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The quintuple helix model and the future of mobility: The case of autonomous vehicles.

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1. Introduction

In the present century, mobility has come to be understood as one of the main issues of our contemporary society, being a central topic discussed worldwide. Autonomous Vehicles (AVs) are considered an integral part of the new forms of mobility and have become focus of the automotive industry R&D projects, being considered the most popular application in the recent history of such industry (Fan & Chang, 2016).

Considering the rapid industry change, and 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 in a new era, in which the value creation relies entirely on the dynamic relations in an open ecosystem of innovation with moving boundaries in the long-run (Attias, 2016).

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

Although the developments of technical issues should be stimulated for the consolidation of this technology, there are several non-technical aspects that have not yet received considerable attention, such as the societal implications of this technology' advancement (Schreurs & Steuwer, 2016). In this way, the timing, scale, and direction of the AVs' impacts are uncertain and the opportunities to influence investment decisions are limited (Guerra, 2016).

When it comes to technology and innovation models, one that is very influential among academics is the triple helix. Created by Etzkowitz and Leydesdorff (2000) the model describes the innovation process via government-university-business cooperation. Although widely used, over the years the concept has evolved including two other main players: society and the environment. Therefore, nowadays the concepts of the Quadruple Helix and Quintuple Helix, both created by Carayannis and Campbell (2009) have also emerged.

In these new theories the three original helices operate in a complex urban environment, where market demand, governance, civil involvement 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 important element of Quintuple Helix is the "knowledge" feature, which encompasses the whole system. The model that can be used both in theory and practice highlights the exchange of knowledge resources, based on five social subsystems to generate a sustainable development of society (Carayannis, Barth & Campbell, 2012).

We realize that there is still a lack of coordination among companies, government, universities and even society, so that AVs can bring economic, social and sustainable development for all. In this

sense, the Quintuple Helix model can fill up the gap among such agents. Thus, it remains to be known “when” and, most importantly, “how” this innovation will be disseminated.

Considering mobility as an incisive aspect that impacts directly on people’s routine, it is necessary to understand such concept from a more integrated and holistic perspective, in order to obtain strong and significant advances. Therefore, this paper aims at understanding if the Quintuple Helix model can positively help in the advancements of urban mobility from the insertion of AVs in the society. To this end, we drew five propositions: the relations among autonomous vehicles and: government (P1); companies (P2); academy (P3); society (P4) and; environment (P5), providing an advancement on urban mobility, based on the technological development. We propose that each helix could help in a positive way to verify that the model as a whole could support the development.

Besides this introduction, this paper presents more four blocks: a) the methodology of the article - including the research design, b) the theme identification c) the analysis and discussion including the inflection points and the theoretical framework and, finally, d) the final considerations, which include the practical contributions of the study.

2. Methodology

Considering the idea to approach the theme of mobility based on the AVs and the Quintuple Helix (Carayannis & Campbell, 2009), we carried out an investigation on academic articles, government and consulting firms reports, and various AVs-related websites. The research design adopted in the present study was characterized as a qualitative approach of qualitative-exploratory nature. It is qualitative, because it prioritizes an interpretive view of reality from the point of view of the researched context (Silva, Gobbi & Simão, 2005). In addition, it is exploratory because there is little material on the subject of urban mobility focusing on AVs. The idea is to look for depth on the subject, inserting approach of Quintuple Helix in a joint analysis (Raupp & Beuren, 2006). Figure 01, highlights the research design carried out in this study.

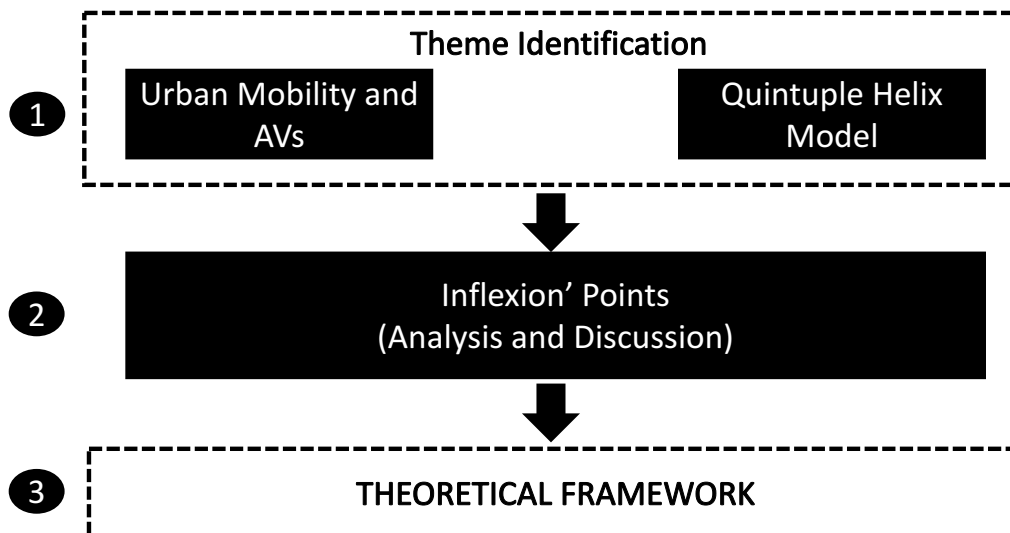


Figure 1: Study design.

- **Theme identification (step 1):** In this first stage we discussed, from an investigation on academic articles, the main approaches related to urban mobility and AVs and Quintuple Helix Model, in order to understand how these fields of knowledge are being established. The

investigation' criteria were established with the intention to contemplate the state of the art of the theories, current papers and relevance to the proposed themes.

- **Inflexion' points - analysis and discussion (step 2):** After this, we established inflexion points among these fields in order to seek a meaningful theoretical contribution that adds value to current thinking on the themes, seeking to deepen knowledge and open research fields in both areas. The inflexion' points were based on the research theme' identification and, from this, were used government and consulting firms reports, articles, and various AVs-related websites.
- **Theoretical Framework (step 3):** Therefore, in addition to understanding and discussing both issues jointly, a theoretical framework will bring the results with the main practical implications found. From this framework, it was possible to see the real theoretical contribution of the Quintuple Helix in the urban mobility.

3. Urban Mobility and Autonomous Vehicles.

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

Among the currently available transportation' modes, the automotive industry plays a fundamental role in mobility, such industry has been witnessing in recent years a transformation movement. It is gradually being transformed into a new ecosystem, known as "intelligent mobility", to which AVs are inserted and, consequently, 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 the issues of urban mobility.

Although the AVs' development focuses on the automotive industry, it is observed that their evolution will eventually overflow to other modes of transportation, impacting directly or indirectly on mobility. Hodson (2016) points out that AVs are only a part of a major revolution in urban transport, as there are simultaneous movements in expanding autonomous technology to public transport services (such as some metro lines that already operate without a driver in major cities in Europe and Canada) Corroborating with this, Attias (2016) proposes that in a medium-term perspective, this evolution will not stop in the AVs and will open the field for the design of similar technical objects (e.g. trucks, buses) and even boats and autonomous plans.

The convergence process of such dynamic movements between the traditional transport model and intelligent mobility culminates with consumers even more connected who seek more accessible mobility solutions with 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), the author goes further stating that AVs will accelerate this convergence process, due to the various advantages.

In relation to such advantages, positive impacts can be attributed: increased mobility; better usage of urban spaces (e.g. less need for parking in shopping centers, in view of the return of the AVs to the residence); reduction of congestion costs; increased road safety; user comfort; reduction in fuel consumption and pollutant emissions (Schoitsch, 2016; Geldmacher & Pleşea, 2016; U.K. Department for Transport, 2015), among others.

However, negative impacts still surround the AVs' development, which are: social risks (as in terms of rebound effects); protection of personal data' problems (e.g. hacking attack); increased

cost of insurances; loss of revenues related to the reduction of individual traffic (e.g. reduction of parking revenues, therefore, impact on local income); attracting passengers from public transport systems, resulting in job losses, if drivers become obsolete (e.g. taxi drivers, truck drivers and bus drivers may lose their livelihoods and occupations); possible investments in infrastructure; rules and regulations, among others (Schoitsch, 2016; Geldmacher & Pleșea, 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 synergistically all these spheres (government, companies, society, academy, environment), in order to optimize this dynamic' process of transformation in the contemporary urban mobility.

4. From the Triple Helix to the Quintuple Helix

Countries' innovation systems have been gaining strength given that sources for knowledge generation are useful in 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 social blackspots of the economic development practiced 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, for example: universities, small and medium-sized enterprises, and large corporations, government innovation networks and knowledge clusters (Carayannis & Campbell, 2011).

Such actors are pressured by the accelerating pace of change and innovation in both scientific and technological environments. Thus, even cutting-edge companies in the process of manufacturing autonomous cars are facing issues regarding ethical, moral, technological, urban mobility aspects, because evidences of the long-run impact of such innovations are not yet clear and well mapped.

The first step to be stimulated within this innovation system begins with the introduction of education inputs. As more investments flow into the helix of the education system means the production of new equipment, new locations for scientists and teachers and a greater opportunity for research, so 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 by the input of knowledge. The second step begins by human capital in the helix of the economic system, represented by companies. Any investment in knowledge and a promotion of the production of knowledge brings new impulses crucial to innovation, know-how and the advancement of society (Carayannis, Barth & Campbell, 2012).

Leydesdorff (2012) argument that to go further, towards the fourth or fifth helix would require greater specification, operationalization in terms of potentially relevant data, and sometimes additional development of relevant indicators. In order to do so, companies must focus on their productive activities in a cooperative sense, and the university reserves the role of construction, dissemination and transfer of knowledge (Vieira et al, 2015).

The "fourth helix" of the model refers on the culture and values of society. In this way, innovation policies and strategies must recognize the important role culture have for promoting a knowledge-based economy. The politics of knowledge and innovation should be inclined to reflect the dynamics of "media-based democracy", for the elaboration of strategies so that they become a policy of innovation, in order to generate economic performance and, thus, be linking the whole system of innovation of a country (Carayannis & Campbell, 2009).

By adding the fifth helix to the model, it 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, Quintuple Helix's innovation system is ecologically reliable, since it is based on the understanding of the production of knowledge (research) and application of knowledge (innovation) that to consider environmental issues (Carayannis, Campbell & Rehman, 2016).

We believe that the model has the strength to aggregate new knowledge helping in the creation and development of creative innovations and also new learning methods. At the same time, innovation on AVs (even though they are already being developed, with some brands placing already testing prototypes on the streets) is still lacking coordination among the companies, governments, universities and even society, so that these vehicles could effectively bring economic, social and sustainable development overall.

4. Inflexion' points - analysis and discussion

The automotive companies, suppliers, government, regulators, legal authorities, rating agencies, road operators, and the general public have got to be 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 the AV's and the impact on each of the 05 helices: (P1) government; (P2) companies; (P3) academy; (P4) society and; (P5) environment.

4.1. (P1) The government can positively impact Autonomous Vehicles

The relations among the institutional spheres of university, industry, and government can help generating solids 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 on economic growth of different industries (Etzkowitz & Leydesdorff, 2000).

In this sense, the organization of the political system is of crucial importance, for 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 an active political and legal capital, through incentives, ideas, laws, plans, 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 is about the AVs' regulation and encouragement of the motor vehicle industry. Regulation should ensure safety and accompany the development of the emerging 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 discussion with the automated driving theme where industry, academia and government met to define specific areas of action to support the introduction of automated driving in the country, including topics such as: infrastructure, legislation, innovation, interconnectivity (Frisoni, et al 2016).

Sweden, for its part, 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 also safety. This report involves R&D activities worth approximately

€100 million per year (half of this amount is publicly funded), including research into automated vehicles and connected transport systems (Frisoni, et al 2016).

Along these lines the French government is encouraging a new strategic alliance among the main French automotive companies in order to favor the development of AVs in the country. Called the industrial strategy "*La Nouvelle France Industrielle*" promoted by the Ministry of Economy and Finance in 2014, AVs are mentioned as a key point for technological development in the country.

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

4.2 (P2) The companies can positively impact Autonomous Vehicles

We observed that governments of some countries offer fiscal support and create public policies to strengthen the relationship with the university and industry. As an example, some European countries are already dealing with regulation of incentives to the AVs industry. Regulation should ensure safety and monitor the development of such 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 the driving license. “In case the vehicle would be completely autonomous and no driver intervention is allowed, it is 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 large parts of cases, different parties that have interest should cooperate for the advancement. The following figure seeks to summarize and conceptualize the main stakeholders involved in the implementation of the AVs (European Parliament, 2016).



Figure 02: Stakeholders involves in urban mobility future.
 Font: European Parliament (2016).

It is important to emphasize that it is not only vehicles manufacturers that are being benefited by the advancement of urban mobility, but the economic system as a whole. Corresponding telecommunication companies, shared vehicles services, technology and insurance companies will all have new services and demands from the synergy generated by the Quintuple Helices

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

The industry can be important doing patent applications per inhabitant, and improving: employment rates in knowledge-intensive sectors, employment rate in high tech and creative industries, renewable energy and energy efficiency systems, financial intermediation and business activities, culture and entertainment industry commercial services, transport and communication (Lombardi et al, 2012).

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 the urban mobility, industry players must collaborate to overcome technology challenges (Mosquet et al, 2015).

Launched in 2015 “Drive Sweden” that is a document that stipulates goals and directives for the future of the country, an already has several projects underway that are notable for the complexity

and breadth of the issues they seek to address. Cooperation and collaboration are cornerstones. The program seeks to combine data from all types of connected vehicles and traffic management systems "to enable" industry and research partners to collaborate nationally and internationally (Lang et al, 2016).

In the sense, actors in the private sector should consider partnerships that go beyond traditional sectoral 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 being marginalized (McKerracher, 2016). According to the European Automobile Manufacturers Association, the European car industry annually invests € 41.5 billion in R&D, around 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 advanced automated systems represents one of the major interests of car manufacturers (Tan et al, 2016).

4.3 (P3) The academy can positively impact Autonomous Vehicles

The convergence between basic and applied research is an opportunity to universities to transfer their knowledge to another sphere. In this regard, universities, in turn, may contribute to research on innovative prototypes in a collaborative development environment with companies. 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 field in earlier decades. During the 1990s the USA Defense Department promoted the development of self-driving vehicles for military purposes by financing projects across the academia and automotive companies (U.K. Department for Transport, 2015). Nevertheless, non-technical aspects are still an incipient knowledge field among this theme. In a previous search, in AVs field, on the "*Web of Science*" database, from 1945 to 2016, it was observed that there is a predominance of sciences more related to the technical evolution of AVs (e.g. engineering, computer science, automation and control system).

In order to understand how important non-technical aspects are, Yun et al. (2016) sustains that the technological development that permeates the AVs and the intelligent robotic industry is part of a dynamic result established among technology, business models and the market (Yun et al., 2016). In this context, the possibility of changes in the dynamic relations among these three factors in order to obtain expected results is evident. This change may be part of an inherent process in the role of a business model that has not yet been established, which in the future, will be necessary to develop dynamic systems models and more concrete simulation research on political leverage, including the growth of the market standard.

In this sense, Cavazza et al. (in press) identified five knowledge categories that could contribute to the AVs field's dissemination: policy issues (law); ethics, moral, liability; transport planning; consumer behavior and business model. Despite the fact of this categories are identified, they still need a deeper research to foster contributes to the field (Cavazza et al., in press).

Finally, it should be highlighted that, even with the academy efforts in projects that stimulate a synergy among the spheres, it is observed that, there are still a gap that contemplates all the interested parties as proposed by the Quintuple Helix model.

4.4 (P4) The society can positively impact Autonomous Vehicles

In the 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 the companies should be open to new society groups capable of promoting a culture of challenge.

There are three categories of users: (1) primary users, those who are likely to be frequent users of the system; (2) secondary users, those who use the system through an intermediary; and (3) tertiary users, those affected by the introduction of the system or who will influence their purchase (Arnkil, 2010).

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

While consumers expect automakers to produce reliable, high-quality and safe vehicles, they also believe that technology companies must bring 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).

The BCG (Boston Consulting Group) and the World Economic Forum from 5500 consumers in 10 countries (Asia, North America, Europe, Middle East and Asia) highlighted the fact that the 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 most reliable (between 50 and 58% of reliability) and they think about other technology players like 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, could change their minds quickly. If, for example, a horrible accident involving an AV occurs in the early stages (market introduction), regulators could face the pressure to take a sturdy position against such vehicles. In order 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 technology (Lang et al, 2015).

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

4.5 (P5) The 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, being elementary in the conception of products and academic research nowadays. 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 environment. 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 options 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, infrastructure manufacturing (Mladenovic & McPherson, 2016).

There is an expectation that AV's can reduce fuel use and pollution (due to the fact that they are electric) by strictly following hypermiling strategies and provide the possibility to position themselves closely behind other cars, since AVs have a faster reaction response and do not need to have the same safety margin that humans (Spieser et al. 2014). In the future, the progressive replacement of the combustion vehicles' fleet for electric vehicles will also be positive in this regard.

Difficulties arise because the environmental advantages could be nullified by a higher total number of car users (e.g. children and the impaired). Additionally, some raise privacy concerns due to the need of AVs to communicate constantly for the network to work efficiently. Mladenovic and McPherson (2016) raise the question of how to engineer social justice into traffic control, especially concerning the dimensions of safety sustainability, and privacy.

For example, Fagnant and Kockelman (2014) investigated whether the AV system is environmentally sustainable. The results of the study indicated that for each AV it has the potential to replace approximately 11 private vehicles. In addition, some environmental benefits, such as 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 at the expense of harm to future generations are unquestionably important. To further complicate the issue, it is plausible that sustainability itself requires attention to social justice along with economic and environmental issues. For these reasons, sustainability is a crucial point for engineers and policy makers who consider vehicles design, public transport vs. private transport, and infrastructure manufacturing (Mladenovic & McPherson, 2016).

4.6 Theoretical framework

The theoretical model of the Quintuple Helix establishes positive relations to the urban mobility with the insertion of the AVs, considering that synergic analyzes among all the spheres proposed by the model contribute with these relations.

Based on the analysis of inflection points, between the fields of knowledge analyzed, a theoretical framework was drawn (Figure 03). It was observed that the spheres (helices) present synergetic relations, which should act in consonance so that a positive development of the AVs is established and, consequently, contribute to the forms of urban mobility. It is noted that the government can exert a direct influence in all spheres (from political stimuli, transport plans and laws), and that this influence can determine positive or negative paths, through its posture of incentives and ways in which the devices inherent in the development of AVs and the future of mobility will be established.

It is understood that the academy must act on the technical and non-technical fronts of this development. In addition, it should be noted that the academy (research institutions) should seek ways to guide directions so that government, based on stimulating factors, can act in harmony in all other spheres in a synergistic way. In other words, it is understood that the role of the academy is to act like

a trigger by identifying the demands of other spheres in order to point out scenarios that allow an orchestrated thought among government, industry, society and the environment.

Regarding the social sphere, it was observed that it presents cultural, consumer and infrastructure related specificities, and that these factors must be taken into account, through the development of global regulatory aspects of the AVs.

With regard to the environmental sphere, it is important to emphasize the strong interface between the AVs and the sustainability issues. Several studies point to the gains generated by these vehicles with regard to sustainable development and social ecology such as reduced fuel use, reduced traffic, etc.

Finally, in the context of companies, it is important to highlight the role that the industry (as a whole - 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 the AVs as well as in the development of this new mobility model.

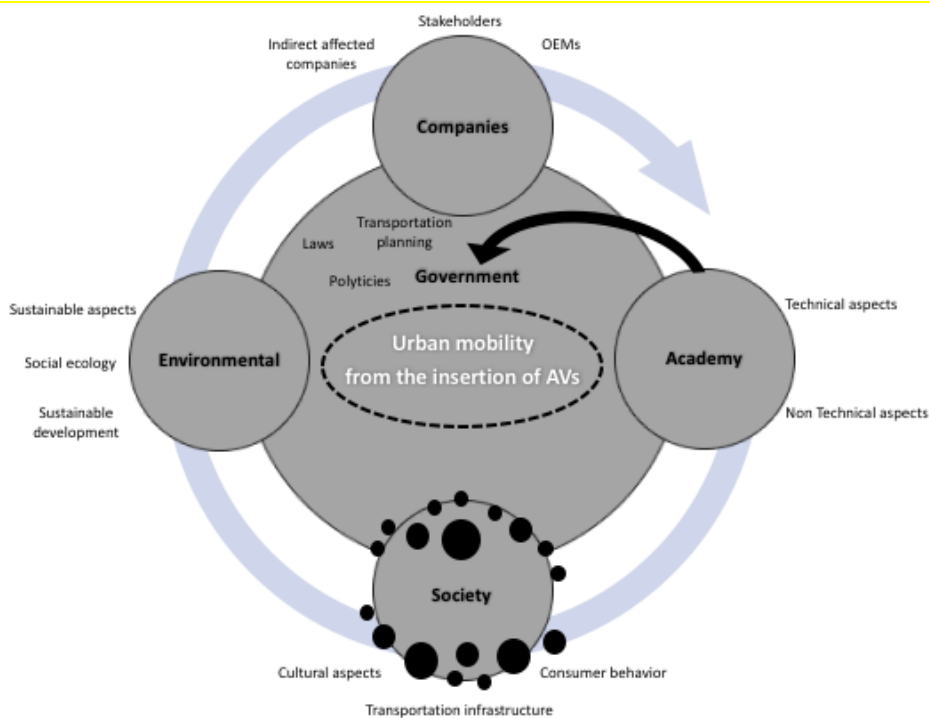


Figure 3: Theoretical framework - quintuple helix model positively assist in advancements of urban mobility from the insertion of AVs in the society.

5. Concluding remarks

This work has sought to understand the contribution that the Quintuple Helix can have in the future of urban mobility, through the use of Autonomous Vehicles. The first highlighted point is: we observed that the Quintuple Helix model contributes favorably to the future of urban mobility in which AVs' innovation is present. 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.

The synergy among agents proposed by the Quintuple Helix model is essential for the impacts on the development of this innovation to be minimized, and although we observed the need for action of all agents, this was observed in a fragmented way on 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 AVs dissemination. This study opens the discussions on the topic by demonstrating the importance of establishing the AVs' innovation in a synergistic way among all directly. The academy will be responsible for the search for a model among the stakeholders responsible for the development of AVs.

Secondly, it is necessary to understand the AVs' development not only as a technological innovation that will bring comfort to society, but rather to realize that this radical innovation can turn the future of urban mobility around the world. Thus, developing this technology without looking at all the spheres proposed by Quintuple Helix model, without look at cultural and environmental specificities of each scenario, would be like "driving with one eye closed". Governments should be aware of this, but this paper agreed that the academy has an important role in stimulating this thought, in order to contribute to the construction of ways so that the government can certify that this revolution happens with minimum negative impacts.

In addition, this is a theoretical paper, therefore interviews or surveys have not been carried out. In this way, we suggest practical studies that raises data in order to corroborate or refute with our theoretical framework. Only in this way will we discover how much our ideas can be useful to both academia and society. Finally, we also suggest deeper studies for each helix in order to find out the importance of each one for the Quintuple Helix model. Finally, it is important to highlight that this study represents a starting point regarding analyzes involving AVs and the spheres of the Quintuple Helix model, and that it can contribute to advances and future studies on the issue of mobility

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References

- Arnkil, R., Jarvensivu, A., Koski, P., & Piirainen, T. (2010). *Exploring Quadruple Helix—Outlining user-oriented innovation models*. Work Research Centre. Institute for Social Research, University of Tampere, Tampere, Finland.
- Attias, D. (2016). *The Autonomous Car, a Disruptive Business Model?*. In *The Automobile Revolution* (pp. 99-113). Springer International Publishing.
- Attias, D., & Mira-Bonnardel, S. (2016). Extending the Scope of Partnerships in the Automotive Industry Between Competition and Cooperation. In *The Automobile Revolution* (pp. 69-85). Springer International Publishing.
- Botelho, M. dos R., A., Carrijo, M. de C. & Kamasaki, G. Y. (2007) Inovações, Pequenas Empresas e Interações com Instituições de Ensino/Pesquisa em Arranjos Produtivos Locais de Setores de Tecnologia Avançada. *Revista Brasileira de Inovação, Rio de Janeiro* (RJ), 6 (2), p.331-371.
- Carayannis, E. G., Barth, T. D., & Campbell, D. F. (2012). The Quintuple Helix innovation model: global warming as a challenge and driver for innovation. *Journal of Innovation and Entrepreneurship, 1(1)*, 1–12.
- _____, E. G., & Campbell D.F.J. (2010). Triple helix, quadruple helix and quintuple helix and how do knowledge, innovation and the environment relate to each other? A Proposed

- framework for a transdisciplinary analysis of sustainable development and social ecology. *International Journal of Social Ecology and Sustainable Development*, 1(1), 41–69.
- _____, E. G., & Campbell, D. F. (2009). 'Mode 3' and 'Quadruple Helix': toward a 21st century fractal innovation ecosystem. *International Journal of Technology Management*, 46(3-4), 201-234.
- _____, E. G., & Campbell, D.F.J. (2011). Open Innovation Diplomacy and a 21st Century Fractal Research, Education and Innovation (FREIE) Ecosystem: Building on the Quadruple and Quintuple Helix Innovation Concepts and the “Mode 3” Knowledge Production System. *Journal of Knowledge Economic*, 2(1), 327–372.
- _____, E. G., Campbell, D. F., & Rehman, S. S. (2016). Mode 3 knowledge production: systems and systems theory, clusters and networks. *Journal of Innovation and Entrepreneurship*, 5(1), 17.
- Cavazza, B.H., Gandia, R.M., Antonialli, F., Nicolai, I., Zambalde, A.L., Sugano, J.Y., & Neto, A.M. *Management and Business of Autonomous Vehicles: A Systematic Integrative Bibliographic Review* (in press). 12th European Conference on Innovation and Entrepreneurship, Paris, France.
- Department for Transport. (2015). *The Pathway to Driverless Car: A detailed review of regulations for automated vehicle technologies*. Accessed in January, 20th of 2017, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536365/driverless-cars-proposals-for-adas-and_avts.pdf
- Enoch, M. P. (2015). How a rapid modal convergence into a universal automated taxi service could be the future for local passenger transport. *Technology Analysis & Strategic Management*, 27(8), 910-924.
- Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and “Mode 2” to a Triple Helix of university–industry–government relations. *Research policy*, 29(2), 109-123.
- European Parliament. (2016) *Research for TRAN Committee – Self-piloted cars: the future of road transport?*
- Fagnant, D. J., & Kockelman, K. M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research, C: Emerging Technologies*, 40, 1–13.
- Frisoni, R., Dall’Oglio, A., Nelson, C., Long, J., Vollath, C. & Ranghetti, (2016). D. Research for TRAN Committee. *Self-piloted cars: The future of road transport*. European Union Brussels.
- Geldmacher, W., & Pleșea, D. A. (2016). *SWOT Analysis and Evaluation of a Driverless Carsharing Model*. In Proceedings of The 11th European Conference on Innovation and Entrepreneurship 15-16 September 2016 (p. 921).
- Guerra, E. (2016). Planning for cars that drive themselves: Metropolitan Planning Organizations, regional transportation plans, and autonomous vehicles. *Journal of Planning Education and Research*, 36(2), 210-224.
- Hodson, H. (2016). I am your guardian angel. *New Scientist*. Accessed in January, 20th of 2017, from <http://www.sciencedirect.com/science/article/pii/S0262407916308545>
- Lang, N., Rubmann, M., Mohr, J. (2015). *Revolution Versus Regulation The Make-or-break Questions About Autonomous Vehicles*. Boston Consulting Group.
- Lang, N., Rubmann, M., Mei-Pochtler, A., Dauner, T., Komiya, S., Mosquet, X. & Doubara, X. (2016). *Self-Driving Vehicles, Robo-Taxis, and the Urban Mobility Revolution*. Boston Consulting Group.

- Leydesdorff, L. (2012). The triple helix, quadruple helix,..., and an N-tuple of helices: explanatory models for analyzing the knowledge-based economy?. *Journal of the Knowledge Economy*, 3(1), 25-35.
- Leydesdorff, L., & Zawdie, G. (2010). The triple helix perspective of innovation systems. *Technology Analysis & Strategic Management*, 22(7), 789-804.
- Lombardi, P., Giordano, S., Farouh, H. & Yousel, W. (2012). Modelling the smart city performance. *Innovation: The European Journal of Social Science Research*, 25:2, 137-149.
- McKerracher, C., Orlandi, I., Wilshire, M., Tryggestad, C., Mohr, D., Hannon, E., & Ramkumar, S. (2016). *An integrated perspective on the future of mobility*. New York, NY: McKinsey & Company, Inc. and Bloomberg New Energy Finance. Accessed in January, 20th of 2017, from www.bbhub.io/bnef/sites/4/2016/10/BNEF_McKinsey_The-Futureof-Mobility_11-10-16.pdf.
- Mladenovic, M. N., & McPherson, T. (2016). Engineering social justice into traffic control for self-driving vehicles?. *Science and engineering ethics*, 22(4), 1131-1149.
- Moonzur, R., 2012. *Les voitures autonomes, bientôt sur nos routes ?* Techniques de l'Ingénieur.
- Mosquet, X., Dauner, T., Lang, N., Rubmann, N., Mei-Pochtler, A., Agrawal, R., & Schmieg, F. (2015). *Revolution in the driver's seat: The road to autonomous vehicles*. Boston Consulting Group, 11.
- PWC. (2015). Connected Car Study 2015: *Racing ahead with autonomous cars and digital innovation*. Accessed in April, 20th of 2017, from <https://www.strategyand.pwc.com/media/file/Connected-Car-Study-2015.pdf>
- Raupp, F. M., & Beuren, I. M. (2006). Metodologia da pesquisa aplicável às ciências sociais. *Como elaborar trabalhos monográficos em contabilidade: Teoria e prática: Atlas*.
- Schoitsch, E. (2016) Autonomous Vehicles and Automated Driving Status, Perspectives and Societal Impact. Information Technology, Society and Economy Strategic Cross-Influences: *Schriftenreihe Informatik*, 45, 405-423.
- Schreurs, M. A., & Steuwer, S. D. (2016). Autonomous Driving—Political, Legal, Social, and Sustainability Dimensions. In *Autonomous Driving* (pp. 149-171). Springer Berlin Heidelberg.
- Silva, C. R., Gobbi, B. C., & Simao, A. A. (2005). O uso da análise de conteúdo como ferramenta para a pesquisa qualitativa: descrição e aplicação do método. *Organizações Rurais e Agroindustriais/Rural and Agro-Industrial Organizations*, 7(1).
- Spieser, K., Treleaven, K., Zhang, R., Frazzoli, E., Morton, D., & Pavone, M. (2014). *Toward a systematic approach to the design and evaluation of automated mobility-on-demand systems: A case study in Singapore*. In *Road Vehicle Automation* (pp. 229–245): Springer
- Tan, X., Di, L., Deng, M., Huang, F., Ye, X., Sha, Z. & Huang, C. (2016). Agent-as-a-service-based geospatial service aggregation in the cloud: A case study of flood response. *Environmental Modelling & Software*, 84, 210-225.
- Vieira, A. C. P. Estevam, V., Zilli, J.C. & Bruch K.L. (2015) *Triple Helix e Inovação: A Relação com os Vales da Uva Goethe*. Anais da Altec. Accessed in January, 22th of 2017, from https://www.researchgate.net/profile/Adriana_Vieira3/publication/283289974_TRIPLE_HELIX_E_INOVACAO_A_RELACAO_COM_OS_VALES_DA_UVA_GOETHE/links/5630c95808aedf2d42beeb54.pdf
- Yun, J. J., Won, D., Jeong, E., Park, K., Yang, J., & Park, J. (2016). The relationship between technology, business model, and market in autonomous car and intelligent robot industries. *Technological Forecasting and Social Change*, 103, 142-155.
- Zakharenko, R. (2016). Self-driving cars will change cities. *Regional Science and Urban Economics*, 61, 26-37.