%). However, casual carpooling is a user-organized system (Shaheen, Chan & Gaynor, 2016). In this way, establishing prices per ride/trips to be practiced among passengers and drivers would be quite complex due to a lack of governance structures and mechanisms. In addition, stipulating prices per ride/trips could cause rebound effects (Manzini & Vezzoli, 2003) and transform casual carpooling into a business, such as Uber.

In this way, we propose that the financial rewards should be converted into credits into the drivers' MaaS accounts. A similar proposal to obtain credit is pointed out by Datson (2016). Thus, the driver (consumer) becomes the service provider and user of the MaaS platform. For instance, the consumer can offer, as a driver, the casual carpooling (service provider), however eventually it can choose to use public transport, a bike-sharing service or even casual carpooling but as a passenger (user).

Users and service provider perspectives are similar to those perceived on the Blablacar platform. However, unlike the platform that focuses on intermunicipal trips with medium/long length and planning, casual carpooling has an urban environment target with a short length and unplanned trips. Thus, some customizations preferences from Blablacar that we found in the web scraping technique, either do not apply to casual carpooling (transport of pets) or are likely to have lower adherence (music or smoking).

On the other hand, chattiness, seems to have applicability as customization for short length trips. This preference was the one that pointed out the greatest number of interventions in Blablacar platform (39.34%) and could contribute to the "loss of freedom", indicated by 50% of the drivers as inhibiting ride factor. In this way, from the customization, users can delineate their profile and show a willingness to converse or not and even expand to topics of interest, hobbies, among others. Thus, drivers who do not want to have their freedom compromised can choose passengers who do not want to talk for example.

Furthermore, when it comes to passengers, the web scraping analysis illustrated a price sensitivity. The prices charged by the Blablacar platform are generally 50% lower than those charged by road transport companies (see Table 8). Also, the simple fact that casual carpooling is free already indicates this sensitivity to the price. Thus, we suggest that the casual carpooling in a MaaS system should be also offered for free to passengers.

This is justified because this modal does not need governance, on the contrary, it must remain user-run and act only as support for MaaS implementation (Figure 5). In addition, the destinations served by casual carpooling are specific to certain regions. Also, we observed in our sample that casual carpooling is better suit to fulfill the last-mile issue given that the passengers who live near to the final destinations are more willing to get a ride (see Table 2). For this, casual carpooling users are most likely to need transport connections to complement their transportation needs in order to commute to other locations.

Thus, a strategy for implementing a casual carpooling in a MaaS system is based on 4 pillars:

1. **Unified drop-off points:** with universities or enterprises as compelling alternatives due to their large number of commuters. Also, such commuters are likely to present similar social circles, which may contribute to the act of sharing (Belk, 2010).
2. **Modal customization:** casual carpooling will not be for every MaaS user. This modal will be only available for users who are inserted in certain environments (e.g., unified drop-off points) that allow the creation of supply and demand.
3. **Remuneration for credit in MaaS:** it would feedback the system, making providers of casual carpooling to be included in MaaS as users as well.
4. **No additional costs for passengers.**

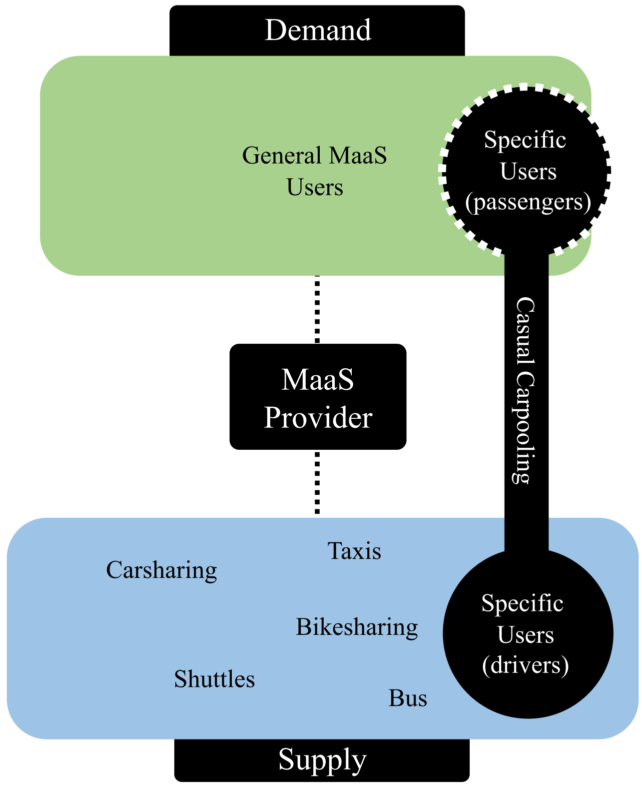


**Fig. 5:** Theoretical model of casual carpooling in a MaaS system
Source: Prepared by the authors

The strategy of implementing casual carpooling expands the possibilities for MaaS users who are part of specific institutions. Thus, casual carpooling is a positive strategy for the urban mobility scenario, as the incentives offered to drivers are expected to expand the offer of drivers willing to offer a ride, while still meeting demand (the maintenance of this free mode). Thereby, casual carpooling as a transport mode within MaaS will remain simple, free of charge for passengers, encouraging drivers with incentives and rewards and targeted at specific audiences.

## Concluding remarks

Most studies on MaaS are being carried out in developed countries with efficient public transportation systems. This study aimed to contribute to initial discussions about MaaS systems in developing countries through more efficient private vehicles' usage.

Considering MaaS as modular and adaptable, the context in which this model will be inserted should be analyzed. Thus, we observed that the practice of casual carpooling, can be a viable proposal in the reality of this study.

In order to propose a strategy to implement the modal ride in a MaaS system, it was necessary to understand the motivating factors of this practice. Thus,. we identified four main motivators factors for casual carpooling; (1) driver's solidarity, (2) simplicity and agility, (3) no costs to passengers, and (4) positive influence of pick-up points.

The act of drivers sharing their vehicles with strangers without expected rewards, in a certain way, mitigates the personal boundaries imposed by materialism. This fact, places casual carpooling for drivers closer to the concept of "sharing in" (Belk, 2010). In this sense, we understand that casual carpooling may be more efficient (even without rewards) in places which some social unified contact exists, such as universities and enterprises.

Nevertheless, we noted that the consumers' acceptance of casual carpooling can be also further stimulated and improve the lack of sharing culture and/or solidarity. For this, as a strategy to implement casual carpooling in a MaaS system, we identified four pillars: (1) Unified drop-off points; (2) Modal customization; (3) Remuneration for credit in MaaS; and (4) No cost for passengers. The unified drop-off points and modal customization are needed to stimulate sharing in (Belk, 2010) and keep the act of casual carpooling simple. The remuneration for credit in MaaS system seeks to avoid rebound effects (Manzini & Vezzoli, 2003) that financial rewards may be responsible and transform the service provider into "another" Uber. At last, the lack of costs to passengers seeks not to configure casual carpooling, even inserted in MaaS, as a service but still as a form of sharing.

In this way, casual carpooling may prove to be a feasible transport as a supplement mode on MaaS systems in last-miles commutes or in places where public transport is not efficient. However, we also infer that the city's infrastructure (pick-up points) and local culture stimulate casual carpooling practices Although this study needs more in-depth analysis, we have brought initial thoughts about casual carpooling in a MaaS system, which as far as we know, has not yet been addressed in the literature. As a future agenda, we propose to expand our sample to other countries, in places where there are MaaS systems already running, such as Finland and Sweden.

**Acknowledgements**

This paper would not have been possible without the support of the *Laboratoire Génie Industriel* (LGI / *CentraleSupélec – Université Paris-Saclay /* France), the Post-Graduate Program in Administration of *Universidade Federal de Lavras* (PPGA/UFLA - Brazil), and the Statistics Department of *Universidade Federal de Lavras* (DES/UFLA – Brazil). We also would like to thank the founding institutions: *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES - Brazil) and *Fundação de Amparo de Pesquisa de Minas Gerais* (Fapemig - Brazil).

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**ARTICLE 5: The quintuple helix model and the future of mobility: The role of autonomous vehicles in a developing country.**

**Preliminary version of the paper published on the proceedings of 25th International Colloquium of Gerpisa, Paris, 2017.**

Gandia, R. M.; Veroneze, R. B.; Antonialli, F.; Cavazza, B. H.; Sugano, J. Y.; Castro, C. C.; Zambalde, A. L.; Miranda Neto, A.; Nicolaï, I. (2017). The quintuple helix model and the future of mobility: The case of autonomous vehicles. In: 25th Gerpisa International Colloquium, Paris. R/Evolutions. New technologies and services in the automotive industry.

**Full Paper accepted on RASI Journal.**
**ISSN: 2447-8156, Qualis Capes: B3**

# The Quintuple Helix Model and the Future of Mobility: The role of Autonomous Vehicles in a Developing Country

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**Abstract:** This descriptive paper of qualitative approach aimed at understanding whether the Quintuple Helix Model (QHM) can positively foster advancements on urban mobility from AVs' insertion in the society, as well as discuss the dynamic of the QHM in the Brazilian context. Synergy among agents proposed by the model is essential for minimizing the impacts on innovation development. It is necessary to understand AVs' development not only as a technological innovation that will bring comfort to society, but rather to realize that this radical innovation can transform the future of urban mobility worldwide. In a Brazilian context, we observed that the country needs to improve in many aspects in order to carry on the future of urban mobility. Brazilians tend to be early technology adopters and the country has good mobile networks, but it will need to improve on regulations, local innovation and road quality to take advantage of AVs (KPMG, 2018). Finally, QHM can corroborate to such needed improvement and, our proposed theoretical framework could explain how this dynamic works.

**Keywords:** Quintuple Helix Model; Urban Mobility; Autonomous Vehicles

## Introduction

In the 21st century, mobility is understood as a major issue and is a focal topic of discussion worldwide. Autonomous Vehicles (AVs) are considered an integral part of the future of mobility and have become a focus of many R&D projects in the automotive industry; in fact, they are considered one of the most popular application of R&D in the recent history of the industry (Fan & Chang, 2016).

Considering the rapid change in the automotive industry and the new players that are ready to shape the automotive industry of tomorrow, there are still a number of legal, ethical, social, environmental and market barriers to overcome. The industry has entered a new era in which value creation relies entirely on dynamic relations in an open ecosystem of innovation, with moving boundaries to be addressed in the long run (Attias, 2016).

AVs are bound to change the future of urban mobility, and this transformation will not only affect means of transport but also society as a whole. Nevertheless, there are many issues that still need to be addressed in the development of AVs, such as the possible impacts of autonomous driving on mobility behaviors and human-machine interactions, as well as related aspects of protection and safety (Schreurs & Steuwer, 2016). AVs will change the structures of our cities (Zakharenko, 2016), and we do not fully understand how our lives will be affected by this automobile revolution.

Although technical developments should be stimulated for the purpose of consolidating this technology, there are several non-technical aspects that have not yet received adequate attention, such as the societal implications of this technology's advancement (Schreurs & Steuwer, 2016). The timing, scale, and direction of AVs' impacts are uncertain, and the opportunities to influence investment decisions are limited (Guerra, 2016). In regard to technology and innovation models, one that is very influential among academics is the triple helix. Created by Etzkowitz and Leydesdorff (2000), this model describes the innovation process via government-university-business cooperation. Although widely used, the concept has evolved to include two other main players: society and the environment. Therefore, the concepts of the Quadruple Helix and Quintuple Helix created by Carayannis and Campbell (2009) have also emerged.

The most important element of the Quintuple Helix is the "knowledge" feature, which encompasses the entire system. This model, which can be used both in theory and practice, highlights the exchange of knowledge resources based on five social subsystems in order to promote the sustainable development of society (Carayannis, Barth & Campbell, 2012).

The quest to reduce uncertainties has motivated a number of countries to take significant steps to be at the forefront of AV research (Cavazza *et al*, 2017). Universities, industries and governments worldwide (especially in the USA, China and the European Union) are studying AVs to determine how this innovation may affect cities and be implemented as part of urban mobility solutions.

Currently, the concept has evolved, and the triad of university-industry-government has been strengthened by new models of knowledge generation that include society (Quadruple Helix) and the environment (Quintuple Helix) as important aspects of innovation dynamics. According to Lombardi et al. (2012), the Quintuple Helix operates in a complex urban environment, where market demand, governance, civic involvement and citizens' characteristics, along with cultural and social capital endowments, shape the relationships among the traditional helices of university, industry and government.

A key reason for policymakers to consider AVs now is that the spatial planning and infrastructure investment decisions that we make today will determine the development of our countries and cities for decades (KPMG, 2018). Thus, adopting this perspective, other countries, especially in Europe, have already begun to design and plan AV-related actions, anticipating the future of mobility by thinking about policies that favor the propagation of this new technology. However, this is far from the reality in Brazil. We realize that there is still a lack of coordination among companies, government, universities and even society – coordination that would enable AVs to promote economic, social and sustainable development for all. In this sense, the QHM can fill the gap among the abovementioned agents. Thus, it remains to be seen "when" and, most importantly "how", this innovation will be disseminated.

In this sense, our research problem can be summarized in the following questions: How can the QHM positively support the implementation of AVs to advance urban mobility? What are the dynamics between the QHM and the Brazilian context? Therefore, this paper aims **to understand whether the QHM can positively foster advancements in urban mobility via the insertion of AVs into society**. Furthermore, we seek to discuss the dynamics of the QHM in the Brazilian context.

The mobility systems of the future are likely to be very different from what exists in most of the world today. It is therefore important to understand that people are at the center of this evolution (Ramkumar, 2016). In addition to thinking about safety aspects, other issues should be discussed in a coordinated way (Schoitsch, 2016) because increased AV availability increases workers' well-being, displacement distances and the sizes of cities, while also improving traffic coverage and collective transportation (Zakharenko, 2016).

## Urban mobility and autonomous vehicles

Considered part of the lifeblood of our cities, mobility is what keeps our urban centers running (McKerracher, 2016). The concept of urban mobility is considered to encompass the characteristics of all transport modes and their relationships with land use, environmental quality and urban planning (Oliveira et al., 2017). Issues related to sustainability and overpopulation, among others, make mobility one of the main concerns of our contemporary society, making it a central topic that is discussed worldwide.

Among the currently available providers of transportation, the automotive industry plays a fundamental role in mobility. In recent years, this industry has been witnessing a transformative evolution into a new ecosystem, known as “intelligent mobility”, into which AVs are being inserted. Consequently, this new ecosystem presents several possibilities for new scenarios (Attias & Mira-Bonnardel, 2016). In this sense, it is understood that AVs’ development is a disruptive innovation that promises to have a substantial impact on issues of urban mobility.

Hodson (2016) notes that AVs are only a part of a major revolution in urban transport, as there are simultaneous expansions of autonomous technology to other modes of public transport (e.g., metro lines that already operate without drivers in major cities worldwide). Corroborating this, Attias (2016) proposes that in a mid-term perspective, this evolution will not stop with AVs and will open the field for the design of similar technical objects (e.g., trucks, buses) and even boats and autonomous planes.

The convergence process of such dynamic movements between the traditional transport model and intelligent mobility culminates with consumers being even more connected and seeking more accessible mobility solutions at more competitive prices. In this sense, Enoch (2015) proposes that traditional transport models (cars, buses and taxis) will converge to intermediate transport models (centered on sharing), and the author goes further in stating that AVs will accelerate this convergence process due to their various advantages, such as increased mobility, better usage of urban spaces, reduction in congestion costs, increased road safety, user comfort, and reduction in fuel consumption and pollutant emissions (Schoitsch, 2016; U.K. Department for Transport, 2015).

However, negative impacts still surround the development of AV, such as social risks (rebound effects); personal data protection (e.g., hacking attacks); increased insurance costs; loss of revenues related to the reduction in individual traffic (e.g., reduction in parking, speeding and infraction tickets); attraction of passengers from public transport systems, resulting in job losses (e.g., taxi drivers, truck drivers and bus drivers may lose their livelihoods and occupations); possible investments in infrastructure; and rules and regulations, among others (Schoitsch, 2016).

In this sense, it is understood that any positive or negative impacts of this innovation go beyond organizational and governmental limits, affecting many other spheres of our modern society. Therefore, it is important and necessary that the building and execution of this technology contemplate all these spheres (government, companies, society, academy, environment) synergistically to optimize this dynamic process of transformation in contemporary urban mobility.

**From the triple helix to the quintuple helix**

Countries' innovation systems have been gaining strength given that knowledge-producing institutions are essential to fighting the issues faced by our modern society. Thus, companies, governments, universities and even the population must work together on trying to curb, or minimize, the negative social consequences of the economic development that has occurred so far.

The main difference between the traditional triple helix model and the newer quintuple helix is in the "innovation ecosystem", which combines and integrates social systems and environments, emphasizing the importance of the diversity of actors and organizations, such as universities, small and medium-sized enterprises, and large corporations, government innovation networks and knowledge clusters (Carayannis & Campbell, 2011).

In the triple helix model, the relationships are overlapping, creating hybrid environments, leading to dilution of barriers and enabling greater cooperation (Silva et al., 2019). For this, the government has the role of elaborating public policies that foster innovation processes, and the government is also responsible for regulating and normalizing economic activity. Companies must concentrate on their productive activities in a cooperative sense, and the production, dissemination and transfer of knowledge are reserved for universities (Vieira et al, 2015).

The above actors are pressured by the accelerating pace of change and innovation in both scientific and technological environments. Thus, in the process of manufacturing autonomous cars, even cutting-edge companies are facing ethical, moral, technological, and urban mobility challenges because evidence of the long-run impact of AVs is not yet clear and well mapped.

The first step to be stimulated within this innovation system begins with the introduction of education inputs. Because more investments flowing into the helix of the education system means the production of new equipment, new locations for scientists and teachers, and greater opportunities for research, a greater outlet for innovations in science and research can be created (Carayannis, Barth & Campbell, 2012).

For this to happen in an integrated way, the other helices must be interconnected via the input of knowledge. The second step begins with human capital in the helix of the economic system, represented by companies. Any investment in knowledge and in promoting the production of knowledge brings new impulses crucial to innovation, know-how and the advancement of society (Carayannis, Barth & Campbell, 2012).

Leydesdorff (2012) argued that to go further – i.e., towards the fourth or fifth helix – would require greater specification, operationalization in terms of potentially relevant data, and sometimes additional development of relevant indicators. To do this, companies must focus on their productive activities in a cooperative sense, and the university reserves its role in constructing, disseminating and transferring knowledge (Vieira et al, 2015).

The "fourth helix" of the model refers to the culture and values of society. In this way, innovation policies and strategies must recognize the important role culture plays in promoting a knowledge-based economy. The politics of knowledge and innovation should be inclined to reflect the dynamics of "media-based democracy" and their role in the elaboration of strategies. The goal is to develop a policy of innovation to generate economic performance and thus link the whole system of innovation in a country (Carayannis & Campbell, 2009).

By adding the fifth helix to the model, the model becomes more comprehensive because, in addition to the analytical and explanatory approach it already possessed, the "natural environments of society" are added in the macro analysis (Carayannis & Campbell 2010). Now, the socio-ecological environment is taken into account, that is, the Quintuple Helix's innovation system is ecologically reliable because it is based on the understanding of the production of knowledge (research) and the application of knowledge (innovation), both of which consider environmental issues (Carayannis, Campbel & Rehman, 2016).

We believe that the model has the advantage of aggregating new knowledge, helping in the creation and development of creative innovations and new learning methods. At the same time, innovation in AVs is still characterized by lack of coordination among OEMs, governments, universities and even society; such coordination is necessary if these vehicles are to effectively support economic, social and sustainable development overall.

## Methodological Approach

With the dual aim of understanding whether the QHM can positively foster advancements in urban mobility as a result of AV insertion into society and discussing the dynamics of the model in the Brazilian context, the adopted research design (Figure 01) was characterized as a qualitative approach of a descriptive and exploratory nature.

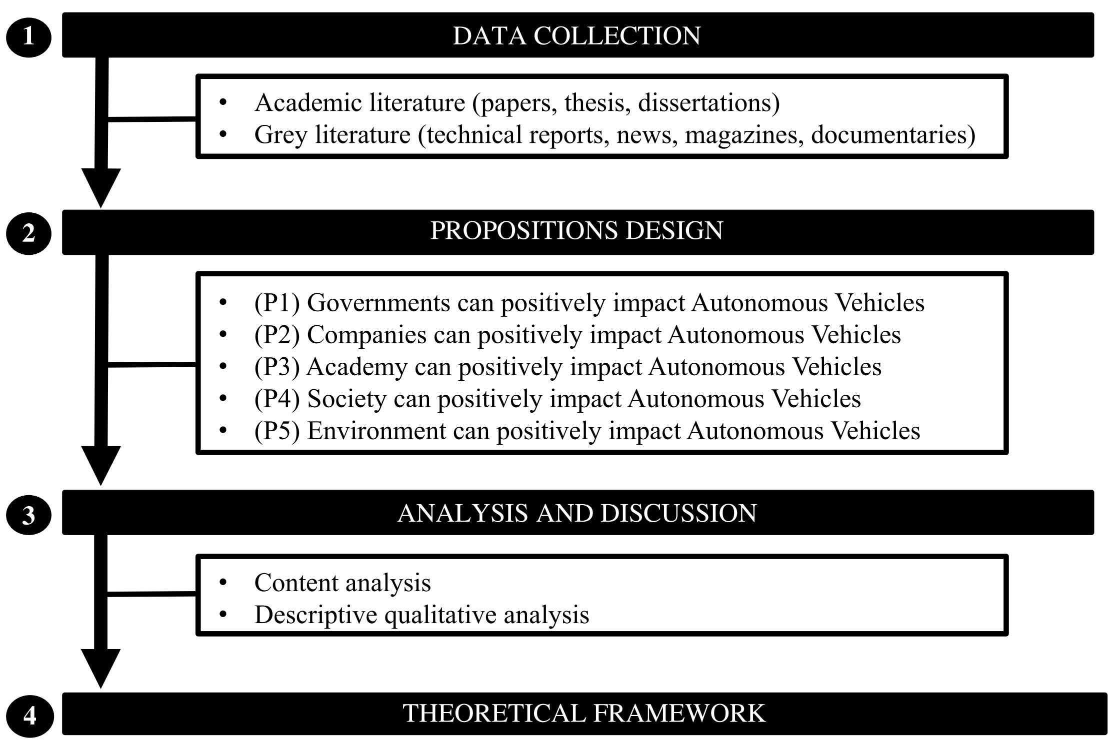


**Fig. 1:** Methodological research design.
Source: prepared by the authors.

On **Step 1**, the data collection was performed in both academic and grey literature by using the saturation criteria as a stopping point (Fontanella; Ricas; Turato, 2008; Guerra, 2006). Through this literature review it was possible to define parameters to contextualize the insertion of AVs in Brazil instead of other countries. Moreover, it was observed that the alignment between the helix proposed by the QHM model could propose statements for the insertion of these vehicles in a country and the theoretical establishment of these propositions had not yet been realized.

In this sense, on **Step 2** we created five propositions based on QHM that could positively impact AVs. These propositions not only sought to establish isolated relationships between the impacts of each stakeholder but also to highlight interrelationships between the helix and the impact of this connection on the insertion of AVs in Brazil (presented as the theoretical framework). In order to achieve our aim, on **Step 3**, we used categorical content analysis and descriptive qualitative analysis (Bardin, 2010; Vergara, 2005). The information collected was categorized in order to establish parameters so that the analyzes could be established as close as possible to the reality found.

Last but not least, on **Step 4**, we created a theoretical framework based not only on isolated analysis of the helices but on the interrelationship between the propositions. Our idea was to bring the results and practical implications together to illustrate the theoretical contribution of the QHM to urban mobility in Brazil based on AVs' insertion.

## Results and Discussion

Automotive companies, suppliers, government, regulators, legal authorities, rating agencies, road operators, and the general public have been prepared for what is the greatest inflection point for the automotive industry since the introduction of the assembly line (Mosquet et al, 2015). In this session, we tried to show the impact that the Quintuple Helix could have on AVs and the impact on each of the 05 helices: (P1) government; (P2) companies; (P3) academy; (P4) society and; (P5) environment.

### (P1) Governments can positively impact autonomous vehicles

The relations among the institutional spheres of university, industry, and government can help generate solid strategies for economic growth and societal transformation. From a political perspective, national innovation systems can be defined as a relevant reference framework for governmental interventions, which are aimed at the economic growth of different industries (Etzkowitz & Leydesdorff, 2000). In this sense, the organization of the political system is of crucial importance because it formulates the "will" of the state, that is, where the state is directed both in the present and the future and how it organizes the general conditions of the nation. Therefore, this helix has active political and legal capital through incentives, ideas, laws, plans, and partnerships that can benefit companies and the population, as well as emerging sectors (Carayannis, Barth, & Campbell, 2012).

An issue that is already on the agenda in some European governments concerns AVs' regulation and encouragement of the motor vehicle industry. Regulation should ensure safety and accompany the development of the emerging AV industry, avoiding any market failures. Different countries have created rules on prototypes allowing testing, licensing and operation of this technology on public roads (Frisoni, et al., 2016).

For instance, in Germany in 2015, the federal government started a round table on vehicular automation where industry, academia and government met to define specific areas of action to support the introduction of autonomous driving in the country. Discussions included topics such as infrastructure, legislation, innovation, and interconnectivity (Frisoni, et al. 2016).

Sweden is supporting a national program to promote alliances among the various stakeholders. In 2009, the country established a partnership with the automotive industry, called "Strategic Vehicle Research and Innovation", with the aim of investigating innovative solutions for the climate, environment and safety. This report involves R&D activities worth approximately €100 million per year (half of this amount is publicly funded), including research in AVs and connected transport systems (Frisoni, et al 2016).

France is encouraging a new strategic alliance among the main French automotive companies to favor the development of AVs in the country. This industrial strategy is called "*La Nouvelle France Industrielle*" and was promoted by the Ministry of Economy and Finance beginning in 2014. AVs are mentioned as a key point of technological development in France.

Based on the above reports, we see that the discussions between government and industry in the aforementioned European countries are moving towards partnerships. Despite the progress initiated by some countries, there seems to be little coordination of the actions taken by different jurisdictions; the jurisdictions are restricted to targeting their own individual actions (Frisoni, et al., 2016).

The analysis of the Brazilian context points to the Government helix as the weakest link. Undoubtedly, the Brazilian government has several issues and problems that need to be overcome so that the implementation of AVs can be made feasible. According to the KPMG (2018) report "*Autonomous Vehicles Readiness Index,*" which seeks to access countries' openness and readiness for AVs, Brazil "has the weakest scores of the 20 surveyed countries for policy and legislation".

Recently, the Brazilian government inaugurated the new automative sector regulation, called "Route 2030". The program, launched more than a year late, aims to replace and broaden the scope of its predecessor, "Inovar Auto" as well as to set rules for the manufacture of automobiles produced and marketed in Brazil over the next 15 years.

The expectation around this new government program is high, investments in the areas of electric mobility, energy efficiency, manufacturing 4.0, internet of things, production digitization and connectivity have already been announced.

Although initiatives such as the Rota 2030 are already beginning to develop in the national context, there is still a lack of articulation and more tangible advances regarding new developments in the Brazilian automotive industry. Specifically, these results clearly state the deficiency of the Brazilian government concerning the legislation and incentives surrounding AV technology. Thus, there is still a large chasm to be overcome so that Brazil can really be ready for the imminent arrival of AVs.

**(P2) Companies can positively impact autonomous vehicles**

We observed that the governments of some countries offer tax support and create public policies to strengthen their relationships with universities and industries. For example, some European countries are already addressing the regulation of incentives for the AV industry. Regulation should ensure safety and monitor the development of this emerging industry, avoiding any market failures. These nations have created rules regarding prototypes that allow testing, licensing and operation of this technology on public roads. These changes, in turn, directly impact manufacturers in the automotive industry, as all actors must work together to implement a “common language” solution.

Moonzur (2012, p. 12) also mentions the likely disappearance of driving schools. “In case the vehicle would be completely autonomous and not require driver intervention, the vehicle that will be in sole command”. Morally, the relevant decisions would have been made by the developer of the underlying algorithm. In any case, the automatic system would act, and the consequences cannot be considered accidental because they are determined beforehand. In many cases, different interested parties should cooperate to advance such solutions.

It is important to emphasize that it is not only vehicle manufacturers that are benefitting from advancements in AVs but also the economic system as a whole. The main stakeholders of this advancement are described as telecommunication companies, shared vehicle services, and technology and insurance companies (European Parliament, 2016), and it is expected that they will all have new services and demands as a result of the synergy generated by the QHM.

Botelho, Carrijo and Kamasaki (2007) say that this helix concentrates “economic capital” (e.g., entrepreneurship, machines, products, technology, money). Given this concentration, relations with customers and suppliers, with companies competing with research institutes and/or universities, appear to be one of the most important issues (Leydesdorff & Zawdie, 2010).

To ensure strong and sustained public support, the industry will need to engage with the general public and be direct about the limitations and benefits of the technology (BCG, 2015). To accelerate AVs’ adoption and, consequently, urban mobility, industry players must collaborate to overcome technology challenges (Mosquet et al., 2015).

In this sense, actors in the private sector should consider partnerships that go beyond traditional sectorial boundaries (many of which have already begun to blur). Consumers will judge the vehicles by how they are integrated with the services they provide: from in-car entertainment to on-demand rental platforms. Those players in the industry who can unlock new partnerships between technology and service providers will have the best chance of avoiding marginalization (McKerracher, 2016). According to the European Automobile Manufacturers Association, the European car industry annually invests € 41.5 billion in

R&D, approximately 5% of its total turnover. Although this amount is spent on a variety of research and testing programs, it is undeniable that the development and implementation of AVs represents one of the major interests of car manufacturers (Tan et al, 2016).

Although the automotive industry has strong relevance on the national scene, it is worth noting that Brazil is a “technology importer and commodity exporter,” and this fact demonstrates certain weaknesses in our OEM industry. According to the KPMG report, Brazil “received the lowest scores on R&D hubs, AV technology company headquarters, patents and investments” (KPMG, 2018, p.33).

In this context, it is worth highlighting one of the main actions of the Rota 2030 program, which enables the automotive chain industries to invest the money that would be spent on import duties and taxes in R&D programs. Initiatives like this can be important in fostering new partnerships between industry and academia, significantly increasing the industry's innovative capacity.

The Brazilian industrial scenario is paradoxical: on the one hand, we see growing interest and investment in some companies, e.g., Uber operation has been authorized in large cities in the country since 2016, and Brazil is considered one of the largest Uber markets globally (KPMG,p.33, 2018). On the other hand, we know that there are many problems related to infrastructure and legislation that need to be addressed. The same report notes that Brazil “gets the lowest rating for people’s use of technology.”

**(P3) The Academy can positively impact autonomous vehicles**

The convergence between basic and applied research is an opportunity for universities to transfer their knowledge to other spheres. In this regard, the academy plays a central role between the government and industry, especially car manufacturers. It was observed that universities from different countries are now cooperating with large programs involving both public and private actors for the development and application of automated mobility systems.

Technical aspects that permeate AVs were research fields in earlier decades. During the 1990s, the USA Defense Department promoted the development of self-driving vehicles for military purposes by financing projects across academia and automotive companies (U.K.

Department for Transport, 2015). Nevertheless, non-technical aspects are still an incipient knowledge field (Gandia *et al*, 2017).

In this sense, Cavaza *et al.* (2017) identified five knowledge categories that could contribute to the dissemination of AVs: policy issues (law); ethics, moral issues, liability; transport planning; consumer behavior and business models. It should be highlighted that even with the academy's efforts in projects that stimulate synergy among the spheres, there is still a gap that affects all the interested parties as proposed by the QHM.

As for the academic area, Brazil does not have an impressive percentage of publications according to information extracted from the Web of Science database. Regarding the field of AVs, the country ranks 17th in publications worldwide. Although it ranks first in Latin America, the discrepancy in numbers of publications is huge (95 publications for Brazil versus 1796 for the first-place country); Brazil is responsible for just 1.41% of all publications in the world (Gandia *et al* 2017).

If we consider the business and management fields, the results are even worse. According to a previous investigation in the 3 main international databases, of the 644 papers found (244 from Scopus, 56 from WoS and 344 from SD), there was no single paper originally from Brazil (Cavazza *et al*, 2017).

It is important to highlight that this lack of academic knowledge in our country regarding this object of study (Gandia *et al*, 2017; Cavazza *et al*, 2017) has a direct impact on AVs' development, as academia is a valuable actor as a provider and manager of information and knowledge for other helices.

**(P4) Society can positively impact autonomous vehicles**

In an era where innovation is blooming, in which social innovation and ecological innovation imply behavioral changes at both individual and social levels, the challenges of health, poverty and climate change, and especially the future of cities, must be addressed. The regional governance system and companies should be open to new groups in society that are capable of promoting a culture of challenge.

This new era also includes perceptions of consumption that are different in each country; for instance, in emerging economies (e.g., Brazil), the ownership of a car is perceived as conveying status, independence and power. In this sense, it is also worth understanding consumers' needs (Attias, 2016).

While consumers expect automakers to produce reliable, high-quality and safe vehicles, they also believe that technology companies must bring in their expertise. Apple and Google are top-of-mind possibilities. Consumers in India, in the United States, and China are more likely to see a technology company as an ideal coordinator of the entire chain. One reason may be the importance and visibility of the technology industry in these economies (Mosquet et al, 2015).

A survey conducted by the Boston Consulting Group and the World Economic Forum with 5500 consumers in 10 countries (North America, Europe, Middle East and Asia) highlighted the fact that users who adhere most to the AVs are more numerous in emerging countries such as India (85 %) and the United Arab Emirates (70 %) than in France (60%) and Germany (44 %) or Japan (36 %). Another point to note in this survey is that traditional manufacturers are by far those that consumers consider the most reliable (between 50 and 58% of reliability), and they think about other technology players such as Apple and Google as bringing "relevant, but complementary expertise" (Mosquet et al, 2015 WEF 2015).

On the other hand, social pressure can be an obstacle. Generally, audiences who are very keen on new technologies may change their minds quickly. If, for example, a horrible accident involving an AV occurs in the early stages (market introduction), regulators could face pressure to take a strong position against such vehicles. To ensure strong and sustained public support, the industry will need to engage with the general public and be direct about the limitations and benefits of this technology (Lang et al, 2015).

Clearly, societal acceptance is very crucial to AVs' adoption, especially considering that stakeholders must address the interests and concerns of consumers and policy makers. Overcoming this challenge requires strong collaboration among the parties involved, especially industry and government, to address concerns adequately (e.g., by establishing stringent safety standards) and to transparently provide economic alternatives to those who are adversely affected (Lang et al, 2015).

Contrary to the government helix, the societal one emerges as the strongest link in the Brazilian context. First, it is important to note that the Brazilian auto market stands out on the world stage and can be considered the gateway to Latin America (ICCT, 2015; SEBRAE, 2015). Another important factor is the Brazilian consumer profile:

> Brazilians are the keenest of all 20 countries on AV technology, mobile phone penetration is more than 100% of the population and Brazilians are known for being early adopters of new technologies. Despite this, the country gets the lowest rating for people's use of technology (KPMG, 2018, p.33).

When analyzing the profile and the behavior of the Brazilian consumer, we can observe great acceptance potential for AVs in our country. Such characteristics, which are linked to the size and potential of the Brazilian market, have attracted attention from researchers and industries worldwide and serve as a counterpoint to the shortcomings presented by other helices.

**(P5) Environment can positively impact autonomous vehicles**

One could argue that concepts such as "sustainability", "sustainable development" or "social ecology" are already, *per se,* interdisciplinary and transdisciplinary, as they are now fundamental to the conception of products and to academic research. Research questions and problem-solving in relation to ecology, the environment, environmental changes and environmental protection increasingly depend on interdisciplinary and transdisciplinary network configurations of different knowledge and innovation modes. Cross-linking human rights, human development and the environment already bridges analytically into sustainable development, clearly including features of social ecology (Carayannis & Campbell, 2010).

In this context, AVs can reduce fuel consumption and pollution; moreover, this emerging technology promises several potential benefits, such as reducing collisions and deaths, reducing traffic congestion, improving mobility for people incapable of driving and mitigating environmental impacts. Sustainability is a crucial desideratum for engineers and policy makers considering vehicle design, public versus private transportation, and infrastructure manufacturing (Mladenovic & McPherson, 2016).

There is an expectation that AVs can reduce fuel use and pollution (because they will be electric) by strictly following hypermiling strategies. They may position themselves closely behind other cars because AVs have a faster reaction response and do not need to have the same safety margin as humans (Spieser et al. 2014). In the future, the progressive replacement of fleets of combustion vehicles by electric vehicles will also be positive in this regard.

In a study carried out by Fagnant and Kockelman (2014), the authors found that a single shared AV has the potential to replace approximately 11 private vehicles. In addition, reductions in energy consumption and emissions of air pollutants can be expected when the AV system begins to be used by 5% of the population.

Sustainability is also an important element in the pursuit of social justice: institutions that ensure fair relations between people and reduce harm to future generations are unquestionably important. For these reasons, sustainability is a crucial point for engineers and policy makers who consider vehicle design, public transport vs. private transport, and infrastructure manufacturing (Mladenovic & McPherson, 2016).

Perhaps this is the helix with fewer inputs to discuss in the national scenario. The Brazilian population in July 2016 comprised 206,081,432 inhabitants (IBGE, 2016), and it is possible to calculate an average of 4 inhabitants per car (automobile). This is a relevant environmental impact, especially considering the impressive number of people using private transportation. A study from the Institute of Applied Economics Research (IPEA, 2011) showed that 65% of the population of Brazilian capitals uses public transportation to commute, and this number drops to 36% in non-capital cities. Only 2.85% of capital populations commute by foot, while in other cities, this percentage rises to 16.63%. On average, in all Brazilian cities, 23% of the population uses a car as a means of transportation.

Once again, if we consider the new technologies, the image is not promising: "Brazil shares the bottom spot with Russia on market share of electric cars which are not generally available, although hybrid cars are starting to be imported" (KPMG, 2018, p.33).

## Triggering AVs via Academy Helix in Brazil

In order to summarize the main analyzes and implications generated by the propositions presented in the previous topics, we used the theoretical model of the Quintuple Helix to establish positive relations between urban mobility and the introduction of AVs (Figure 2). It was observed that the helices present synergetic relations, which should act in consonance so that a positive development of AVs is established and, consequently, AVs contribute to urban mobility.

It is noted that the government can exert a direct influence on all helices (from political stimuli to transport plans and laws), and such influence can determine the positive or negative paths along which the devices inherent to the development of AVs and the future of mobility will be established. The academy must act on both the technical and non-technical fronts of this development; it should act like a trigger by identifying the demands of other spheres to point out scenarios that allow orchestrated thought among government, industry, society and the environment.

The social sphere presents cultural, consumer and infrastructure-related specificities, and these factors must be taken into account as the global regulatory aspects of AVs are developed (e.g., automotive technology imports from other countries to Brazil must take into account the cultural aspects of Brazilian consumers). Regarding the environmental sphere, it is important to emphasize the strong interface between AVs and sustainability issues. Several studies point to the gains generated by these vehicles with regard to sustainable development and social ecology.

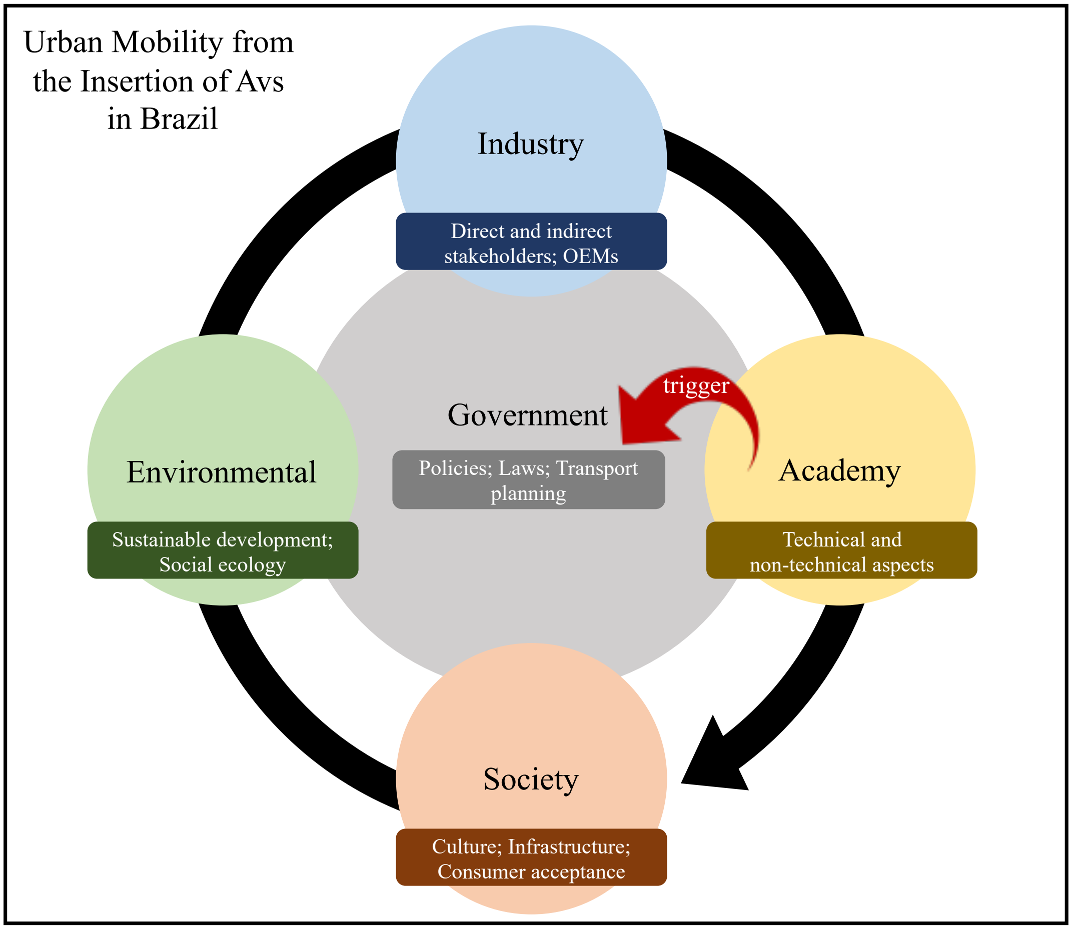


**Fig. 2:** Theoretical framework – the QHM positively assists with advancements in urban mobility as a result of the insertion of AVs into society.
Source: Prepared by the authors.

According to Santos & Benneworth (2019) the collaboration academy-industry is increasingly important. In this context, it is important to highlight the role that the industry (including the entire network of stakeholders, OEMs and companies and businesses that will be indirectly impacted) will play in the articulation, deployment and dissemination of AVs. However, in order to achieve the technical and non-technical features of this new technology the industry will need to work together to the academy. Only in this way will the government helix have subsidies to implement regulatory actions for the insertion of AVs in Brazil with a lower risk of rebound effects.

Among several examples of the dynamics of this model as a trigger for insertion of AVs, we can cite the industry's efforts to understand, based on studies conducted by the academy, the consumer's perspective in their acceptance of the use of autonomous shuttles over conventional buses in public transportation. Based on the results of these academic efforts, governments could establish regulatory guidelines and / or transportation planning programs that would best suit the replacement of a conventional road line with, for example, an autonomous shuttle.

## Concluding Remarks

This study has sought to understand the contribution that the QHM can make to the future of urban mobility via the insertion of Autonomous Vehicles. We observed that the QHM contributes favorably to the future of urban mobility, in which AV-related innovation plays a crucial role. It is noteworthy that among projections and scenarios of the future of mobility (Lang 2016; McKerracher, 2016; PWC, 2016; Mosquet, 2015; Lang et al, 2015), AVs are a key factor, even though this innovation is still surrounded by uncertainties.

According to the QHM, the synergy among agents is essential if the impacts of the development of this innovation are to be minimized, and although we observed a need for action by all agents, this was observed in a fragmented way in the documents and studies analyzed. It is understood that the technological development of AVs can be considered at a global level; however, in the case of urban mobility, local specificities should be taken into account, considering social and governmental particularities as determining factors for AV dissemination. This study opens discussions on the topic by demonstrating the importance of establishing AV innovation in a synergistic way. Among the stakeholders responsible for the development of AVs, the academy will be responsible for the search for a suitable model.

Second, it is necessary not only to understand AVs development as a technological innovation that will bring comfort to society but also to realize that this radical innovation can change the future of urban mobility around the world. Thus, developing this technology without looking at all the helices proposed by the QHM would be like "driving with one eye closed". Governments should be aware of this, but this paper agrees that the academy has an important role to play in stimulating this line of thought; the academy must help the government ensure that this revolution happens with minimum negative impacts.

In the Brazilian context, it was observed that the country needs to improve many aspects of the way it is preparing for the future of urban mobility. Brazilians tend to be early technology adopters, and the country has good mobile networks, but it will need to improve its regulations, local innovation and road quality to take advantage of AVs (KPMG, 2018). The QHM can corroborate those needed improvements, and the theoretical framework can explain how this dynamic works.

In this sense, we proposed a concept in which Industry, Academy, Government Society, and Environment (Quintuple Helix Model) has synergetic relations, which should act in consonance for a positive development of AVs. As the government can exert a direct influence on all helices (from political stimuli to transport plans and laws), such influence can determine the positive or negative paths along which the devices inherent to the development of AVs. At the same time, the academy must act on both the technical and non-technical fronts of this development. The Academy-Industry outputs should act as a trigger for the positive transport planning pathway considering the future of AVs in the Brazilian context.

In addition, this is a theoretical paper; therefore, interviews or surveys have not been conducted. Regarding future research, we suggest practical studies that generate data in order to validate our theoretical framework. We also suggest deeper studies for each helix to determine the importance of each to the QHM. Finally, it is important to highlight that this study represents a starting point for analyses involving AVs and the spheres of the QHM and that it can contribute to advances and future studies on the issues of mobility, eco-innovation, sustainable innovation, smart cities, industry 4.0 and more.

## Acknowledgements

This paper would not have been possible without the support of the Post-Graduate Program in Administration of *Universidade Federal de Lavras* (PPGA/UFLA - Brazil) and the *Laboratoire Génie Industriel* (LGI / *CentraleSupélec – Université Paris-Saclay /* France). We also would like to thank the founding institutions: *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES - Brazil) and *Fundação de Amparo de Pesquisa de Minas Gerais* (Fapemig - Brazil).

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# PART THREE

*"The whole is more than the sum of its parts."*

*(Aristotle)*

## 5. GENERAL CONSIDERATIONS

As This thesis was drawn up in the form of scientific articles. The detailed conclusions are displayed on Part Two of this manuscript within each of the five articles. The general considerations are presented here, as well as some of the research limitations and suggestions for future studies (Figure 1).

From the objective of analyzing the concept of MaaS to identify its implementation and acceptance in the future of urban mobility, this doctoral 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. It is worth to highlight that the general considerations are not looking for the separate scientific article' result of this doctoral thesis but the sum of its parts.

The results have shown that the concept of Mobility as a Service' may present as a foundation the theoretical tripod of Product-Service System, Business Ecosystem, and Eco-Innovation. We observed that all of those knowledge fields are related to the state-of-the-art regarding MaaS founded in literature. MaaS can be considered a result-oriented PSS. From this perspective, the mobility function is what should be considered as a result of a MaaS system. To this end, the business ecosystem contributes by the concept of coopetition with distinct stakeholders creating value for users in terms of mobility through a platform. The eco-innovation perspective has made us reflect upon the real need for vehicle ownership and its efficient use. We observed that current MaaS systems are subjected to rebound effects if private car users may not find the value needed to replace their vehicles, which, in consequence, would not characterize MaaS as an eco-innovation.

In this sense, Mobility as a Service can be thought not only as a concept, phenomenon, or transportation solution but also as a business model. More specifically, MaaS, as a PSS, can be named as a result-oriented business model. Thus, we proposed MaaS 2.0 as "a business model that should, via a single platform, integrate result-oriented services among different stakeholders in an ecosystem with a value proposition sufficiently greater for private car users to switch to the platform or use their vehicles more efficiently."

Therefore, as a business model, MaaS has to be oriented to the users' value proposition, and, like any other business model, the concept of MaaS must be "tropicalized" in order to successfully implemented in developing countries. It is worth highlighting that we understand that the complexity of the ecosystem that permeates MaaS should be related to the context where the business model will be established.

By this, studies dedicated to the deployments of MaaS business models should also be oriented to the consumers' willingness to use MaaS. However, to our knowledge, MaaS studies have been so far only carried out in developed countries – with efficient public transport networks that act as a backbone for the MaaS systems. Consequently, it was observed a gap with regards to both academic studies and practical deployment of MaaS systems in developing countries.

In this sense, this doctoral thesis' results present an exploratory analysis in the willingness to use a MaaS business model among commuters in a developing country. Our results presented a substitution' probability of a MaaS business model for car users and non-car users in a developing country. Also, we observed that, despite the lack of decent and reliable public transportation to act as a backbone, there are alternatives within the modal-split to implement a MaaS business model. For instance, the act of sharing a car may be used as a transport modal in a MaaS system and, casual carpooling may be an alternative to implement MaaS in the context where this transport mode is accepted. Therefore, the choice of transport modes must be oriented by the MaaS ecosystemic business model based on these users' result-oriented value proposition.

Regarding Autonomous Vehicles, it is undeniable that this technology will comprise the future modal-split of urban mobility. In order to achieve AVs' dissemination, technical aspects are already waiting for the evolution of non-technical knowledge fields, such as consumer behavior, ethics, laws, and public policies. Based on this, we observed migration of the field from a multidisciplinary approach to a pluridisciplinary one, with a higher number of studies converging to the latter. However, our results indicate that the deployment of AVs will not be the same in every context, and – as the same of MaaS business models – AVs' implementation in developing countries must be "tropicalized".

Corroborating with this, our results indicated that, despite the technological development of AVs can be considered at a global level, local specificities should be taken into account, considering social, academic, and governmental particularities as determinant factors. In the Brazilian context, improvements in many aspects are needed while paving the way for the future of urban mobility. By this, the academy should act as a trigger to the dissemination of AVs stimulating the other stakeholders – especially government and industry.

We conclude that the technical development of Autonomous Vehicles, by itself, is not the solution for urban mobility. In the same way, the phenomenon of Mobility as a Service should be better analyzed via other perspectives. In order to take place in the future of urban mobility, MaaS must be considered as a modular and adaptable business model, applicable to any context (the efficiency – or inefficiency – of public transportation should not be limiting). For this, the business model of MaaS should be established under the ecosystemic approach – and sustainability should not be considered as an intrinsic feature in a MaaS business model.

This innovative ecosystem business model must consider consumer acceptance and the transport modals that fit the specific context established. In other words, a successfully implemented MaaS system in Sweden will likely not have the same success rates in Brazil, whether not "tropicalized." Thus, AVs' implementation will complement, in specific contexts, the demands of users in a MaaS' ecosystem. The deployment of AVs can also occur outside a MaaS business model ecosystem, in specific places and contexts. In this sense, AVs should be considered as one among several elements in the future of the urban mobility ecosystem.

**General Consideration' Highlights**

- The The concept of MaaS is modular, adaptable, and can be applied to various contexts;
- MaaS can be considered as a Business Model;
- The efficiency of public transport should not be limiting the implementation of MaaS. Given a particular context, public transportation inefficiency should be balanced by different private transport offerings;
- MaaS is not for everyone; there are specific demands for this business model;

- There is a willingness to use MaaS in developing countries;
- MaaS and AVs must be “tropicalized”;
- Sustainability should not be considered as an intrinsic feature in the design of a MaaS system, the use of private vehicles should be analyzed;
- The technology for the implementation of AVs is more advanced than other non-technical knowledge fields. In order to achieve AVs’ dissemination is necessary to seek pluridisciplinarity;
- The technical development of AVs, by itself, is not the solution for urban mobility; AVs should be considered as one, among several elements, an urban mobility ecosystem. Their implementation will complement, in specific contexts, the demands of users into this ecosystem.

**RESEARCH QUESTION**
**How can a MaaS system be implemented the future of urban mobility?**

**GENERAL OBJECTIVE**
**Analyze the concept of MaaS in order to identify its implementation and acceptance within an urban mobility system.**

| Individual Objectives | Main Results | Limitations | Future Studies |
|---|---|---|---|
| Article 1<br>The business ecosystem of Mobility as a Service as a product-service system: An eco-innovation. | - Theoretical Background for MaaS concept;<br>- MaaS is disruptive whether eco-innovative;<br>- Proposition of MaaS 2.0;<br>- MaaS as a BM (modular & adaptable). | - Theoretical essay, empirical studies are needed. | - Empirical analyzes in contexts where MaaS can be applied (e.g. developing countries);<br>- Further analyzes in each pillar (theoretical tripod). |
| Article 2<br>Autonomous vehicles: Scientometric and bibliometric review. | - Maturity of technical aspects, needed to non-technical researches on AVs' field.<br>- Migration of the research field from multi to pluridisciplinarity (crucial for AVs' spread). | - Single database source (Web of Science), not considering other possible works related to the area;<br>- Possibility of mismatch of search terms. | - In-depth analysis of publications in terms of individual search terms, as well as the sub-areas identified as trends in this paper. |
| Article 3<br>Willingness to use Mobility as a Service in a developing country. | - There are users' demand for MaaS' schemes in a developing country;<br>- Distinctions in value perceived among users' profile (car and non car' users). | - Non probabilistic sample (over 300 interviews), Require more in depth analyzes;<br>- Research applied in a specific context (Small university town). | - Aspects related to the integration of actors (considering AVs) and the MaaS ecosystem;<br>- Implementation of MaaS (specificities and strategies) in a developing country. |
| Article 4<br>Casual carpooling as a strategy to implement Mobility as a Service schemes in a developing country. | - MaaS can be implemented without an efficient PT (MaaS modular & adaptable);<br>- The act of sharing a car may be used as an eco-innovative strategy in a MaaS scheme. | - Non probabilistic sample (over 300 interviews), Require more in depth analyzes;<br>- Research applied in a specific context (Small university town). | - Validate the variables (4 pillars to implement casual carpooling in MaaS);<br>- Expand the sample to other contexts and countries. |
| Article 5<br>The quintuple helix model and the future of mobility: The role of autonomous vehicles in a developing country. | - Brazil must improve many aspects to receive AVs;<br>- Academy helix as a trigger for AVs initiative in Brazil. | - Theoretical essay, empirical studies are needed. | - Empirical studies in order to validate the theoretical framework;<br>- In depth studies for each helix to determine their implication on the insertion of AVs. |

**INTEGRATIVE CONCLUSION**
**The technical development of AVs, by itself, is not the solution for urban mobility. In order to take place within an urban mobility system, MaaS must be considered as a modular and adaptable Business Model, applicable to any context (the efficiency – or inefficiency – of PT should not be limiting). For this, the BM of MaaS should be stablished under the ecosystem approach – and sustainability should not be considered as an intrinsic feature in a MaaS BM. This innovative ecosystem business model must consider the consumer acceptance and the transport modals that fit the specific context stablished. Thus, the AVs' implementation will complement, in specific contexts considering the social-political level and the demands of users into MaaS' ecosystem. In this sense, AVs should be considered as one, among several elements in the urban mobility ecosystem.**

**Figure 1:** Summary of General Consideration - Contribution Matrix of Mooring (CMM).
Source: Prepared by the author inspired by Costa et al. (2019).

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