Innovation radar for disruptive technology insertion: the case of autonomous vehicles in Brazil and France

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Abstract: This paper seeks to identify the critical success factors, to propose a theoretical model of the innovation radar for the insertion of autonomous vehicles as a product-service system in a country, and to map and discuss the radar in the context of Brazil and France. Fundamentally, it seeks to address the gap between the development of AVs, the differences between two national contexts, and the lack of specific knowledge about how to manage disruptive innovation in countries. From the results, the intent is to clear diagnosis about the innovation, allowing the formulation of guidelines and actions for the capacity development of a country. The results obtained in Brazil and France were crossed with official data and statistics as a way to corroborate the use of the innovation radar as a tool.

Keywords: innovation radar; Brazil; France; critical success factors; autonomous vehicles; product service system; trends in mobility; technology and innovation; social and political environment; consumer and market; infrastructure and patterns.

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1 Introduction

Industries, markets, and governments worldwide are experiencing several trends that will fundamentally change our business ecosystems and the way that value is generated (Corwin et al., 2016; McKinsey, 2018).

In this context, we can highlight the automotive industry – which, for decades, has been mainly stable and traditional in terms of business models and incremental in terms of innovation shifts – as one of the major areas of disruption. The imminent arrival of autonomous technologies and systems has stirred up industry giants and key stakeholders all over the world.

Autonomous vehicles (AVs) in the highest level of automation (levels considered in this paper: levels 4 and 5) do not require any sort of conductor or teleoperation control (Frazzoli et al., 2002). Being considered by many authors as the most significant disruptive innovation in the automotive industry, AVs are believed as an important innovation that promises to impact in several spheres (Poorsartep, 2014; Enoch, 2015; Fagnant and Kockelman, 2015; Schellekens, 2015; Schreurs and Steuwer, 2015; Attias, 2017; Attias and Mira-Bonnardel, 2017; Mutz et al., 2016). In this sense, policymakers and urban planners will have to adapt and rethink mobility from the insertion of AVs.

The fact is that there is a long way to go from the current concept of having/owning a vehicle – including here symbolic, instrumental and affective factors (Steg, 2005) – to this new configuration with autonomous vehicles. In this sense, complementary trends in shared rides and vehicles may lead us from vehicles as a privately-owned asset to an on-demand service (Fagnant and Kockelman, 2015). In fact, with the emergence of issues related to mobility as a service (MaaS), is consistent to think that the deployment of AVs will occur in a model that combines a bundled offer of product and service to provide value to society, which leads to a product-service system (PSS) (Johnson and Mena, 2008).

This models' change means a re-evaluation of the structure of the innovation process according to mobility requirements. Models seeking this new configuration are already seen, especially about passenger transport. This scenario, with the insertion of AVs, has an even greater potential for impact and change. An AV as a PSS has a shift from vehicle

ownership to a service focus, which demands a rethought of related dimensions (Antonialli et al., 2018).

In this sense, it is essential to consider that a disruptive innovation such as AVs, which are expected to have an impact on the economy, also requires a particular 'disruptive innovation policy'. The literature on disruptive innovation presents approaches related to the effects of this on management practices (Yu and Hang, 2011). However, policy implications need to be more discussed in terms of the design of innovation (Cavazza et al., 2019b; Selhofer et al., 2012). On the other hand, it would be possible to determine policies prepared to 'react' to disruptive trends (Selhofer et al., 2012).

When facing several changes that will occur from the insertion of AVs as PSS, especially regarding a macro scenario, it is essential to consider aspects according to specificities. The optimal AVs' future may differ depending on countries' patterns. However, there are basic standards that "will need to be put in place across countries and potentially entire continents" [Threlfall and ThoughtLab, (2019), p.7]. In this sense, to become a successful innovation, key aspects related to AVs as a PSS must be considered, such as business, social, political, and legal systems (Sawhney et al., 2006; Threlfall and ThoughtLab, 2019).

The changes will require an ecosystem framework that considers what is the need in terms of actors and actions (Kowalkowski, 2011). Thus the strategic response of economic and innovation policy should consist of creating favourable conditions for innovation in a given country aiming to strengthen the national innovative capacity. In other words, to make countries able to produce and commercialise a flow of innovative technology over the long term (Wu et al., 2017).

As pointed out by Wu et al. (2017, p.2), the "national innovative capacity depends in part on the overall technological sophistication of an economy and its labor force, but also an array of investments and policy choices by both the government and the private sector". In this sense, it is worth to comprehend national competencies that are important to promote disruptive innovations and include them in the policies programs.

Thus, considering these approaches as a framework for a holistic and systematic view of AVs as a PSS inserted in a country, some questions emerged as guidelines for this study, such as: which are the critical success factors in a country and how can these be used to implement AVs?

In this sense, this paper seeks to identify the critical success factors, to propose a theoretical model of the innovation radar for the insertion of autonomous vehicles as a product-service system in a country, and to map and discuss the radar in the context of Brazil and France. Fundamentally, it seeks to address the gap between the factors related to AVs' insertion, the differences between two national contexts, and the lack of specific knowledge about the governance of disruptive innovation in countries.

2 Theoretical background

2.1 AVs as a PSS: a disruptive innovation

Many issues still need to be addressed, such as the possible impacts of autonomous driving on mobility behaviours and human-machine interactions, as well as consumer

acceptance, regulatory, and liability frameworks (Schellekens, 2015; Schreurs and Steuwer, 2015).

The traditional business model of selling cars as products is losing ground to alternative forms of commerce. As pointed out by Johnson and Mena (2008), manufacturers are combining products and services in order to provide higher value to the customer and to facilitate more extended and more profitable business relationships.

A PSS can be defined as consisting of tangible products and intangible services designed and combined to fulfil users' needs or of a given function (Tukker, 2004; Poulain, 2017). In other words, PSS may be defined as a solution offered for sale that involves both a product and a service element to deliver the required functionality and expected benefits (Manzini and Vezzoli, 2003; Wong, 2004).

Based on Tukker's (2004) PSS categorisation, Antonialli et al. (2018) argue that AVs are better fitted on the 'use oriented' category of Tukker's (2004) PSS model that is: the traditional product (AV) still plays a central role. However, the business model is not geared towards sales; in this sense, the product is not in the ownership of the service provider consumer. Instead, it stays in the ownership of a service provider (or even other ownership forms) and is made available to the service provider's consumers in different ways (typologies) (Antonialli et al., 2018).

Given the aforementioned, AV as PSS could arise as a promising business model (both in business and national contexts). Therefore, AVs as a PSS can be considered a disruptive innovation that promises to have a great impact on urban mobility. Thus, it is crucial for governments and policymakers worldwide to consider all the aspects of this innovation and its relation to governance and public policies.

In this sense, it is worth highlighting that, although the term disruptive technology is widely used, disruptive innovation seems more appropriate since few technologies are intrinsically disruptive. Instead, it is the business model that the technology enables that creates the disruptive impact (Christensen, 2001). That is, few technologies or business ideas are intrinsically sustaining or disruptive; their disruptive impact must be moulded into strategy as managers shape the idea into a plan and then implement it.

Also, it is crucial to consider that disruptive innovation can have a totally different meaning in services than in manufacturing. While in manufacturing the emphasis is in the product itself, in services, disruptive innovation is typically linked to new business models that have been made possible by innovative uses of technologies provided by other sectors, notably ICT, rather than conducting R&D. In this context, if we consider the bundle of characteristics of AVs as a PSS, the implications for innovation policy are therefore quite different.

When we start to analyse the disruptive innovation in a macro concept, considering its adoption and management in a country, it is necessary to consider some specificities. In fact, "Christensen's framework has been widely discussed in management literature, but not yet in terms of its implications for innovation policy design" [Selhofer et al., (2012), p.5]. It is important to consider that governments and policymakers need to explore whether and how innovation policy should pay specific attention to disruptive innovation developments in order to give policy responses properly to emerging innovation needs, trends, and phenomena (Selhofer et al., 2012).

AVs are being run on public roads, while only in a handful of locations such as Phoenix in the US State of Arizona and Singapore. Even though this innovation could take 10 or 30 years to effectively 'reach the market', the social and political implications

"are so far-reaching that policymakers need to start planning now for our AV future" [Threlfall and ThoughtLab, (2019), p.6].

In this context, many public policymakers are already focusing their attention on autonomous transportation and on understanding its potential impact (BCG, 2016). It is worth mentioning that policymaking and policy implementation do not occur in a vacuum. "Rather, they take place in complex political and social settings, in which individuals and groups with unequal power interact within changing rules as they pursue conflicting interests" [World Bank, (2017), p.29].

Thus, a strategic response for the policy must address the cross-sectoral nature of disruptive innovations, as well as to manage some 'business case conflicts' considering that desired and expected externalities from accelerating disruptive innovation deployment do not coincide with the industry's business case as well as to anticipate unwanted side-effects of interventions and disruptive innovation in service sectors (Selhofer et al., 2012).

We defend that, if innovation policy decides to support the insertion of AVs, probably the best approach is, therefore, to encourage the move to 'mobility as a service' that leads to the concept of AVs as a PSS. This could have positive side-effects such as reducing emissions and freeing up parking space in cities.

Due to the complexity and relevance of the theme, some studies have been carried out to develop tools and methods to assess the openness and readiness of countries for autonomous vehicles (Threlfall and ThoughtLab, 2019), as well as to map and analyse the critical success factors for insertion of AVs into different national contexts (Cavazza et al., 2019b; WEF, 2019). The following topic presents the theoretical framework used in this study to identify and measure CSFs for the insertion of AVs in a country.

2.2 Critical success factors and innovation radar

There are several definitions and concepts for the term critical success factors (CSFs) in the literature. Initially, Rockart (1979, p.9) states that CSFs are the:

> "Limited number of areas in which results, if satisfactory, will ensure successful competitive performance for the organization. They are the few key areas where 'things must go right' for the business to flourish. If results in these areas are not adequate, the organization's efforts for the period will be less than desired. "

For Brotherton and Shaw (1996), CSFs can be understood as the essential aspects that must be achieved by an organisation or areas that produce the greatest competitiveness. They are not goals, but actions or processes that can be controlled and affected by management to achieve organisational objectives. Also, Grunert and Ellegaard (1992) point out that these skills or resources explain most of the observable differences in perceived value and relative costs.

The identification of CSFs can be effective for:

1 determining where management attention should be directed

2 developing success measures

3 identifying the key information as well as the main characteristics of an organisation and thus limiting gathering unnecessary data

4 assisting the definition of knowledge and technologies essential for the survival and competitive advantage of the analysed object (Rockart, 1979; Colauto et al., 2004; Nascimento, 2015).

Thinking about methods and measures for important aspects of an organisation or country, a valuable tool to have disruptive products or services creating and delivering value is the Innovation Radar proposed by Sawhney et al. (2006). According to the authors, "successful business innovation requires careful consideration of all aspects of a business" and thus "when innovating, a company must consider all dimensions of its business system" [Sawhney et al., (2006), p.36].

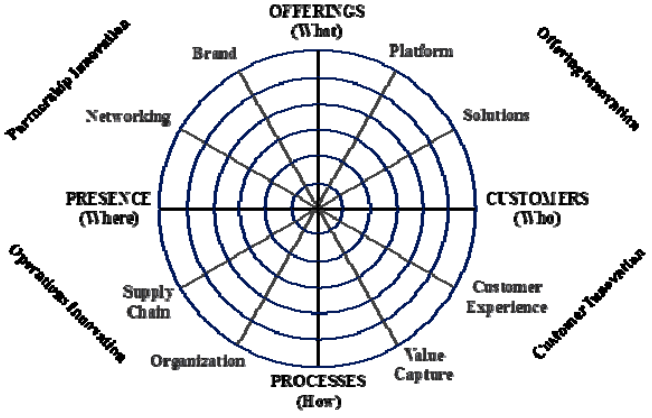
In this sense, there are three basic premises or characterisations related to business innovations:

a business innovation is about the creation of new value (for customers and consequently for the firm), not new things

b business innovation can occur in any dimension of a business system

c business innovation is systemic and requires careful consideration of all aspects of a business (Sawhney et al., 2006).

Figure 1 Innovation radar



Source: Adapted from Sawhney et al. (2006)

Starting from these three basic statements, the framework radar of innovation was proposed (Figure 1). It highlights 12 key dimensions for business innovation and explores the relation among them. The framework presents four key dimensions that work as a business anchor:

1 the offerings a company creates

2 the customers it serves

3 the processes it employs

4 the points of presence it uses to take its offerings to market.

Between these four anchors, they embed eight other dimensions of the business system that can serve as avenues of pursuit (Sawhney et al., 2006; Sawhney and Chen, 2010).

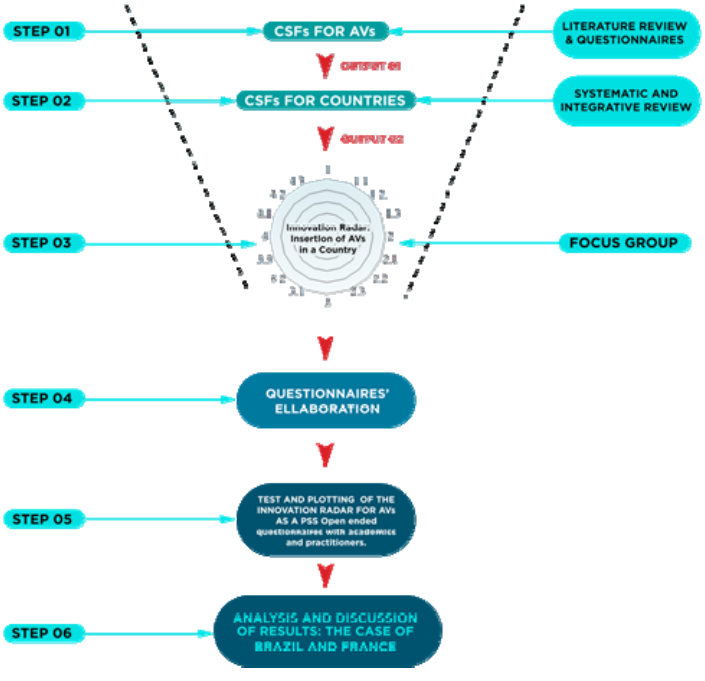
The innovation radar presents itself as a significant tool for discussing and structuring a field based on trends in a targeted way (Golovatchev et al., 2008). However, while working on a holistic picture, Sawhney et al.'s (2006) proposal addresses broader issues in an organisational context, not dealing with aspects of heterogeneity in sectors, contexts, and objectives.

Thus, taking innovation as an indisputably relevant factor in the present era for all contexts, it is crucial to consider it beyond the local level, expanding the focus to regional as well as national aspects, as focused in the context of the European Union by De Prato et al. (2015). Thus, an innovation radar, as a way of guiding innovation, demands adaptations (Oliveira et al., 2014). From an adaptation from Mansell and Wehn (1998), this study will focus on the national context for the development of an Innovation Radar.

3 Methodology

Aiming to identify the critical success factors, proposing a theoretical model of the innovation radar for the insertion of autonomous vehicles as a product-service system in a country, and testing a theoretical model of the innovation radar for autonomous vehicles as a PSS, the adopted research design was characterised as empirical, quantitative-qualitative of exploratory-descriptive nature. Figure 2 details the research design adopted.

Figure 2 Research design (see online version for colours)



Source: Elaborated by the authors

On Step 01, the data collection was firstly performed via secondary data, using academic literature and grey literature such as technical reports, news, magazines, documentaries (Cavazza et al., 2019a; Threlfall and ThoughtLab, 2019). Through this literature review, it was possible to define key dimensions and to list a series of general CSFs that could fit in the AVs' scope. This data served as pre-defined categories of analysis to be used on the next step. Thus, we were able to select 18 factors that were organised in a questionnaire, containing their labels and a guideline so that the respondents could rank them in order of importance from 0 (lowest importance) to 5 (highest importance).

As the methodological intent of step 01 was to map and realise a general verification about CSFs closely related to the insertion of AVs as PSS in a country, it is worth to highlight that, based on the SAE levels of automation (SAE, 2016), for the questionnaires were considered the levels 4 and 5 (any kind of human intervention required during the operation).

The questionnaires were submitted to pre-tests with professors and doctoral students from the Federal University of Lavras – Brazil before conducting the primary data collection. After this, they were applied to experts in urban mobility at the 26th International Colloquium of Gerpisa from 11 June to 14 June 2018. Were obtained 37 responses, being these from eight different countries: USA (1), Norway (1), Germany (1), England (1), Colombia (1), Mexico (2), France (7) and Brazil (23).

Next, all the questionnaires were tabulated in order to comprehend which CSFs are more and less critical in terms of AVs as PSS. These outputs were transformed into extra input to generate a matrix for data analysis and categorisation.

On Step 02, a systematic integrative review was developed to cover all the possible CFSs (at a macro level) for countries found in the literature. The articles for the integrative were searched on Web of Science (WoS) and Science Direct (SD) databases in a single search, looking for articles published since the very first year available in the databases – 1945 to 2018. For the search, the Boolean operator 'AND' was used. The following terms were selected in the title, abstract, and keywords of the articles: *critical_success_factor** and *country*.

The first stage of this search resulted in 352 articles (133 from WoS and 219 from SD). These were collected based on the filters: language (English), document type (articles, proceedings papers, and review), categories (management, business, economics, econometrics, planning development, public administration, transportation, urban studies, transport science technology, environmental studies, environmental sciences, multidisciplinary sciences, social sciences interdisciplinary, and political science). As a result, 154 articles were selected, and, of these, 30 duplicate and unavailable articles were excluded.

With a sample of 124 articles, a scope analysis to verify the CSFs listed in each one was performed. The goal was to select articles with CSFs related to the context of countries rather than firms. Through this, as the final sample, 36 articles were selected, and these were organised in a content matrix to be analysed in terms of title, journal, type of publication, author, year, country, CFSs, CSFs' categories, and general observation.

Step 03, another round of information acquisition, was performed in order to validate the outputs of the previous analysis and to cross-check them with the ones identified through the questionnaires. Using this set of information, we were able to conduct a focus group with professors and doctoral students from the Terrestrial Mobility Laboratory from the Federal University of Lavras – Brazil. It was composed of six participants from several areas of knowledge, such as business, production engineering, mechanical

engineering, and, systems engineering and computing. With the focus group, it was expected to validate the categories previously established according to the questionnaires and the integrative review. As a result, from the focus group, we were able to design a theoretical framework for the innovation radar in the context of AVs as PSS.

Next, on Step 04, after the gathering of secondary data, we were able to formulate the open-ended questionnaires. This instrument was submitted to pre-tests with five specialists related to the four key dimensions of the framework. Aiming to test and plot the framework of the innovation radar, on Step 05, open-ended questionnaires were sent via GoogleDocs within the Automotive Industry and Urban Mobility fields in Brazil and France. We were able to reach 20 specialists from Brazil and nine from France.

On the questionnaire, the respondent had a brief explanation for each of the 12 factors presented. Next, it was introduced two conceptual phrases that described the ideal situation for this factor in a country. Thus, considering that Critical Success Factors are determinant for the insertion of a product/service in the market, the respondent was invited to choose if they disagree (1) or agree (5) with the statements specified in the following tables according to the following scale:

1 strongly disagree (SD)

2 disagree (D)

3 neither agree nor disagree (ND/D)

4 agree (A)

5 strongly agree (SA)

On Step 06, all questionnaires were tabulated and quantitatively organised, therefore, generating a descriptive qualitative analysis as well as the final plotting of the Innovation Radar. The index of each factor was calculated through the average of all respondents in the country. After analysing each dimension's results, we were able to discuss the relevance of the critical success factors for AVs as a PSS, emphasising their main characteristics in both countries.

4 Results and discussion

4.1 The innovation radar for the insertion of AVs as PSS

From secondary data obtained through a literature review, four key dimensions were defined that will assist as analysis categories and guidelines:

1 infrastructure and patterns

2 social and political environment

3 consumer and market

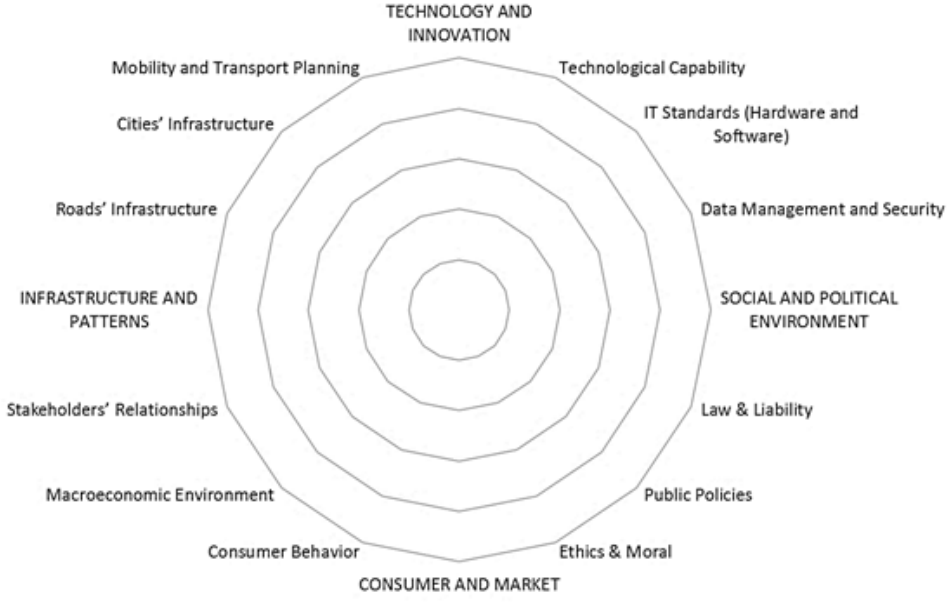
4 technology and innovation.

From the questionnaire, the CSFs were filtered as a way to organise and reach a final list that was strictly aligned with the scope of the AVs: was obtained four dimensions and 12 CSFs.

In order to refine and to align the CSFs with the national context, a systematic and integrative review was carried out. From the analysis of the 36 selected articles, all the indicators originated from the search[1] that could be related to our scope were identified and distributed into the key dimensions and their corresponding CSFs.

The focus group resulted in the definition of the CSFs presented in the innovation radar for the insertion of AVs as PSS in a country. The framework is represented in Figure 3.

Figure 3 Innovation radar for the insertion of AVs as PSS in a country



The framework radar AVs-PSS presents the four key dimensions working like anchors:

1 Technology and innovation

2 social and political environment

3 consumer and market

4 infrastructure and patterns.

Between these four anchors were embedded 12 factors of the innovation system that can serve as avenues of pursuit. The radar's dimensions, as well as a brief concept explanation about its concepts and factors, are presented in Table 1.

These parameters enable the identification of the CSFs for the insertion of AVs in a country. From this conception, this study proposes that the CSFs be measured and plotted in an innovation radar considering the AVs as PSS. This effort will be developed in the next session.

Table 1 Dimensions of the innovation radar

KEY DIMENSIONS	*GUIDELINES*	*DIMENSIONS*	*GUIDELINES*
TECHNOLOGY AND INNOVATION (T&I)	In a knowledge-based economy, technology is an important resource to create innovation. In this sense, considering technological assets and requirements, it is fundamental to pay attention to knowledge and competences and policies and patterns of hardware (equipment) and software in order to achieve specific knowledge domain and scandalisation and to benefit the society. Finally, data management and security are very important, especially in terms of confidentiality, integrity, availability, and authenticity of the information.	TECHNOLOGICAL CAPABILITY (TC)	It is referred to knowledge and competences to technology transfer, Information and Technology leadership, technology innovation and Information and communication technology (ICT)/information technology system (ITS) technologies
		IT STANDARDS – HARDWARE AND SOFTWARE (IT-S)	Considering that in the related hardware and software system that configure AVs as PSS, are resources that need to be written and read frequently with accuracy.
		DATA MANAGEMENT AND SECURITY (DM &S)	Data management and security have to be based on quality and standard as main aspects to data sharing and exchange. Especially in terms of confidentiality, integrity availability, and authenticity.
SOCIAL AND POLITICAL ENVIRONMENT (S&P)	The presence of different stakeholders increases the complexity of a system. In this sense, it is essential to manage questions related to the social and political context. Political support, social support and governance are needed to determine legal and political conditions of a country as well as political-economic initiatives (financial and non-financial?).	LAW AND LIABILITY (L&L)	Harmonised regulations are essential for the functioning of AVs as PSS. Basically, legal framework is a fundamental source of security in the new context promoted by the PSS.
		PUBLIC POLICES (PP)	The government has a fundamental role in regulating and standardising the structure needed for AVs' insertion. Governments should treat public policies as crucial strategic assets that ensure investors' attractiveness as well as to improve the competitiveness of the country.
		ETHICS AND MORAL (E&M)	Culture is a background related to a value system based on shared norms and beliefs which are variable according to the context

Table 1 Dimensions of the innovation radar (continued)

KEY DIMENSIONS	*GUIDELINES*	*DIMENSIONS*	*GUIDELINES*
CONSUMER AND MARKET (C&M)	Market is an aspect that is embedded by several factors because it is related to many different stakeholders, which have different goals and activities. Here, the main idea is: stakeholders need to be managed, macroeconomic objectives must be aligned in order to develop a viable and attractive environment, and the cultural background must be considered in strategies to promote and improve consumers' behaviour that benefits from the insertion of AVs as PSS.	CONSUMER BEHAVIOUR (CB)	Related to the consumers' openness (willingness to ride a car without a driver and/or share a car with other people, mindset shift and trust).
		MACROECONOMIC MARKET (MM)	A stable macroeconomic condition is related to the existence of economic policies and a favourable legal framework as a way to designate an appropriate risk allocation providing sources of benefits for multiple objectives.
		STAKEHOLDERS' RELATIONSHIPS (SR)	In a national context there is broader stakeholders' involvement because the extent of projects demands different partnerships among them. We highlight here specially the public sector; private sector, society, and academy.
INFRASTRUCTURE AND PATTERNS (I&P)	AV as a PSS will connect with its surrounding ecosystem and infrastructure, that is, other transportation models, users' devices and other systems and services. In this sense, considering that changes and adaptations in different aspects of infrastructure will be necessary for the operation of AVs, countries must pay attention to physical and technological patterns to supply these new demands. The core premise related to this dimension's critical success factors is that is necessary to develop a systems' network.	ROADS' INFRASTRUCTURE (RI) CITIES' INFRASTRUCTURE (CI)	An intelligent environment is characterised by places with intensive use of technology and communication through three main areas: 1 internet of things (IoT) 2 path management and planning based on actions built by algorithms applied to the context 3 processing and analysis of a large amount of information (big data).
		MOBILITY AND TRANSPORT PLANNING (M&TP)	For the success of mobility projects, it is essential to plan transport and mobility based on a dynamic and integrated view.

4.2 *Innovation radar for the insertion of AVs as PSS: the case of Brazil and France*

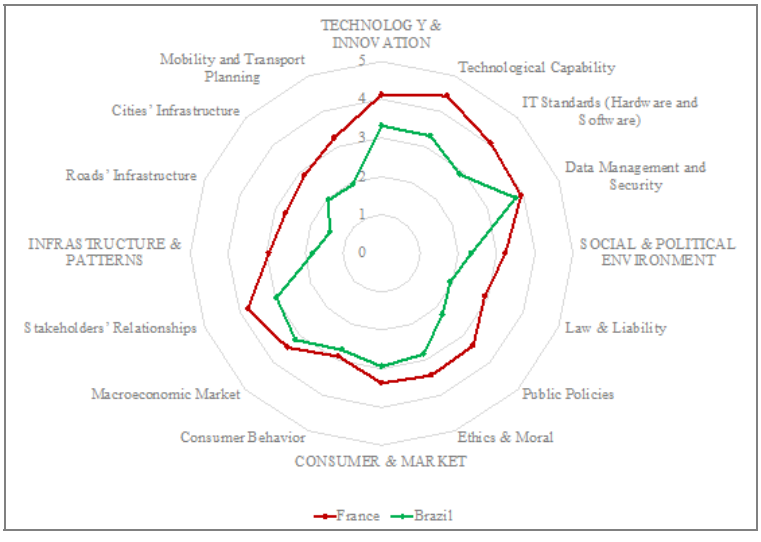
This topic displays the plotting of the Innovation radar for Brazil and France, and discusses the main aspects and differences between the outputs as well and its context relation. Table 2 and Figure 4 present the results of the data collection.

Table 2 Key dimensions and CSFs index

Dimensions	*France*	*Brazil*
Technology and innovation	4,13	3,33
Technological capability	4,43	3,33
IT standards (hardware and software)	4,05	2,90
Data management and security	3,93	3,78
Social and political environment	3,23	2,34
Law and liability	2,90	1,93
Public policies	3,38	2,25
Ethics and moral	3,43	2,85
Consumer and market	3,38	2,95
Consumer behaviour	2,90	2,70
Macroeconomic market	3,45	3,18
Stakeholders' relationships	3,78	2,98
Infrastructure and patterns	2,93	1,79
Roads' infrastructure	2,70	1,48
Cities' infrastructure	2,85	1,95
Mobility and transport planning	3,25	1,95

Source: Elaborated by the authors

Figure 4 Innovation radar Brazil x France (see online version for colours)



Source: Elaborated by the authors

The indices for each dimension were obtained through the average response of the participants. France indicators are displayed by the red line and Brazil's indicators by the green one.

As can be observed, France has better metrics in all the dimensions when comparing to Brazil. This is not a surprising outcome, being corroborated by studies and reports that seek to map the macroeconomic, political, and social conditions of these countries (Threlfall and ThoughtLab, 2019; WEF, 2019). One must also consider that, because it is a developed country, France has at its disposal a series of material and human resources that have been employed in this 'race' to put autonomous vehicles on the road. In fact, France plays a significant role in global affairs thanks to its political, economic, and cultural influence (WEF, 2019).

On the other hand, we must ponder the Brazilian importance and influence when it comes to the international automotive scenario. In an article written by Muller (2012) for Forbes Magazine, what carmakers see when they look at Brazil is South America's largest consumer market, a still-bustling economy- and a lot of potential customers. Besides, it is the fifth-largest country in the world, and only 14% of its roads are paved, in economic terms, incomes are rising, lifting almost 40 million more Brazilians into the middle class since 2003 and putting a vehicle purchase within their reach for the first time.

In this sense, the Brazilian auto market stands out on the world stage and can be considered as the gateway of Latin America given that, currently, Brazil is the fifth-largest auto industry consumer market in the world, also accounting for more than half of the vehicles sold in Latin America (ICCT, 2015; SEBRAE, 2015).

The results of both countries for each key dimension are discussed in more detail below.

4.2.1 Technology and innovation

As highlighted in the introduction of this study, in a country, the national innovative capacity depends on a commitment to innovation projects, the innovation environment, the strength of the relationship between infrastructure and industrial side, the intensity of financial and human resources, and technological capacity (Furman and Hayes, 2004). As national innovative capacity is one of the main drivers for long-term economic growth, several countries have heavily invested in high-tech strategy and policies in order to try to increase it.

Regarding T&I, France has its greatest scores (4.13), which could be partly explained by the institution of the public-private VedeCom Institute, which aimed to deliver an available autonomy by 2020. Also, Renault, one of the leading companies in the automotive sector, has a local project in Rouen with public and private authorities. Transdev, a transport operator, through this project, "aims to establish an on-demand mobility service on pre-set routes and PSA Group joined in activities with start-ups AIMotive and nuTonomy". France ranks the tenth position on the technology and innovation pillar of the KMPG Autonomous Vehicles Readiness Index. The country is well rated on research and development hubs and in the World Economic Forum ratings (Threlfall and ThoughtLab, 2019), and, also, in a recent rank published in the *Journal Transport Reviews* regarding the total number of academic publications on the scope of AVs, the country ranks the fourth position (Gandia et al., 2018).

As for Brazil results, that, similarly to France, the country also reaches its highest scores (3.33) on this dimension. On the KPMG Index, 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. It received the lowest scores on research and development hubs, AV technology company headquarters, patents and investments" [Threlfall and ThoughtLab, (2019), p.33]. The World Economic Forum's Global Competitiveness Report (WEF, 2018) named Brazil as best in its region in terms of innovation capability - though it noted that the country remains below its potential.

It is worth remembering that this dimension also contemplates the issue of data management and security, a topic that has been widely discussed. Nowadays, the vehicle is becoming the fourth screen for information, entertainment, and communications, generating increasing amounts of data, raising questions about ownership and security (WEF, 2019). Vehicle security is a real issue; such systems will need to be much more robust than those offered in today's vehicles. Hackers could access to the vehicle's control system and cause a car to accelerate, brake, or manoeuvre unexpectedly causing a vehicle crash. Today's vehicles are designed to protect against these types of intrusions. However, the hardware does not consistently protect against threats such as hackers. The mean time between failures (MTBF), a measure of the reliability of a hardware component, for security systems is far too high to be commercially viable today.

4.2.2 Social and political environment

Regarding the relationship between AVs and the social and political environment surrounding it, there are some important questions to discuss, such as "How disruptive will these vehicles actually be in transforming the city of today?" And "how can city governments take advantage of autonomous technology to achieve broader goals with regard to urban mobility and livability?" And also, "How much control and regulatory influence does the city take in shaping mobility flows and shifting the modal mix?" "Which datasets are needed to make the right investment decisions?" [WEF, (2018), p.26].

AVs have the potential to catalyse the most significant transformation in urban mobility since the creation of the automobile. However, their social benefits can only be unlocked if governments understand and implement the appropriate policies and governance structures. "Cities, nations, and the world will need to embrace a regulatory and governance framework for AVs that nudges us towards an 'AV heaven' scenario and away from 'AV hell'" [WEF, (2018), p.5].

Regarding the framework's scores, the dimension 'social and political environment' is one of the weakest, for both countries (Brazil – 2.34 / France – 3.23).

According to the World Economic Forum's Global Competitiveness Report (WEF, 2018), Brazil ranked 111th out of 140 countries in terms of reliability of police services, 124th in terms of the efficiency of its legal framework in settling disputes, 83rd in terms of freedom of the press, 133th in terms of the homicide rate, and last in terms of the burden of government regulation. Brazil's government was also deemed among those least 'future-ready' according to the report, and overall the country slipped three places compared to the prior iteration of the ranking, to 72nd place.

France has a legal framework adopted to allow the testing of driverless cars on public roads in 2015, which was broadened the following year. Along with Germany, the French government has announced plans to test self-driving vehicles on a cross-border road from

Metz in France to Merzig in Germany. However, the country is rated poorly for government capabilities by KPMG's Change Readiness Index. In fact, the dimension 'Law & Liability' is the one with the lowest score (2.90) between all the 16 dimensions for this country.

4.2.3 Consumer and market

The dimension consumer and market (C&M) presents the second-highest rate for both countries (Brazil – 2.95/France – 3.38).

Consumer openness and acceptance is a potentially significant barrier to the insertion of AVs. Consumers have their perspective, centred on optimising the balance of convenience, cost, and environmental impact when making mobility decisions. Questions such as "How can consumers understand and compare mobility alternatives and make integrated and informed decisions for their individual travel patterns?" or "How will society receive and react to such disruptive innovation that will fundamentally change the way we have mobility today?" make the consumer behaviour a shrinking obstacle and one that will likely dwindle with experience and familiarity over time (BCG, 2016; Corwin et al., 2016).

Brazil, a country of continental proportions, is internationally recognised by its population passion for cars. Indeed, the car is one of the most favourite items by Brazilians and goes much further than a simple transportation tool. When buying a car, it is also bought an idea linked to social status, glamour, and power; therefore, automakers have been investing heavily in this extremely promising market.

Like the KPMG's outcomes, on Brazil's innovation radar, the dimension consumer behaviour is one of the highest scores (2.70), being almost equal to the French score (2.90). On the French side, consumers are fairly enthusiastic about AV technology, but the country has a middling score on people's technology use in KPMG's Change Readiness Index research (Threlfall and ThoughtLab, 2019).

At this point, it is important to understand the difference between the concepts 'willingness' and 'awareness'. When we talk about the willingness to ride (that it is higher in Brazil), we are only considering if these consumers are keen to try the AVs without measuring or considering their maturity and awareness about all the AVs implications. According to the BCG report, the relationship between knowledge (awareness) and openness (willingness) is inversely proportional: the more conscious and mature the consumers are, the less open they will be to accept/test the AVs (BCG, 2016).

Another critical dimension to be discussed refers to the necessary partnerships between the different types of stakeholders that are involved in the AVs insertion. "In the new mobility ecosystem, value creation opportunities will likely require stakeholders to rethink their business models" (Corwin et al., 2016). In this context, WEF Report (2018) points out that policymakers, consumers, and mobility providers are key stakeholders that have different interests and incentives, in this sense, it is essential to have a holistic view and a multi-stakeholder approach.

4.2.4 Infrastructure and patterns

It is a consensus that cities worldwide need to develop a strategy for moving towards an integrated mobility platform (WEF, 2018). Numerous trends, ranging from energy

decentralisation to the Internet of Things, are likely to come together to create drastic changes in mobility systems over the next 10 to 15 years.

I&P is responsible for Brazil's worst score (1.79). It can be a result of issues in terms of transportation infrastructure and public transport – elements that will require huge investments (Bagloee et al., 2016).

In fact, the WEF report mapping global transformation points out that the country's infrastructure gap as one of the key issues for analysis. However, the same report points out that Brazil's infrastructure needs may be an attractive location for related investment (WEF, 2019).

Also, concerning infrastructure, it should be noted that road modal in Brazil is the country's main logistics system. According to CNT Transportation Yearbook (CNT, 2016), the country has a network of 1,720,643.20 kilometres (1,069,157.79 miles) of national roads and highways (the fourth largest in the world), accounting for more than half (approximately 56%) of all cargo transported in Brazil, also being the system of highways the primary means of passengers' transportation in the country.

Still based on CNT (2016) data, about 10,000 kilometres (6,213.71 miles) of the highway system are composed of motorways, mainly in the state of São Paulo. However, about 30% of the entire Brazilian road network is badly damaged by the lack of maintenance, and only 210,618.80 kilometres (130,872.414 miles) are currently paved. As a way of supporting the infrastructure of the sector, according to the Petroleum, Natural Gas, and Biofuels Statistical Yearbook (ANP, 2016), there are 40,802 automotive fuel retailers spread around the country.

Still, in terms of infrastructure, concerning the connection capacity, according to the KPMG report, Brazil has good coverage of 4G (more than 90 percent of cities are covered), but few electric charging stations; only Russia has worse roads. Corroborating with these appointments, the IR dimension 'roads infrastructure' is responsible for the worst score.

Regarding France, this dimension is also responsible for the lowest score (2.93). This fact is corroborated by the outputs of the KPMG report were the country is credited with having excellent roads and good road infrastructure, but poor 4G coverage and a low density of electric charging stations (Threlfall and ThoughtLab, 2019).

Thus, AVs and its background of infrastructure will require much more than contemporary vehicles and patterns. According to McKinsey (2018), this demand will boost the uptake of vehicle-to-infrastructure technologies to enable aspects such as road pricing, traffic flow optimisation, and accident prevention systems. In this sense, mobility infrastructure will be inserted in a broader system and its function will, increasingly, mix physical and software components, delivering value as a service.

5 Concluding remarks

No one can predict the future. However, the advancing of autonomous technology is fast, and it brings complex and multifaceted impacts to many parties, such as markets, consumers, auto industry, technology industry, urban planners, governments, and policymakers. In this regard, taking a look into the future is necessary as a way to understand and plan improvements for urban life and policy (BCG, 2016). In other words, even if the future is not set, we need to prepare for the outcomes, not wait for it (Heineke et al., 2017).

Hence, the main contribution of this work is the integration of data and information from different sectors (social, political, economic, technological, and structural) of a given country, making it possible to map, discuss, and delve more in-depth about the real situation for the insertion of the AVs. The impact of the proposed approach on public policies should also be emphasised, since, when dealing with insertion, there is the preparation of the context for the diffusion of technology.

We sought to fill a gap in the literature related to the definition, adequacy, and application of an artefact to support the insertion and management of disruptive innovation in a country. Finally, there is a proposal for methodological advancement associated with critical success factors, with an empirical approach and easy adaptation and application around the world. A radar framework to identify CSF to be used to contribute to processes related to innovative capacity, governance, and market reach efficiency, and effectiveness in the current and real context of the countries.

Although some studies and research present - in a partial and generalised way - some determinant factors for the insertion of the AVs in a country, there is a need to obtain a clear and assertive diagnosis that allows the formulation of guidelines and actions for capacity development of a country. The results obtained in Brazil and France were crossed with official data and statistics as a way to corroborate the use of the innovation radar as a tool.

The limitation of this work can be the number of respondents. These could be increased, looking for new validation. Besides this, considering that AVs and their concerns are dynamically disrupting scenarios, it is valuable to update the perception in a national panorama.

It is worth highlight that the idea of critical success factors, in the context of this work, is a macro approach involving a national scenario. However, further studies and further developments may lead to specific indicators for each factor, providing a micro approach, whether for states or cities. In other words, starting with a macro view, new studies can go deeper into a micro perspective.

Still, future studies can extend the data collection to other countries, and, also based on the outputs of this research, a future agenda must include the elaboration of critical guidelines for AVs governance, including short, middle, and long-term actions and requirements for the complete and successful insertion of AVs in the countries.

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Notes

1 The numbers in front of each indicator correspond to the article identification.